


Then, Now, and Beyond

Volume 2:We Were There 1960-2021

A book of essays about how the world has changed
written by members of the MIT Class of 1964

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Preface

"Then" is the late 50's early 60's. You took exams with your "slip stick" and often you could bring anything into an exam except another person. Telecommunications was often teletype and computer input was punched cards and tape. Computers were big and not very powerful – such as the IBM 709, 7090, 7094, TX-0, or PDP-1. You waited your turn for the main frame much as a supplicant to the gods. Then there was Project MAC (MIT Project on

Mathematics and Computation) which introduced timesharing – no not shares in a vacation home or jet.

"Now" is well NOW. Computers abound – they wait on our wanting to use them and applications get written with stuff you don't need to prove you need an update and a faster machine. More power in a tiny device than existed in a room full in 1964. Wi-Fi antennas abound. Calculators have solar cells in part because the batteries are more expensive than the electronics. The Internet has a lot of information including stuff about our undergraduate days, where we live, what we do, meetings we go to, etc. etc. Would George Orwell have recognized the "New privacy?"

And **"Beyond"** is well BEYOND. Its in the offing - much like what a landlubber sees when she stares toward the horizon and see the ships going to far off places. Its where predictions of the future don't necessarily come true. But hardly a reason not to predict.

Introduction to Volume 2

The members of the MIT Class of 1964, in this second volume, look at a 62-year period in time through a lens shaped by being brought together to experience "Tech is Hell" and then at graduation, with beaver rings turned around, being ejected into the world. The essays that make up this book are a blend of history and biography written by those who led, participated, and observed the unfolding events in many disciplines, not just science and engineering. Some are about professional life, others about hobbies and interests. Many also share their author's view of what the future might hold.

When we arrived in August of 1960 Dwight Eisenhower was President, the Cold War was still alive and well, the Soviet launch of Sputnik was still fresh in memory, and ROTC was popular on campus. MIT was a bit smaller than today – signs in Kendall Square (now enveloped in MIT) directed us to campus. International students were few, women (aka co-eds) fewer and black students even fewer. Academic disciplines were more likely to live in their silos than be housed together, and many biology related disciplines were yet to emerge. Most freshman wanted to go into physics, but that changed. Lasers were new enough to be the subject of a demonstration in physics class. Computer programming was learned on our own to solve a billiard table problem. Computer time was something you stood in line for. $1,500 tuition was a bit lower than now – there was even a "$1,700 is too damn much" campus protest to a tuition increase ($14,957 in 2020 dollars).

While we were holed up at the Tute a number of major and less-major events took place with ripples into the 21st Century. The following selection is taken from a list prepared by Leon Kaatz for our class website.

1960 September to December

- USS Enterprise – the first nuclear powered aircraft carrier is launched
- Nikita Kruschev shoe pounding incident at the United Nations
- Discovery XVII shot into orbit
- John F. Kennedy elected President

1961

- Chimpanzee Ham completes one day flight in Mercury space capsule
- Leakeys unearth bones of earliest Australopithecus
- Yuri Gagarin becomes first man in space
- Alan Shephard becomes first US man in space with suborbital flight
- White mob attacks Integration Freedom Riders at Birmingham, Alabama bus station
- Great Britain applies to join European Common Market
- The Twist by Chubby Checkers is No. 1 on the pop charts
- James Davis becomes first American killed in the Viet Nam conflict

1962

- Decca, major British recording studio, rejects Beatles, convinced they would never make it on the music charts
- U.S. Rocket Ranger strays off path, misses Moon by 20,000 miles
- Cuba sentences Bay of Pigs invaders to 30 years in prison
- First live worldwide television show broadcasts with Telestar communications satellite
- House of Representative passes bill mandating equal pay regardless of sex
- World population exceeds 3 billion
- Maiden flight of Boeing 727
- Mariner 2 spacecraft sends close up photography of Venus

1963

- Viet Cong down 5 U.S. helicopters in the Mo Key Delta in Viet Nam
- France opposes entry of Great Britain in the European Common Market
- Robert Oppenheimer wins Fermi prize for research in nuclear energy
- Boston Celtics win 5th straight NBA title
- Dr. No, first James Bond movie, premieres
- Martin Luther King "I Have a Dream" speech at the Lincoln Memorial
- Los Angles Dodgers sweep New York Yankees in World Series
- President Kennedy assassinated

1964

- President Johnson pledges war against poverty
- Beatles arrive in America for Ed Sullivan Show appearance
- First US Gemini test flight orbits earth 3 times
- MIT Class of 1964 Receives their diplomas

Essay authors in Volume 2 explore changes in a variety of areas including:

- The impact of the NCAA on coeducational and woman's sports.
- Helping poor countries meet the climate change challenge.
- Currency technology to meet counterfeiting challenges.
- The legal environment.
- Architecture.
- Computer science, telecommunications and artificial intelligence.
- Atmospheric sciences and auroral observations and our understanding of the world above us.
- Amateur astronomers can now star gaze remotely.

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Arts and Culture

Left, When the Class of 1964 arrived at MIT, NCAA rules forbad participation of women in all sanctioned sporting events. The ICYRA governing intercollegiate sailing had no such rules, as demonstrated by Carol Dorworth '60, who as a team member crewed in the 1958 North American Intercollegiate Dinghy Championship for the Morss Trophy, which MIT won.

Below, MIT Women's sailing team won the Emily Wick Trophy in 2019. In 2018 the MIT co-educational team won the Morss Trophy, for the first time since 1961. The team had four women and three men.

Coeducational and Women's Sports vs. the NCAA

Robert M. Gray

Abstract

From its founding in 1910, the National Collegiate Athletic Association (NCAA) was a male-only organization, officially opposing female participation in its programs and events. This endured until it lost its court battles to defeat Title IX, or at least exempt intercollegiate sports from Title IX. Intercollegiate sailing programs provide a rare example of a sport managing to mostly avoid and eventually escape the clutches of the NCAA's Evil Empire, resulting in thriving coeducational and women's competitive sailboat racing programs. MIT sailors played a key role in this story.

Preface

MIT was instrumental in the development of intercollegiate competitive sailboat racing in New England and beyond. In the 1950s-1970s it also became a microcosm of several national stories playing out in mid century, especially the question of who controlled college sports and whether or not women were permitted to participate, either in women-only events or in coeducational sports, where teams included both women and men. From its founding documents until the failure of its efforts to overthrow or escape Title IX, the NCAA provided a simple answer — competitive intercollegiate sports run by the NCAA were for men and only men, and it had no interest in whatever women wanted to do on their own.

Somewhat hidden in the big story of the resulting struggle was the case of one naturally co-educational competitive sport — sailboat racing — and the organizations supporting it, including MIT.

Introduction

Competitive intercollegiate sports have played an important role in higher education as a means of physical exercise, character development, entertainment, building institutional identity, and, of course, fund raising. In the United States in the late nineteenth century, such competitive sports were exclusively male (and white) and women were not encouraged to participate in sports or almost any serious physical exercise. Intercollegiate sports were usually informal and loosely organized, with little oversight by the institutions or governments. This began to change in the late nineteenth century with the rise of American football, which drew increasingly large audiences along with occasional chaos due to the lack of standardized rules, increasing injuries and even deaths to athletes. As a result, various groups began to propose and promote creating official bodies to regulate such sports.

Spurred on by President Teddy Roosevelt, the Intercollegiate Athletic Association of the United States (IAAUS) was founded to regulate football and "other collegiate athletics." All early documents refer to participants as "young male," "boy," or "young man." Sports, athletics, and physical education were aimed at "the needs of young white males who they envisioned would be the country's leaders." [5] Women and minorities were invisible.

The name was changed in 1910 to the National Collegiate Athletic Association (NCAA). In the Constitution, By-Laws, and Executive Regulations, women are explicitly prohibited from competition with men in sanctioned events. The rule was not dropped until years after the 1972 inaction of Title IX. Quoting Carter [5]:

> ***"Things would remain the same at the NCAA until Congress passed Title IX in 1972. In light of that statute, and upon advice of legal counsel, the NCAA rescinded its rule prohibiting female athletes from competing in NCAA-sponsored events. That same year, the first female competed in a NCAA Championship, the NCAA's National Swimming and Diving Championship. But separate championships for women would not be created until 1981."***

In the early days of the NCAA, women educators were increasingly promoting athletic programs for women at both women-only institutions and a few coeducational institutions. In the late nineteenth century, women had expressed increasing interest iin clubs for competitive sports such as tennis, croquet, bowling, archery, and even basketball. Some men's clubs allowed women to become associate members, but denied them full membership. Women and supportive men saw positive benefits in regional and national organizations to help standardize the rules of competitive games, help organize multi-institutional competition, and promote physical education requirements and the implied access to athletic facilities at institutions. One of the earliest such organizations was the Committee on Women's Athletics (CWA), founded in 1917. These organizations for women appreciated the benefits of the NCAA in terms of standardization of rules and organizational, but they were well aware of its faults. In a 1929 report, *American College Athletic,* produced by the Carnegie Foundation for the Advancement of Teaching reported that amateurism was being eliminated or modified from athletics at the college level as colleges turned athletics into big business Bell (2008) [3].

The CWA evolved over many years, through many name changes and mergers, including the Commission on Intercollegiate Sports for Women (CISW), which had been created in 1970 in response to the growing awareness of civil rights and rights for women and minorities of the 1950s and 1960s. The evolution culminated in 1971 with the founding of the Association for Intercollegiate Athletics for Women (AIAW) with 278 charter institutions.

Such organizations for women's athletics were mostly ignored by NCAA prior to the enactment of Title IX in 1972 — they were not taken seriously as sporting events and they did not involve major financial benefits to the institutions or to the NCAA. This neglect by the NCAA was not benign, but it did allow the AIAW to grow significantly before becoming a target of the NCAA, containing more than 800 institutions by 1981, when the NCAA turned its significant financial and political power against the AIAW.

While the AIAW pursued similar administrative and organizational attributes to the NCAA, their goals were vastly different. Bell (2008) [3] states that:

> ***"Their mission was to "lead and conduct" programs at the collegiate level that were competitive for women. The AIAW focused on the female student-athlete's education, not on athletic performance, and thus rejected the 'win or die' attitude of the NCAA. Instead, the AIAW emphasized participation in sport as the most important aspect and de-emphasized winning."***

This set the stage for the one-sided and sad story of the NCAA's efforts to destroy the AIAW following the enactment of Title IX.

The focus of this essay is intercollegiate sailing — a sport that is a natural candidate for co-educational participation, and which never fell under the direct domination of the NCAA. Unfortunately, however, it was caught in the middle as the NCAA pushed institutions to follow its dictates in *all* sports at the institution, whether or not they were governed by the NCAA. Violation could result in an institution's entire sports program being penalized by the NCAA by withdrawing its sanction for more remunerative sporting events.

Much of this multifaceted story occurred in the 1960s, with development in the 1970s, resolution in the 1980s, and enduring impact. Women's athletic programs, competitive sports, and, in particular, sailing at MIT provide a specific and important example of the story. I was present at MIT 1960-66 and an active sailor for two years. My long term interest in the history of coeducation at MIT (see [6]) and my return in retirement to active racing of Bullseyes in Rockport Mass. kindled my interest in this story, which led to my researching and writing this story.

Before 1960 - Intercollegiate Sailboat Racing and MIT

The Intercollegiate Yacht Racing Association (ICYRA) was established in 1930, reportedly in conjunction with the first intercollegiate dinghy regatta, the Boston Dinghy Club Challenge Cup. No explicit gender-based restrictions were stated in the founding documents, unlike those of the NCAA.

The ICYRA became the Intercollegiate Yacht Racing Association of North America (ICYRA/NA) and, in 2000, changed its name to its current name Intercollegiate Sailing Association (ICSA). This essay is about history, however, so I will stick to the ICYRA name as the one most commonly used during the period treated, since only the epilog involves the new name.

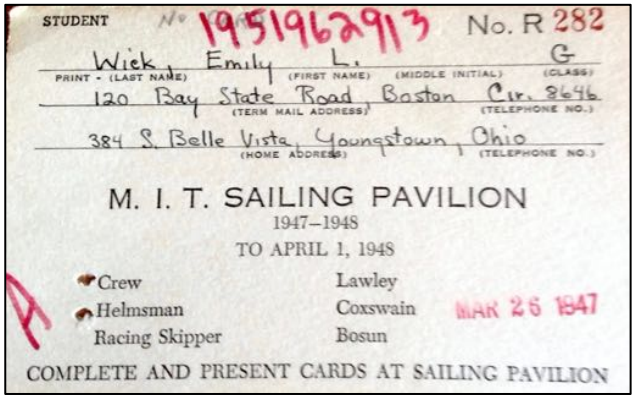
Tech Dinghy 1936

Led by Walter "Jack" Wood MIT '1917, the MIT Sailing Pavilion was built and opened during 1935-6. The first fleet of wooden Tech Dinghies were designed by MIT Naval Architecture Prof. George Owen and built by the Herreshoff Manufacturing Company — founded by Nathanael (Nat) Greene Herreshoff (MIT 1870) and his brother John in 1878 in Bristol RI.

The first generation Tech dinghies served until 1952.

MIT won the first Henry A. Morss Memorial Trophy, the North American Intercollegiate Dinghy Championship sponsored by the ICYRA, in 1937. MIT would win the championship 11 times more out of the 25 run through1961, occasionally with women crew members. It did not win again until 2018. In the 1961 Morss Cup, I was the heavy weather crew for my brother, Peter Gray '61. The other MIT skipper was Don Nelson '61. Both Pete and Don were later elected to the Intercollegiate Sailing Hall of Fame.

Several women at MIT participated in the sailing program at MIT. One was Emily Lippencott Wick, who arrived at MIT in September 1946 from Mount Holyoke College as a new PhD student in chemistry. Emily played a major role in my earlier article on coeducation at MIT in Volume 1 [6] of this series, but here she plays a different role as an *éminance grise* in the background of the MIT sailing program. She did not race competitively at MIT as she was a graduate student, but she was an avid sailor and racer in her hometown of Rockport Mass. As both an advisor and later an Associate Dean of Students, she was a counselor and advisor for the women's athletic program and for women student athletes. So her story is intermingled with the MIT sailing theme.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M. I. T. SAILING PAVILION
1947–1948
TO APRIL 1, 1948
Crew
Helmsman
Racing Skipper
Lawley
Coxswain
Bosun
MAR 26 1947
COMPLETE AND PRESENT CARDS AT SAILING PAVILION

Emily Wick's Sailing Card

In March 1947 Emily joined the MIT Nautical Association by getting her sailing card. The cards are allegedly for one year, but the original cards from the early days on are still kept in a file by the front desk of the Sailing Pavilion. Emily's card shows she qualified as Crew and Helmsman, but not as a Racing Skipper — because she was a graduate student. In her oral history, she said that she did take advantage of the MIT sailing resources, but not to a great extent because she preferred to spend her free time in Rockport, where she had a succession of sailboats, including an O-Boat, a Star Boat, a Jolly Boat, a Firefly, and finally a Cape Cod Bullseye.

On March 26, 1949 the *New England Intercollegiate Sailing Association* (NEISA) was formed in Cambridge as part of the ICYRA. Leonard (Len) M. Fowle, yachting editor of the *Boston Globe* and correspondent for the *New York Times*, was a founder and leader of both NEISA and ICYRA, which is made up of such regional organizations as NEISA.

In 1952 the second generation Tech dinghy fleet arrived, fiberglass instead of wood and built by Cape Cod Shipbuilding.

In 1953 the ICYRA regulations made explicit the rule that member institutions must be either all male or coeducational and that women-only institutions were not allowed. ICYRA

correspondence show attempts to follow closely the strict standards of the NCAA "with possibly some modifications." The allowance of coeducational teams was in direct conflict with NCAA rules.

At MIT, the general issue of extending more athletic programs and facilities to women was increasingly being considered. In December 1955 the MIT Director of Athletics wrote to the Athletic Administrative Board and Committees for the Planning of Athletic Facilities and Program regarding "basic assumptions that it is felt must be made in considering the need for additional athletic facilities at M.I.T." including:

- That we plan in the Athletic Program to include facilities for approximately 200 women.
- That there be no intercollegiate program for women.
- That there be a limited intramural program for women, such as badminton, archery, bowling, etc.
- That there be no required program for women.

Antonia (Toni) Deutsch's MIT Junior Varsity Letter

After several discouraging attempts to participate in MIT sports, Antonia (Toni) Deutsch (later Schuman) was welcomed by Jack Wood and Hatch Brown at the Sailing Pavilion—provided she could handle a Tech Dinghy and a 110, and tie the prerequisite knots. In 1956 following her crewing in several regattas, she became the first woman to receive an MIT Junior Varsity letter. She was the President of the Association of Women Students (AWS) in her Junior Year, and many years later the MIT *Toni Deutsch Regatta* was named after her — *but women were still not allowed in the MIT Athletic Association or Varsity Club!*

In 1958 the ICYRA noted - "where sailing is a regulated sport, it is a part of the athletic program which in most colleges is regulated to some extent by outside groups, such as the National College Athletic Association (NCAA). The policy of this and other similar groups does not recognize the participation of women with men" and began consideration of creating an Affiliate Membership for women's sailing associations[1].

---

[1] Gordon Bently, Graduate Secretary, ICYRA to Kay Leland, Trinity College, December 3, 1958. Mystic Seaport

The MIT sailing team included Carol M. Dorworth '60, who crewed for Team Captain Dennis Posey '59 in the New England and the National championship regattas sailed in Firefly sloops, winning both championships. [8]

To finish setting the stage for the 1960s, in 1959 Emily Wick was appointed Assistant Professor in the Department of Nutrition and Food Science at MIT, and Julius Stratton became MIT President.

1960-1971 - The Plot Thickens

In 1960 the class of 1964 arrived at MIT, and in 1961 the University of Rhode Island, an NCAA school, announced it would follow NCAA rules in all sports and exclude women from all intercollegiate sports and refuse to play any teams including women [8].

This illustrates the basic tactic of the NCAA, to bully institutions wishing to have their remunerative male sports like football and basketball be within the NCAA fold; forcing all of their sports programs to comply with NCAA rules, even if those programs were not governed by the NCAA. This effectively eliminated women from participation in any varsity sport.

Seeing the writing on the wall, NEISA adopted the NCAA prohibition (to be effective in 1966), but actively supported formation of the Women's Intercollegiate Sailing Association (WISA) and the New England WISA (NEWISA) "To encourage and promote women's intercollegiate sailing; to form college sailing teams; to inspire interest in sailing; to create and instruct sailing groups."

The idea seems to have been first proposed in Lucie Sheldon's 11/19/60 letter to Len Fowle, whose 12/5/10 reply suggested bringing it up at a 12/10/60 NEISA meeting. The idea was further discussed in a 2/18/61 meeting of several women students, administrators, and Fowle at Walker Memorial at MIT, where a constitutional committee including MIT's Eleanor (Ellie) Chance was appointed and an initial regatta schedule for spring 1961 was drawn up, and the MIT women's sailing team came into existence.

Collections.

18 February 1961
Walker Memorial
Cambridge, Mass.

The meeting was called to order at 1:30 by Polly Hogan.

Present were: Boston University, Leslie Andrews; Conn. College for Women, Lucie Sheldon; Jackson, Kaarin Stieglitz, Heidi Haner, Sheila Thompson, Lannie Dawson, Denise Valtz, Polly Hogan; MIT, Ellie Chance; Mt. Holyoke, Carolyn Darrance; Pembroke, Miss Janet Lutz, faculty, Betsy Hammett; Radcliffe, Mrs. Theodore F. Parker, faculty, Mary Jo Wheeler, Ann Knowles; Regis, Pat Lilly; URI, Mary Davey, Diane Pierson; Wellesley, Jane Paige, Sybil Healy, Sally Oakes; Wheaton, Nancy Mann.

1. Mr. Leonard M. Fowle, Graduate Secretary of NEISA, spoke for a few minutes on the opportunities for joining the Inter-collegiate Yacht Racing Association of North America, if desired, and the advantages resulting from such action.

2. A spring schedule was set up, copies of which are to be sent out to each college.

3. It was decided that any college that registered for a meet and did not attend or withdraw at least two weeks before the date of the regatta would be held responsible for payment of the entry fee.

4. A committee was appointed to set up a constitution to be voted on at the first spring regatta. Members are: Nancy Mann, Ann Knowles, Polly Hogan, Ellie Chance and Betsy Hammett.

5. The meeting was adjourned at 5:30 P.M.

Respectfully submitted

Polly Hogan

Minutes of February 18, 1961 meeting at Walker Memorial

Unlike the NCAA, NEISA worked behind the scenes to help create an independent but parallel women's organization, and worked for consistency of rules and organization between NEWISA and NEISA in anticipation of an eventual unification. The NEISA was aware of the intentions and power of the NCAA, but they were quiet and sneaky in their opposition.

This was all going on in 1961, while I was at MIT, a member of the Nautical Association, on the sailing team, and, apparently, clueless. I did not learn these details until 2019 during visits to the archives of the Mystic Seaport Museum [11].

WOMENS INTERCOLLEGIATE SAILING ASSOCIATION
Regatta Schedule Spring 1961

April 3rd, Monday - Open regatta at Medford, Mass.
Reporting time - 9:30 A.M. Five dollar entry fee, bring life jackets.
Wheaton, Pembroke, Radcliffe, Mt. Holyoke, Wellesley, Bu, Regis,
MIT, Jackson, Conn.

April 15th, Saturday - Tufts College Cup at Medford
Reporting time 12:30 P.M. Five dollar entry fee, bring life jackets.
Radcliffe, Mt. Holyoke, Wellesley, BU, Regis, MIT, Pembroke, Conn,
Wheaton, URI

April 19th, Wednesday - Regis Invitational at Regatta Point, Marchester, Mass.
Reporting time - 9:30 A.M. Five dollar entry fee.
MIT, SSC, Conn, Radcliffe, Mt. Holyoke, Pembroke, BU, Wellesley, Regis.

April 22nd, Saturday - Pembroke Invitational at Pembroke
Reporting time - 12:30 P.M.
SSC, Conn, URI, BU, Radcliffe, Mt. Holyoke, Pembroke, Regis, Wheaton,
Jackson.

May 6th, Saturday - URI Invitational at URI
Reporting time - 12:30 P.M.
SSC, Conn, URI, BU, Radcliffe, Mt. Holyoke, Pembroke, Wheaton.
Alternate - Jackson.

Women's Intercollegiate Sailing Association - Regatta Schedule Spring 1961

MIT student Eleanor Chance played a key role in the development of women's sailing as the MIT student representative in the February 1961 meeting at MIT initiating the organization of WISA and NEWISA, their relationship to NEISA and ICYRA, and scheduling the first spring regattas. Earlier in 1960 she is mentioned in the 11/18/1960 *"The Tech"* as a member of the MIT team along with Marjory Harper as a participant in "an unusual intercollegiate event" — a regatta for women sailors held at MIT. She was still on the NEWISA mailing list in 1962, but then disappeared from MIT records, I could not even find a sailing card for her at the MIT Sailing Pavilion. It turns out, however, that her life was intimately involved with sailing — but only briefly at MIT. On February 2, 1964 *The New York Times* published an announcement of her marriage to Bradford N. Swett along with the biographical information that she is an alumna of the Baldwin School in Bryn Mawr, Pennsylvania, and the University of Pennsylvania and that she also attended the University of Uppsala in Sweden and MIT. Her father, George Britton Chance, was a Professor at the University of Pennsylvania School of Medicine and a 1952 Summer Olympic Gold Medalist in 5.5 Meter sailing. Eleanor built a significant sailing reputation sailing Finns and later larger boats at the New York Yacht Club under the names Eleanor Chance Swett and Eleanor Chance Burgess. She sailed with Jerome (Jerry) Milgram '60, who was coincidentally mentioned in the same "*The Tech"* article mentioned above, and was reported to have taken command of Milgram's controversial cat-rigged catch Cascade following races. Milgram was a star MIT sailor and a long-time professor at MIT. Eleanor appears again in August 7, 1972 *New York Times* article as skipper of the second-place *Cascade* in the New York Yacht Club's Astor Cup race. Eleanor's daughter Hannah Swett was the Rolex Yachtswoman of the Year in 2004. Ellie Chance's role is clear from the earliest documents in the NEWISA archives in the Mystic Sea-

port Museum Collections [11]. NEISA provided high-level liaisons with NEWISA, advice (led by Len Fowle and Jack Wood), organizational cooperation, and the long-term goal of an eventual merger. MIT played an active role as a host for NEISA regattas.

Unfortunately, the MIT women's sailing team and NEWISA were not able to sustain their initial burst of activity and little more happened until autumn 1964 when once again MIT fielded a team and NEWISA organized five spring regattas.

In 1962 Sailing and fencing were approved as women's club sports, but women had very low priority in using MIT athletic facilities.

This photo of Emily at the Sailing Pavilion is accompanied by an excerpt from her oral history [12].

Interviewer: Sailing? Did you [take] advantage of the MIT. . . did they have a sailing team?
Wick: Well, I did. Sure MIT did, but I did not do a lot of it there because I had a boat out here in Rockport and I did not want to use up my goof off time in town. But, when things got thick, I would walk down to the sailing pavilion and smell the fresh air.

In 1963 Margaret (Scotty) MacVicar was the president of the MIT AWS and was also an avid sailor.

MARGARET "SCOTTY" MACVICAR, '65, is a sailing enthusiast, a physics major, and president of the Association of Women Students. She has worked summers in the Michigan State University spectroscopy laboratory and for AC Spark Plug on the Apollo project.

From Dec. 1963. P. 80 The Technology Review

In 1964 a women's athletics program was formally established at MIT, beginning with 44 women students.

WISA incorporated several ICYRA procedures at MIT. Ruth Beckley '67 chaired the NEWISA Scheduling Committee. Beckley was a member of the MIT women's sailing team organized in the fall of 1964 in anticipation of the expected enforcement of the prohibition of women on the Varsity sailing team in 1966. In 1967 Beckley won the first MIT Pewter Bowl Award, given annually to the "Female senior who has shown the highest qualities of inspiration and leadership in contributing to women's athletics."

In response to appeals from women's sports and athletics organizations and its own long-range planning committee, the NCAA clarified its position [5][9]:

> ***"NCAA categorically rejects participation of women in their championship events: The games committee shall limit participation to eligible male athletes."***

On January 21, 1965 the MIT Athletic Board invited Associate Dean of Students Jacquelyn Mattfeld and several undergraduates to discuss the women's athletics program at MIT. The undergraduates include Ruth Beckley. The following excerpts from the minutes of the meeting provide added information on renewed attempts to form an active women's inter-collegiate sailing program.

M.I.T. ATHLETIC BOARD MINUTES

FEB 17 1965

January 21, 1965

Present: Professor G. A. Brown, Chairman
Messrs. S. Edgerly, T. P. Heuchling, G. P. Strehle
Professors K. F. Hansen, J. W. Mar
Dr. A. O. Seeler, Mr. O. R. Simha, Professor R. H. Smith,
Dean K. R. Wadleigh
Messrs. W. R. Brody, W. David Carrier, III, R. E. Lucy,
R. I. Mandle and F. S. Souk

Absent: Messrs. J. S. Merriman, Jr., and E. Pollard

Guests: Mrs. J. A. Mattfeld, Associate Dean of Student Affairs for Women, Ruth Beckley, Barbara Desmond, Sandra Foote, Diane Pickering and Martha Redden

The meeting was called to order at 7:45 p.m. by Chairman Brown.

I. DISCUSSION OF THE ATHLETIC PROGRAM FOR WOMEN AT M.I.T., INCLUDING OBJECTIVES, PHILOSOPHY AND THE PRESENT SCOPE OF THE PROGRAM.

Chairman Brown suggested that Dean Mattfeld review for the Athletic Board the current statistics on the number of women enrolled at the Institute, and indicate as accurately as possible the probable increases in enrollment.

Ruth Beckley '67, Sailing Team. A women's sailing team, organized this past fall, attracted a group of 15 women, mostly freshmen and sophomores. Coaching was provided by the staff at the Sailing Pavilion and several members of the men's sailing team. The team competed in 5 regattas sponsored by the New England Women's Intercollegiate Sailing Association. Highlight of the season was an M.I.T. victory in a regatta of 17 women's college teams on the Charles River on November 7 and 8, 1964.

Coed sailors host New Englands

Tech's women sailors are ready to defend their New England Intercollegiate title this weekend. The girls will be going for their third straight blue ribbon in the championship regatta, scheduled for MIT's Sailing Pavilion.

The women's sailing team came into existence in the spring of 1962 after the New England Intercollegiate Sailing Association announced that they would bar women from competition by the fall of 1966. Under the guidance of coach Stu Nelson, and with the assistance of the Tech varsity sailors, the coeds entered their first competition in the spring of 1965. Since then, the girls have competed in twenty-five New England Women's Intercollegiate Sailing Association regattas, which have averaged eight schools entered per competition.

The women's sailing team for 1966-67: shown with coach Stu Nelson are (from left) Alix Smullin '68, Sue Downs '68, Maria Karpati '69, Ruth McDowell 67, and Douggie Gordon '68. MIT hosts the New Englands this weekend.

Their record in two years of competition has included two New England Championships, thirteen first places, and seven runner-up finishes.

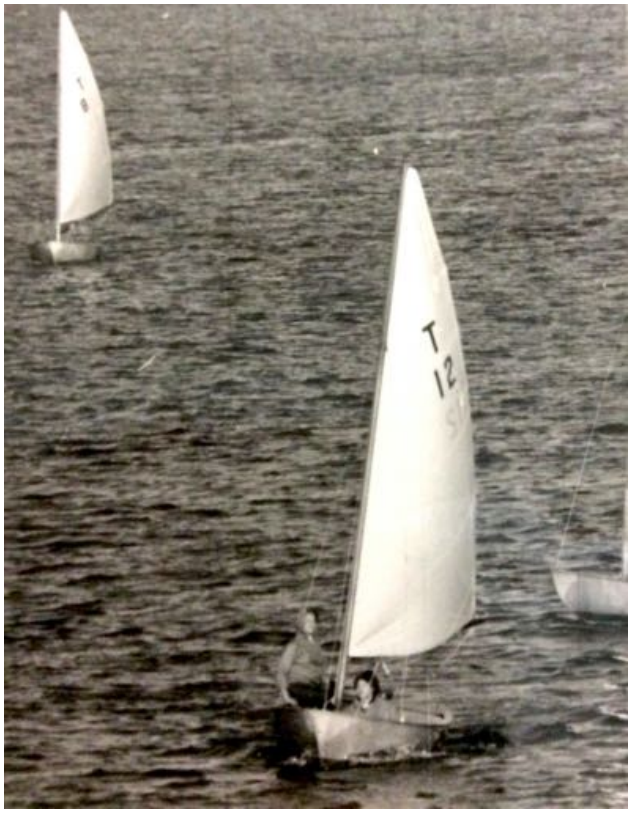
Fourteen schools to compete

By far the most active women's sport at MIT, sailing has attracted over twenty coeds to the intercollegiate competition. Fourteen New England intercollegiate women's teams will be lined up for the starting gun Saturday. Women's sailing teams from Boston University, Connecticut College, Emerson, Emmanuel, Merrimack, MIT, Northeastern, Radcliffe, Rhode Island School of Design, Simmons, Tufts, Vernon Jr. College, and Wellesley are entered.

The MIT girls are hosting the championships and are eager to maintain an unblemished record of having never lost a regatta held on home waters.

The Tech, 10/22/1966

Tech women sailors continued their success in the first year of their banishment from Varsity sailing by the NEISA. The article incorrectly states that the women's sailing team came into existence in spring of 1962 and that its first intercollegiate competition was in the spring of 1965. As we have seen, the team was first formed and had its first intercollegiate regattas in 1961.



The Tech, 11/1/1966 "Coeds first in Man Lab Regatta; win trophy for third straight year"

In 1967 NEWISA and her sister organization, the Middle Atlantic Association of Women Sailors, (MAAWS), organize the first women's nationals for 1967.

Fran Charles, MIT Sailing Master (at MIT since 1992), relates stories told to him by Hatch Brown, former MIT Varsity Sailing Coach and Sailing Master, and Stu Nelson, women's Varsity Coach at MIT for 39 years and first full time women's coach for the ICYRA:

> ***"During the mid 1960s Emily spent many weekends organizing and hosting New England women-only sailing regattas and was instrumental in founding the New England Women's Intercollegiate Sailing Association when the New England Intercollegiate Sailing Association would not allow their participation in varsity sailing. Emily even organized the do-it-yourself sandwich lunches for the regattas. She also lobbied the Athletic Association for approval of women's sailing as a varsity sport."***

Excerpts from *Athletics and the Women Students at MIT*, March 17, 1967 Memorandum from Associate Dean Wick to Dean Wadleigh:

> ***"The MIT Women's Sailing Team has a distinguished record in that it won the 1966 New England Intercollegiate Women's championship and was undefeated throughout the fall season. . . . Because of their demonstrated activity in athletics and their need for assistance and a structure within which to schedule meets, the question of admitting women students to the MIT Athletic Association was discussed at a meeting of the Athletic Board. Their membership was approved by the Athletic Association in February 1967."***

Women's Crew was also admitted to membership in the Athletic Association. But women were not yet permitted in the Varsity Club. MIT viewed the women's Varsity Sailing team as

having officially begun in 1969 with the Athletic Department funding of a women's coach, Stu Nelson — a decision strongly influenced by Emily [7].

Later in the year women's sailing and crew were designated "Varsity Teams" retroactive to 1963, all other women's sports considered "club sports."

In 1970 ICYRA recognized NEWISA women's nationals and set policies and procedures. Sailor Carole J. Bertozzi '70 won the 1970 MIT Pewter Bowl Award.

In 1970 Emily wrote for the 1971 MIT *President's Report* that:

> ***"A high point in the history of M.I.T. women was reached when Kathy Jones '71 and Maria Bozzuto '73, members of the Women's Varsity Sailing Team, received M.I.T's highest athletic award, the Straight T, at the Athletic Association's Awards Banquet."***

This was the first time that women were invited to the annual Awards Banquet! Jones won the 1971 MIT Pewter Bowl Award and Bozzuto won it in 1972.

MIT women won the 1971 ICYRA National Women's Dinghy Championship.

1972 - Sea Change: Title IX

A tidal wave occurred for women's sports (and all other educational activities involving Federal funding) with the 23 June enactment of Title IX of the Education Amendments Act of 1972:

> ***"No person in the United States shall, on the basis of sex, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any education program or activity receiving Federal financial assistance."***

Colleges and universities were not required to comply until 1978, but intense activity began immediately. Title IX was strongly supported by the AIAW. Their early reaction to the legislation was the optimistic hope that women's involvement in the administration, coaching, policy, and funding will increase and no longer be in the shadow of the NCAA male-dominated view of sports [4].

The NCAA fought the legislation ferociously with lobbying, influence, and lawsuits. The intensity of the attack is described in many sources, including [2], [4], [5], [10], and [3]. The NCAA's executive director Walter Byers states that Title IX signaled the "possible doom of intercollegiate sports," and many argued that that "doom" included what few women's sports existed at the time. These tactics all failed, so the NCAA adapted an old industry strategy — it initiated efforts to take over governance of women's sports rather than ignore or fight their existence. That would keep their power over policy, budgets, and personnel intact while taking over the rapidly growing programs for women's athletics. It also had the effect of putting the control of women's sports in the hands of the largely male NCAA administration as well as replacing the AIAW stated goals of placing student interests and ed-

ucation first, with the NCAA's goals of economic power and winning at any cost. The onslaught did not happen overnight, the NCAA would not win until 1982.

MIT Ad Hoc Committee on the Role of Women Students

In 1972 MIT formally appointed an Ad Hoc Committee on the Role of Women Students at MIT, including many members of the Women's Forum, a group of over one hundred members including students, faculty, and staff (including a few men). The committee produced a report by the end of spring[2]. The report included an "Athletic Report" which begins:

> ***"There is one major problem that coed athletes at MIT encounter; they are often not taken seriously by the Athletic Department. This, however, is merely a reflection of the attitudes which pervade society in general with regards to women athletes. Rather than providing positive motivation, as for men, which involves tangible rewards, e.g., varsity letters and recognition, women athletes must overcome a negative social image, that is, one of being competitive and unfeminine."***

The Committee made many recommendations, which unfortunately mostly led to more discussions and committees without solid changes for several years. An important exception was the extension of the Physical Education Requirement to women undergraduates, giving them equal priority of access to athletic resources.[3] Another welcome result of the report was that the students on the Ad Hoc Committee on the Roll of Women won a Karl Taylor Compton Prize — "the highest award presented by the Institute to students and student organizations in recognition of excellent achievements in citizenship and devotion to the welfare of MIT." The Ad Hoc Committee Compton Prize was used to fund the Emily Wick Trophy regatta, a women's intercollegiate sailing event.

The MIT women's varsity sailing team won the 1973 ICYRA National Women's Dinghy Championship.

A Future for Women's Sailing

In May 29, 1976 NEWISA and ICYRA agreed to merge NEWISA into NEISA and become a self governing committee for women's sailing. At the MIT Sailing Pavilion the Women's Intercollegiate Sailing Committee (WISC) was formed from NEWISA and its sister organizations "to encourage and promote women's intercollegiate sailing." The merger was accomplished by ICYRA direction in 1978. So unlike the NCAA, the governing organization of intercollegiate sailing managed to incorporate both women-only and coeducational sailing, the historically women's sailing organizations, with whom it had cooperated in the background during the years of NCAA dominance. But the NCAA was not done.

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[2] *Role of Women Students at MIT*, A report by The Ad Hoc Committee on the Role of Women students at MIT, July 1972. MIT Archives, AC-22, Box 3.

[3] "Historical Outline of Women's Athletics at MIT," Dottie Bowe, unpublished manuscript in MIT Archives.

1980-82 -The Empire Strikes Back

The NCAA fought back against Title IX by planning and implementing its own championships in women's sports, developing competing programs to those of the AIAW and its component and sister organizations. The NCAA offered incentives to institutions to join it rather than the AIAW, including free travel funds for women's teams and free women's memberships for institutions whose men's teams joined the NCAA. The NCAA signed TV contracts to televise its own women's team championships on the same day as AIAW championships, costing the AIAW its primary financial source [4]. The NCAA dwarfed the AIAW, which could not survive the onslaught. The AIAW filed an antitrust suit, but lost because the judge did not believe that the NCAA was or threatened to be a monopoly. The AIAW collapsed financially in 1982 and the NCAA took over almost all intercollegiate men's, women's, and coeducational sports — the latter of which there were virtually none beyond sailing, rifle, and high diving. Carpenter and Acosta in [4] drew the sad conclusion on unintended consequences:

> ***"As the brief, ultimately sad history of the Association of Intercollegiate Athletics for Women (AIWA) will show - a model of competitive but humane intercollegiate athletics once existed. Ironically, the NCAA demolished it in the wake of federal legislation intended to provide equity, including equity for women in sports."***

Epilog

Sailing and the ICYRA (now known as the ICSA) remained independent, not directly governed by the NCAA. Unfortunately, they are still affected by rules agreed to by institutions belonging to the NCAA.

In 2018 the MIT women won the Emily Wick Trophy and the coeducational sailing team won the Morss Trophy for the first time since 1961.

Acknowledgements

I am grateful to the MIT Museum and the Special Collections (aka Archives) and to the Mystic Seaport Museum Collections. Most of the images are from these collections. The details of the NCAA successful war on the AIUA draw heavily from Barnes and Scannell [2], Carpenter [4], Carter [5], and Bell [3]. Special thanks for discussions of women sailing at MIT to Antonia (Toni) Deutsch Schuman MIT '58 and for editorial and content discussions with Bob Popadic, Class of 1964 Historian and former *Technique '64* Editor-in-Chief.

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Robert M Gray '64 Course 6, Electrical Engineering, arrived at MIT in 1960 and received his BS and MS in EE at MIT in 1966 and the PhD from the University of Southern California in 1969. He is a Stanford Professor Emeritus and lives in Rockport, Massachusetts.

MIT and a Life at the Edge of Science

Al Teich

It was a Van de Graaff generator that started me on the road to MIT. You might say it sparked my interest in the Institute. A Van de Graaff is a device that generates a high voltage, low amperage static electricity charge. I built one for a science fair project in ninth grade and it won first prize in the district competition.

The large, but harmless, sparks it gave off made my exhibit a major attraction at the fair. A reporter for my high school newspaper (*The Shoreline* at South Shore High School in Chicago) interviewed me and my picture appeared in the school paper together with a short article. The reporter asked about my plans for the future and I replied, without giving it a great deal of thought, that I hoped to go to MIT and become a physicist. That was it. Throughout the rest of my high school career whenever I was asked about my college plans, I didn't need to give the matter any further thought. I said I was going to go to MIT and study physics. Even though I really didn't know much about what a physicist actually did, and I had only the haziest idea of what an MIT education was like, I was now on record publicly -- I had made up my mind that I would go to MIT and become a physicist. Well, I did go to MIT and I did get a degree in physics, but I didn't become a physicist. My career has been in science policy -- a field that barely existed in the early 1960s. Much of it has been at AAAS (American Association for the Advancement of Science), which has played a key role in the growth and evolution of the field.

Freshman Year: A Major Milestone

Anyway, there I was, four years later, stepping off the plane at Boston's Logan Airport in September 1960 to start my freshman year at MIT. I had only a vague notion of what I was getting myself into. I had never gone to camp and had never been away from home by myself for more than a few days. I had only been to the Boston area once, on a New England vacation with my family the previous summer. During that visit I had seen the MIT campus, but only from the outside. I had interviewed with an MIT alumnus in Chicago, the uncle of a friend, and I had studied the recruiting materials the Institute had sent me after I wrote to indicate my interest.

I was valedictorian of my class of 368. The Harvard Club of Chicago had courted me, awarding me the Harvard Prize Book, beautifully bound in red leather with gilt edges. I thought Harvard was too snobbish, however, and I didn't bother to apply.[4] I applied to the University of Chicago, the University of Michigan, Caltech, and MIT. I was on my own financially; my parents did not have the resources to support me. I received partial scholarships from the Pullman Foundation, the Sears Roebuck Foundation and several other sources. The University of Chicago offered me a full scholarship, but it was too close to home. Michigan admitted me and offered some financial aid. Caltech probably laughed at my application and didn't bother to read it. They admitted only 250 applicants and I was probably well below the low end of their list. But it didn't matter since I had known from the beginning that I was going to MIT. They offered enough financial aid, in a mix of scholarships, loans, and work-study that, together with the scholarships I had already received and the money I had saved from summer jobs and bar mitzvah gifts, I had just enough to cover my tuition and living expenses.

My parents saw me off at O'Hare and tearfully watched me board my flight to Boston. I was excited not just because I was leaving for college, but because it was my first flight. Flying was nowhere near as common in 1960 as it is now. I checked a large suitcase, and had shipped a footlocker with the rest of my clothes, books, and other possessions by Railway Express a week or so earlier.

My first few days in Cambridge were kind of a blur. I found my assigned room in Senior House, MIT's oldest dorm, built in 1916. It was steeped in tradition -- and about 50 coats of paint. The front of the building faced the river and had a great view of the sailboats on the Charles River basin and the Boston skyline. The back, where my room (Runkle 203) was located, looked out on a rather grim industrial neighborhood. Charlie The Tech Tailor, where I took my shirts for laundering and pressing at $0.25 each, occupied part of the old red brick and stucco building directly across the street.

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[4] The book was presented by Chester White, class of 1915. The captain of our basketball team and the captain of our football team in my year both went to Harvard on athletic scholarships.

Charlie the Tech Tailor

Beyond it were several square blocks of the still-active remnants of the industrial revolution, including the NECCO candy and the Lux soap factories whose aromatic emissions blended in a distinctive and memorable scent, "essence de Cambridge circa 1960."

I didn't know a soul at MIT. I was the only person from my high school class to go there. In fact, I knew of only one other person from South Shore High who had gone to MIT, and he was a legendary mathematical genius a few years older than I was, who focused exclusively on math, ignored all his other courses, and flunked out in a year. I was a top student in my high school and regarded myself as kind of a big shot there. Well, it turned out that everyone else felt the same way about themselves. Rather than a big shot, I was an average member of the entering class, or maybe a bit below average. That took some getting used to.

One of the many joys of my freshman year was getting to know the Boston area, its restaurants and other attractions. Some of my favorite eating places included two Italian restaurants in Cambridge, Simeone's and Edelweiss, where I discovered lasagna, still a favorite food. I also became a fan of 29 and 39 Newbury Street, a pair of restaurants with homestyle food that catered to MIT and Harvard students. Among the other attractions were Fenway Park (of course), Harvard Square, and Scollay Square. The last of these was a rather seedy, disreputable area that had been immortalized in the Kingston Trio's song about Charlie on the MTA. It was torn down not long after I arrived in Boston and replaced by Government Center.

Speaking of landmarks, one Saturday during orientation a few upperclassmen from Senior House took a number of us freshmen to Durgin Park, a historic 150-year-old restaurant in Faneuil Hall, for a kind of initiation rite[5]. The drill here was for the grumpy old waitresses to bark at the freshmen, hand us stone water pitchers that weighed about a ton and a half each, and leave us to pour water for the table while struggling not to spill it or to drop the pitchers. We were then required to order huge slabs of roast beef, each of which was roughly a side of beef, followed by strawberry milkshakes served in gallon-sized vases. And then try not to throw up.

Souvenirs of my first year at MIT include a desk calendar that I recently rediscovered in which I kept track of exams, meetings, dates, and the like. Some entries are cryptic or illegible and leave me wondering what they could possibly mean, but others have served to jog my memory and reopen chapters in my life that I had long forgotten. The first entry is from

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[5] Sadly, Durgin Park closed in January 2019.

Sunday, September 18, for a talk by the president of MIT, Julius Stratton. I assume it was a welcome to the entering class, all 950 of us, including 22 women. Since classes started two days later, I assume I must have arrived on campus a week or so earlier. I remember a trip during orientation to Wingaersheek Beach on the North Shore, to which we were transported by a parade of buses. It's a beautiful beach and, although I'm not positive, I think this may have been the first time I swam in the ocean. I think we had a cookout there. Probably the most significant part of that excursion was meeting Mark Ain, a freshman from Long Island, who lived in my dorm and with whom I quickly became friends. Within a few days we had expanded to a small circle that included Donald Levy, also from Long Island, and Arthur Rieser, from Manhattan.[6] Though our lives have taken different directions, the four of us have remained friends over the past 60 years. Having friends made the adjustment to college life much easier.

I didn't need to spend much time choosing courses. Four core courses were required of all freshmen: Physics (or 8.01, as it was known at the Institute -- everyone at MIT spoke in numbers), Chemistry (5.01), Calculus (18.01), and Humanities (21.01). We also were allowed one elective; I chose psychology. The first three consisted of lectures attended by several hundred students and taught by senior professors, plus smaller "recitation" sections at which graduate students tried to explain what the professors had said in the lectures. I'm guessing that we didn't have much choice in scheduling the days and times of our classes because I remember having a calculus recitation section at 8 a.m. on Saturday. All in all, MIT's freshman year in 1960-61 was pretty rigid academically.

We had more flexibility in extracurricular activities. My calendar indicates that I sampled many possibilities: *The Tech* (the student newspaper), soccer (intramural, definitely), Voodoo (the humor magazine), the Science Fiction Society, the Lecture Series Committee (which sponsored Friday night movies as well as concerts, and lectures), Hillel, the Debate Society, the Dorm Social Committee, and something called "Fresscomm," a committee that organized banquets for residents of Senior House. I apparently joined Fresscomm since its meetings appear several times on my calendar, and I undoubtedly partook of its feasts. I don't recall going out for any of the other activities, although I think I did write an article or two for *The Tech*. I also signed up for weightlifting to satisfy my phys ed requirement, which I enjoyed and which, together with Fresscomm and the pasta, mashed potatoes, and other starchy foods from Walker Memorial, the dining hall, helped me build up my body from a scrawny 125 pounds to a somewhat less scrawny 145 pounds. I still weigh 145, but my weight is distributed differently these days.

MIT had many events on campus and attracted big name speakers and performers. According to my calendar, in October I attended lectures by Aldous Huxley and Werner von Braun, and in early November a concert by folksinger Oscar Brand, and one by Pete Seeger in December. I met a girl from someplace in upstate New York at a mixer at Lesley College (a

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[6] The four of us moved into two adjacent rooms in Senior House, creating a quad, for our sophomore year and subsequently rented an apartment together in Harvard Square.

small girls' school in Cambridge) in October. I asked her out and went on my first college date a few days later.

Huxley lectures on "What a Piece of Work is a Man"

Nineteen-sixty was a presidential election year and I listened to the Kennedy-Nixon debate on September 26 on the radio, attended a Kennedy rally at Harvard's Sanders Theater on November 1 and another one at Boston Garden on November 7, the night before the election. The Garden was jammed. When the Celtics played there, a capacity crowd was famously 13,909. The *Boston Globe* reported that attendance at the rally was over 22,000. Kennedy was the favorite son and his victory over Richard Nixon was the cause of much rejoicing in the Boston area.

I survived various quizzes, exams, problem sets, and papers. It was a grind. Freshman year at MIT, it was said, was like drinking from a fire hose. It was a relief to leave for Christmas vacation. I got a ride home to Chicago off the ride board.

Like many colleges and universities in those days, MIT started in mid-September. Following this calendar meant we went home for vacation on December 19, returned on January 3, had two more weeks of classes, four days of "reading period," four days of finals, and then returned home for a ten-day "intersession," starting classes again in early February. Reading period was intended to allow us to prepare for finals, but my friends and I spent much of it at the Kendall Diner (aka the "Red Death") playing pinball.[7] Looking at my final grades that semester, I probably would have been better off using reading period to study.

February brought Barry Goldwater and Isaac Asimov to campus for lectures. My dating scene got a little more interesting in the spring. Donald and I were cruising the shops at Quincy Market in Boston one Saturday when we spotted a couple of cute girls working at one of shops. They were sisters and high school students from suburban Newton. The shop belonged to their father. We flirted for a while, asked them out, and ended up dating them for several months. Donald paired with the blonde older sister. I went with the younger pony-tailed brunette.

The highlight of the spring semester at MIT was the Centennial Celebration, the 100th anniversary of MIT's 1861 founding. There were special events throughout the spring -- con-

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[7] There were two diners in Kendall Square frequented by MIT students. They were known as "The Black Death" and "The Red Death," distinguished by the color of their signs.

vocations, conferences, and lectures. The celebration culminated on April 21-23, Centennial Weekend.

Painting the Centennial railroad coaches

Pete Seeger sang to students at Sturbridge Village

There was plenty of pomp and circumstance, including a Centennial Procession with MIT faculty and other dignitaries in full academic regalia. On Friday night there was a formal Centennial Ball. The next morning we boarded a special train, provided by Alfred Perlman, president of the New York Central Railroad and an MIT alumnus, for a trip to Sturbridge Village, an outdoor museum in Western Massachusetts. I recall vaguely that each living group was allocated a car on the train, and that the Senior House car made for a rather raucous ride. Entertainment at Sturbridge included Pete Seeger, the Four Freshmen, the Modern Jazz Quartet, and comedian Lenny Bruce. Seeing Lenny Bruce, whose profanity-laced monologues were legendary and kept getting him into legal hassles, in person was especially memorable.

I had invited my high school girlfriend to be my date for the weekend. I was excited when she accepted and agreed to make the trip from Chicago. I was less excited when she told me that her parents were going to escort her, bring her pesky younger brother and make a family trip out of it. I was definitely ***not*** excited when she got sloppily drunk and sick after the formal dance on Friday night. It was a memorable weekend -- though not quite in the way I had hoped. It was also the end of that relationship (although we are still friends).

Aside from not inviting your high school girlfriend to your first big college weekend, I learned several other important lessons from my first year at MIT. I found physics more difficult than I expected and liked it less than I expected. I stuck with it because I figured I'd like it more after I got past the basics and into the more interesting stuff. (Spoiler alert: I didn't.) I liked my psychology elective best among my courses, followed by chemistry and

humanities. I began to question my vocational choice but decided that I needed to give it more time. I also learned how important it was to have good friends. My freshman year would have been much more difficult and much less fun without my friends Mark, Donald and Arthur. And finally, I learned, though I hadn't really doubted it, that I could make it at MIT, even if my grades were less than stellar.

While my family gave me plenty of encouragement and emotional support, they were not in a position to provide financial support. In addition, my father suffered the first of a series of heart attacks not long after I left for MIT and, hoping it would improve his health, my parents and younger sister moved to Florida following my sophomore year, cutting themselves as well as me off from the friendships and other support systems we had in Chicago.

Part of the financial aid package that MIT gave me was a work-study job as a custodian in a nearby dorm, a job that I hated and in which I did as little as I could get away with. Fortunately, there was minimal supervision, so I made it through the first semester without getting fired.[8] After a short stint as a stock boy in a brassiere factory in Cambridge, early in my sophomore year I was able to find a job as a lab assistant at Moleculon, Inc., a small chemical R&D firm in Kendall Square. I enjoyed that job. It involved science. I learned from it. And I stayed with it for the next three years, gradually gaining responsibility until I was able to conduct my own experiments under the firm's research contracts, some of which required me to obtain a security clearance.

When I reflect on the experience years later, I believe it was this job that kept me engaged in science. I enjoyed constructing and using experimental apparatus far more than I enjoyed most of my coursework. My favorite was a device that used a xenon flashtube to illuminate a chemical sample (in this case a benzimidazole, an organic compound) with a very brief pulse of light. The sample, normally non-conductive, responded by temporarily becoming a conductor of electricity, and I used an oscilloscope to measure the time in milliseconds it took for its conductivity to peak and decay back down to zero.

I was not nearly as engaged in my courses in differential equations, quantum mechanics, and physical chemistry. I had a literature minor and enjoyed (and got better grades in) Russian Literature and The Nature of the Comic. I thought about changing majors, and had a brief flirtation with psychology, but ultimately decided to stay in physics. I maintained a less-than-stellar GPA, wrote a senior thesis on electroluminescence under Professor M.W.P. Strandberg, and graduated in June 1964 with a B.S. in Physics.

I had a girlfriend whose family lived in Brookline and who went to Boston University, and I wanted to stay in the Boston area after graduation. However, I didn't think I was cut out for graduate school in physics at MIT. I applied and was admitted to the less competitive physics graduate programs at Brown and Boston University, and I interviewed for entry-level positions with several local firms. Avco Everett Laboratory, a local aerospace firm that

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[8] I also received loans from MIT's Technology Loan Fund each year throughout my undergraduate career. At 1% while I was in school and 2% after graduation, I was paying them off at $25 a month until 1980.

worked on the new technology of lasers, made me an attractive job offer that included paying my graduate school tuition. Still, I wasn't sure that physics was the right direction for me.

Peter Paul and Mary and Fats Domino entertained us on Junior Prom weekend. Ahead were senior year, graduation and graduate school.

Graduate School, But Not in Physics

As graduation approached, I needed to make a decision about what to do next. The choice I made was a critical one. It led to a career path that has kept me on the periphery of science but not as a practicing scientist. The decision grew out of a seminar that I had attended in the fall of 1963 in the Physics Department. The speaker was a young engineer who had recently returned from several years at the Office of Science and Technology in the Kennedy White House. I had no idea that such an office existed, and I was intrigued by the notion that a scientist or engineer could play a role at the center of power in Washington. The speaker, Eugene Skolnikoff, had gotten a degree in electrical engineering at MIT, had been a Rhodes Scholar, and was returning to MIT after his White House years to complete a Ph.D. in political science.

Connecting science and policy -- that seemed like the kind of career in which I could see myself. I could begin by remaining at MIT and pursuing a Ph.D. in political science. To get a sense of what I might be getting into, I signed up for an elective in "Science, Technology, and Government" with Professor Robert C. Wood.[9] Professor Wood's course was a superb introduction to science policy and reinforced my growing belief that this was the field for me. So I applied to MIT's Ph.D. program in political science.

The admissions committee was less certain than I was, however, about this being my field, since my exposure to it was limited and my ability to do the work was unproven. So, instead of being admitted straight away, I became a non-matriculated "special student" with the understanding that if I received "A's" in several graduate political science courses, I would be considered for admission as a regular student. I overcame that hurdle, became a

[9] Professor Wood later became Under Secretary of Housing and Urban Development and, after that, President of the University of Massachusetts.

regular graduate student, and during the summer following my first year I was pleasantly surprised by being awarded an NIH graduate fellowship.[10]

In political science, I took courses with Ithiel de Sola Pool, William W. Kaufman, and Daniel Lerner, as well as Skolnikoff, who subsequently became my dissertation supervisor. I enjoyed these courses, which involved learning about international communications and development, nuclear strategy, and science policy. I did well in them and passed my comprehensive exams in the fall of 1966, thereby becoming a doctoral candidate.

In addition to Gene Skolnikoff, I had connected with Daniel Lerner, who was in the midst of a study of the political views of opinion leaders in the decade-old European Community. He was interested in including scientists in his study and, seeing the potential for science contributing to European unification, I proposed a dissertation in this area. The dissertation was a survey of attitudes among scientists at a number of multinational European laboratories: CERN (the European Center for Nuclear Research in Geneva), ESTEC (the European Space Technology Center in the Netherlands) and the Euratom Joint Research Center (JRC) at Ispra, in Northern Italy, as well as several smaller labs. The MIT Center for International Studies and the Center for Space Research provided support for my travel expenses through various grants.

I had married my college girlfriend in June 1965 and my wife, who was funded to work with me under one of Professor Lerner's research grants, and I spent nine months in Europe, about four of them in Paris, making contacts and arrangements, studying French, and drinking many liters of French wine. The remaining five months were devoted to a tour of European labs, interviewing and collecting written questionnaires from over 300 scientists. I gathered reams of data which, over the next 18 months, I analyzed and shaped into a dissertation, on the basis of which I was awarded a Ph.D. in political science in June 1969.[11] With Lerner's encouragement and assistance, I published a condensed version of the dissertation as a chapter in a book of five condensed MIT Political Science dissertations that I edited, entitled *Scientists and Public Affairs*. The fact that it took MIT Press four years to publish it in an ugly and cheap-looking format, and that they apparently spent approximately 50 cents promoting it, kept it from making *The New York Times* best-seller list.

A Career in Science Policy

Armed with my political science Ph.D. from MIT and a dissertation on international scientific cooperation, I ventured into the job market, primarily seeking, like most of my graduate school colleagues and role models, a faculty position.

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[10] I had applied for the fellowship without any expectation of receiving it. I was so sure that I would not receive the fellowship that, when the letter from NIH arrived, I didn't bother to read it for several days and almost tossed it in the trash unopened.

[11] My dissertation Entitled "International Science and International Politics: A Study of Scientists' Attitudes," is available free from me as a PDF. Physics Nobel Laureate Isidore I. Rabi wrote a preface. Used copies are available from Amazon.com and elsewhere.

I soon had an offer for a tenure-track faculty position from a large Midwestern university that had just received a grant to establish a science policy program. It was a good offer. However, having spent nine years at MIT, I was not excited about leaving the Boston area for a small college town in the Midwest. In addition, my wife, who was a confirmed Bostonian, was not eager to be uprooted from her family. And to top things off, my father passed away suddenly in the midst of my deliberations. So, I decided to decline the offer.

Fortunately, I soon had two other job offers, one as a research fellow at a new policy institute at Syracuse University, the other at a Harvard program on technology and society funded by a grant from IBM. The Harvard program was rather lavishly funded and was doing some interesting work, but it struck me as oddly disconnected from Harvard's academic mainstream. The most memorable part of my interview at Harvard was lunch. The director and a couple of staff members took me to a popular restaurant in Harvard Square. To this day, I am still not sure whether ordering raw oysters was some kind of bizarre test to see how I reacted, or whether they were just amusing themselves, or whether they simply wanted oysters for lunch, but in any case, they ordered a plate of them as an appetizer for the table. Although I had never encountered raw oysters before and I found them rather disgusting-looking, I managed to overcome my reluctance and slid a couple of them down my throat without gagging. If it was a test, I must have passed, because I got the offer. However, I was uneasy about the program's relationship with the university and decided to sit on the offer for a while. In the end, I declined it in favor of the one from Syracuse.[12]

So, in the summer of 1969, my wife and I and our six-month-old son climbed into our VW Beetle and headed west on Interstate 90 to Syracuse, New York. My position was as a research fellow at Syracuse University Research Corporation (SURC) with an adjunct appointment in the Maxwell School of Syracuse University. I was based at SURC and drew my salary from there, while teaching one course a semester at the Maxwell School.

After four years in Syracuse I left to take an administrative post at SUNY Binghamton, which in turn led to an offer of a high profile position as director of research at new policy research institute in SUNY's Central Administration in Albany. These were good jobs, but it wasn't really the type of career trajectory I had in mind. Ultimately, it took the New York state budget crisis of the mid-1970s and the abrupt termination of the institute in Albany to get me to Washington and to the career in science policy I had been seeking all along.

George Washington University had created a Program in Science, Technology and Public Policy (STPP) in 1971. The director, John Logsdon, and I had met and become friends, and for some time we had been discussing the idea of my joining the GW faculty and becoming deputy director of STPP. The collapse of my situation in Albany offered the opportunity to

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[12] Although turning down Harvard in favor of Syracuse might have seemed odd at the time, it proved to be the right decision when, in July 1971, Harvard announced it was terminating the program on technology and society.

make this idea a reality. John was able to obtain a new faculty line for STPP. I applied and was hired.

I started at GW in the fall of 1976. I enjoyed my position in STPP as well my colleagues and our graduate students, but I also became involved in consulting with the then-new Congressional Office of Technology Assessment (OTA) which I enjoyed even more. So, after a decade in the academic world, I began to think about life outside the ivory tower.

As I was beginning to consider my options, an opportunity came across my desk. The American Association for the Advancement of Science (AAAS) had initiated an annual analysis of research and development (R&D) in the federal budget in an effort to engage the scientific community in the budget process more deeply than it had been in the past. The budget project was headed by Willis Shapley, a former official of the federal Office of Management and Budget (previously BoB, the Bureau of the Budget) where he had been responsible, among other things, for developing the templates and data collection instruments for the R&D items in the budget.[13] Shapley was a consultant to AAAS; he was assisted by a member of the AAAS staff who was preparing to leave AAAS and the Association approached me to work with Shapley and eventually take over the project.

Although I had been a member of AAAS since I was in graduate school, at first I didn't think the job was an especially good fit. Analyzing the federal budget seemed like a rather tedious and boring task. As I thought more about it, however, it began to look more interesting. I realized that the budget is the key to policy in the federal government. And I also realized that AAAS was about the closest thing to a *science policy* association that existed in the U.S. (or anywhere, for that matter). Finally, the pay and benefits were considerably better than what I'd been earning as an associate professor at GW. So I took the job, with the understanding that I'd stay about three years.

I ended up staying 32 years.

They were by far the best years of my career. My identity became interwoven with AAAS and, though I left at the end of 2011, it still is. In fact, many people who I met during my time at AAAS didn't even realize that I had a career before coming to AAAS. And although I didn't appreciate it at the time, the position into which I was stepping provided an opportunity to help transform the venerable 130-year-old Association from a rather sleepy organization to a major player in the science policy world.

AAAS is a membership organization and the publisher of *Science* magazine. It also pursues its mission of "advancing science and serving society" through a number of programs in science education, public engagement, and science policy. When I joined the staff in January 1980, science policy consisted mainly of two programs: the Congressional Fellows and the aforementioned R&D Budget Project. The unit was staffed by a handful of professionals and

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[13] A son of famous astronomer Harlow Shapley, he had joined BoB in 1942. He later served as the third highest ranking official of NASA and in a number of important behind the scenes roles in the space program.

supported by two secretaries. During my years there, I expanded science policy to a directorate that included about 40 people, many of them with advanced degrees, and half a dozen internationally-known programs.

I joined the AAAS staff on January 2, 1980. In those days, AAAS held its Annual Meeting during the first week in January, which meant I got to spend my first week on staff on expense account in San Francisco. Back in Washington, DC, I began to learn what I needed to know about the budget. The project involved collecting data from the major federal R&D agencies and OMB, using that data to prepare spread sheets that sliced through the budget in various ways, and writing a narrative interpreting the numbers. Willis Shapley knew where the bodies were buried and could cut through the verbiage and obfuscation in the agency presentations and the often-confusing tables of numbers. I learned from him.

This was 1980. The Internet was still a few years away from becoming a public utility and computers were mostly room-sized machines. Lacking one of those, we did our calculations on pocket calculators and typed (or rather wrote on legal pads and our secretaries typed) our text on IBM Selectrics. When Willis had a presentation to do, he prepared his overheads ("Vu-graphs") by hand using a china marker. We did three reports a year, reflecting the rhythm of the federal budget cycle. We also organized and ran a meeting called the "R&D Colloquium" (which I later changed to the "S&T Policy Forum") at which the President's science advisor and other major science and policy figures spoke before an audience that had started at about 100 and grew over several years to 400-500.

Preparing the first two reports and organizing the Colloquium meant I had a pretty full plate. It helped to have Willis's guidance as well as an assistant who been through the process a couple of times. She left, however, to go to graduate school. Fortunately, I was able to hire an excellent replacement. Jill Pace was a recent graduate of SUNY-Binghamton. She joined me on a half-time basis. The other half of her time was devoted to running the AAAS Mass Media Fellows Program. The two of us, plus Willis Shapley and a shared secretary, constituted the staff of the R&D Budget project. Jill is a quick study, and she and I hit it off well and worked together closely through several budget cycles.

Willis retired after a couple of years. Jill left AAAS after four years, but not before we had made major changes in the content of the R&D budget project and the process by which we produced the reports, taking advantage of the rapid developments in information technology. We also had the first of many additional projects fall into our laps, a contract from the National Science Foundation to prepare the policy section of a "Five-Year Outlook for Science and Technology." This proved to be a substantial job that resulted in a book that I co-edited with former Congressman Ray Thornton.

In 1984, my boss retired and I was appointed head of the Office of Public Sector Programs, home to a growing roster of AAAS science policy activities, led by the R&D Budget Project

and the Congressional Fellows Program[14] which recruited and placed scientists and engineers in one year policy positions on Capitol Hill. Three years later, AAAS acquired a new CEO, Richard Nicholson. As new CEOs are wont to do, Nicholson reorganized the AAAS staff, putting himself firmly in charge. My office was merged with another and, after a national competition, I became Director of Science & Policy Programs, reporting directly to the CEO, with a substantial increase in responsibility. Nicholson was an excellent manager but a reserved public presence. In his absence, I became the public face of AAAS in the science policy world.

Testifying before the House of Representatives Subcommittee on Research and Science Education

Nicholson's successor, Alan Leshner, who took the helm of AAAS in 2001, was much less reserved as a public leader and was quick to make sure the world knew that he was running the show. Meanwhile, my managerial role had grown substantially during these years as our suite of programs expanded. In one instance the National Science Foundation came to us for assistance in responding to a congressional mandate to strengthen research in rural states and those without a strong research tradition. We responded with an ambitious project that later became the Research Competitiveness Program. In another case, one of my senior staff initiated a "Program of Dialogue on Science, Ethics and Religion" (DoSER) with a multi-million dollar foundation grant. Initially, the idea of bringing religion into a scientific association upset many scientists and the program was quite controversial, but it has proven its value and is now an established part of the array of AAAS programs. In addition, we grew major programs in science and law, ethics, and human rights.

My knowledge of U.S. science policy and my friendships with members of the community of science diplomats in Washington led to invitations to visit and speak in a host of countries ranging from Canada to China, Sweden, Hungary, South Africa, Israel, New Zealand, and Iceland. I enjoyed these visits and I look back on the travel, research and entrepreneurship I did during my years at AAAS as the highlight of my career.

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[14] That program, which began in the mid-1970s with six Fellows, today places over 270 Ph.D. scientists and engineers in Congress and federal agencies every year and has contributed to a substantial increase in the amount of technical talent available to the federal government.

Science and technology conference Seoul

AAAS Board view 3D video at Jet Propulsion Lab

I retired from AAAS at the end of 2011. A group of my colleagues organized a *festschrift* -- a conference and collection of essays in my honor -- in the AAAS auditorium, a far better retirement gift than the traditional gold watch. Several of my colleagues spoke on topics related to my work and contributed chapters to a book published by AAAS entitled *The State of Science Policy*. About 150 people attended. My retirement did not last long, however. A few weeks later I moved into an office at the Institute for International Science and Technology Policy (IISTP) at George Washington University and became a Research Professor of Science, Technology and International Affairs, a position I hold today, a position at the edge of science, launched by degrees in physics and political science from MIT.

Al Teich '64 Course 8, Physics, Ph.D., MIT, Political Science (Course 17), '69. After a decade in academia, Al joined the staff of the American Association for the Advancement of Science (AAAS) in Washington, DC, where he spent 32 years, 25 of them as director of science policy, building a department that became one of the major centers for relations between the science community and the government. He retired from AAAS at the end of 2011 and is currently a research professor at George Washington University. Al and Jill Pace have been married 32 years; they have one daughter. Al has two sons and four grandchildren from his first marriage.

A Journey with Alice through Wonderland

Don Kunze

Introduction

Like Sir Isaac Newton, Einstein was a true mystic with an understanding of the universe that transcended science.

> ***"Everyone who is seriously involved in the pursuit of science becomes convinced that a spirit is manifest in the laws of the Universe - a spirit vastly superior to that of man." - Albert Einstein***

This essay will look at the how the integration of science, mysticism and spirituality has evolved over the past sixty years. What lies "Beyond" is the truly exciting period where time may no longer exist and quantum mechanics opens the doors to metaphysical reality. I begin with the 17th Century "Then" period where the birth of the scientific method took root. In his will Robert Boyle, a natural philosopher (scientist in today's terms) endowed a series of lectures on the subject of Christianity and natural philosophy. Today the broader category for the lectures is Religion and Science.

The first lecture was given in 1692 by Richard Bentley titled, "Confutation of Atheism." Impressed by the lecture Sir Isaac Newton wrote Bentley,

> ***"Sir, When I wrote my Treatise about our System, I had an Eye upon such Principles as might work with considering Men, for the Belief of a Deity; nothing can rejoice me more than to find it useful for that Purpose."***[15] [16]

The 2021 Robert Boyle lecture was given by the University of York's physics Professor of Natural Philosophy, Tom McLeish. The title was, "The Rediscovery of Contemplation through Science."

In Rupert Sheldrake's 2012 book, "Science Set Free" he argues that discovery through science is limiting because it defines itself through measuring the physical world. Quantum theory has thrown ill-defined consciousness into the equation while psychologists struggle with understanding the unconscious mind. McLeish argues for the mystical role contemplation and meditation play in opening the mind to discovery.

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[15] Scholars and Antiquaries (*The Cambridge History of English and American Literature in 18 Volumes (1907–21)*)

[16] "Notes on the Religious Orientation of Scientists" by Gerald Holton in *Science Ponders Religion*, Harlow Shapley, Appleton-Century-Crofts, 1960, p. 59

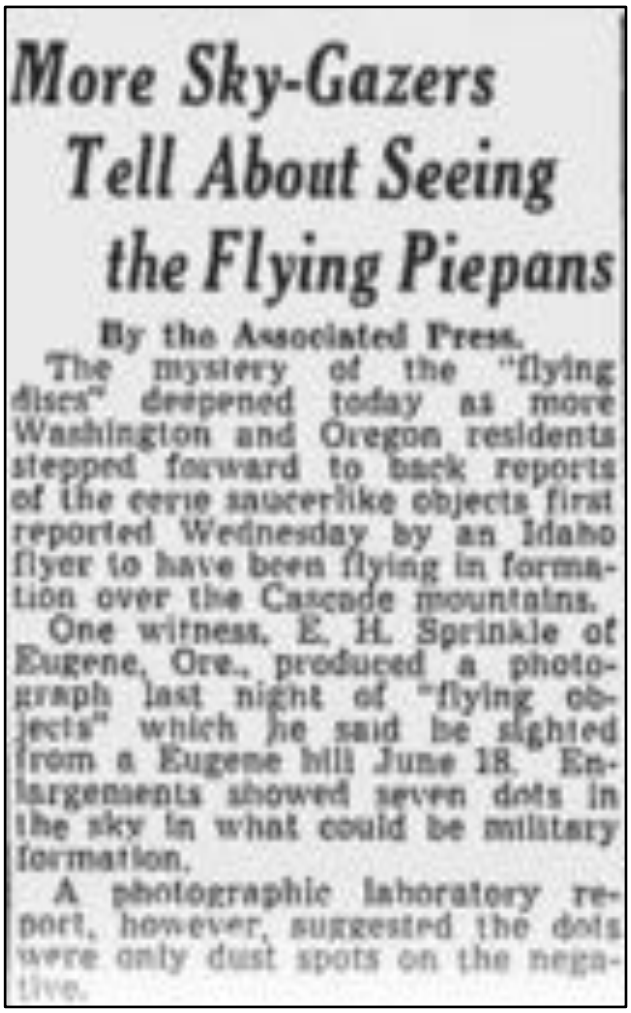
This essay takes me through my journey into seeking a greater understanding of how (the science) and why (the psychology of spirituality) of the life experience. The deeper question, "What is science for?" must be considered in the context of thousands of years of wars and human suffering. I have been joined on my journey by several teachers, some not of this physical world, to guide me. I will introduce them as they joined me on my path. Entering the unknown inevitably leads to more questions than answers. Prepare to enter a future world where Alice and Star Trek become reality.

The Beginning

On June 24th, 1947, Kenneth Arnold, flying his plane near Mount Rainier, saw a line of unidentified flying objects traveling at speeds estimated to be at least 1,200 mph. Thus, began a series of investigations by the U.S. Air Force into unidentified flying objects (UFOs). Today the more inclusive term, Unidentified Aerial Phenomena (UAP) has become the popular designation although the skeptic, Michael Shermer, prefers the term, Completely Ridiculous Alien Piffle (CRAP).

My Dad grew up in the small farming town of Alpena, South Dakota. During the 1920s period of barnstorming a small fee could get you a plane ride with a stunt pilot. This experience gave birth to my Dad's love of flying. He joined the Army Air Force and was a pilot during WWII. After the war he served as a test pilot and then joined the Federal Government's Civil Aeronautics Authority (CAA), the forerunner of the Federal Aviation Administration (FAA). His work at the CAA included certifying pilots for their commercial flying licenses, investigating airplane crashes, and assisting foreign governments in establishing commercial airlines and military air forces. He carried a top government security clearance enabling access to information in classified investigations.

Love of Flight, My Dad & Piloting at Age 11



More Sky-Gazers Tell About Seeing the Flying Piepans

By the Associated Press.

The mystery of the "flying discs" deepened today as more Washington and Oregon residents stepped forward to back reports of the eerie saucerlike objects first reported Wednesday by an Idaho flyer to have been flying in formation over the Cascade mountains.

One witness, E. H. Sprinkle of Eugene, Ore., produced a photograph last night of "flying objects" which he said he sighted from a Eugene hill June 18. Enlargements showed seven dots in the sky in what could be military formation.

A photographic laboratory report, however, suggested the dots were only dust spots on the negative.

1947 – The Birth of UFO Investigations

By age nine as an enthusiastic flying saucer fan, I started collecting books on UFOs and alien encounters, began a scrapbook of newspaper articles on UFOs, and corresponded with other UFO fans in the U.S. and England. I wondered how our civilization would respond to a more technically advanced alien civilization. Would their view of God or religion be different than our traditions or would alien views undermine our religious and moral beliefs? How times have changed! Earlier this year the Institute on Religion in the Age of Science sponsored a talk given by an anthropologist and a Jesuit astronomer from the Vatican titled, "Extraterrestrial Species: Will They be Moral? Will they be Religious?"

When I quizzed my Dad about UFOs he couldn't say much; it was classified information. A young kid with unanswered questions can be pretty persistent. A year before my father died, he finally offered a clue to my question of whether UFOs were real. He said, "*There is something to it.*" Maybe he was just getting me off his back. Who knows? Then finally in 2020 the Pentagon releases videos of UFOs filmed by Navy pilots in 2015 and 2004.

My nature is to understand how things work. Science could provide the answers I was seeking. During my adolescent years I used money earned from mowing lawns and babysitting to buy a six-inch reflecting telescope. Getting up at 2 AM, I would scan the heavens and marvel at the rings of Saturn and the moons of Jupiter. When Sputnik 1 launched in 1957 I followed it across the sky during its short life hoping in the process to catch sight of a UFO. Given my Dad's career in flying and my fascination with space it is no surprise that by the 7th grade I wanted to become an aeronautical engineer.

"*How does it work?*" a question that lends itself to physical things with determinant cause and effect results. On the other hand the question, "*Why?*" lends itself more to philosophical and social issues where answers are less likely to be black or white. In time I found the "*Why*" questions more interesting as I expected science would eventually answer the "*How*" questions. The nature of consciousness has since muddied the water of both how and why questions.

In the seventh grade I had a debate with a classmate on the issue of Papal infallibility. He was a practicing Catholic with an occupational goal to become a priest. Why can man claim the right of supremacy that only belongs to God? Does that allow man to be God when he wants to, and can any man claim that right? Unfortunately, belief and faith do not fall under the scrutiny of the scientific method so there can be no resolution, just a difference of opinion. Decisions will always have consequences for cause and effect is fundamental to the action of free will.

During high school I had an ongoing argument with a classmate as to whether the U.S. should recognize Red China. Who would have guessed 70 years later the China problem will dominate the future of the U.S. – China relationship. Action taken one way or the other has consequences governed by the uncertain nature of human consciousness. Science is much more adept at solving physical problems than social ones as is clearly evident in war and today's climate change debates. Eventually I applied to several engineering schools offering aeronautical engineering programs.

The 1960s

As the summer of 1960 drew to a close, I shipped a footlocker to MIT and hopped into the back seat of a car with a couple of MIT upperclassmen for the ride sharing journey from Miami to Cambridge. Growing up in a family that frequently relocated, I was comfortable with adjusting to new environments. Besides, I was born just the other side of Logan Airport and my parents still had friends living in the Boston area if I needed to be fed on weekends.

In hindsight, one incident was a small window of things to come later in life. I was taking an exam which consisted of one question with many parts, and I had absolutely no idea how to answer it. After sitting in thought for a few minutes thinking I really blew this test, ideas and equations just started flooding my mind, the ideas were not familiar nor made much sense, but I began writing furiously and handed in my paper. You can imagine my surprise when I received an A. What happened was weird but as I was to learn later, not unusual in events that have directed many chapters in the history of the arts and sciences.

How does one explain the genius of Alma Deutscher who played the piano at age two, the violin at three and began writing compositions at five? In interviews during her early years (she is now 16) Alma explained the music flows into her mind and she just writes it down. Often compared to Mozart she insists she just wants to be Alma. How does one explain this gift and why does it happen?

The San Diego Experience

In1969 I was living in San Diego working in the aerospace industry on a number of satellite projects. The excitement around the culmination of the moon landing project dominated the news that summer. San Diego was still a Navy town.

While I did not realize it at the time, an evening at a local night club was going to have a profound effect on how I would think about reality. Dr. Dean (stage name of Sanford Berman) was a professor of semantics, linguistics and communication at a local university. On

weekends he performed as a stage hypnotist at a local night club. This was my first experience with a hypnotist where volunteers from the audience become the stars of the show. That evening I witnessed the power of the mind I could not understand and my inquisitive nature needed to know more.

The following day I went to the San Diego Public Library and took out every book they had on hypnosis. A whole new world of the mind was opening for me to explore. Persons surviving possible imminent death often report their whole life passes before them as though in real time but actually occurring in a second. What game is the mind playing with time? The impact of my San Diego experience would lay dormant for many years, but the seeds were planted that would lead to exploring the world within as a window into reality.

1980 - The Inner Journey Begins

Following the moon landing in1969 and with the Viet Nam war needing financing the Government cut back funding on its space programs. I decided to take my MBA degree and deploy to places afar by joining the international department of David Rockefeller's Chase Manhattan Bank. I moved to London at a time London was considered a hardship post. In 1980 having returned to New York, a colleague pestered me to take a meditation class. After several months of protesting, an inner voice told me it was time to go. I called Ella, the meditation teacher, and said, "I think I am supposed to attend your meditation class." She explained this meditation was very spiritual and not like EST. EST, later called "The Forum," was a human potential empowerment program founded by Werner Erhard in the 1970s. I ran into another colleague later that day and explained I was beginning meditation classes and he said, "Knowing you, Don, you probably looked at a dozen meditation courses, did a cost benefit analysis of each one and made a selection." I explained that was not the case. It chose me.

At the first session I met ten other participants all of whom had been attending these sessions for various periods of time. I was the newest member but quickly felt comfortable as the group consisted of similar professional types varying from a CEO of an insurance company, to a Catholic priest. Ella began by introducing me and asked how my life was going. I said it is going fine, a wonderful family, great career, lots of fun travels. She replied, "What about the Beatitudes?" Not being especially religious I was at lost what to say but my life was about to change.

Ella led the Thursday meditation sessions that included certain visualization exercises. The unsettling thing was Ella could read our minds and if necessary, correct our visualizations. About once a month there would be a weekend workshop led by RW who was channeled by Ella's daughter. When growing up in the New York suburbs she would visit NYC and meditate at St. Bart's Church on Park Avenue. At 13 an inner voice (RW) told her she would become a medium and at 18 she was told it was time to begin.

RW had been a physical person on the earth whose profession was in psychology. After his transition he chose not to reincarnate but continue his journey toward the "light." As part of his service, he counsels individuals on the earth who chose to be mentored. RW has access to the Akashic records that store every soul's experience, feelings and emotions for all

their multiple lifetimes. Unlike traditional worldly therapists who must uncover your hidden issues, RW knows everything about you. One has no secrets. Earth is seen simply as a school where souls come to learn lessons that will eventually free them from the limits of their ego.

The priest in the group told me it took him a couple years before he felt comfortable with RW. In his first individual session he thought RW was very critical and judgmental. He listened to the taped session a year later and he did not hear any criticism or judgment, illustrating how the ego projects. It took me two years before I was sufficiently accepting to have an individual session with RW.

In one workshop assignment we were instructed to pick one day during the week to speak out loud every thought that came to mind. RW suggested it might be best not to choose a workday! Of course, no one could do the assignment, but its purpose was to point out the secret nature of one's mind chatter.

In some of the RW's workshops a few participants noticed and commented on seeing other "pesons" attending in what one might call the rafters of the room. Most of us did not see these beings. When asked who these "light beings" were, RW said there were many souls on the other side taking the workshop. [Another clue to other dimensions].

On an occasion in the seminary the instructor stopped in the middle of her lecture to note that my mother and father were standing behind me. Unfazed she just continued with her lecture. It appears there is much to learn once we leave our earth bodies.

More Doors Open

I have had a number of teachers not of this world. Why so many? I suspect when it comes to D experiences, I am a reluctant student and repetition becomes an essential part of my learning. While this essay is about my personal journey it is also about everyone's journey. Many of my experiences will be understandable for those readers who have had similar experiences. For other readers the events do not fall within their cognitive world and acceptance of a different view may have to await one's later and hopefully wiser years or inevitable transition.

Following a lecture by Dr. Eben Alexander, the neurosurgeon and author of "Proof of Heaven," a woman commented to Dr. Alexander, "Your experiences had a profound effect on how you see the world, but these are not my experiences. As an atheist, I find your story interesting, but it doesn't change my view of life." This woman was sitting behind me and I turned to her and said, "Your view might be correct but just in case you are wrong wouldn't it be worthwhile to explore an alternative view to lessen any shock when you make your transition?" Her response, "You have a good point!" Dr. Alexander explained the title of his book has nothing to do with proving heaven. Rather the title was chosen because the publisher thought it would sell more books. Capitalism reigns supreme!

The Connecticut Period - Westport

Compared to the advances made in the physical sciences over the past sixty years, the social sciences have lagged far behind in addressing the society's problems around anger, anxiety, depression, violence, poverty, discrimination and mental health. Inevitably all these conditions can be defined in terms of relationships with the self, family, community, nature and one's environment. The hard sciences offer solutions to increasing the world's standard of living but do little in addressing society's social problems. It is in the soft sciences that major breakthroughs are needed to truly make this world a better place.

The Town of Westport is an affluent commuter community for New Yorkers preferring the quieter country life. When I moved to Connecticut, I found Westport also had this blossoming spiritual community and Pymander, the best New Age bookstore in Connecticut. Founded in 1973, Pymander had the most comprehensive collection of new age and spiritual material. The smell of incense greeting you upon entering and the sparkle of gems and crystals had a feel of ancient wisdom. Authors gave lectures and had book signings and there was a large bulletin board with notices of every new age event and practitioner in the area. Once a month there was a social gathering at the Westport Unitarian Church where merchants peddled their spiritual wares, discussion groups met, and the evening progressed to music and dancing.

Westport in the late 1980s was the setting for an evening with Emmanuel. Pat Rodegast was a psychic medium that channeled the spirit entity, Emmanuel. Whenever Pat was visiting her daughter in Connecticut she would host these evenings with Emmanuel at the Westport Women's Club. These evenings were always full house, standing room only events. Half the evening was devoted to a talk by Emmanuel followed by a period of questions and answers from the audience. One evening I asked Emmanuel to comment on the book, A Course in Miracles. He said it was the best book about truth today, but it was not really truth. Rather it was a path to experience truth because truth can only be experienced. Ah! another piece to the puzzle!

During Pat's time in Westport, she also held small seminars led by Emmanuel at her daughter's house. Unlike the Women's Club lectures, these gathering were small and intimate. There is a compilation of some of Emmanuel's teachings published as Emmanuel's Book I, II, and III.

The Course

I dated a woman I met at one of the Unitarian church spiritual soirees. She was a student of A Course in Miracles (ACIM or The Course) but she never would tell me what the Course was about. Her comment always was, "It is a personal thing." Such secrecy was very unlike the "born again" sharing mentality of persons discovering meaningful spiritual wisdom. When the relationship ended, I thought I might gain some insight into the relationship by studying the Course. So I headed for Pymander where I secured a copy of The Course.

The Course was channeled by Dr. Helen Schucman, a professor of medical psychology at New York's Columbia University's College of Physicians and Surgeons. For seven years be-

ginning in 1965 Dr. Schucman served as the scribe to a voice she heard say, "This is A Course in Miracles, please takes notes." Each day Helen would take her notes to the office and her boss, Bill Thetford, who ran the department, would type up the notes, Xerox copies, and lock them away in a filing cabinet. There was no need to let the scientific community tarnish Bill's and Helen's professional reputations.

The Course consists of a textbook, a workbook of 365 lessons, a teacher's manual, and a couple of pamphlets on prayer and psychotherapy. The Course says it is only one of a thousand paths to experiencing truth, the peace of God. The approach the Course teaches is undoing the thought system of the ego that is found in every human mind. The Course offers the most sophisticated explanation of the nature of the mind since Freud's work introduced the concept of the ego.

The voice dictating the Course is Jesus and this fact appears to make it easier for Jews to accept its authority than do Christian traditions. In part what Jesus teaches in The Course conflicts with Christian theology and there lies the rub. Who is the authority to resolve differences? Are we back to the infallibility doctrine of the pope?

Ken Wapnick spent a year with Helen preparing the material for publication and went on to become the master teacher of the Course. One of the Course students bought Ken a resort in the Catskills where Ken taught during the spring, summer and fall seasons. I spent a couple of weeks and many weekends every year attending Ken's classes.

The resort could accommodate 100 students. Long term students provided the housekeeping and meal services. One staff student was Mary, a former nun from Australia. There was a large common room and kitchen for students to use when the main dining room was not in service. During one lunch break a number of us, including Mary, retreated to the common room to have our lunch. At one point a woman remarked to Mary that a man was dancing behind her. A second woman began to describe him, and Mary said, "That is my father." Now neither Mary nor the rest of us saw anyone behind Mary. The two women said Mary's father wanted to tell her he was glad she left the Catholic Church and found ACIM. This was very confusing to Mary because her relationship with her father was hostile, estranged and alienated during the time he was alive. He had died eight years earlier but now he was full of joy, happy, and supportive.

This event became the subject for the class the following day. Mary was totally confused, trying to reconcile her past experience with a new reality of her father. Ken explained that she was ready for healing that opened the door for both she and her father to find peace.

Albany, New York and Archangel Gabriel

One morning in October 1987 Rev. Penny Donovan stepped to the lectern in the church she founded to give the Sunday sermon. She began with a meditation and the next instant the whole congregation was standing and applauding. The only thing she could remember was beginning the meditation and she wondered what happened? The people were saying,

"*It was wonderful. A teacher came."* That was the beginning of 12 years of teaching by Archangel Gabriel.

During that period, I traveled every month to Albany to meet with clients. When I visit a new city, I often check with the Miracles Distribution Center worldwide directory of ACIM study groups for weekly scheduled meetings. This is a great way to fill an open night with likeminded warm genuine people. At one such meeting it was mentioned that Archangel Gabriel regularly gives seminars. Always curious what "the other side" was offering I decided to attend one of the seminars. It was an opportunity to see how Gabriel's teachings lined up with the other experiences I had with non-physical teachers.

One of the attractions of the seminars was the opportunity for participants to dialogue with Gabriel. We could ask anything with the single exception we were not to ask personal questions. Of course, a clever mind can pose a question in a way it is not personal and still receive an answer that addresses the personal Issue.

We asked Gabriel why he just didn't manifest in some physical form. He replied that people would tend to focus on the form and not the message. He explained that he had been working with Penny's energy for 500 years (our time as there is no time in the spirit world) to prepare for this teaching period. He added he comes about every 2000 years to formally teach as it can take that long for the limited mind to accept new ideas. We asked him where Penny goes when he is using her physical body. He said, "She goes horseback riding." [More clues about higher dimensions].

Gabriel does not see form like humans do but he sees people as separate energies. Gabriel was never angry or judgmental. He has a great sense of humor. His use of English was entertaining, calling ice cubes little glaciers and homes, abodes. He finds communicating with words very limiting as there simply are not words in English to explain some concepts. He can read people's minds saying telepathy is a much better way to communicate. He would often answer the question behind a question before it was asked. One can imagine that twelve years of lecturing produces an immense library of knowledge. All of Gabriel's sessions were recorded and some are available in CD form at www.sacredgardenfellowship.org. A number of seminars have been transcribed, grouped by topic and are available in book form at Amazon.com.

2010+ The Reluctant Messiah

As I reflect on nearly seven decades of dreams and realities and joys and sadness there is realization that comes into focus. It is as though a force has been trying to guide me and I finally begin to surrender. I remember in a workshop RW had given an assignment to do during the following week. When the class reconvened, he asked who wanted to report. When there was not an immediate volunteer, RW said, "Don, why don't you go first." As the workshop concluded he addressed me, "There is a reason I called on you first. You are here to be heard, so speak up, join a choir, and find a way to use your voice." My thought at the time was, what was that about?

Several years later I was in training to be certified as a Reiki practitioner. Reiki is a Japanese technique of channeling universal life force energy (qi) through one's hands to bring about a balance of the body's energy fields. This healing technique promotes relaxation and stress reduction caused from anger or anxiety thus is treating the symptom rather than the cause. Reiki opens the energy flows of the student's chakras. All was going well in my certification process until she reached my throat chakra and she started coughing uncontrollably. To unblock the energy flow, she advised I needed to give my voice its purpose.

A number of years later I attended a healing workshop in Palm Springs, California given by a psychic medium. During the course of the three days the medium's guides told me I was an outspoken critic of the Church during the period of the inquisitions and for my blasphemy was burned at the stake. That memory has been a barrier to fulfilling my purpose, I was reminded the world is different now and it is time to let go of that fear.

2013, Entering the Interfaith Ministry

As I approached retirement a clergy friend suggested I attend seminary, specifically, an interfaith seminary. Interfaith recognizes oneness as the underlying essence of mankind. I thought studying all the religions will help prepare me for teaching. I was ordained in 2013 as an Interfaith Minister. While I have served as a guest pastor in Interfaith and Protestant churches, I am drawn to exploring the spiritual relationship between science and religion. In 2015 I gave a talk on science and spirituality at the Parliament of the World's Religions held in Salt Lake City. It was a great place to connect with like-minded interfaith science types. Another field of study I find interesting is progressive revelation, the idea that messengers of God take an active role in every generation.

A Revisit with MIT

As the raging and sometime calm currents of life have taken me on this spiritual journey, that boyhood wonder of exploring the universe remains a bright light within my ageless mind. When I attended the Aero/Astro Department's Centennial Celebration in 2014, enthusiasm for the mysteries of space brought renewed excitement. And again, as I watched the recent landing of Perseverance on Mars the excitement of being part of the space program reminded me that there is something sacred about the innocence of youth. Elon Musk had renewed the spirit of discovery through the goal to send men to mars. Looking back over my aerospace years there hasn't been any major breakthrough in flight since 1960. The Concord offered a glimpse of supersonic commercial travel but the economics didn't make sense. Technology had no solution to the environmental problem of excessive engine noise on takeoff and landing or the shock wave boom when going supersonic over land. All electric aircraft prototypes demonstrate the viability of electric flight but power to weight energy storage is the main constraint. The real solution to space travel will require a system that can use the energy naturally existing in space to power flight. Maybe we need to capture a UFO and reverse engineer its technology!

The Astronauts of MIT Aero/Astro Dept. Centennial 2014

The Spiritual Journey in Form

Camino de Santiago -- A 500 Mile Pilgrimage Across Northern Spain

In early 2018 when my son returned from his 18-month motorbike trip from Connecticut to the tip of South America he suggested we get the family together for a real pilgrimage across northern Spain, the Camino de Santiago. Known as "The Way of Saint James" for the apostle James' who taught on the Iberian Peninsula, this pilgrimage has different starting points in Europe all ending at the tomb of St. James in Santiago, Spain. The most popular route is 500 miles in length and begins at the foot of the Pyrenees in the French town of St. Jean Pied de Port. In April and May of 2018, before my body would wear out, I undertook this journey that is captured in the movie, "The Way," starring Martin Sheen and Emilio Estevez.

Reflections for Contemplation

A major challenge in teaching is language. Words are very limiting. I use the word man and the listener hears it filtered by his experience and perception. It is difficult to hear the word man and not think of a body. ACIM states, "…words are but symbols of symbols. They are thus twice removed from reality."

Try to explain what an avocado is to someone with no experience of that fruit. It is only by experiencing an avocado can one knows what it is. But two individuals seeing, touching, smelling and tasting an avocado for the first time will still have different experiences. Great teachers, like parents explaining something to their children, must use the limited language and awareness of their students, trusting this approach will awaken in them a path to truth. Jesus used parables as a teaching tool for that is what his audience could understand. My teachers often presented concepts that the English language is not capable of describing. Thus the reader may find some of the following ideas too extreme to believe. They aren't my ideas but come from entities in dimensions beyond the limitations of our space-time universe. The intent here is to arouse curiosity that can lead to exploring the greater mysteries of life.

Our world is full of problems and we must learn to look beyond our perception to find the solutions. All minds are joined and connecting to the universal mind will allow the power within to help us see differently. Setting aside arrogance and learning to ask for directions is a quicker way to return home.

> ***"You cannot solve a problem with the same level of consciousness that create it." – Albert Einstein***

There is nothing new to learn. We need only to remember.

> ***"What has been will be again, what has been done will be done again: there is nothing new under the sun," -- Ecclesiastes 1:9***

The Illusion of Time

Time remains one of the great mysteries of science. The Big Bang is generally accepted as the birth of space-time, but does that mean there is a characteristic of reality that is no-time? What existed before the Big Bang? In the three dimension of space we are free to journey in any direction. Add the fourth dimension axis of time and we are caught in the Arrow of Time. Time appears to move in only one direction from past to present to future. This is not the case in the physics and math of the very small universe of particle and quantum mechanics.

One's past, present and future are all occurring simultaneously. Super string theory may suggest these incarnations represent different dimensions. It is like having a personal reincarnation video library where one can choose the video of any lifetime to view at any moment. Reincarnation is a linear time concept but since time is an illusion, so reincarnation is not true. That makes reincarnation part of the dream. Still the experience of reincarnation may be necessary in helping the mind awaken from Adam's dream.

If the mind has the ability to manipulate the experience of time one can postulate that the mind exists beyond four-dimensional space-time. Gabriel explains that time does not exist in the angel world. Time was invented to measure change. Timelessness is no time. Now that sounds very boring. Man experiences time as linear but that is true only in a dream state where the dreamer can make up the laws. The human mind has chosen to live in a dream of linear time, limited by the Arrow of Time that flows in just one direction. None of this will make sense until we wake up from the dream.

The Split Mind

What is the mind? The answer can only be given in symbolism. The apostle Paul expresses the idea of a split mind in Romans 7:20-23, "Now if I do what I do not want to do, it is no longer I who do it, but it is sin living in me that does it. So, I find this law at work: Although I want to do good, evil is right there with me. For in my inner being I delight in God's law; but I see another law at work in me, waging war against the law of my mind…" A more contemporary explanation was given by the comedian, Flip Wilson, "The devil made me do it!" ACIM explains that the mind is inhabited with two opposed thought systems, spirit and ego. Gabriel taught that unlike angels who can only do the will of God, the mind has free will. Endowed with the power of creation a mind thinking what it would be like to be separate from its source, created separation, this dream of duality. With this illusion came the ego. The question for which I have no answer is, "Who is the dreamer that must decide which mind to follow, spirit or ego?"

What is the Ego?
The ego is the thought of separation from which the dualistic world arose. It is a thought system of limitation, hate, scarcity, judgment, guilt, punishment and suffering, sickness and pain. Guilt arises from judgment and the ego gets rid of guilt by projecting and suffering. This process only reinforces the cycle of guilt. The ego is like Hal, the computer in 2001: A Space Odyssey. The ego's goal is survival, and its motto is "kill or be killed" whether it requires killing a body, including its own, or a string bean. The thought system of spirit is the opposite of that of the ego: love, joy, abundance, health, innocence and peace. There is infinite energy from which the mind (spirit or ego) can create anything.

God is a symbol for something unknowable
The ego mind perceives linearly and thinks in terms of a beginning. But time is an illusion that has no beginning. The Book of Genesis starts with, "In the beginning…" but if there is no time, there can be no beginning. The student must be taught within the framework of his perspective because that is the only way he can learn. What is the nature of the source from which the mind was birthed? These questions are best answered with myths, like teaching with parables. Myths provide direction, a path but not truths.

The split mind uses the body but is not the body
Man defines his reality by the attributes of the body's five senses. This is very limiting except to the mind that believes death of the body is the end of reality. The physical body is the vehicle used by consciousness for having experiences on the earth. Different dimensions may simply be universes of different vibrations, different frequency worlds. When Gabriel explained Penny goes horseback riding when he is using her body to teach, that implies Penny's consciousness has moved out of the low dense frequency of this dimension to another dimension where there is form. Likewise, when attending one of RW's workshops some participants saw non-physical entities also attending. Form was seen at a higher frequency, a higher vibrational dimension. I suspect these non-physical entities exist in a dimension of UV frequencies. Just as butterflies, deer, sockeye salmon, bees and some dogs and cats have vision in the UV portion of the EM spectrum, humans who see auras and ghosts have this fringe sight ability as well.

Sickness is of the mind, not the body
A consistent teaching among my teachers is there is no need to experience illness nor is there a need for the body to age or go through suffering in the dying process. Harvard psychology professor Ellen Langer led a radical study in 1981 by creating an authentic 1959 time warp in a New Hampshire monastery. Her subjects, eight men in their 70s, were to spend five days immersing themselves in the experience. Biometric measurements were done before and after the study. The results showed a clearly measurable reversal of aging suggesting the power the mind has to affects the body's health. Prof. Langer's study has been replicated by other researchers. Currently she is using VR (virtual reality) to update and expand the scope of her original counterclockwise study.

Our Spiritual DNA

The NBA Curry brothers, Steph and Seth, carry the DNA of their NBA father, Dell Curry. The football Manning brothers, Cooper, Peyton and Eli carry the DNA of the NFL father, Archie. These families speak of the power of good DNA. Likewise, having been created in the image of a Creator, the mind is endowed with great wisdom and power. This describes the spirit mind or Christ self before the separation. Consciousness of mind is not a body but energy with free will, created in the image of God and therefore the mind carries the spiritual DNA of God. Thought is the creative mechanism. Jesus says in ACIM, "There are no idle thoughts. All thinking produces form at some level." We have to consider the whole universe is a creation of the ego mind. This is not a problem given the ego also has the creating power of God. Where time exists, so lives the dream. Reality may then exist on the other side of the Big Bang.

Energy is the foundation of all form

We know from Einstein's simple formula ($E=mc^2$) all things are a form of energy. Intangibles are also energy like love and hate. Energy can sustain form like the rays from the sun sustains life on earth. There is an energy source referred to in the Bible as the silver cord (Ecclesiastes 12:6). This cord represents a conduit through which energy flows to sustain life in a body. It is not measurable by today's science, but death occurs when the cord is severed. God is in all things because God is the energy from which all form arises. The mind of man being made in the image of God has the power to create. The quantum idea that nothing exists until it is observed describes a process of creation. What the mind seeks it will find through its power of creation.

The universe is an illusion

It is not uncommon for people to have an experience of waking up from a sleeping dream and feel it actually happened. In Genesis 2:21 the Lord God cast a deep sleep upon Adam but nowhere in the Bible does it say Adam ever woke up. The Big Bang brought forth space-time and that introduced another level of dreaming or the linear time universe from which we have yet to awaken. Lucid dreaming is a state where the dreamer realizes he is dreaming and as this awareness grows it can allow the lucid dreamer to take control of what happens in the dream. Since all minds are joined there are an infinite number of combinations of events and outcomes. The dreamer is the playwright.

Christianity and the Mind

The mind is energy of consciousness consisting of competing thought systems, spirit and ego. Jesus at one time was a man like any of us with an ego and spirit or Christ mind. Prior to his incarnation as Jesus, he had many previous lives that prepared him for his final incarnation. Before his lifetime as Jesus, he was the Buddha where he learned compassion, the final preparation for his last incarnation. It was in his last lifetime Jesus released his ego and became the Christ. He said, "I and the Father are one." [John 10:30]. With no ego, His mind was now one with the Creator. In John 14:12 Jesus says, "Very truly I tell you, whoever believes in me will do the works I have been doing, and they will even do greater things than these." Jesus controlled the weather when a storm arose while he was in a boat with his disciples. The implication is there is a power within the mind of man to manage

the global warming crisis. Following his crucifixion Jesus materialized in the upper room to meet with his disciples. When Captain Kirk instructed his chief engineer, "Beam me up Scotty," maybe the same science used in Star Trek to get Kirk back to the Starship Enterprise was used by Jesus to enter the upper room. Mrs. Schwartz seemed to have access to this science.

Ten months after her death, Mrs. Schwartz, a terminally ill participant of one of Dr. Elizabeth Kubler Ross' seminars on Death and Dying materialized in the halls of the University of Chicago to ask Dr. Ross to promise not to give up her research on death and dying. A personal account of this incident can be found in Dr. Ross' book, "Death is of Vital Importance." Archangel Gabriel gave a number of fascinating lectures on the Life of Jesus that are compiled in a book, "Christ Becoming, The Lives of Jesus and His Path to the Christ," available on Amazon.

Implications for a troubled world

How can mankind harness these teachings to bring about a more peaceful and abundant world? First, by realizing man is not a body but chooses a body for a particular life learning experience. This awareness would go a long way to eliminating racial, ethnic, and gender prejudice, discrimination and persecution. In any given lifetime, based on the lessons a person chooses to learn, an individual can incarnate as any gender, of any race or ethnicity and in any economic or health condition. Such awareness supports a culture of equality, compassion and oneness. Realizing that thought creates coupled with the abundance of energy, poverty would begin to disappear as mankind learned how to use these natural laws. A widespread knowledge of how the mind creates the condition of his health would have a massive effect on individual well-being and the world's health systems. The healing of the thought system of any one individual benefits all mankind because all minds are joined. When all minds attain the Christ state, the world would no longer serve a purpose and the universe would disappear. The dream would be over.

Looking Back and Forward

An interesting aspect of invention and discovery is science can be a distraction to the goal of waking up from the dream. Science has been used for war and destruction as well as improving life on this planet. So what is science for? The answer lies in the free will of men where science can be used by the ego to keep the mind trapped in the prison of limitation or released into the bountifulness of spirit. Dr. Jerry Jampolsky, founder of the Center for Attitudinal Healing International, author of 20 books and an inspirational leader in the ACIM movement, died this past December at the age of 95. When asked shortly before his passing how he felt, he answered, "Still learning." Rabbi Joseph Gelberman, author and founder of the first interfaith seminary, passed away in 2010 at the age of 98. Just before his transition he said, "I have so much more work to do." My journey has led to a much-energized period in my life where my cup is overflowing. With fewer years in front of me than behind me, there seems so much to do. But then, time is an illusion.

> **"The intuitive mind is a sacred gift and the rational mind is a faithful servant. We have created a society that honors the servant and has forgotten the gift."**
> **Albert Einstein**

Don Kunze ‘64 Course 16, AeroAstro, ’65 Masters Aerospace Engineering, Cornell University, ’68 MBA University of Chicago, ’13 Ordination All Faiths Seminary International, started his career as an aeronautical engineer. With the post man-on-the-moon period leading to less funding of the aerospace industry, Don having obtained an MBA entered the world of finance. He later pursued his humanistic and spiritual calling. He is on the staff of the All Faiths Seminary International and active in a number of organizations including the Sacred Garden Fellowship, Parliament of the World’s Religions, Institute on Religion in the Age of Science, Connecticut Council for Inter-religious Understanding, International Society for Science and Religion and the Foundation for Inner Peace. He now resides in Plymouth, Mass.

Helping Poor Countries Meet the Climate Challenge

Shyamadas Banerji

"To myself I am only a child playing on the beach, collecting a few pebbles while the vast ocean of truth lies undiscovered before me." Sir Isaac Newton.

Introduction

Having worked on international development for almost fifty years, I am conscious of the great strides that many developing countries have achieved in improving human welfare and reducing poverty. But much remains to be done, particularly in Sub-Saharan Africa, South and East Asia and parts of Latin America. Poor governance, corruption, weak institutions and low education levels are major barriers to development. However, another significant exogenous factor has emerged over the past two decades as a major constraint to the development of these countries, namely Climate Change[17]. This is affecting their ability to use their own natural resources such as coal and oil on which developed countries based their industrialization. Climate is also impacting agriculture which accounts for the highest share of Gross Domestic Product and employment in many poor countries.

I prepared an initial draft of this paper for the MIT Alumni Climate Action Group (MACA) which I joined late last year. At Robert Popadic's request for an article for the 57th class reunion publication, I thought Climate Change would be an area of interest and decided to revise and expand the original paper. This version provides a deeper dive into the climate crisis, describing known approaches to addressing them with a special focus on assisting developing countries which are the most vulnerable and lack the resources to address them. Jim Monk has helped me enormously by editing this paper. I am grateful for his assistance. The footnotes provide links to publications which I have drawn on to write this paper and provide more detailed information on the topics.

This paper has five sections:

1. Background to the Issue
2. Developing and Implementing a Climate Action Program (CAP)
3. Implementing CAP: Apex Implementing Agency
4. Mobilizing Resources for Climate Action
5. The Way Forward: Some Reflections for the Future

The broad framework guiding this paper is:

- Reduce Green House Gasses (GHG) Sources: Bringing emissions to zero from fossil fuels.
- Support Carbon Sinks and carbon capture: Use nature's carbon cycle.
- Improve society by reducing vulnerability and building resiliency.
- Reallocate capital to focus on mitigation and helping the poor to adapt.

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[17] The first mention of climate change according to Elizabeth Kolbert in her new, very readable book "Under a White Sky: The Nature of the Future" was in 1965 when a report on the problem was provided to President Lyndon Johnson with a proposal to use solar geo engineering to reduce global warming.

Background to the Issue

I have been observing the impact of a changing climate for many years both in Arlington, Virginia, where I live and my home in Kolkata, India, which I try to visit every year. Increasing summer high temperatures in both places are just one sign of this phenomenon. Because of my career in global development, I follow news stories and journal articles about climate change and its impact on developing economies. Misguided government policies can lead to dramatic environmental disasters. The Aral Sea in Uzbekistan was a massive inland sea providing water for agriculture, fishing and tourism. But overuse of the water for cotton cultivation has left it a trace of its former self. A National Geographic cover photo from 2010 (actual photo taken by Philip Micklin in 2005) of fishing boats stranded in sandy shores is iconic of climate disasters.[18]

Climate change is a global phenomenon that does not respect national boundaries. Impacts are visible everywhere from coral reef bleaching off the coast of Australia, melting ice shelves in Antarctica, receding Himalayan glaciers to increased desertification in the Sahel,

[18] More details in https://earthobservatory.nasa.gov/world-of-change/AralSea

all of which pose a serious crisis to human lives and livelihoods[19]. Climate change is visible in more frequent extreme weather events such as unusually strong hurricanes and cyclones as well as steadily rising temperatures and the phenomenon known as the polar vortex which brings extremely low temperatures to the southern USA. One of the two hottest years on record in the USA was 2020. New Jersey and Rhode Island are two of the states with the highest temperature increases.[20] The February 2021 snowstorm in Texas which created havoc in the state is another event which is very likely linked to climate change. Scientists have now established with high confidence that anthropogenic (human caused) factors are responsible for the steadily rising temperature from preindustrial times.

The human impact of the Climate Crisis is most pronounced in developing countries where poor people are affected badly, lacking the capacity and resiliency to cope. Tangible and intangible impacts are affecting living standards and economic growth, increasing income inequality, and generating strife and conflicts over access to scarce resources such as arable land and water. The most visible manifestation of these impacts is international migration from the developing world to richer countries (West Africa, Afghanistan, Middle East, Myanmar and Central America).

The poor living in cramped slums in cities and villages which lack basic infrastructure are the worst affected by the increasing occurrence of serious climatic events resulting from steadily rising temperatures. Water shortage from severe droughts, heavy rainfall from cyclones, prolonged high temperature spells cause adverse health impacts from new viruses, pathogens and bacterial infections. Morbidity and mortality rates are much higher than in the wealthier sections of the community. The ability of the poor to earn a decent living and contribute to society is severely compromised as agriculture, small industries, and services such as tourism which provide most of the employment to the poor in some areas, are adversely impacted.[21]

An important objective is to inform developing country governments of the urgency to build institutional capacity to develop national climate action programs to deal with the urgent climate crisis and assist the poor build resiliency to the adverse climate impacts. This latter need has become even more urgent as few developing countries have taken any action to improve on their pledges made in the 2015 Paris Agreement on Climate for submission at the forthcoming Glasgow climate conference, aka COP-26 (discussed later).

Multilateral development banks (MDBs) such as the World Bank are taking measures to support developing country governments build policy and institutional capacity and are increasing their financing for mitigation and adaptation projects. But the challenge is daunting, and progress will require coordinated collective international effort. Mark Car-

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[19] This website offers different visualizations of the impact of climate change https://visme.co/blog/climate-change-facts/. See also https://www.climatewatchdata.org/key-visualizations

[20] https://www.washingtonpost.com/graphics/2019/national/climate-environment/climate-change-america/?itid=lk_interstitial_manual_5

[21] Read the book by Kim Stanley Robinson "Ministry for the Future: A Novel, Orbit 2020 The novel is about climate change and poor countries and how climate change is affecting the poor inequitably. Its main protagonist, Mary Murphy, heads a UN agency responsible for representing the interests of future generations and getting world governments to align behind a climate solution.

ney, the new UN Climate Envoy made this statement recently-"Climate change affects the least well off in our society the most, but if we get it wrong, the transition [to net zero] will also affect those very same people." Larry Fink, CEO of Blackstone Group, the largest asset management firm in the USA commented recently on climate change as follows: "A successful transition – one that is just, equitable, and protects people's livelihoods – will require both technological innovation and planning over decades. And it can only be accomplished with leadership, coordination, and support at every level of government, working in partnership with the private sector to maximize prosperity. Vulnerable communities and developing nations, many of them already exposed to the worst physical impacts of climate change, can least afford the economic shocks of a poorly implemented transition. We must implement it in a way that delivers the urgent change that is needed without worsening this dual burden." Unfortunately, global commercial banks seem blind so far to the urgency of halting financing of fossil fuel projects.

Climate change as a research and policy topic has attracted the attention of scientists and policy makers worldwide. The domain of climate change is vast and covers many disciplines and no overview paper can hope to capture all aspects of the problem such as biodiversity impacts. I have attempted to synthesize many news reports and studies to bring out key lessons for policy makers in developing countries. Any failure to include critical issues is mine alone. In writing this overview, I am reminded of the quote from Sir Isaac Newton headlined at the beginning of this paper about how little we know about nature and the scientific factors influencing climate and the vast realms of scientific knowledge that remain to be discovered.

Predicting the Earth's Future Climate

Because future climate depends on current and future human behavior, which is inherently unpredictable, scenarios are used to characterize a range of plausible climate futures and to illustrate the consequences of policy choices. In the most recent Intergovernmental Panel on Climate Change (IPCC) Assessment Report (AR5), four scenarios known as Representative Concentration Pathways (RCPs) were developed.[22] The RCP scenarios, as used in global climate models, are based on historical greenhouse gas emissions until 2005, and projected emissions subsequently (see below). There is considerable uncertainty in these future predictions. The worst-case scenario RCP 8.5 assumes that pre 2005 emission trends will continue with no reduction in emissions. However, new knowledge is emerging every day on various ways to address the myriad problems associated with climate change which provides hope that this problem will be successfully contained.

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[22] IPCC (2014) *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Geneva, Switzerland: IPCC. Available at: https://www.ipcc.ch/report/ar5/syr/.
IPCC (2018) *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change*. Available at: https://www.ipcc.ch/sr15/.

The defining property of the RCP family of scenarios is radiative forcing which is the additional amount of energy in Earth's climate system because of a certain concentration of greenhouse gases, with each RCP having a prescribed increase by 2100 relative to preindustrial levels. For purposes of driving forward global climate simulations, a single emissions trajectory consistent with a specified radiative forcing was chosen for each RCP. In evaluating any RCP scenario, it is fundamental to understand that scenarios are not predictions, which is why they are not associated with likelihoods. Since the increase in the global-mean temperature is determined by cumulative emissions of greenhouse gases, cumulative emissions are an important metric by which to assess the usefulness of scenarios. It should be noted that climate system feedbacks also influence the global temperature increase, but these, too, are strongly influenced by cumulative human greenhouse gas emissions.

By this metric, among the RCP scenarios, RCP 8.5 agrees most closely with total cumulative CO_2 emissions for 2005 to 2020, within 1%. The next-closest scenario, RCP 2.6, underestimates historic cumulative emissions by 7.4%. Therefore, not using RCP 8.5 to describe the previous 15 years' emissions assumes a level of mitigation that has not occurred, thereby skewing subsequent assessments by lessening the severity of warming and associated physical climate risk. It is significant here that the design choices for RCP 8.5 were articulated *ex ante* and without any attempt to predict the future, yet this close agreement should not surprise. In previous IPCC scenario catalogs, historical emissions have been in closer agreement with more extensive fossil fuel use scenarios. Finally, the usefulness of RCP 8.5 is not changed due the ongoing coronavirus disease pandemic. Assuming pandemic restrictions until the end of 2020 reduced emissions by 4.7 Gt CO_2, this represents less than 1% of total cumulative CO_2 emissions since 2005 for all RCPs and observations. The figure below shows expected cumulative GHG emissions for various RCP in the future. End-of-century warming outcomes in RCP 8.5 range from 3.3 °C to 5.4 °C (5th to 95th percentile) with a median of 4.5 °C. The level of overlap with outcomes under policies in place, where warming is anticipated to range from 2.3 °C to 4.1 °C with a median value of 3.0 °C, is modest. It is important to note that no RCP was designed to project existing trends forward—the common assumption of what a "business as usual" scenario would entail. Relative to historical and anticipated trends the stylized facts underpinning RCP 8.5 show faster economic growth, overestimates in carbon intensity, overaggressive coal use, and overpricing renewables relative to fossil fuels.[23, 24]

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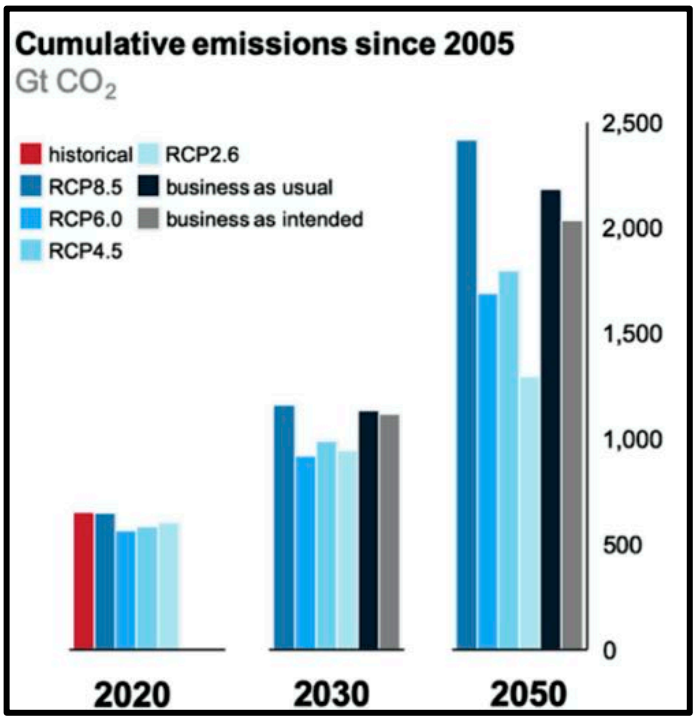
[23]Source: National Academy of Sciences first published August 3, 2020 https://doi.org/10.1073/pnas.2--7117117

[24] RCP Database Version 2.0.5 (https://tntcat.iiasa.ac.at/RcpDb/)



The Market for Climate Change Action

The demand for climate action is still low generally and particularly weak among the poor because of lack of knowledge and understanding of how steadily increasing temperatures of both land masses and oceans are causing severe tail risk climate events leading to economic distress from crop failures, pandemics, severe droughts and business failures. Policy interventions such as carbon taxes are not understood nor the need for mitigation[25]. There is a need to mount educational programs to raise knowledge about climate change and its impacts and what remedial adaptation actions they can take. Even in developed countries, there is a poor understanding of climate change and even downright disbelief among some sections of the population. I recall listening to a lecture by President Raphael Reif in Washington DC some years ago about the future thrust of MIT's research and academic programs with scant mention of climate change as a priority problem. At the end of the presentation, I asked him about this overarching worldwide issue to which he responded by promising to take a deeper look. I don't claim to be a catalyst, but that gap has been gradually addressed over the past decade.

The Climate change market is beset with market failures. The invisible hand does not generate adequate solutions to address the needs of poor farmers, service providers and small businesses. Demand for solutions is weak as often climate change deniers are obstructing interventions whether new regulations, performance standards or community actions because they don't want to lose revenues or bear the cost of creating the public good.

The climate crisis demands immediate action. The 2014 and 2018 reports of the Intergovernmental Panel on Climate Change (IPCC) demonstrate how the world's climate has changed since preindustrial times, how anthropogenic (human caused) activities have con-

[25] On February 27, 2021, President Biden announced a new policy to reset the social price of carbon to $51, a large jump from the Obama days ($37) and a giant leap from the Trump administration's policies which had slashed the social price of carbon to between $1-$7 allowing loosening of regulations and approval of carbon intensive projects on public lands. This is not a tax on carbon but a policy guideline which will have profound impacts on future regulatory actions and investment projects in both the government and private sectors. See additional discussion in a later section.

tributed to climate change and what actions need to be taken to keep global temperatures from rising beyond 2 degrees Celsius, preferably less than 1.5 degrees Celsius, by 2050 to avoid an existential crisis. But most developing countries do not have the capacity to prepare and implement Climate Action Programs to mitigate and adapt to the impacts of Climate Change. Policy makers feel overwhelmed faced by the lack of adequate institutional capacity to prepare effective climate action plans as well as the resources in terms of technology, human skills and finances to implement such plans. They also don't have access to the new technologies emerging from advanced countries and the human resources to take advantage of these developments. It is also imperiling the achievement of the UN 2030 sustainable development goals.[26]

MIT has embarked on a vigorous climate action research program including establishment of a MIT climate information portal to disseminate research findings as well as climate information. The MIT Sloan School has developed an interactive climate simulation model called En-Roads which shows how climate outcomes change with various policy measures (www.climateinteractive.org). This provides an educational instrument to teach policy makers and students the interaction of various policy actions which impact global warming. Another climate model for the US is available at https://us.energypolicy.solutions/docs/ which is also a systems dynamics model. Other interactive models have been developed by the World Resources Institute (WRI) and applied to several developing countries. Its application to Hong Kong is discussed later in this paper**.** Other universities such as Yale and Columbia as well as many in the UK and EU have started their own climate research centers. It would be important that researchers collaborate more closely so that issues are analyzed in a coordinated way.

The Importance of Carbon Pricing

Pricing carbon appropriately is considered by many policy makers and academics as the most important policy measure to incentivize society to reduce GHG emissions. The social price of carbon is the value society places on the benefit of carbon reduction measured as dollars per ton of carbon emission saved from any conservation activity. Set too low, environmental projects which reduce carbon emissions would not be economic and rejected. Set at an appropriate level, more carbon reduction projects would be economic[27]. Setting an appropriate price is a complex problem as it involves valuation of intergenerational benefits and costs as well as yet to be determined technological advances which could alter the cost/benefit relation. The International Monetary Fund[28] considers an appropriate carbon tax in the range of $75 per tonne of CO2 in current dollars to be extremely important in achieving the envisaged GHG reduction by 2050 (see figure below for applications to several Asian countries). To the extent that carbon prices remain constrained by politics or other factors, it will need reinforcing with other instruments.

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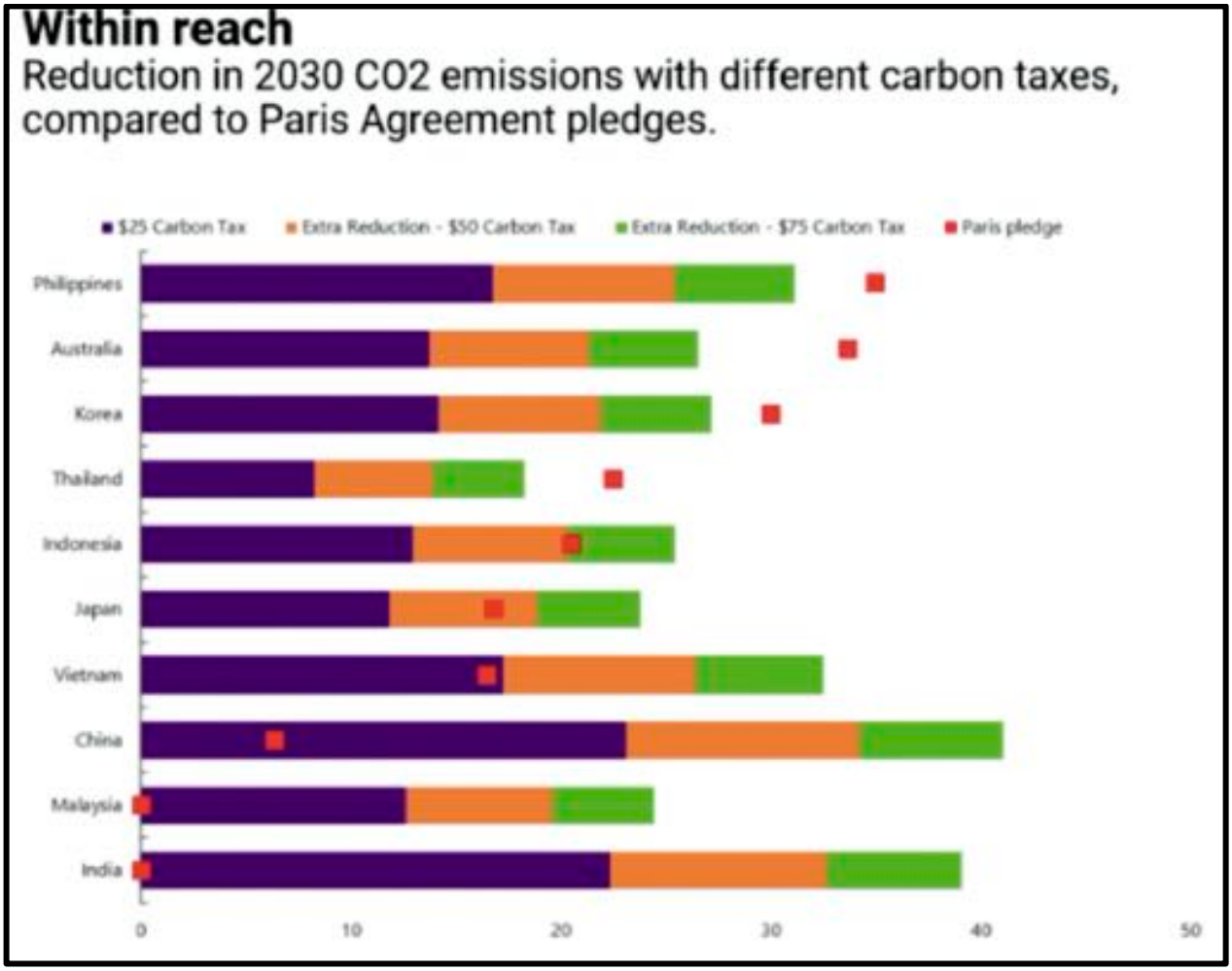
[26] United Nations *About the Sustainable Development Goals* Retrieved on March 13, 2021 from https://www.un.org/sustainabledevelopment/ sustainable-development-goals/

[27] https://apple.news/AbxO48Ki5SgSwnXp2fYRNSQ

[28] This section draws on a recent IMF blog, particularly on feebates. Also google the special climate issue in the IMF's publication Finance and Development, 2021.



Source: IMF Staff Calculations.Note: Countries with zero emission-reduction target from the Paris Agreement climate pledge are assumed to be able to achieve the target in the baseline scenario. Paris pledges reflect newly submitted proposals and updates in 2020.

Feebates as an Alternative to Carbon Taxes

A promising alternative approach is feebates, which impose a fee on products or activities with high carbon dioxide emission rates and provide a rebate to products or activities with low carbon dioxide emissions rates. For example, a feebate for transportation would apply a tax on new vehicles equal to the product of a carbon price, the difference between the vehicle's emissions per mile and the fleet average, and the average lifetime mileage of a vehicle. A feebate with a shadow price of $200 per ton of carbon dioxide would provide a subsidy of $5,000 for electric vehicles and a surcharge of $1,200 for a vehicle with fuel economy of 30 mpg. Subsidies for clean vehicles would decline (and taxes for high emission cars would rise) as the average emission rate declines over time. Analogous schemes could be applied to other sectors, including power generation, industry, buildings, forestry, and agriculture.

A combination of feebates might be more palatable than carbon pricing, as it would avoid a large increase in energy prices (since there is no pass through of carbon tax revenues in higher energy prices). At the same time, it would not promote some of the demand responses of carbon pricing: for example, unlike higher fuel taxes, feebates do not encourage people to drive less. Feebates do, however, tend to be more flexible and cost effective than regulations, and (unlike clean technology subsidies) they avoid a fiscal cost. But it may be quite complex to design and administer compared to a straight carbon tax.

Demand side action needs to be complemented by supply side measures to help the poor adapt better and build resiliency to adverse climate impacts. These actions need to be broad, covering all economic sectors and involve a combination of policy and regulatory changes, technology and capital resources. There are plenty of existing supply side solutions which if adopted widely can help mitigate adverse impacts and build resiliency. However, adoption requires catalysts or "Accelerators" which create the conditions for moving existing solutions forward [29]. The seven Accelerators for climate solutions are:

1. Setting clear goals, identifying priority areas for investment, setting performance metrics and implementing a robust monitoring and evaluation system to assess progress and take corrective measures.
2. Reshaping behaviors and cultures of individuals and firms to internalize the importance of dealing with the climate crisis and accept higher costs from carbon taxes.
3. Empowering people in an inclusive way to give them voice and build commitment to climate change actions which might affect them adversely in the short term.
4. Altering overall policies, regulations and incentives so that economic and sector plans and investments give priority to climate impacts.
5. Reallocating capital to priority problems and vulnerable groups caused by climate change within sectors and between sectors. Creating new jobs for displaced workers from sectors such as coal mining and oil should be a priority.
6. Educating people to generate demand for climate actions from governments and large corporations.
7. Incentivizing adoption of already available improved technologies, processes and evidence-based best practices to improve resource use and carbon management in key sectors such as energy, transportation, construction and buildings, industry and agriculture.

The Need for Climate Action Programs

A holistic Climate Action Program (CAP) needs to be implemented with all stakeholders playing a role at all spatial levels from the nation to the local community. Because of climate market failures, even in advanced countries, governments must take the lead in de-

[29] Adapted from the recommendations of the Drawdown Project, USA "Drawdown"— the point in the future when levels of greenhouse gases in the atmosphere stop climbing and start to steadily decline, thereby stopping catastrophic climate change — as quickly, safely, and equitably as possible. https://drawdown.org

veloping and implementing the CAP by building a high-level institution to plan and implement the CAP. However, developing country governments lack capacity for this. International assistance should be provided towards this effort. Bear in mind that the role of government in the USA and some European countries is quite different than its role in the developing world. Where state capitalism is predominant as in China, Russia, Vietnam and some other countries, governments have a commanding role in deciding on public and private investments. In mixed economies such as India, governments regulate many aspects of the market and work closely with the private sector. Setting the right policies and regulations would facilitate the transition to a net zero economy.

"Climate solutions are interconnected as a system, and we need all of them. The notion of 'silver bullets' has persistent appeal — 'what's the one big thing we can do?'—but they simply don't exist for complex problems such as the climate crisis. A whole system of solutions is required."[30] Some of the most powerful climate solutions receive comparably little attention, reminding us to widen our lens. In September 2019, Swedish climate activist Greta Thunberg testified before the U.S. Congress. "You must unite behind the science," she urged. "You must take action. You must do the impossible. Because giving up can never ever be an option."

The CAP should be designed to be consistent with the Paris Accord and the UN's 2030 Sustainable Development Goals (SDGs): 12 of the 17 total of 17goals deal with climate change. The Paris Accord commits countries through individual voluntary efforts to set highest national emission reduction targets (Nationally Determined Contributions -- NDC) and implement plans for limiting temperature increases to well below 2 degrees Celsius by 2050, preferably 1.5 degrees Celsius. Without a net zero emissions situation being reached soon, even this goal might be overly optimistic as carbon dioxide takes a very long time to dissipate (up to 100 years) while human activity is constantly adding to the accumulated level.

The newly released report by the UNCCC (February 26, 2021) on the revised NDCs by counties in preparation for the November 2021 Glasgow climate conference is a matter of great concern. Out of the 75 countries submitting revised NDCs, only the UK and EU have reduced their NDCs substantially. In sum, the revised NDCs would result in a 1% reduction in emissions compared to the anticipated 45%. A broad-based program of reducing fossil fuel use coupled with a wide array of actions in all sectors to improve resource use is essential[31]. The poor and underprivileged sections of communities would need to be given priority in resource allocations. That should be one of the central aspects of the CAP. There has been controversy about the lack of intermediate goals for Greenhouse Gas (GHG) reductions before 2050 to monitor the actions of governments and the urgency of remedial measures. It is obvious that unless actions are taken sooner than later, more severe measures will need to be taken. One study indicates that the probability of meeting the goal

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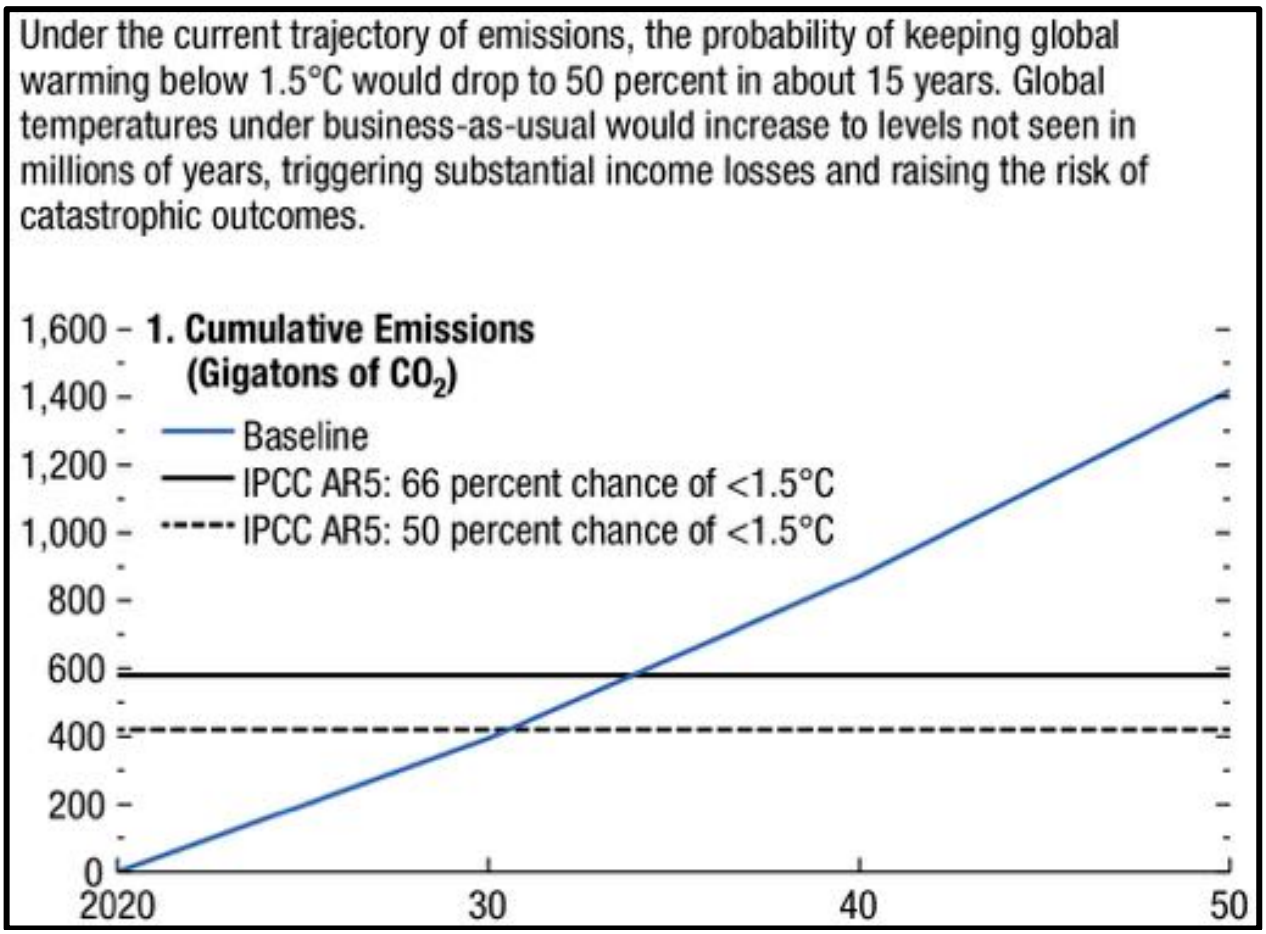
[30] Quoted from Drawdown Project

[31] For more data on sectoral distribution of GHG emissions https://www.climatewatchdata.org/ghg-emissions?chartType=percentage&end_year=2018&source=UNFCCC_NAI&start_year=1990

of limiting temperature increases to below 2 degrees Celsius target in 2050 is only 67% if GHG emissions are halved by 2030, a very ambitious target for almost all countries[32].



The CAP could start out as a national roadmap to lay out a broad strategy for reducing emissions which then could be developed into more detailed action programs at regional and sub-regional levels for each sector and at the firm level. Large firms are the biggest emitters and their active involvement in CAPs is critical as investments need to be made to allow more, greener, facilities. A committee of the US Senate has prepared a comprehensive roadmap as an initial strategy to deal with the climate crisis. The report is downloadable from https://www.schatz.senate.gov/download/sccc-climate-crisis-report. Many firms have announced goals of becoming carbon neutral or reducing their net emissions to zero by a future date. However, very few have spelled out concrete policy changes or investment plans to reduce their carbon footprint.

Europe has made more progress than the USA, adopting the European Green Deal (EGD) which calls for a 55% reduction of GHG emissions by 2030 compared to 1990. Net zero is targeted by 2050. The EGD plans an expenditure of Euro 1 trillion over the decade and es-

[32] "The New climate War" by Michael E Mann, Penn State University, 2020

timates that the program will lower GDP by 0.3% -0.7%. The EGD covers nine policy areas and comprises six action programs. The program will ensure that no country is left behind. A major component involves the closure of coal powered power plants and the decarbonization of natural gas. Carbon decarbonization will cost EU60 billion, of which EU5 billion is allocated for workers. Also included is an emissions trading system and a clean trading system which will involve a carbon border adjustment scheme to reduce leakages from trade. The entire program is regulated by the European Climate Law, passed in March 2020.[33]

Developing and Implementing a Climate Action Program (CAP)

> ***"Footholds of agency exist at every level, for all individuals and institutions to participate in advancing climate solutions. The climate crisis requires systemic, structural change across our global society and economy. The reality of intervening in a complex system is that no one can do it all, and we all have an opening to show up as problem-solvers and change-agents and contribute in significant ways—even when we feel small. The range of climate solutions illuminates diverse intervention points across individual, community, organizational, regional, national, and global scales. Accelerators expand that array of action opportunities even more and increase their effectiveness. It will take a whole ecosystem of activities and actors to create the transformation that's required".***[34]

The CAP needs to be developed by the government in consultation with all stakeholders and implemented as well with the participation of all stakeholders. (More in Part 3 below). CAP calls for innovation and disciplined action with adequate attention to the poor and under privileged. It should aim to address their needs in terms of resource allocation and help build resiliency for the target groups and the communities in which they live. CAP could be an overlay on sector development plans to refocus their priorities and actions to consider climate change impacts and reallocate resources to address the impacts of climate change on the sector with the goal of achieving net zero emission by a target date. This target date would vary from sector to sector and regionally depending on the complexity of the problems in the sector and region. Building resiliency of the poor through policies and investments would be at the forefront of CAP. The Catalysts/Accelerators mentioned above would be the main instruments in achieving this overall goal.

Large corporations do not necessarily have the incentives to make investments which create public goods that they cannot monetize. But they are usually the biggest carbon emitters and need to take priority action to reduce emissions. Regulations and setting an appropriate social price for carbon as announced by President Biden[35] or even better, a carbon tax would provide the incentives for green action by all. Unfortunately, there is a lot of

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[33] See https://www.climatechangenews.com/2019/12/12/eu-releases-green-deal-key-points/ee
[34] Quoted from the Drawdown Project
[35] See footnote 4 above about the social price of carbon. A more detailed exposition is available in this paper https://www.project-syndicate.org/commentary/biden-administration-climate-change-higher-carbon-price-by-nicholas-stern-and-joseph-e-stiglitz-2021-02

unproven claims being made by large firms when they announce goals for reaching net zero emissions by a target date without specifying a concrete monitorable program (green washing)[36]. However, there is growing awareness of the need to move beyond just energy efficiency to net zero emissions by a target date. Growing numbers of public companies have signed up on the initiative called the Climate Pledge, co-founded by Jeff Bezos. These include IBM, Microsoft, Johnson Controls, Coca –Cola, Uber, Best Buys, etc. FedEx announced plans to achieve net zero by 2040 and plans to invest $2 billion in electrifying its massive fleet of 180,000 vehicles. It has also donated $100 million to start the new Yale Center for Natural Carbon Capture. The problem is complex because decarbonizing will need to include all firms in supply chains, many based abroad. Microsoft announced its decarbonization goals, but its progress has been slow even though it is not an intensive energy user. As academic studies at Northwestern University has shown, radical innovations and change often come from universities, small inventors and social change agents who can introduce innovations leading to behavioral change and community participation rather than large corporations which engage in incremental change to existing intellectual property.

Climate action initiatives using existing technology in six sectors are briefly discussed below[37]. This is not an exhaustive list but is illustrative -- aiming only to indicate the possible impact of disseminating innovation more widely. The internet, mobile communications and smart phones are enabling many new energysaving technological developments to be implemented in all areas[38]. It is extremely important to note that actions in one sector affect all others since GHG emissions result from all sectors. There are also global temperature reduction initiatives such as sulfur aerosol injection into the stratosphere to reduce solar radiation which can reduce mean surface temperatures by 3 degrees Celsius or more. The impacts of such a drastic intervention on various regions have not been modeled and its actual implementation is very uncertain. Such methods are not included in this overview.

Energy

Initially reducing and ultimately eliminating fossil fuel consumption is the most important action towards the net zero goal. A lot of the carbon reduction proposals in all sectors depend on the availability of clean renewable energy. It is a complex problem which will require large investments and varied technological knowhow. Improving the energy efficiency of industries whose operations require large amounts of energy such as steel, cement, chemicals and fertilizer is difficult and should be a priority to reduce energy intensity and

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[36] Shell, BP, and Total recently announced their plans to reduce production of fossil fuels and invest in renewable energy. Utilities like Dominion Energy are also investing heavily in wind and solar power to reduce their dependence on fossil fuels.

[37] See World Bank Report #78281 Assessing Low-Carbon Development in Nigeria: An Analysis of Four Sectors, 2020

[38] This publication covers the adoption of mobile technologies in addressing climate change - https://www.gsma.com/mobilefordevelopment/resources/the-role-of-digital-and-mobile-enabled-solutions-in-addressing-climate-change/?utm_source=staff&utm_medium=referral

hence energy demand. The existing legacy investments in fossil-fuel based power plants, mainly coal, however, pose a big problem, particularly for developing countries which have recently invested in these plants so they have many years of useful life. Often the projects are paying off loans used to finance the plants. One solution is carbon capture and sequestration (CCS) of CO2 emissions. The technology has evolved significantly although its applicability is limited by the scale, complexity and economics of a particular location and project. Since flue gases contain 100 times the normal atmospheric carbon dioxide levels, CCS can be an efficient mechanism of carbon removal in this case[39]. There are six different proven ways to extract carbon from the atmosphere[40] including natural processes such as forests and some farming methods as well as ocean farming of Rhodophyta seaweed which absorbs bicarbonates in ocean water[41].

Established technologies incudes bioenergy and carbon capture (BECCS) which is the most mature of all the carbon removal technologies, as both bioenergy production and CCS have been separately proven at commercial scale. It is also the only negative emission technology currently included in the mitigation pathways in the IPCC 1.5-degree scenarios (IPCC, 2018). BECCS has been successfully used in a biomass fueled power plant in the UK (Drax Plant) as well as in smaller waste to power plants[42]. Direct carbon capture (DAC) has made progress and a new on-demand carbon sequestration service has been just announced. A new carbon dioxide removal service was launched by Carbon Engineering (CE) that allows customers to purchase the removal of carbon dioxide from the atmosphere using CE's large-scale DAC technology[43]. Shopify, a leading global commerce company, has signed on as the first customer for the service, reserving 10,000 tones of permanent carbon removal capacity from a large-scale DAC project. The carbon dioxide removal will be achieved through CE's plant development partner, 1PointFive – the US development company currently engineering CE's first industrial-scale facility that is expected to be operational in 2024.

Eliminating subsidies to fossil fuels, adopting an appropriate social price of carbon, and reflecting this in the pricing of goods such as water, chemicals, cement, steel, and energy are

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[39] Friedmann, J., Zapantis, A. and Page, B. (2020) *Net-Zero and Geospheric Return: Actions Today for 2030 and Beyond*. Available at: https://www.globalccsinstitute.com/resources/publications-reports- research/net-zero-and-geospheric-return-actions-today-for-2030-and-beyond/.

[40] https://www.wri.org/blog/2020/06/6-ways-remove-carbon-pollution-sky

[41] https://bmcplantbiol.biomedcentral.com/articles/10.1186/s12870-020-02629-4

[42] The principle of BECCS is that biomass is grown and used for energy purposes. Biogenic CO2 is typically counted as a net-zero emission in most greenhouse gas accounting schemes. Therefore, if some of the biogenic CO2 is captured and stored, this is a net reduction of CO2 from the atmosphere.

[43] Founded in 2009, CE is a Canadian-based clean energy company focused on the deployment of Direct Air Capture (DAC) technology that captures carbon dioxide (CO_2) directly from the atmosphere so it can be permanently stored deep underground or used to produce clean, affordable transportation fuels. From a pilot plant in Squamish, British Columbia, CE has been removing CO_2 from the atmosphere since 2015 and converting it into fuels since 2017. With its partner 1PointFive, CE is engineering a commercial scale DAC facility that will capture one million tons of CO_2 per year, equivalent to the work of 40 million trees. More information can be found at carbonengineering.com.

strong market signals to consumers to adopt efficiency and use inputs economically. A comprehensive set of market pricing measures in all sectors can ensure that resources will be used efficiently and obsolete methods and technology such as blast furnaces would be scrapped. Note the emphasis on market setting prices which reflect the social price of carbon or a carbon tax. These policy actions need to be taken at the highest levels of all national governments and implemented in all sectors (see footnote 20 on President Biden's action on increasing the social price/cost of carbon). The media needs to play a significant role in this effort in educating the public about the negative impacts of climate change caused by fossil fuel use and the use of carbon levies to shift purchasing behavior. Ultimately, the success of these policies depends on public understanding and acceptance of the short term, higher costs of carbon pricing.

China, USA and India are the three largest GHG emitters in that order, although on a per capita basis, India is one of the lowest in the world. Per capita GDP and per capita carbon emissions are closely correlated. The previous US government actively undermined regulations and projects to reduce carbon emissions. With the new Biden administration rejoining the Paris Accord, a more aggressive carbon mitigation program is being adopted. However, this four-year lapse in adopting carbon mitigation has made the task more difficult not only for the USA but for the world by signaling that the USA did not consider global warming to be a serious issue requiring concerted action. President Biden has announced the goal for the USA to reach net zero emissions by 2050. The US private sector has independently recognized the reality of climate change and is proceeding swiftly with decarbonizing actions. In the energy sector, advances in solar power and wind power generation have brought their nominal cost of electricity close to or the same as the most efficient fossil fuel powered plants. A recent auction bid from a solar bidder in India to supply the grid was less than US 3 cents for a 250 MW plant.

China has set its net zero emissions target for 2060. It is currently the world's largest producer of wind and solar energy, and the largest domestic and outbound investor in renewable energy. Four of the world's five biggest renewable energy deals were made by Chinese companies in 2016. As of 2017, China owned five of the world's six largest solar-module manufacturing companies and the world's largest wind turbine manufacturer. Of the 7,623 TWh (tera-watt hours) electricity produced in China in 2020, 261 TWh was generated by solar power, equivalent to 3.4% of total electricity production. However, this was almost a 300 % increase since 2016, when production was 67.4 TWh, equivalent to an annual growth rate of 40%. Hydroelectricity is currently China's largest renewable energy source and the second overall after coal. China's installed hydro capacity in 2015 was 319 GW, up from 172 GW in 2009, including 23 GW of pumped storage hydroelectricity capacity. In 2015, hydropower generated 1,126 TWh of power, accounting for roughly 20% of China's total electricity generation.

China's total grid connected wind power capacity in 2020 is estimated at 71.7 GW, a huge increase over 2019 of about 41 GW. According to the Beijing Declaration, China plans to install 50 GW of new wind power capacity annually from 2021-2025 and more than 60 GW annually after 2026 to reach its net zero target by 2060. This surge in wind power illustrates that large increases are possible with funding and resolve. Solar water heating is also

extensively utilized in China, with a total installed capacity of 290 GW at the end of 2014, representing about 70% of world's total installed solar thermal capacity. The goal for 2050 is to reach 1,300GW of Solar Capacity. If this goal is to be reached it would be the biggest contributor to Chinese electricity demand. This simple technology, often overlooked, should be more widely adopted everywhere as it is extremely cost effective. While its investment in renewable power is laudatory, its overall net zero program appears inconsistent as coal powered electricity plants will continue to operate, generating vast amounts of carbon emissions.

The new 14th five-year development plan for 2021-25 has no provision to close coal powered plants. Coal remains at the heart of China's flourishing economy. In 2019, 58 percent of the country's total energy consumption came from coal, which helps explain why China accounts for 28 percent of all global CO2 emissions. And China continues to build coal-fired power plants at a rate that outpaces the rest of the world combined. In 2020, China brought 38.4 GW of new coal-fired power into operation, more than three times what was brought on line everywhere else. A key risk to China maintaining a 'moderately prosperous society' remains a lack of cheap energy to drive its economy. A total of 247 GW of coal power is now in planning or development, nearly six times Germany's entire coal-fired capacity. China has also proposed additional new coal plants that, if built, would generate 73.5 GW of power, more than five times the 13.9 GW proposed in the rest of the world combined. Last year, Chinese provinces granted construction approval to 47 GW of coal power projects, more than three times the capacity permitted in 2019. China has pledged that its emissions will peak around 2030, but that high-water mark would still mean that the country is generating huge quantities of CO2 — 12.9 billion to 14.7 billion tons of carbon dioxide annually for the next decade, or as much as 15 percent per year above 2015 levels[44].

Other developing countries such as India have increased solar power generation five-fold in the past five years and have the potential to do much more. Renewable sources of power in India, including hydro, accounted for 36% of total power generation from all sources which amounted to 1,600 TWh in 2020. About 55% of India's total commercial energy demand is met through the country's vast coal reserves. Transitioning to carbon free energy is critical to meeting the GHG challenge. The annual per capita CO2 generation in India is about 1.6 mmt compared to 16.2 mmt in the USA. Even with a trebling of electricity demand in India by 2035, CO2 generation will be less than one-third the US level per capita in 2035. Electricity demand in a country like India where per capita consumption (based on total consumption across all sectors divided by the population) is about 1200 kwh per year now, is likely to triple by 2035 as incomes increase and more electrical equipment is utilized. Individual household demand may be a quarter of this. Contrast this with the USA where average per capita consumption is about 7200 kwh and Singapore and Japan at 3700 kwh. This is partly due to smaller size homes in India. But this number says something about energy efficiency of the USA given that most home heating is with natural gas which is not reflected in these numbers.

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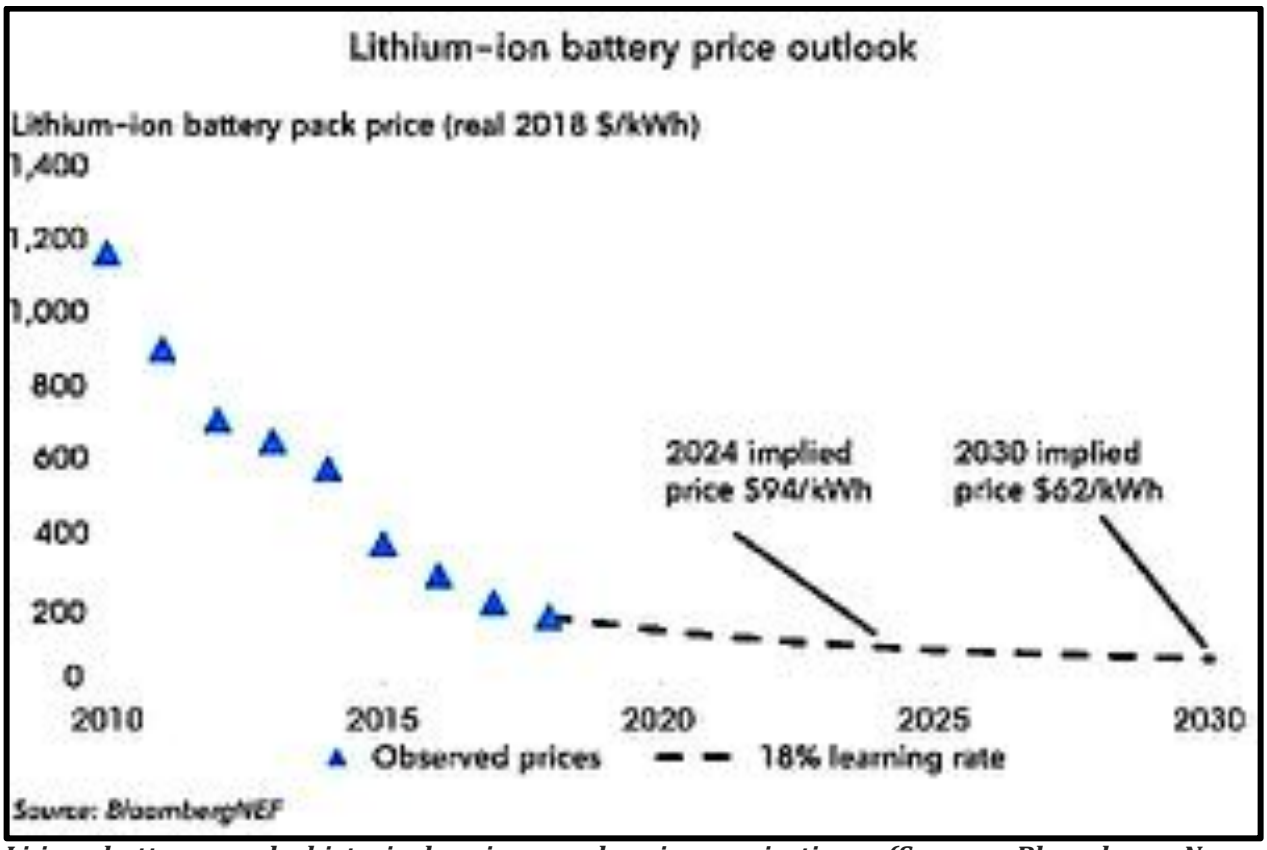
[44] This section on China's coal-based power growth is based on an article published March 24, 2021 - https://e360.yale.edu/features/despite-pledges-to-cut-emissions-china-goes-on-a-coal-spree

	Actual as on 31.12.2020		Target as on 31.03.2022		Target as on 31.03.2030	
	(GW)	(%)	(GW)	(%)	(GW)	(%)
Thermal:	206.63	55.05	217.0	45.40	267.0	32.09
Hydro:	45.80	12.20	51.0	10.67	76.0	8.77
Gas:	25.00	6.66	25.0	5.23	25.0	3.00
Nuclear:	6.78	1.81	10.0	2.09	19.0	2.04
Renewable:	91.15	24.28	175.0	36.61	450.0	54.09
Total:	375.37	100.00	478.00	100.00	837.00	100.00

India's Installed Electricity Capacity and projection (Source: Central Electricity Authority)

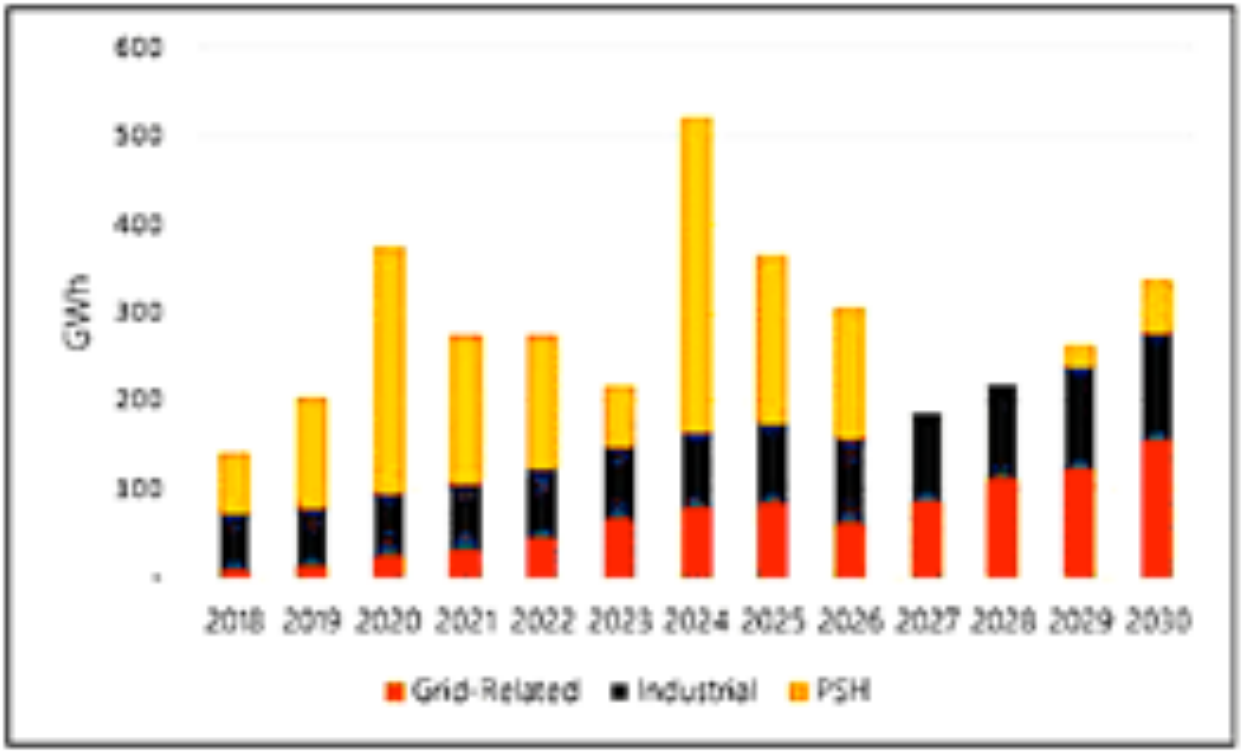
Perhaps more than that of any other major economy, India's future energy demand depends on yet-to-be-built buildings and vehicles. The International Energy Authority estimates nearly 60% of India's CO_2 emissions in the late 2030s will come from infrastructure and machines that do not exist today. This represents a huge opportunity to steer India onto a more sustainable course. If India follows this path, it needs to address the critical challenge of the industrial sector through efforts like more widespread electrification of processes, greater material and energy efficiency, the use of technologies like carbon capture, and a switch to progressively lower-carbon fuels. Electrification, efficiency, and fuel switching are also the main tools for the transport sector, alongside a determined move to build more sustainable infrastructure and shift more freight onto India's soon-to-be-electrified railways (elaborated in the industry section).

As mentioned earlier, the reliability of wind and solar renewable power depends on the availability of energy storage backup facilities. The cost of battery storage is falling rapidly (see figure below), and grid storage capacity in the USA is increasing with new facilities being constructed at the scale of 350 MWh such as the ones in San Diego and Florida. Elon Musk of Tesla announced plans to construct a battery storage pilot plant of 10 GWh with the goal of expanding to 200 GWh. The new Tesla 4680 Bell model EV battery is claimed to have a 500% higher energy density than the old model. The new design involving tabless cylindrical cells and with supercharging will increase vehicle range significantly. This is absolutely necessary for enabling the transition to net zero in transport by allowing deployment of EV in heavy trucks (see Tesla Annual Report 2020). GM also recently announced its plan to start producing EVs on a large scale using its new lithium metal battery -Ultium which will double the range of its Bolt EV and has plans to produce a 1000 HP Hummer. Ford also has a new electric Mustang. China has several EV producers. New battery technologies are evolving such as Vanadium Flow batteries.



Li-ion battery pack historical prices and price projections (Source: Bloomberg News Environment Finance 2019)

Advances in grid level battery technology and energy storage based on hydrogen generation with surplus power should enable self-reliant distributed power networks based on renewable energy to provide reliable power on a 24/7 basis off grid. The figure below shows the increase in grid storage projected over the next decade by the U.S. Department of Energy (DOE), by 2030, the stationery and transportation energy storage combined markets are estimated to grow 2.5–4 terawatt-hours (TWh) annually, approximately three to five times the current 800-gigawatt-hour (GWh) market. By 2030, annual global deployments of stationary storage (excluding PSH) are projected to exceed 300 GWh, representing a 27% compound annual growth rate for grid-related storage.



Annual global stationary storage deployment projection (Source: DOE, Energy Storage grand challenge)

Recognizing the transformative potential of battery energy storage and the imperative to limit climate change and achieve sustainable growth, India launched a National Mission on Transformative Mobility and Battery Storage (NMTMBS, 2019) that will support the deployment of battery storage in both e-mobility and across the power sector, with the objective of reducing India's energy import dependence, by reducing direct oil demand and increasing the uptake of renewable energy in the power sector.

Hydrogen offers a path to efficient energy storage of the excess electricity produced by intermittent renewable sources. Hydrogen also provides an efficient energy source for heavy transportation such as ships and industrial use. Over $300 billion of investments in hydrogen projects are underway currently[45]. Saudi Arabia is planning a $500 billion investment in solar power-based hydrogen production which will be converted into ammonia for export in a bid to reduce its dependency on fossil fuels. Green hydrogen is produced by using renewable energy rather than fossil fuels. The current cost of producing a kilogram of hy-

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[45] The report "Hydrogen Insights 2021: A Perspective on Hydrogen Investment, Deployment and Cost Competitiveness" released by Hydrogen Council in collaboration with McKinsey & Company shows over 30 countries have released hydrogen roadmaps and governments have committed public funding for hydrogen technologies.
Globally, 228 large-scale projects have been announced with 85 per cent located in Europe, Asia, and Australia. These include large-scale industrial usage, transport applications, integrated hydrogen economy, infrastructure, and giga-scale production projects.

drogen is a little under $5, according to the International Renewable Energy Agency. Saudi Arabia possesses a competitive advantage in its perpetual sunshine and wind, and vast tracts of unused land. The project Helios's costs likely will be among the lowest globally and could reach $1.50 per kilogram by 2030.

That is cheaper than some hydrogen made from non-renewable sources today. Green Hydrogen based on biomass offers carbon free energy through large and small fuel cells based on advances in electrolysis technology. These technologies are rapidly becoming common place and have the potential to revolutionize conventional power systems. Other countries in the Middle East and North Africa, such as Libya, Niger and Chad, also offer vast potential for solar power generation and intercontinental energy trade with Europe through undersea power cables. Such projects could replace fossil fuel generation in a significant way. Implementation will require a high level of security and trust in these governments before investors would be willing to invest the vast sums involved.

The advent of small (2-5mw), highly safe ceramic encapsulated electricity generating nuclear reactors from the Ultra Safe Nuclear Power Corporation offers enormous opportunities for generating carbon free power at a long-term fixed price, reducing risk. Advanced power control systems in tandem with these reactors now allow cost competitive off grid power supply to US defense bases. The same systems are available to hospitals and other facilities and could supply power to small cities at a competitive price. New compact nuclear reactor designs are also emerging based on liquid sodium cooling rather than pressurized water enabling higher temperature operations and storage of energy using molten salt, similar to technology employed by parabolic mirror based solar power units. Bill Gates is investing in new nuclear power technologies through the Natrium project[46].

Hydro power has long been an important source of renewable energy in many countries. But it is a double-edged sword, affecting the ecosystem and wildlife in catchment areas and needs to be well planned. As an example, the Blue Nile Dam -- while beneficial to Ethiopia -- can impact the livelihoods of millions of farmers and cities in Egypt and the Sudan who are totally reliant on the Nile for water. Chinese plans to build hydro power projects in the Tsang Po which is the name of the Bramhaputra river in Chinese territory is controversial as it can affect water availability in Bangladesh and India by reducing the flow in Assam, India.

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[46] TerraPower, founded by Gates in 2008, is developing two separate SMR technologies. The sodium fast reactor used in the Natrium concept produces large volumes of heat over and above what is required to drive its steam turbines. The company has previously flagged this as a potential source of process heat or for energy storage. Natrium is being developed in partnership with GE Hitachi Nuclear Energy. It could be used to boost a 345-megawatt small modular reactor (SMR) to around 500 megawatts for a period of up to five hours.

Agriculture

This is an area with enormous significance because it employs the largest number of poor people in developing countries: almost 70% of the labor force in India, of which up to 80% are women, are employed in agriculture. Moreover, the percentage of women coming from the disadvantaged strata of society is 90% and disruptions in agricultural production can hurt the poorest. Agriculture has enormous implication for climate change but also offers the potential of significant greenhouse gas emissions reduction[47] as a carbon sink (see footnote 27 also) depending on what crops are grown and the use of land for forests which can be utilized later for economic purposes[48].

However, wrong decisions on cropping patterns can inflict serious damage to the environment at a huge human cost. The Amazon rain forests are an enormous carbon sink and significantly contribute to reducing GHG levels. However, a recent study shows that the carbon storage capacity of Amazon trees are declining.[49] Brazil has permitted indiscriminate gold mining and exploitation of forest resources negating much of GHG reduction efforts made by the country elsewhere. President Biden has offered Brazil $20 billion as compensation to stop the indiscriminate rain forest exploitation[50]. These positive incentives need to be accompanied with negative ones such as tariffs on Brazilian agricultural products produced on previously forested land. This might be controversial to some, but bold action is required. Forests have been used as carbon offsets by firms who have invested in carbon generating projects such as a chemical plant. The idea is to offset the carbon production of the project or activity, e.g., a flight from Washington DC to London, with either enlarging the area of forests or preserving forests which would have been cut down. Many firms have used this "get out of jail card" to claim carbon neutral operations. However, many of these claims are dubious and some environmental NGOs have been exposed in the media for arranging such transactions. Also, the carbon stored in forests must remain in trees for over 100 years according to experts. The other fundamental weakness of the offset concept is that it does not change the project sponsor's behavior or incentives to reduce carbon. Lastly, there is a timing mismatch issue in the sense that a new forest will take a long time to grow and absorb the carbon generated by an air journey of six hours or a project's carbon produced over five years.

Overall, fossil fuels are essential for modern, mechanized agricultural production systems. Petroleum products are used directly to power tractors, machinery, and irrigation, and to transport, transform and package agricultural products. They are also used to manufacture fertilizers and

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[47] In December 2020, subnational governments, UN agencies, and non-governmental organizations working on food systems and climate change launched the Glasgow Food and Climate Declaration. This acknowledges the importance of Greenhouse Gas (GHG) emissions of current food production systems which account for 21-37% of total emissions produced by all sectors.

[48] To deliver this climate change mitigation goal, countries aim to achieve "*a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century*" (Paris Agreement, 2015). Sinks are defined as "*any process, activity or mechanism which removes a greenhouse gas [...] from the atmosphere*" (United Nations Framework Convention on Climate Change, 1992).

[49] https://apple.news/ACJxE8CMdTYu4CbnnKkmdJw

[50] https://earthinnovation.org/2020/03/joe-biden-offers-20-billion-to-protect-amazon-forests/

pesticides and prepare seeds (See reports from the UN Environmental Program). Nitrogen fertilizer is the biggest energy consumer in non-organic production. The production of one ton of nitrogen fertilizer utilizes one to one and a half tons of equivalent petroleum (Food and Agricultural Organization, Rome). Moving to organic farming can reduce dependency on fossil fuels but is fraught with risk as modern agriculture produces vast amounts of grain and other foods which feeds the population of the world with adequate reserves in case of weather emergencies. Also, the diet of populations of poorer countries is changing towards more animal-based products which increases the demand for animal feed such as based on soya beans and other crops. China is the largest importer of US soya beans for animal feed, most of which is used to feed pigs. Pigs produce 1.5 kgs of methane every year compared to cows which produce 100 kgs methane/year/head, a gas which is 20 times more potent in terms of GHG equivalency to CO2. India has some 300 million cattle or about 20% of the world population. Cattle (excluding buffaloes) are an important part of the religion, culture and society of India and the numbers will be extremely difficult to reduce, almost as hard as changing religious practices (imagine riots and civil wars over conversions). Nevertheless, reducing the cattle stock in India should be a priority which is not even on the table in climate action programs when it comes to reducing emissions.

Innovations in synthetic meat products might reduce the demand for animal meat but their market acceptance is highly uncertain. Some reduction in fossil-fuel based agriculture is possible through adoption of modern ecological farming practices. For instance, some organic farms and regenerative crop-systems use approximately half the energy of that used by industrial agriculture and have the potential to significantly "draw down carbon from the atmosphere". In these systems, converting to no-till methods which allow the producer to phase out the use of pesticides and fertilizers were shown to be effective as they significantly reduced fossil fuel use. These alternative approaches are based on the use of more renewable sources of soil fertility, e.g., recycling crop waste, long-term rotations - methods that help to decouple food production from the fossil fuel industry which has always been at the core of conventional farming[51]. Mobile communications and smart phones offer an inexpensive pathway to improve farming efficiency by providing farmers timely local information on weather, crop diseases and prices among many other topics enabling greater productivity and less energy and input use. See Footnote 33 for details.

Water Use in Agriculture

The textile industry is a large water usage industry starting with cotton growing and ending with finished textiles. Cotton growing can be very profitable and this has led countries like Uzbekistan to engage in mono cropping leading to serious environmental degradation. The Aral Sea has all but vanished. In India, cotton cultivation employs over 50 million workers and a huge number in upstream value chains leading to the finished garments. Cotton is grown on land, half of which is irrigated. Yet the areas under cotton are experiencing the highest water stress levels according to the World Resources Institute (WRI). According to the WRI, India is on the brink of a water crisis which is visible in large cities

[51] Energy-smart agricultural systems: decoupling oil from food production, Ana Benoliel Coutinho, Published by Development Aid, February, 2021

such as Chennai and New Delhi, which has serious water shortages and limited water availability in the poorer areas. The water shortage has led to bankruptcy of cotton farmers who have used high-priced genetically modified seeds which require high levels of water and fertilizer. Many highly indebted farmers have committed suicide unable to repay bank loans.

Improvement in the sustainability of cotton farming requires significant changes in farmer behavior through continuous education. Soil and water resiliency have to be strengthened. Water budgeting to help farmers understand water availability and use is essential. "Farmers only understand the value of water when the well goes dry". Demand side measures are important to reduce water use and allocation. Supply side measures such as recycling wastewater can increase water availability. The Institute for Sustainable Communities in India suggests a three-pronged approach: (1) Robust education and extension programs, (2) Better market linkages including certification of products as sustainably produced to provide incentives to practice sustainable farming and (3) the convergence of water and agricultural policies to ensure sustainable farming for communities.

The MAIS Program (*Modulo Agroclimático Inteligente e Sustentável*) is helping family agricultural operations adapt to climate change in the Jacuípe Basin, Brazil's semi-arid region. It is one of the first ever climate smart agricultural programs to mainstream climate disruptive technologies among farmers in Brazil. The Program helps farmers implement best practices in animal nutrition, farm management, food and water security, and restoration of degraded pastureland soil to help them prepare for times of intense drought and ensure food security in the region. Over 3 tonnes of CO2 is estimated to be offset for each hectare of restored pastureland. The Program has also resulted in a 30% improvement in pastureland, a 50% decrease in the water footprint of the area's farms and a 30% reduction in production fluctuations. Each US dollar invested in the program has generated about USD 7 in the Jacuipe Basin.

Urban Sector Water Supply

People in cities in developing countries are being increasingly impacted by black swan events (unexpected, rare events with severe consequences) in temperature and rainfall which are drastically reducing access to potable water. For example, in Chennai, India, potable water is so scarce, that water tankers from long distances are supplying water to residents at very high costs. Industry such as automobile manufacturing is affected, reducing investments and jobs. There are a host of measures which the community and the government can take to address the problem and respond constructively to adapt to droughts and heat waves. Some are technological such as increased water harvesting, more efficient use of water in homes and industry, reduction of non-revenue water by water supply companies and organizations, and widened access to water sources such as through desalination and recycling of waste-water. Policies to promote conservation and more efficient use would need to include full cost recovery pricing of water including adoption of water metering and progressive tariff structures to protect the poor as well as market- based pricing of water for industrial users. Educating both consumers and local governments is a way to address this challenge. Chennai is not the only city facing this problem. New Delhi, Dhaka, Bangkok, Manila, etc. all face this problem. What is the best approach to addressing this

problem in a holistic way? Perhaps an App can be designed to help educate and train residents/ consumers in various aspects of conserving water and inform them of current and medium/ longer-term forecasts of rainfall, climatic variables and pest afflictions specific to their locations to help them adapt to climate change on a real time basis. Accuweather, an App available on smart phones in the USA, provides a detailed short term local weather forecast for the specific location of the user as well as weather related news. More generally, an App like this from the national weather authorities with links to farming and crop information would be invaluable to farmers. Initiatives involving digital communication technology being implemented in these areas are covered in the GSMA publication mentioned in footnote 33.

Industry and Construction

The industry and construction sectors offer huge potential and challenges for carbon reduction. The industrial sector includes heavy industry and manufacturing in several categories: cement, chemicals, steel, aluminum, paper, mining, manufacturing, food processing, waste processing, and other manufacturing and processing industries. These industries are diverse, and so there is no one solution for reducing emissions in all heavy industries. Many, however, are energy-intensive, consuming about 40 percent of global energy demand. Direct emissions from heavy industry make up between one-fifth and a quarter of global greenhouse gas emissions. Industrial activities emit carbon dioxide (CO2), nitrous oxide, methane, and fluorinated gases—all potent GHGs. Approximately 76 percent of industrial GHG emissions is CO2. Iron and steel production and cement production each contribute about 27 percent of the sector's direct CO2 emissions. Chemicals production emits 15 percent, and aluminum, pulp and paper, and other industries collectively make up the remaining 31 percent. Excluding the emissions from purchased electricity, the two main sources of GHG emissions in the industrial sector are energy used for heat and conversion processes.

Many heavy industries require high-temperature heat, which is usually generated by the combustion of fossil fuels and is more difficult to generate using electricity. Some alternative sources, such as hydrogen made from renewable electricity or electric resistance heating from renewable sources, are coming into use but will require further research and development and/or rapid deployment and quick scaling to decarbonize the sector on a timeline relevant to the 2050 deep decarbonization goal. Some processes, such as iron and steel production or ammonia production, also generate emissions in the production process, so decarbonizing them will require new processes rather than simply substituting a different energy source[52]. New initiatives are emerging to address this problem. For example, Startup Boston Metal is marketing its metal oxide electrolysis process which it claims will convert iron ore to iron and oxygen with electricity instead of using natural gas (direct iron reduction) or coking coal. This would avoid the CO2 emissions from the coking coal, limestone, or any of the various processing facilities involved in the steelmaking process. Similarly, in the aluminum industry, Alcoa and Rio Tinto have partnered to develop a carbon-

[52] This section draws on data and findings from the paper "Climate Solution Series-Decarbonizing Heavy Industry," Center for Strategic and International Studies, October 2020

free aluminum smelting process that replaces the traditional carbon anode with a ceramic one, eliminating the resulting carbon. Both of these companies have secured customers for their zero-carbon products, but it will take time to bring their platforms to scale and to eventually replace conventional facilities with their zero-emissions technology. [53]

There is a need to rethink industrial strategies and policies.[54] Some companies in developing countries have recognized the importance of reducing their carbon footprint by adopting energy saving programs. Infosys, the largest IT company in India aims to reach net zero in energy use by the end of 2020. However, no concrete plan has been provided to the public. A good Climate Action Program would include initiatives such as: raising the awareness of enterprises of the environmental impact of inputs used, technologies employed, and environmental pollution generated and incentivize producers through tax and subsidies. Enterprises could be recognized for their contributions to climate change and adoption of mitigation and adaptation measures and be awarded gold, silver and bronze medals like in the UK which awards the Queen's medal for excellence in exports. Private groups have started to engage in assessing firm compliance with commitments. A group called Zero-Carbon 2030 monitors firm's performance and rates progress. Financial institutions could be educated to play an active role in assessing the climate impact of projects when granting loans. The International Finance Corporation as well as over 100 financial institutions use the Equator Principles[55] in assessing the environmental impacts and sustainability of investments before committing to project financing.

Construction, Buildings and Communities

Construction is a large source of GHG emissions because the raw materials used in construction – cement and steel - are extremely carbon intensive to produce. Recycling old building material for use in new construction offers potential for energy savings. Hochstein, a large construction company, recycles up to 82% of building materials in major civil engineering projects. New developments in construction technology not only reduces material and labor costs but the intensive use of heavy equipment such as bull dozers and heavy trucks which are large emission sources. Moreover, new building designs can save energy and improve sustainability over the economic life of buildings. The US Green Building Council certifies the efficiency of buildings using a set of eight factors:

- Energy efficiency and use of renewable energy.
- Water efficiency.
- Environmentally preferable building materials and specifications.
- Waste reduction.
- Toxins reduction.

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[53] See CSIS study https://csis-website-prod.s3.amazonaws.com/s3fs-public/publication/201005_Naimoli_Ladislaw_Climate_Solutions_Decarbonizing_Heavy_Industry.pdf
[54] https://www.resources.org/archives/decarbonizing-global-industry/
[55] The Equator principles provide a framework for financial institutions to manage environmental and social risk in projects. Over the years, the Equator Principles signatories have drawn from the International Finance Corporation's extensive technical resources and have worked closely with IFC to develop practitioner methodology for environmental and social risk management.

- Indoor air quality.
- Smart growth and sustainable Development.

LEED, which stands for Leadership in Energy and Environmental Design, is a green building rating system. Buildings are rated at four levels of efficiency using a point system with Platinum being the highest rating. As of 2017, 6633 buildings in the USA achieved the Platinum certification. World building stock is projected to double by 2050. In India as in many other countries, half of the building stock expected to exist in 2040 does not exist now. Current building energy efficiency levels in the most efficient buildings are around 30%. These levels can be increased to 90% with new designs, building material and energy management systems. Energy efficient sources such as geothermal heating and high efficiency heat pumps can replace natural gas which is very efficient but produces GHG emissions. Natural ventilation systems adopted in building design can also reduce heat loads. An ancient example of this principle is the Grand Mosque in Djenne, Mali, which uses natural convection cooling. Retrofitting existing buildings would cost about $150 per square foot but better insulation and energy management can achieve significant improvements at a lower cost. Other countries, such as the UK and UAE, have also set up green building standards which are being introduced.

Urban energy modeling enables planners to focus on optimal ways to design neighborhoods to reduce energy use. Solar radiation maps help to plan roof top solar installations. Mapdwell, a building optimization software program allows building designers an efficient tool for building energy optimization. Based on cutting edge baseline energy modeling, Mapdwell evaluates distributed energy resources (DERs) like solar PV and battery storage and plans upgrades accurately[56]. Mapdwell allows *inter alia*:

- Best -in-class energy simulation and building energy modeling at the building level
- Easy-to-use configuration tools for instant project /upgrade feasibility analysis
- Remote insights based on deep vision (e.g., existing solar panels, rooftop equipment etc.)
- Access to big scale data to discover and target potential customers
- Intelligent parametric search by geography, energy, demographic criteria
- Exportable reports with full configuration details and benefit/cost analysis

Advances in using smart sensors and artificial intelligence in managing energy systems in homes shows that energy use can be reduced significantly. Better insulation is extremely important in reducing energy transfer between the external environment and the inside. While homes in cold climates have some degree of insulation, buildings in hot climates usually lack any insulation beyond the masonry used in construction, relying on air conditioning to keep inside temperatures reasonable, but at the cost of very high energy use per square feet. In the USA, construction codes are being tightened so that building energy efficiency meets some minimal standards. Also, states such as California are requiring building

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[56] https://mapdwell.com/en/news/40-mapdwell-begins-rollout-of-fluxboard-energy-insight-platform-in-private-beta

materials to meet energy efficiency criteria in production. Cement compositions are changing and concrete mixtures are also being reformulated to reduce energy use. Holcim Lafarge can now produce cement with 50% less carbon emissions but at about 5% higher cost. Carbon dioxide in liquid form is mixed with concrete to sequester the carbon and strengthen the finished concrete.

At the community level, civic bodies need to plan better to implement climate smart cities and communities. Boston, for example, has taken multiple actions to reduce impacts of flooding and other events. Congress[57] could help local communities become climate smart in the following six ways:

- Providing new funding and financing mechanisms for local projects that promote green infrastructure, microgrids, smart growth, and smart and efficient buildings.
- Incorporate resilience priorities into federal programs and projects.
- Provide federal incentives for cities and towns to adopt progressive building and zoning codes, retrofit buildings, and de-risk communities.
- Empower local leaders with climate data and planning tools to spur innovative resilience projects.
- Provide federal support to low-income communities to invest in their own resilience.
- Discourage development in flood-prone areas, and equitably address at-risk properties

Transportation

Transportation is a key sector with the largest potential to reduce GHG emissions. President Biden has recently announced a policy of electrification of federally owned vehicles including postal delivery vehicles. Electric vehicles offer a viable path to reducing carbon emissions and urban pollution which impacts the health of most urban residents in the world. Norway has made tremendous progress in EV adoption with 54% of all cars sold in 2020 being EVs. However, the high investment cost in electric vehicles is a major problem. Intermediate steps can be taken to reducing GHG from cars and trucks so as not to make existing vehicles uneconomic. For example, biodiesels can be an inexpensive way to reduce emissions of diesel trucks throughout their useful life in a significant way. Fleet operators might be more amenable to switching to biodiesel instead of wholesale investing in new electric fleets. Oil and gas companies are becoming interested in this approach.[58] Other variants of electricity powered vehicles should be considered. "All vehicle batteries need not have the highest energy density where space is not a pressing constraint. A combination of lithium batteries, capacitors, flow batteries and hydrogen fuel cells might be a better solution for heavy trucks."[59] Increased research is called for in more energy dense and larger storage lithium batteries, fuel cells, Redox flow batteries[60] and low carbon fuels as well

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[57] https://www.schatz.senate.gov/download/sccc-climate-crisis-report.
[58] Oil Refineries see Profit in Turning Kitchen Grease into Diesel, New York Times December 2, 2020.
[59] This comment is from John Dabels, MIT Climate Action Group C, private post on December 4, 2020
[60] https://www.intechopen.com/books/redox-principles-and-advanced-applications/redox-flow-batteries-fundamentals-and-applications

as business models for recharging batteries including quick battery swapping at gas stations like swapping propane tanks for gas grills. Common battery standards for different classes of vehicles need to be adopted as well as regulations. Sweden is experimenting with charging moving electric vehicles with power rails embedded in sections of roads (dynamic rail charging) which would reduce the need for charging centers. As mentioned earlier, Tesla's new battery design increases energy density and range very substantially.

Car populations are likely to increase substantially in developing countries compared to developed countries where the growth in car ownership numbers is flattening. In India, the number of cars is expected to increase five-fold by 2035 which would increase fossil fuel consumption tremendously unless EVs are introduced. Low-cost electric vehicles are needed with limited range since the distance travelled in urban areas is limited. However, the switch to EVs would result in a large increase in electricity demand and the reduction in GHG emissions would be small unless the electricity to power these EVs came from renewable sources. Studies by the International Energy Agency suggests that the main increase in electricity demand in developing countries will come from the transport sector with the switch to EVs.

While the focus is on electric cars and trucks in developed countries, in developing countries more people currently use bicycles, rickshaws, mopeds and motorcycles. The petrol/gas or diesel powered moped/motorcycles and auto rickshaws are arguably a bigger source of pollutants and GHG gases than cars in many cities such as Hanoi. Hybrid electric bicycles with generators that can recharge batteries in downhill sections can give these a great range and replace small motorcycles, mopeds and auto rickshaws in urban environments. A system of prepaid charging cards or smart phone apps can be used for quick charging of these vehicles from electricity kiosks in urban streets thus ensuring 24/7 availability of electricity. Standardization of batteries for such vehicles would also allow battery swapping at roadside kiosks.

Other transportation modes also have great potential to reduce their carbon foot-prints. Two sub-sectors--air travel and long-distance ocean shipping—stand out. Studies show that ocean shipping using tankers and large container vessels, which currently relies on heavy fuel oil can reduce emissions by switching to hydrogen power plants[61]. Aviation is a more difficult sector to decarbonize because of the high energy density of aviation fuel. But biofuels are being developed to substitute for jet fuel. Biofuels have been successfully used by some airlines to replace jet fuels on a limited trial basis. Also, electric aircraft engines are being developed to reduce emissions. However, this is a sector which may require carbon offsets involving biomass and forests.

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[61] www.energy-transitions.org

Implementing Climate Action Programs

It is important to note that all sectors are interrelated and should not be treated as independent silos. Water, transport, commerce, services etc., are all interconnected and actions in one area have impacts on the others. That is why a holistic approach to the CAP is essential. An overarching agency is needed at the apex level of government which has the full support of politicians and decision makers to oversee the process of formulating and implementing the CAP for the country, specific regions, sub-regions, cities, and rural communities with decentralized units at lower levels to undertake the work with the collaboration of all stakeholders - individuals, civil society and non-governmental associations, think tanks, educational institutions and local and regional governments as well as private industry, including industry associations. The CAP should be designed with clearly designed performance metrics reflecting the climate goals sought to be achieved which should be published on the website of the agency. A monitoring and evaluation system should be established so that results are measured in terms of outputs, outcomes and impacts relative to goals which are specified in the CAP. Most developing countries may need assistance in establishing such an agency and training staff. International assistance would likely be available for this purpose.

Each country should establish at the national level a Climate Action Program Agency (I use CAPA as a generic term), an overarching agency which will work closely with regional and local governments and other stakeholders to introduce and integrate climate change considerations and accelerators into the economic development plans prepared by other government agencies. For example, industrial strategy should take account of environmental considerations, availability and economic costs of natural resources, negative externalities created by industry including water and air pollution, and the risk and impact of intense weather events on sectors and enterprises. The Industry Department within CAPA would be ultimately responsible for preparing and implementing the plan. The same would apply for infrastructure planning for a region where, for example, CAPA would work with state and municipal water companies to ensure that water supply and sanitation projects adequately consider climate caused disruptions and problems. Close coordination with the private sector, particularly large firms, is essential for both plan preparation and implementation.

In some countries that already have economic development boards, these institutions could be broadened into a CAPA type apex agency where climate change is totally integrated into the planning and implementation monitoring process. Sector ministries and agencies including state owned corporations would still have primary responsibility in actual provision of services, but they would work with the apex agency to incorporate climate factors and prioritize the poor in their programs. This alternative approach might be easier for governments to accept as it would not require the creation of a new apex agency, but it would most likely require changes in laws and regulations. Experience suggests that a lot of fundamental changes to planning and monitoring processes would be required for an inclusive process to be adopted including new technologies by existing development agencies which often follow conventional approaches. Although an apex agency is needed to prepare the overall national policies and plans for climate mitigation and adaptations, suc-

cessful elaboration of the national plan at the local levels (states, counties, cities) will require competent local institutions. The Chinese experience with sub-regional and city level climate planning and implementation discussed at the end of this section highlights the importance of local leadership and capability.

Creating a new apex agency or transforming and broadening the scope of an existing agency such as an economic development board requires significant institution building efforts including bringing in new technologies, information and data processing capabilities, and expertise in policy and project formulation as well as in results-based management. Staff would have to be trained in conducting surveys using, for example, remote sensing technologies, large data sets and results interpretation. Monitoring, Evaluation, Research and Learning (MERL) is a rapidly growing field with the use of big data and artificial intelligence for better planning interventions in development and humanitarian programs. Some MERL practitioners have recently begun to use big data and, increasingly, data science and other methodologies to incorporate big data into various stages in the identification, design, management, monitoring, evaluation, reporting, and dissemination of their development and humanitarian programs.

Some Examples of Initiatives in CAP Preparation

The Climate and Development Knowledge Network (CDKN) is a seven-year initiative funded by the UK Department for International Development (DFID) and the Dutch Ministry of Foreign Affairs (DGIS). Started in 2010 to assist developing countries respond to the challenges posed by climate change, it provides research and technical assistance, and channels the best available knowledge on climate change and development to support policy processes at the country level. A key feature of the CDKN is that it is demand led –responding to gaps and needs identified on the ground. The CDKN is being managed by an alliance of partners led by Price Waterhouse Coopers LLP (PWC) and comprising the Overseas Development Institute and three regional partners –Fundación Futuro Latino Americano (FFLA, Latin America), South -South North (Africa) and LEAD Pakistan (Asia). Services are provided through a network of collaborating organizations and individuals around the globe.

Kenya is one of CDKN's 13 priority partner countries. CDKN's continuing country goal in Kenya is to ensure the National Climate Change Action Plan (NCCAP) is implemented at national and sub-national levels of government, and that non-state actors, including the private sector and civil society, are engaged in climate compatible development and help to drive this implementation. In addition to supporting the development of the NCCAP and Kenya's Nationally Determined Contribution. CDKN also has a diverse portfolio of other projects assisting the private sector, non-governmental organizations and research in Kenya. With CDKN support, the flower sector has developed a carbon reduction toolkit, a series of briefing notes with the Kenya Private Sector Alliance to communicate climate change risks and opportunities to the country's private sector, and journalists have been trained to report on climate change. CDKN has also funded research to reduce farmers' vulnerability through the provision of weather forecasting services, and research to understand the adoption of solar home systems to improve uptake of low carbon technologies.

In driving the implementation of the NCCAP, CDKN's goal for the Kenya Country Program also aims to support improved access to international climate finance. The program aims to support not only policy and planning but also the implementation of appropriate climate compatible development strategies and priorities. It is envisioned that through enhancing direct access to climate finance, the Government of Kenya will be better able to leverage and channel resources effectively for the implementation of adaptation activities identified in the NCCAP, Climate Change Bill and Framework Policy, National Adaptation Plan (NAP) and Kenya's NDC. By working with government and non-state actors at national and sub-national levels, CDKN aims to increase political commitment and build institutional capacity that drives climate compatible development action.

Singapore, a small island state with one of the highest per capita incomes and strong institutions including advanced technological capabilities, has taken advanced measures to safeguard the island from climate events.62 Its response to the recent global pandemic is exemplary and indicative of its capacity to implement mitigating measures quickly, which even the USA has been unable to mount. It will take a long time, plenty of resources and political will for developing countries to match the capacity which Singapore has today. But it provides an example of the ingredients needed to combat climate change successfully. Some developing country governments also have made substantial progress in preparing climate adaptation plans with the help of donors.

Hong Kong, which is now an administrative part of China, announced its initial target in 2010 to reduce its carbon intensity by 50 to 60 percent from 2005 levels by 2020. In 2017, the Hong Kong government published *Hong Kong's Climate Action Plan 2030+* report in response to the Paris Agreement. The report details the government's carbon emissions reduction target for 2030 and outlines action plans to meet it. Hong Kong has pledged to reduce 65 to 70 percent of its carbon intensity by 2030, using 2005 as the base. This is equivalent to a 26 to 36 percent absolute reduction and a reduction to 3.3–3.8 tonnes on a per capita basis, compared with 6 tonnes per capita in 2005 (Environment Bureau 2017). In order to mobilize action to advance Hong Kong through a cross-sectoral transition toward long-term deep decarbonization, World Resources Institute (WRI) and Civic Exchange (CE) jointly initiated a project called "Hong Kong 2050 Is Now." Under this project, WRI and CE collaborated with Energy Innovation LLC to develop the Hong Kong Energy Policy Simulator (EPS), which aims to provide technical support for developing Hong Kong's 2050 deep decarbonization strategy. The "Hong Kong 2050 Is Now" project provides policy recommendations based on the results of the Hong Kong EPS. The Hong Kong EPS also allows users to create their own scenarios to see impacts of different policy combinations.

More detail on the technical aspects of the Hong Kong EPS is available in the EPS online documentation at https://hongkong.energypolicy.solutions/docs/. The model is free and open source. It can be used via an interactive web interface at https://hongkong.energypolicy.solutions/ or can be downloaded from the same site. The EPS can estimate the effects of various policies on many indicators, such as emissions, financial

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[62] See Vinod Thomas' book "Climate Change and Natural Disasters" available free on Amazon.

metrics, electricity system structure, deployment of different types of vehicles, as well as many other data. The EPS simulates energy policies as well as non-energy policies, such as those affecting industrial processes. EPS policies are actions taken, not targets. The EPS is generally a forward-simulating, not goal-seeking, model. Therefore, policies generally constitute specific actions or measures that influence actions, such as changing the price of something, rather than specifying targets to be met via unknown actions. The tool allows users to explore various policy combinations to create policy scenarios, including custom policy implementation schedules. The EPS simulates the years 2017 to 2050 by using annual time steps and offers hundreds of environmental, economic, and social outputs. Significant output indicators include emissions of 12 pollutants, cash flows (first- order costs and savings to government, consumer or labor, non-energy industries, and each of the energy industries), capacity and generation of electricity by different types of power plants, market share of different vehicle technologies, and premature deaths avoided by reductions in particulate emissions. These output metrics can help policymakers anticipate long- term economic impacts and costs of implementing new policies. WRI has helped some other developing countries with using its generic EPS model, available at https://www.energypolicy.solutions. However, climate action needs to be taken at sub-regional in larger countries such as Nigeria, Indonesia, and Brazil which requires such models to be implemented for local levels of government. Compare this to the MIT En-Roads model mentioned earlier.

China, over the past two decades, its massive investment in coal fired power plants and energy intensive heavy industries have made it the world's largest carbon emitter. China's unprecedented economic boom has brought with it a 250-percent increase in primary energy production, 70% of which is coal based, causing a significant increase of greenhouse gas (GHG) emissions. While China is increasing renewable energy output at a rapid rate, it has no announced plans to shut its coal powered plants which makes it plan inconsistent. The announcement that China will achieve net zero emissions by 2060 has raised hopes, but also doubts, about the credibility of this announcement. The New Climate Institute[63] estimates that if China achieves its emissions target, this alone will reduce global mean global temperatures by 0.2 -0.3 degrees Celsius. For China to deliver on its international commitments, its cities – which generate 70 percent of the country's emissions – will have to achieve aggressive low-carbon reduction targets. The National Development and Reform Commission is the apex agency responsible for developing climate plans supported by various agencies and ministries. But it is local institutions and leaders that have taken the lead in detailing and implementing climate smart, low-carbon development pathways. China's example shows the importance of involving all stakeholders, particularly at the lowest levels, in effective development and implementation of climate plans.

In 2016, the Climate Smart, Low Carbon Cities Project (CSLCC) was launched to give Chinese urban planners the skills and tools to effectively implement low carbon policies. Implemented by the Institute for Sustainable Communities (ISC)[64] and the International City/County Management Association (ICMA), with the support of the China National Cen-

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[63] See www.newclimate.org
[64] See www.iscchina.org for details about these programs.

ter for Climate Change Strategy and International Cooperation (NCSC). The CSLCC project encouraged Chinese leaders in four urban areas to identify, scale and share best practices in emissions reduction. As an example, The Chang-Zhu-Tan Cluster consists of Changsha, Zhuzhou, and Xiangtan cities with a total population of 14 million located in Hunan Province. The program resulted in several provincial and city- level government departments collaborating on GHG accounting and forecasting, establishing a foundation for low carbon development planning. With support from a CSLCC team, Changsha has developed a Climate Action Plan, outlining a clear early peaking pathway for Changsha to peak emission by year 2025. The plan prioritizes sectors with the highest potential for reductions and identifies projects with the best carbon and cost efficiency, with financing suggestions like green bonds and public-private partnerships. The project includes electrification of public transport, emissions reductions in major industries, increasing the number of green buildings, establishing a low carbon fund for financing emissions reduction projects, a data management system for monitoring projects and a governance system for climate management.

Other city groups covered under this initiative have focused on adoption of low carbon technologies for major industries including developing plans for net zero emissions industrial parks/estates. CSLCC has identified specific cities as near zero emission zones, such as the Shenzen program, and has now expanded the program to some 13 pilot cities in 2020 and in the 13th National Plan will expand very substantially to cover over 100 cities [65]. The China urban emissions reduction program holds a lot of lessons for other countries, particularly developing countries which will need to build local capacity to implement climate actions plans in an effective way. USAID has been assisting this program with support through The Low Emissions Cities Alliance (LECA) including exchange of information between Chinese and US cities.

Mobilizing Resources for Climate Action

There are numerous sources of finance available to assist governments set up a Climate Action Planning Agency with the broad mandate described above. Multilateral banks such as the World Bank, ADB, IDB, provide grant funding from trust funds for institution building and training. So does the UN program on climate change. Bilateral aid agencies such as Japan's JAICA, UK's DFID, USAID, European aid, Swedish aid, Danish aid, etc. are all sources of grant funds and low-cost financing. A major new source for funding both technical assistance and investment projects is the Green Climate Fund (GCF) available to developing countries for financing both mitigation and adaptation projects. See footnote for a brief description of a climate mitigation/energy and material efficiency improvement project in Bangladesh to assist the textile sector.[66]

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[65] https://chineseclimatepolicy.energypolicy.columbia.edu/en/low-carbon-cities

[66] GCF financing of Textile Sector Energy Efficiency Improvement Project in Bangladesh CO2 emissions of Bangladesh increased by an annual average of 8% over the past two decades. The readymade garment (RMG) sector was the largest contributor of emissions at 15.4%, followed by the textile sector at 12.4%. These sectors operate inefficiently because of continuing use of old machinery coupled with poor energy management. If the current industrial energy intensity persists along with the economic growth outlook in the medium to long term, Bangladesh will face severe difficulties in achieving its NDC target of 15% GHG emission reduction under the Paris Agreement. Moreover, textile and RMG manufacturers face several barriers to invest-

Bill Gates, with fellow billionaires, recently established the Breakthrough Energy Fund devoted to financing innovative technology projects to fill the underinvestment in climate innovation. The $1 billion fund has already invested in nuclear power (Natrium) and artificial meat -Impossible Foods- a plant-based burger producer. However, climate funding just received (announced March 9, 2021) an enormous boost from Jeff Bezos who announced the appointment of a new Director- Andrew Steer- the head of WRI -to head his Earth Fund which will provide grants totaling $10 billion by 2030 to meet the climate challenges and address the needs of the poor and minority communities. Steer announced "The Earth Fund will invest in scientists, NGOs, activists, and the private sector to help drive new technologies, investments, policy change and behavior. We will emphasize social justice, as climate change disproportionately hurts poor and marginalized communities.[67]" This will enable a major increase in projects and innovations at all levels to address the climate crisis.

Multilateral bank and UN funding is available on a grant or low-cost basis for projects to combat climate change. For example, a project for the rehabilitation and replanting of mangrove forests in Cuba's coastal regions to help protect the lives of people living in coastal areas from extreme hurricanes is being financed by the UN. The UN has made a grant to Indonesia to preserve rain forests which act as a carbon sink. The cutting and burning of forests to extend cultivation has created a major health hazard to people in Malaysia and Singapore from drifting smoke. A blueprint for helping countries keep carbon in fragile land-based carbon sinks (permafrost and peat land) has been announced by the Food and Agriculture Organization (FAO) which provides funding for these projects.

The multilateral banks are heavily involved in providing both knowledge and funding for a variety of agricultural, urban, water supply and renewable power projects where the main goal is poverty reduction and providing goods and services to the poor. Some funding is blended financing, a combination of grants and soft loans; some involve guarantees to help developing countries raise funding from international capital markets through novel financial instruments such as green bonds and blue bonds[68]. The World Bank Group's partial risk and partial credit guarantees allow financially weak countries to mobilize private capital on favorable terms or extend the maturities of loans to long periods to match the useful life of investments. The World Bank has recently announced a new trust fund for financing

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ing in energy efficiency including inadequate financial incentives, lack of technical expertise and a weak enabling environment. The Project provides an integrated package of concessional financing for textile and garment manufacturers, and technical assistance to create an enabling environment and ultimately reducing 14.5 million tons of carbon dioxide equivalent in emissions.

[67] https://www.wri.org/news/2021/03/release-president-and-ceo-andrew-steer-depart-wri-lead-bezos-earth-fund

[68] A green bond is a type of fixed-income instrument that is specifically earmarked to raise money for climate and environmental projects. These bonds are typically asset-linked and backed by the issuing entity's balance sheet, so they usually carry the same credit rating as their issuers' other debt obligations. Blue bonds are earmarked for marine environment projects such as mangrove preservation in coast lines. Multilateral banks facilitate the issuance of these bonds by developing countries through credit enhancement guarantees reducing risk and interest rates.

climate action plan preparation and implementation.[69] This complements the low-cost loans available for climate investment projects in various sectors.

Unfortunately, big private commercial banks have been financing fossil fuel projects over the past five years, seemingly oblivious of the climate crisis. They are estimated to have financed $3.8 billion in fossil fuel projects with no sign of let up.[70] The private financial sector may need waking up to join in combatting climate change, recognizing their own stake in successful outcomes. The IFC, a member of the WBG is applying the Equator Principles in financing investments by the private sector. Private firms are factoring in climate risks in their investment and normal business operations. Rating agencies such as Fitch and S&P are looking at a firm's exposure to climate risks in rating their debt instruments. So are insurance companies which are directly exposed. Here are some quotations from Mark Carney, appointed special advisor on climate finance to UK prime minister Boris Johnson; Carney, outgoing governor of the Bank of England and incoming UN special envoy on climate action made the following remarks at the City of London on August 27, 2020 addressing banks and investors**.**

According to the PwC report, *The State of Climate Tech 2020*[71], between 2013 and 2019, $60 billion in early- stage capital was invested globally in start-ups tackling the net-zero challenge. However, just under five per cent of this investment came from Asia (excluding China), Africa and Latin America. The report found that climate tech related to mobility and transport, heavy industry and GHG capture and storage are the fastest growing segments, followed by food, agriculture, land use, built environment, energy and climate and Earth data generation. Bengaluru in India is the only city in a developing country to become a climate tech start-up investment hub outside of China.

Setting out strategies to mobilize private finance ahead of the UN climate talks in Glasgow, or COP-26, Mark Carney said "Every private finance decision must take into account climate change and how to decarbonize the world economy to net zero." Such investments "could become the greatest commercial opportunity of our time." "COP-26 is simple," he said, "to make sure that every private finance decision takes climate change into account. Achieving net zero emissions will require a whole economy transition – every company, every bank, every insurer and investor will have to adjust their business models. This could turn an existential risk into the greatest commercial opportunity of our time." Carney said

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[69] A new flagship World Bank trust fund, the Climate Support Facility, was launched on December 10, 2020 with an initial investment of $52 million from the German Federal Ministry of Economic Cooperation and Development, the UK's Foreign, Commonwealth and Development Office, and the Austrian Federal Ministry of Finance. The Facility, whose launch is timed with the 5th anniversary of the Paris Agreement, will provide support for technical assistance and advisory services. In addition to focusing on the green recovery, it will also support countries to enhance their national climate targets (the Nationally Determined Contributions or NDCs) and in their efforts to integrate climate into long-term development planning. It will also fund analytical tools and knowledge development to inform country climate planning and development strategies.

[70] https://www.huffpost.com/entry/banks-fossil-fuels-finance-climate-change_n_605a45b8c5b6cebf58d28d52

[71] Price Waterhouse Coopers, September 2020 Press release on climate startup Finance

that achieving a whole economy transition was not "about funding only deep green activities or blacklisting dark brown ones. We need fifty shades of green to catalyze and support all companies toward net zero".

Larry Fink, CEO of the Blackstone Group made the following remarks recently, "In January of last year (2020), I wrote that climate risk is investment risk. I said then that as markets started to price climate risk into the value of securities, it would spark a fundamental reallocation of capital. From January through November 2020, investors in mutual funds and ETFs invested $288 billion globally in sustainable assets, a 96% increase over the whole of 2019. I believe that this is the beginning of a long but rapidly accelerating transition – one that will unfold over many years and reshape asset prices of every type. We know that climate risk is investment risk. But we also believe the climate transition presents a historic investment opportunity. President Biden has highlighted this opportunity in his climate action plans. Venture capitalists are bringing green innovations to fruition every day. This should give everyone hope."

As mentioned earlier, significant number of firms have announced plans to reduce their GHG emissions to net zero by a target date without spelling out actual policy changes and investment plans. These plans will not materialize unless there is a strong constituency among stakeholders to hold management accountable for results through appropriate incentives. Otherwise, one would face the classical principal–agent problem in that the shareholders will have little leeway unless they can implement changes through voting in shareholder meetings. Including directors who are climate friendly may be one way for shareholders to influence management. The NY stock exchange now requires at least one-woman director on the boards of publicly traded companies. Perhaps this rule can be broadened to include directors who are committed to exercise oversight of the firm's explicitly stated commitments on reducing GHG emissions.

The Way Forward: Some Reflections for the Future

This paper has reviewed the complexity of the challenge posed by the climate crisis facing the world and poor countries, in particular. It has highlighted some lessons in terms of policy, technology, finance, and institutional capacity building required for successfully addressing this challenge. The climate crisis will require a concerted collective effort by all stakeholders and cooperation within and between countries in terms of sharing knowledge and best practices. As the COVID-19 pandemic has shown, without international cooperation, the challenge cannot be addressed by individual countries working in isolation. The climate crisis is a much more complex, longer-term global crisis which will also require close international cooperation. Changes in individual behavior and expectations will be required in all countries. There are short term costs which every individual will have to accept for the common good.[72] Our consumption patterns will need to be altered. People in rich countries who have enjoyed high material standards of living will have to recognize this truth as much as they have in confronting Covid-19.

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[72] See Equity and the Future of Democracy by Anne-Marie Slaughter and Sharon E Burke, Oped published by the Wilson Center and Adelphi, 2020

Inequality is increasing in many developed countries with high rates of GDP growth as pointed out by the economist Thomas Picketty[73]. Awareness of this issue in the USA has emerged recently with the Biden administration ushering in a $1.9 trillion fiscal program to reduce child poverty among other areas. In spite of immense technological progress, the last two decades have not resulted in higher living standards for the bottom 20% or increases in total factor productivity for the economy as a whole in the USA.

Climate justice calls for equitable policies and acceptance of these costs. Developing countries have absorbed the high cost of industrial pollution by manufacturing carbon intensive products for sale to richer countries. This has been one major unrecognized benefit of outsourcing for developed countries. Corporations have to cooperate and look beyond the interests of their shareholders. They have to become transparent with regard to their global climate footprint and take real mitigation actions, not just buy offsets and continue business as usual. Their shareholders and customers will be on watch.

As part of the global effort to combat climate change, developing countries are being asked to leave their natural resources in the ground and adopt new more costly pathways to economic growth. At the same time, large firms are thwarting adoption of more stringent environmental regulations because their existing assets will become stranded or less valuable. Everyone should recognize that the goal of every country is to provide a healthy and fulfilling life to its citizens. Progress is achieved when the basic living standards of the average citizen is significantly improved. It is measured by the living standards of the bottom 10% not by that of the top 10%. India, China, and Brazil have many billionaires but also huge numbers of poor people, although the number living in abject poverty has been cut substantially. It should not matter how the goal of improving living standards for the poor is achieved even if alternative investment pathways are more expensive. Bill Gates in his new book "How to Avoid a Climate Disaster" states 'Everything I have learned about climate and technology makes me optimistic –if we act fast enough (we can) avoid a climate catastrophe". New evolving technologies are lowering these transition costs and providing new employment opportunities. I think we can achieve the Green House Gas reduction goal if we have the political will and engage in international collective, and cooperative, action.

Shyamadas Banerji '64 Course 2, Mechanical Engineering, SM 1965 Mechanical Engineering, spent his peripatetic career working in several different areas. In the first decade he worked as an R&D engineer with DuPont; teaching operations research and business management (MBA) as a faculty member at the Indian Institute of Management, Calcutta, and working as a Regional Planner on regional planning methodologies as an advisor to the Ford Foundation. Beginning in 1976, he spent the next 25 years with the World Bank working on a variety of international development issues in over 25 countries. He started with the Development Banking Department extending lines of credit to industrial firms and progressed to work on industrial and financial sector reforms in developing countries. He then moved to the Inspector General's Department that reviewed the World Bank's pro-

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[73] Thomas Picketty Capital and Ideology; and Capital in the Twenty First Century, both available at Amazon.

jects, policies and economic reform programs and reported to the bank's Board of Executive Directors. After several years, he moved to the Co-financing and Private Sector Development Department responsible for supporting governments to reform public enterprise and privatization of public enterprises as well as extending structured loans and guarantees for infrastructure projects. He retired in 2001 and has been working as a short-term advisor/consultant to governments and various aid agencies. His current interests are assisting governments build capacity to combat the climate crisis -- which is the proximate reason for writing this paper.

Is the Current VP Path to the Presidency a Good One?

David Sheena

Introduction

There is a saying that good health is a crown on the head of the healthy that only the unwell can perceive. I was born in a part of the world that lived in the shadow of an ancient disease - an authoritarian society. I was part of the oldest Jewish community in Iraq, previously Babylon. For the Jewish people, being inconspicuous was a way to avoid trouble. I was unharmed but grew up with memories of my father warning me to be quiet in public and to keep our traditions private.

Having come from a shadow to the light of America, I became aware of the sunshine of an open democracy more than the people already enjoying it. It gave me a palpable feeling of new daylight, a sense of belonging, and a marvel at how this most elegant American system and Constitution were structured.

I knew that democratic security can only thrive in a solid and transparent legal system of government. I paid attention to how this government worked, and naturally, I saw some of its imperfections. Being an engineer, I looked at rules and procedures, and I was uneasy with processes that did not have transparent democratic practices. And, one thing that troubled me was the selection of a vice president. It struck me as perhaps not altogether representative of the people.

Vice President Selection Today

For several weeks before the 2020 presidential election, the American people were bracing for a significant political announcement, like the faithful in front of the Sistine Chapel awaiting the puff of white smoke announcing the election of a new pope. In our case, America was waiting for the "selection" of the presumptive Democratic vice-presidential nominee. When anointed at the party convention, this individual became the vice-presidential nominee. And, when elected, the next vice president of the United States. And, with a significant probability, a future candidate for the presidency. This series of events has often occurred in our country's history.

From our own "Now" perspective, we were observers at the tail end of the historical/political evolution of the process. We may remember in the fifties and sixties that there were actually contested and sought after vice-presidential nominations. A couple of examples we may recall: In John Kennedy's choice of Lyndon Johnson as his vice president, the convention was not a rubber stamp; Johnson was opposed by Minnesota Governor Orville Freeman. For Richard Nixon, his choice Spiro Agnew needed to prevail over Michigan Governor George W. Romney, who was supported by a liberal faction of the Republican Party.

As we moved forward to our more recent experiences, we note that Kamala Harris, Joseph Biden's running mate, and Mike Pence, Donald Trump's running mate, *were* nominated by "rubber stamp" conventions.

The issue is not about the chosen individual but *how* the choice is made. It is extraordinary that, for this most democratic of nations, o*ne* and *only* one individual made this choice, no vote, no primary, no caucus, no convention, but the decision of one person, the presumptive presidential nominee. And, this process came to be more by political evolution than by statute.

But there is more. Our current president, Joe Biden, who can launch a future presidential candidate, was himself appointed by a single individual, Barack Obama, to be *his* vice president and given the outsized opportunity to become president. Also, in recent memory, it can be said that Ronald Reagan "selected" one or perhaps *two* future presidents. He "appointed" George H. W. Bush as his vice president, who succeeded him as president. And, an argument can be made that the first Bush's son George W. Bush rose to prominence *and* the presidency in part because of his father's position. Fifteen vice presidents went on to become president, most recently Joe Biden. Nine of them did so after the president's death or resignation.

The new president will have the duty of submitting for Senate confirmation about 1200 nominees, heads of departments, ambassadors, judges, and others. It is incongruous that, under current custom, his most important "appointment," the vice president, does not require *any* official body confirmation.

How Did We Arrive at Current Practices

Historically, it turns out that the succession component of the vice-presidential duty is *not* minimal. Fully for about 20% of this country's years, we had unelected presidents, that is, vice presidents who rose to the position upon the death or departure of the sitting president. The list is significant; John Tyler, Millard Fillmore, Andrew Johnson, Chester Arthur, Theodore Roosevelt, Calvin Coolidge, Harry Truman, and Lyndon Johnson succeeded because of the sitting president's death. Gerald Ford rose upon Richard Nixon's resignation. Some of these presidents, like Harry Truman and Lyndon Johnson, are counted by scholars to be among the best US presidents. But this may have been a fortunate circumstance. Andrew Johnson, for example, was always at the bottom of historians' lists.

It is difficult to fathom or accept that For a democratic country like ours to have had "unelected" presidents for fully 20% of our history. If people were asked directly if they would consent to being governed by unelected presidents for a fifth of the time, their answer would be obvious.

THE EVOLUTION OF THE SELECTION OF THE VICE-PRESIDENTIAL CANDIDATE

• **1788 US Constitutional Government**
○ **Method:** Electors cast ballots for a president. The candidate with the second most votes became vice president.
○ **Rationale**:
• The Vice president is elected in a democratic fashion
• Vice president, being a presidential contender, is of presidential caliber
• Non-political government, no party involvement
○ **Flaws**:
• Political parties began to form and cause difficulties
• An ineffective partnership such as rivalry between President John Adams and Vice President Jefferson
• Complicated tie in the election of 1800 between Thomas Jefferson and Aaron Burr
• **1804 12th Amendment to the US Constitution**
○ **Method:** Electors cast separate ballots for president and vice president.
○ **Rationale**:
• A presidential tie is avoided
• The intention that the president and vice president run as a pair for a cohesive government.
○ **Flaws**:
• VP candidate is chosen for electability of the team instead of more sound reasons
• **1940s Evolution of political custom**
○ **Method:** Vice-presidential running mate is chosen by party presidential nominee
○ **Rationale**: The candidate chooses a running mate with whom he can be strongly connected to
○ **Flaws**:
• VP candidate is being effectively selected by one person

1788 US Constitutional Government

The concept of running mates or being on the same ticket did not exist at the inception of this office. The vice president's position was almost an afterthought in the Constitution for the purpose of succession, but, at first, it *was* "democratic."

The original selection of the vice president was simple. Each state elector voted for two candidates for president. The one receiving a majority became president, and the one with

the next highest number of votes – not necessarily a majority – became vice president. So the choice *was* intended to belong to the people, represented by the electors. As such, the first two vice presidents, John Adams and Thomas Jefferson, being men of extraordinary ability, were both "elected" with the support of those who trusted that the two were amply qualified to hold the top office. We no longer have this option, as citizens, of being, at least nominally, represented in the vice-presidential choice.

Although the first constitutional phase of the process, the system guaranteed a successor of "statesman" quality, it effectively required that there be no party affiliation.

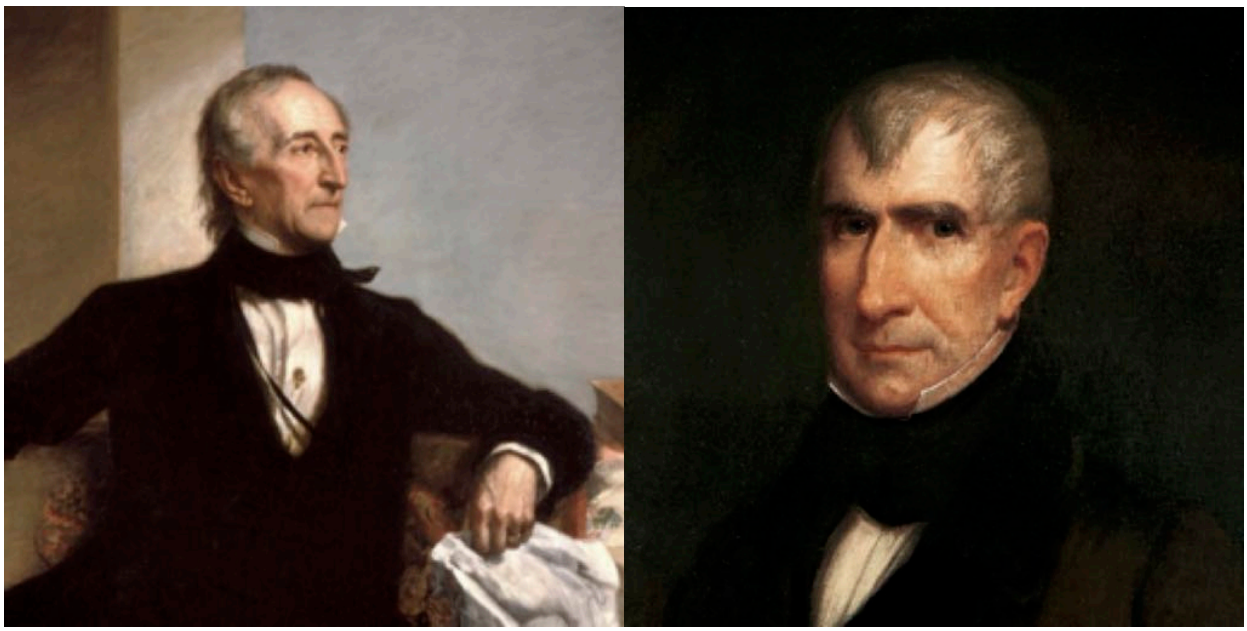
And yet, parties began to materialize. Party affiliation caused a bitter rivalry between John Adams, who became president in 1796, and Thomas Jefferson, who became vice president from a different party. The result was a non-unified executive, less effective than it might have been. There was concern that such a difference could, in theory, lead to a coup d'etat. Europe, after all, had plenty of them.

Thomas Jefferson (center) ran twice against his revolutionary comrade and friend John Adams (left). In 1797, he came in second, and therefore was vice-president under the constitutional electoral method. At this time, they had become political rivals from different parties and did not work as an effective executive pair. Always in vice-presidential conflict, Jefferson ran again against Adams in 1801. He defeated Adams but tied Aaron Burr (right), who was intended to be the vice president. The vote went to the House of Representatives and required 36 ballots for Jefferson to be elected. This tie brought about the 12th Amendment.

It became worse. The next election of 1800 found Jefferson and his proposed vice president, Aaron Burr, tied. The decision was sent to the House of Representatives, where political jockeying resulted in 36 ballots being cast before "correctly" awarding the presidency to the intended Jefferson.

A footnote to the Constitution is that the vice president was supposed to only succeed to "powers and duties" of the presidential office. A non-statutory precedent was set when John Tyler became president upon William Henry Harrison's death in office. Tyler decided

that he was, in fact, president, with name, prerogatives, and salary ($25,000 instead of $5,000). It has been this way ever since.



William Henry Harrison (right) became the first president to die in office. His vice president John Tyler became the first president to serve unelected. To establish a fait-accompli, Tyler insisted he was president rather than the acting president, took the oath of office, moved into the White House, and demanded the president's salary. He set a precedent finally codified by the Twenty-fifth Amendment.

1804 12th Amendment to the US Constitution

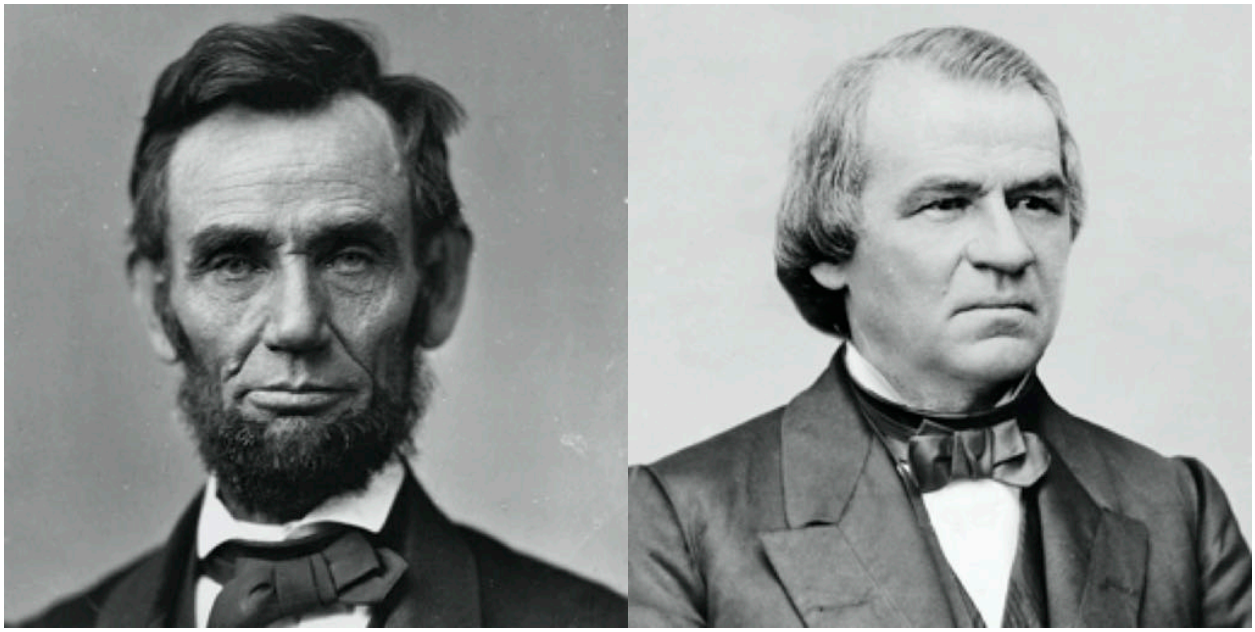
As a result of a tie in 1800, the Twelfth Amendment decreed that the two individuals were to be elected on separate ballots. The problem of a tie was resolved.
With political evolution, candidates began to run as a team for the same ballot's two offices. No laws were ever passed to allow this to happen. After the Civil War, the states began to place candidates for president and vice president together on the same ballot or "ticket."
After 1800, the vice-presidential candidates have been chosen to make the ticket politically balanced and more electable. Since the 1940s, presidential candidates have selected their own running mates, relying primarily on their advisers.

The 1940s

Historically, the vice-presidential candidate was chosen by the political party with the agreement of the presidential candidate. In the late 1940s, it became the practice that the presidential candidate declares his preferred choice of a running mate at the party's national convention. The current custom is for a political party's presumptive nominee to announce a running mate's selection *before* the national convention.

According to historian Joseph Uscinski of the University of Miami, this can have uncertain results. On the positive side, it can provide for a vice president similarly inclined to the president who would have the same philosophy to carry out the same policies. This would

make a transition potentially seamless and least disruptive. What has happened more frequently is that the choice is made to produce a more marketable team. This has been done to balance political views, geography, and, more recently, sex or race.
Even political parties were combined for the sake of electability. Abraham Lincoln, a Republican, was joined with Andrew Johnson, a Democrat. The two men could not have been more different. And, after Lincoln's assassination, Johnson hampered efforts at bringing racial justice to the south.



By the Civil War, vice-presidential nominees were chosen to make the ticket more electable, sometimes with unintended consequences. Republican Abraham Lincoln (left) joined Democrat Andrew Johnson. After Lincoln's assassination, Andrew Johnson did not follow the reconstruction and conciliatory attitude of Lincoln.

This inter-party dance was repeated in our own time. In 2004, Democratic presidential nominee John Kerry asked Republican senator John McCain to join the Democratic ticket. In 2008 John McCain considered partnering with Democrat Joe Liberman. Democratic nominee Barak Obama is reported to have considered Republican senator Chuck Hagel of Nebraska.

Uscinski and others state that while electability is the goal, this fine-tuning does not usually produce the desired electoral benefit. Conversely, and surprisingly, unpopular vice-presidential choices have not punished the presidential candidates.

More Recent Times

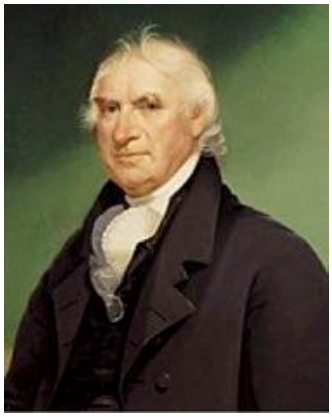
In 1972, George McGovern chose Thomas Eagleton, who admitted to having had troubling mental issues. This seriously disrupted his campaign, but it turns out that all McGovern's supporters would have still voted for him. In 1984, Walter Mondale chose Geraldine Ferraro to gain the women's vote but lost both the women's vote and the election.

In 2008, John McCain's choice of Alaska Governor Sarah Palin was believed to have hurt him. People did not think of Palin as a realistic presidential successor, and she may have cost him as many as two million votes, but the effect on the election was not significant.
The data shows that voters will *not* abandon their preferred candidate simply because they disapprove of his vice-presidential nominee.

Unintended Consequences

Nevertheless, in the case of an unlike-minded pair, there could be and *have been* attempts to forcibly remove the president to install one with the "desired" politics. A violent way to remove the president is assassination to make policy changes with a trigger. Whether they planned it or not, assassins did effect changes in politics, killing Lincoln and replacing him with Andrew Johnson (southern sympathy), killing James Garfield and replacing him with Chester Arthur (patronage system), and killing William McKinley for Theodore Roosevelt (Imperialism and capitalism). No one claims that it was the vice president's views that motivated these killings, but incentives can exist.

Impeachment has at least once been used for a political purpose, again connected to Lincoln. Congress was at odds with Andrew Johnson and impeached him on a trumped-up charge to have a more agreeable presidential successor- his effective vice president, the Speaker of the House.



George Clinton, American founding father and fourth vice president under two presidents, Thomas Jefferson and James Madison, from 1805 to 1812, was the first of two vice presidents to serve under two presidents. His death in office in 1812 caused the first of several vice-presidential vacancies.

Before ratification of the Twenty-fifth Amendment, February 10, 1967, an intra-term vacancy in the vice presidency could not be filled.

Vice-presidential Musical Chairs

Possible wrongdoings forced Vice President Spiro Agnew to resign as President Richard Nixon's vice president in 1973, triggering for the first time the Twenty-fifth Amendment's mechanism to fill the vice-presidential position by presidential appointment and congressional confirmation. Gerald Ford was appointed and confirmed as vice president in 1973.

It happened again. President Richard Nixon's resignation, the first in American history, was due to the Watergate scandal. It triggered the Amendment again,

and Gerald Ford was confirmed as America's first and only unelected president. Again, there was a vice-presidential vacancy. President Ford appointed with congressional confirmation Nelson Rockefeller to become vice president.

Agnew *Nixon* *Ford* *Rockerfeller*

Conclusions

It is a striking irony that whereas the original selection of a presidential candidate was just that, a selection, it has now come closer to the voters' choice. Initially, in our republic, presidential candidates were chosen by elite electors and later by party caucuses and national conventions. Localities picked delegates to state conventions, which in turn elected delegates to national conventions. In the twentieth century, the evolution of primaries essentially enabled voters to choose their candidates. So, the historical trajectories of the democratization of the selection of the US presidential and vice-presidential candidates took opposing arcs. The presidential candidate is "elected," and the vice-presidential candidate is appointed.

As I studied this vice-presidential story, I was surprised that historians, in the majority, see this as the best of nonideal possibilities. Joel Goldstein, a law professor at St. Louis University, believes that the current system is "messy and with anomalies," but "the system we have makes the most sense when all things are considered." Presidential candidates have to choose someone worthy. The election incentivizes them to pick good people.

Another reason for optimism: "There is growing evidence that presidential nominees understand the importance of picking a qualified governing partner over an illusory electoral gain," says Matt Grossmann, a political scientist at Michigan State.

How else is this done? The state model of replacing senators or congressmen does not offer any answers. A caretaker government has difficulties of implementation and continuity. Other democracies do not provide any more attractive models.

I have come upon only one suggestion seriously put forth to address this troubling mechanism. That is to require a Congressional Confirmation of the Vice-presidential selection. All experts agree, however, that this would result in a nightmarish gridlock. Also, it would deprive the nation of a visible candidate.

The Now and Beyond

My study and attempt to research and understand my original question have led me to rethink my concern about the less than fully democratic naming of a vice-presidential candidate. I have become more settled about this being the best system that works.
I am confident that it is, after all, the hearts of the American people that make the difference in keeping America democratically secure and safe.

In our own times, we have experienced at least two events that some have actually upgraded to "constitutional crises," The ends of the Nixon and the Trump presidencies. America survived to live another day.

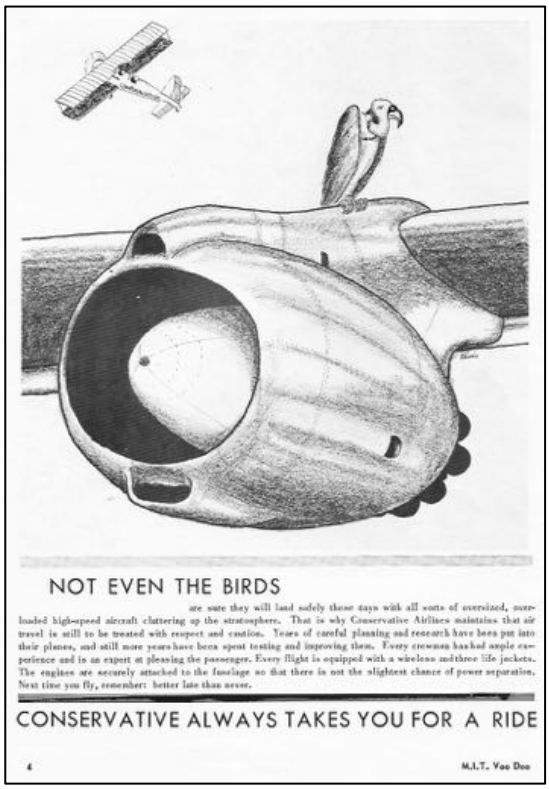
David Sheena '64, Course 6, Electrical Engineering, Ph.D. '69. David was born in Baghdad, Iraq. He immigrated to America in 1955, as all the Jewish communities left the Middle East. After MIT, David worked on pupilometry and eye position measurement technology for psychological and brain research. Having cut his teeth on General Radio equipment at MIT electrical engineering laboratories, David co-founded IET Labs, which became heir to General Radio to design and manufacture calibration and test instruments, and where he still works. He is married to Marlene, and they have four children and eight grandchildren.

The Art and Science of Architecture After 60 Years: What's New, What's Not

Roger Lewis

How I Learned What's New, What's Not

In 1960 during the spring semester of my sophomore year at MIT, I was about to flunk out. I skipped classes due to waning interest, instead spending days and nights in Baker House sleeping, playing bridge, watching TV and periodically going to movies in Boston. Earlier that semester, I had read the differential equations text and then somehow passed the advance standing exam. Today I have no idea why I did this and remember nothing about differential equations. But I do remember feeling pressure to pick a major and career, along with growing certainty that becoming a scientist or engineer was not my destiny. A malaise had set in and, as a full tuition scholarship recipient, a sense of guilt as well.



With few weeks remaining in the semester and growing desperation, I went to see MIT Dean Fassett to explain my plight and my intention to drop out. An amiable, avuncular gentleman, Dean Fassett listened sympathetically to my tale of woe. He perused my MIT record and noted that, as a freshman, I had demonstrated a dean's list level of math, science and engineering abilities. But he then surprised me by asking "what do you <u>really</u> love doing?" "Drawing ever since I could hold a pencil, telling him that I had taken art lessons and had drawn cartoons for "VooDoo," the MIT humor magazine.

"Have you considered architecture?" Dean Fassett asked. I replied no, never, acknowledging that I knew nothing about architecture, even its spelling. He urged me to visit the architecture department in Building 7, talk with students and faculty, look at student work and then report back to him. I recall vividly my first reaction and thoughts seeing all the architectural drawings and scale models on desks and on display: "students actually get credit for this?" My second thought was that architecture might be for me.

Dean Fassett's advice and support changed my life. I followed his advice and returned to Cambridge in September 1960 to begin the MIT five-year B.Arch. program's last four years. Having entered MIT in 1958 as a member of the class of 1962, I was now a member of the class of 1964.

Architecture, Archi-torture

Design studio critics assigned projects varying greatly in size, type and complexity. For our final design studio, visiting Prof. Gerhard Kallman, co-winner of the Boston City Hall design competition, asked us to design a science/engineering library on the MIT campus. My project clearly echoed Kallman's "brutalist" concrete language.

I had little trouble with architectural technology courses, thanks to my previous science, math and engineering courses. I could readily produce drawings and models, yet the first two design studio years proved challenging. Arcane aesthetic language and esoteric critiques voiced by design studio teachers, so different from technology discourse, were initially baffling and hard to decode. Happily, working full time in an architectural office during the summer of 1962 enabled me finally to catch on. During my last two years of design studio work, the mysteries of architectural language vanished.

Design studio faculty of that era at MIT were mostly hands-off teachers using a sink-or-swim approach. We were very much on our own, given free rein to explore ideas but receiving little concrete design guidance and direction. The prevailing pedagogical approach was teaching through criticism, with professors saying only what was wrong or what they disliked about a student's design concept, a kind of osmotic process. Nevertheless, when I graduated in 1964, I believed I would be able to successfully design a building.

Methodologically the early 1960s were an era of T-squares, triangles, measuring scales, compasses, templates, pencils or pen and ink. We drew by hand on tracing paper or illustration boards taped to linoleum-covered drafting boards. As deadlines approached, I and my MIT classmates - one woman and the rest men - worked day and night "en charrette," fueled primarily by coffee, a traditional practice at all American architecture schools. Being en charrette, French for little cart, is an expression borrowed from the Paris Ecole des Beaux Arts. At the deadline, as a cart was pushed around the Paris atelier collecting final drawings, students would continue adding lines to their drawings on the cart as it moved.

In spring 1968, the Washington Post published a story about the University of Maryland's new School of Architecture, and with it a photo of the new dean. Previously Maryland had no architecture school. Curious and out of the blue, I phoned the dean. After describing his mission and challenges, he inquired about my Peace Corps and Russia experiences, then invited me to visit the school to give a lecture about Russia and industrialized housing. It was a serendipitous phone call.

Following my lecture, he offered me a faculty position as a design instructor starting fall 1968. An academic career had never been my goal, but the offer was tempting for two reasons: it was an opportunity to shape and teach in a totally new architecture program; and it would provide a steady salary while I attempted to start an economically precarious architectural practice.

Thus began my academic and professional career. Teaching indeed enabled me and MIT '64 classmate Charles Chavarria to launch our architectural partnership in 1969. One of

our first projects was a housing project for industrial workers in Venezuela. We were hired thanks to my Peace Corps experience, and because construction technology in Tunisia and Venezuela - reinforced concrete skeleton, infill masonry walls, ceramic tile roofs - were essentially the same.

What's New, What's Not

Creating real-world, buildable architecture entails art, science and engineering. Yet aesthetic intent and aspirations differentiate architecture from science and engineering. Of course architectural artistry reflects evolving stylistic tastes, technologies, methods of practice and functional needs. Given this, what principles of architecture are immutable or axiomatic? Are there any timeless theories or guidelines?

Architects have long embraced three "Principles of Good Architecture" set forth by Vitruvius, the 1st century B.C. Roman architect and author of the world's first architectural treatise.

Vitruvius wrote worthy architecture necessitates achieving Firmatis (durability); Utilitas (utility); and Venustatus (beauty), interpreted as "Firmness, Commodity and Delight." These three, timeless principles are sufficiently broad to encompass most present-day architectural necessities.

Firmness pertains to structural stability, resilience and physical safety. Commodity pertains to optimizing functional effectiveness, operational flexibility, environmental comfort, long-term sustainability and economic feasibility. Applying and satisfying these principles requires left-brain thinking, rational analysis based on objective measurement, and logical engineering design using state-of-the-are technologies.

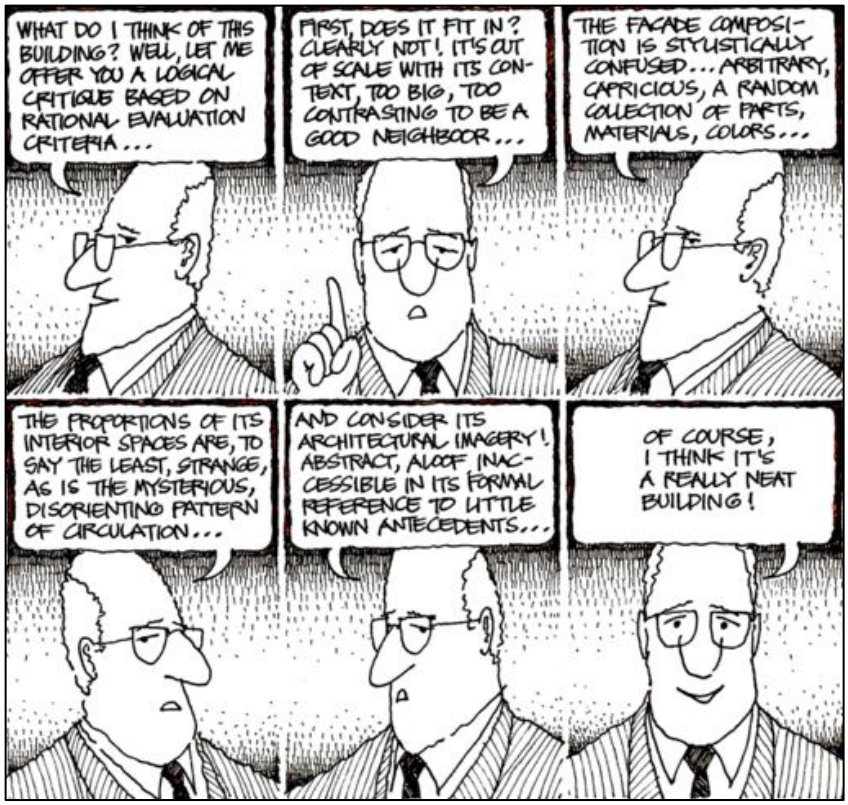
Delight, the third Vitruvian principle, is something else. Substantially reflecting right-brain thinking, delight - or beauty – is achieved through aesthetically inspired invention of architectural form and space. Non-quantitative in nature, it pertains to exploration of essential visual attributes: proportion, scale, massing, spatial relationships, and compositional interweaving, plus materials, color, details and symbolic motifs.

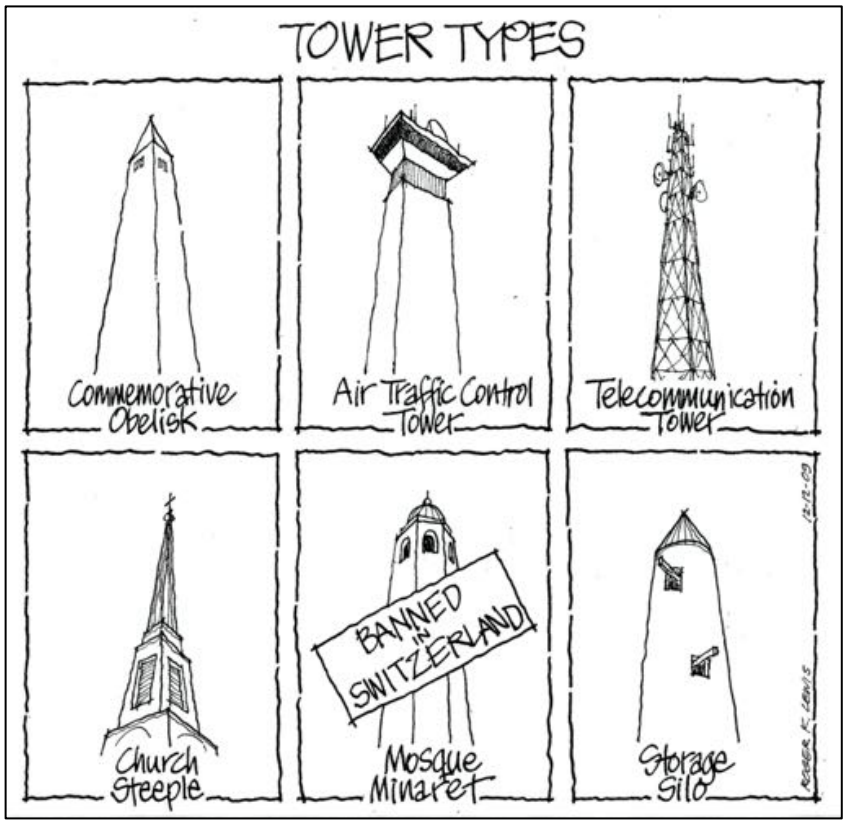
Delight can derive from contextual harmony or historic reference and reinterpretation. An engineering sensibility can produce architectural delight through order and modular repetition, or by exposing a building's structural system as a means of formal expression. This

is why we appreciate Eero Saarinen's Dulles Airport and Kresge Auditorium, in contrast to the Stata Center at MIT (below).

Some works of architecture are admired because of their elegant simplicity of massing, facades and finishes; some because of their geometric and structural complexity; and some because of a unique relationship to their site and surrounding landscape. All such judgments are matters of delight, not firmness or commodity. Buildings don't win architectural design awards just because they came in under budget, didn't fall down, kept out rainwater or made occupants comfortable year-round.

Judging a work of architecture is inescapably subjective. It depends on "eye-of-the-beholder" assessments and feelings. Such judgments reflect personal tastes, biases and especially "zeitgeist," the cultural spirit of the time. Thus today's aesthetic judgment can change tomorrow.

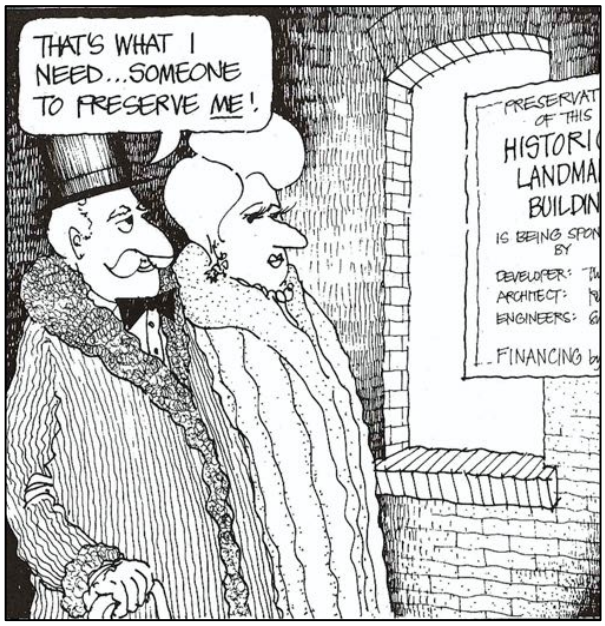


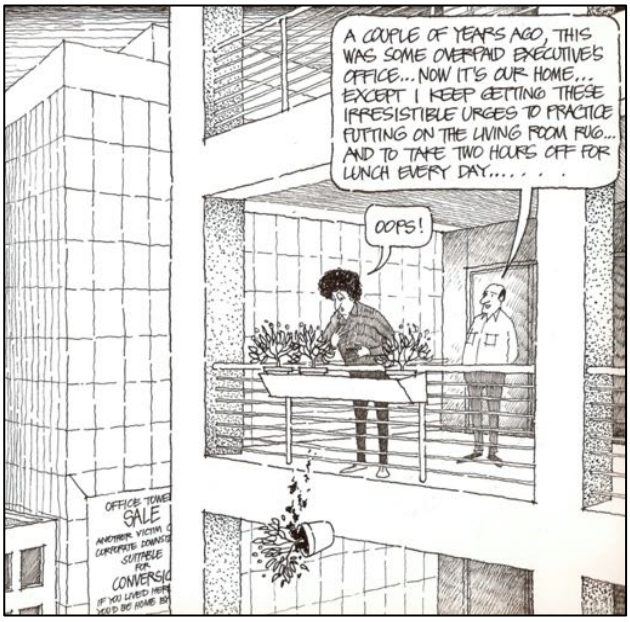


Parisians at first hated the Eiffel Tower, viewing it not as a work of art but as an engineered eyesore. It was fortunately saved and became the beloved, permanent symbol of Paris due to its height, expressive structure and memorable profile. Historically, towers have long been meaningful town and city landmarks.

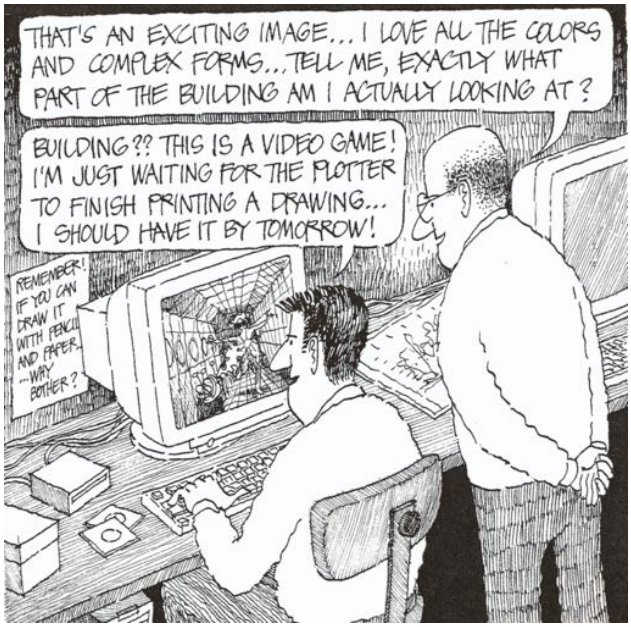
New York City's immense, neo-classically styled Pennsylvania Station was demolished in the early 1960s when modernism was the prevalent zeitgeist. Razing functionally obsolete architecture to make way for something new was acceptable, a bow to progress. But this monumental architec-

tural tragedy aroused strong historic preservation sentiments, changed Americans' views about architectural heritage and motivated enactment of national, state and local historic preservation laws - see left below.





Consequently, since the 1960s, thousands of venerable, at-risk American structures have been saved, restored, renovated and repurposed. Such transformations will be even more prevalent in the 21st century as aging buildings increasingly become underutilized, functionally obsolete or financially unviable - see right above.



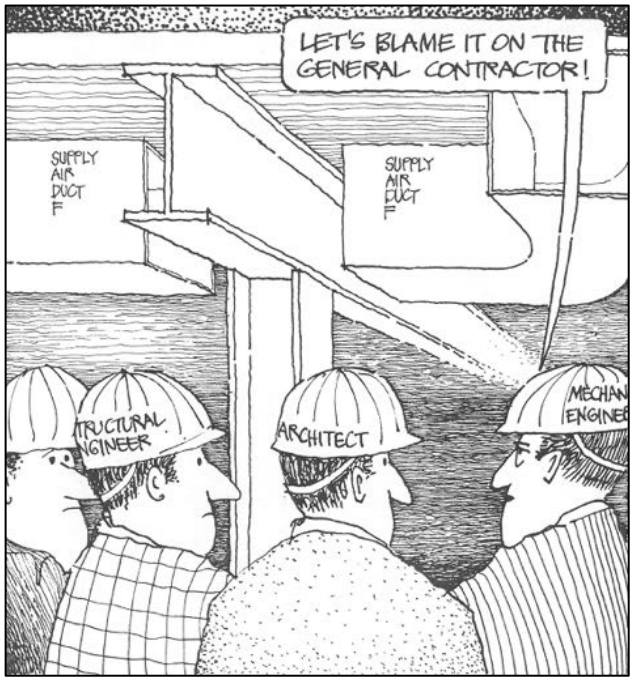
Today increasingly powerful computers and CAD software enable practitioners and architectural students to create realistic, interactive digital models often impossible to draw by hand. Designers can generate not only customary floor plans, sections, elevations and 3-dimensional renderings, but also dynamic videos flying over or walking around and through a proposed building, neighborhood or city. Civil, structural, mechanical and electrical engineers, in collaboration with architects, likewise use advanced digital technologies to more reliably design buildings that will be stable, operational, sustainable and affordable.

Because of digital technology, designers can conceptualize, explore and document buildings more complexly composed and geometrically complicated than ever before.

Now architectural expression is constrained not only by immutable laws of physics and engineering, but also by project budgets, by zoning and building codes, and frequently by local politics. In the past 60 years, the scope and quantity of these laws, regulations, codes and public oversight have expanded greatly.

Ensuring public safety was the original justification for laws and regulations governing architecture and construction. However today laws and regulations do more. Zoning ordinances prescribe land use and density; building types, heights and occupancy; yard setbacks and open space; and required parking spaces. Form-based zoning goes further to shape the visual character of streets and open spaces as well as buildings.

Multiple national, state and local codes regulate energy use and conservation; carbon emissions; indoor environmental conditions; storm-water management; historic preservation; accessibility for the disabled; steep slope stabilization and protection; and urban tree protection. Not surprisingly, complying with the vast array of regulations necessitates diligent research by architects and engineers and numerous jurisdictional reviews, resulting in a much more time-consuming and costly process than 60 years ago.



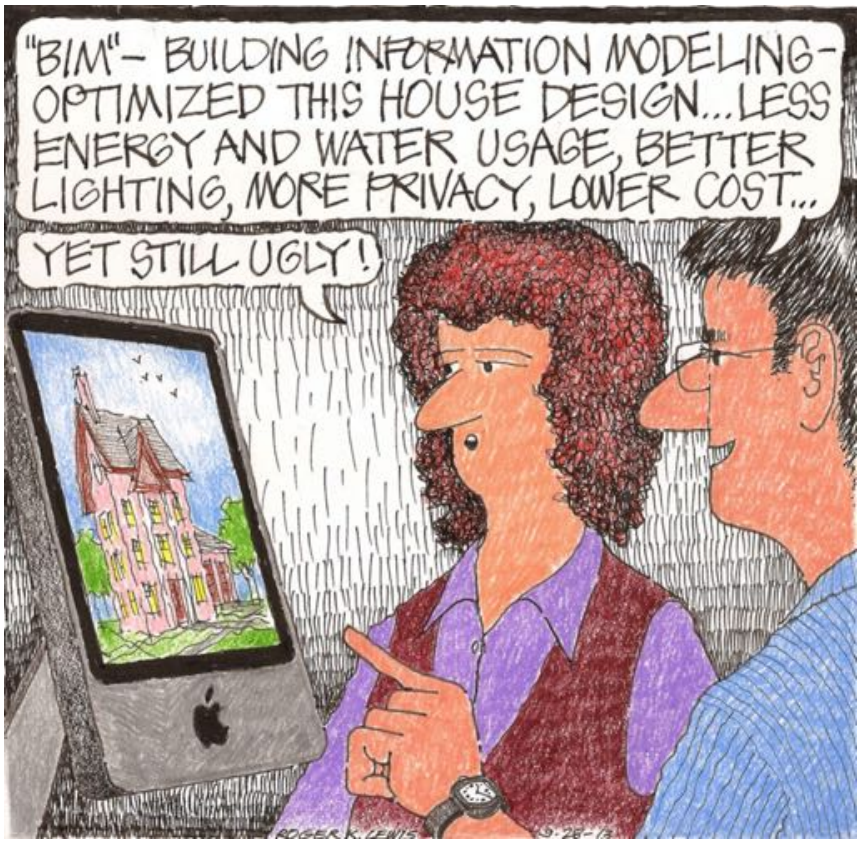
Digital technology and the Internet have made administering architectural firms less onerous and labor intensive while facilitating management and production of architectural and engineering design work, cost estimating and construction administration. State-of-the-art software programs enhance building systems coordination; identify conflicts between building system components; and reduce design and construction errors and omissions.

Instant Internet access enables worldwide communication and real-time, remote collaboration, dubbed “virtual adjacency” decades ago by MIT alumnus, engineer and real estate developer Jay Hellman. Despite being hundreds or thousands of miles

apart, architects - along with their consultants and clients - can work interactively, sharing and retrieving cloud-based data, images and videos at will, typically accessible within seconds. Working virtually lowers architectural firm operating expenses by reducing business travel and amount of rental office space needed.

Visit any architectural office today and you no longer will see drawing boards, tracing paper or drafting equipment. Fewer metal filing cabinets are required for record keeping. Instead you will see an open workspace filled with computers and small printers atop desks or tables, with plotters for printing large drawings deployed around the workspace. Internet access to thousands of building material websites allows architects to efficiently search for and download product information. Thus product reference libraries in offices are smaller than in the past, although product sample storage areas still exist.

Notwithstanding impressive technological advancements since I graduated from MIT in 1964, the Vitruvian challenge remains. Architects still must instruct the machine, telling it how to shape and proportion a room, where to place a door or window, what color brick to use. Even using advanced digital technologies, a marginally talented architect may still come up with an awkwardly configured building, a poorly composed facade, badly proportioned interior spaces or clashing materials and colors.



Technology will continue advancing. More sustainable materials will be available. Architectural styles and tastes will keep shifting. But one principle and conclusive judgment will

always apply to architecture, no matter what its qualities might be: **it seemed like a good idea at the time**.

Epilog: Happenstance Moments & Opportunities

In retrospect my diverse professional and personal explorations, activities and occasional adventures were inevitable. I became aware of polymath tendencies at MIT, when I first realized that it was against my nature to adhere to a single, straight-ahead track, perhaps wearing blinders and never looking sideways.

In fact my journey has been shaped by unplanned, happenstance moments and opportunities that led to unanticipated, usually positive outcomes. Many were attributable to luck and coincidence; to being in the right place at the right time; to curiosity about something new and unusual; or to a random, unexpected encounter with someone from the past or not previously known.

What if Dean Fassett hadn't suggested I consider architecture upon hearing that I loved drawing?

Roger K. Lewis '64, FAIA, Course 4, Architecture, Master of Architecture '67, a retired practicing architect and University of Maryland emeritus professor of architecture, was also a Peace Corps volunteer architect in Tunisia 1964-66. He has designed new communities, multi-unit housing projects, private homes, schools, civic buildings, art centers and recreational facilities in the United States and abroad. Since 1984 The Washington Post has published his "Shaping the City" column about architecture and planning, illustrated by his cartoons featured periodically in exhibitions. Serving on government, academic and NGO review boards and committees, Roger has been a commentator since 2007 on the Kojo Nnamdi talk radio show on NPR affiliate WAMU-FM. He authored The MIT Press best-seller, "Architect? A Candid Guide to the Profession," first published in 1985, revised in 1996 and 2013, and still in print. Japanese, Chinese, Korean and Spanish editions also have been published. Roger has received many professional awards as an architect, journalist and public advocate for design excellence. Currently he is president of the foundation authorized by Congress to create the national Peace Corps Commemorative only steps away from the U.S. Capitol Building and National Mall.

Business

Left, Today the $100 bill is the largest in circulation.

Currency just isn't used the way it once was. Check usage was growing in the 1960s. Today checks after being received are largely converted to images for collection. And Electronic payment methods abound.

Security features in US currency have lagged the rest of the world. The $100 bill shown here is the only denomination with the new security thread (in blue). $1 and $2 bills have only the historical security of engraving and colored threads in the paper. The other denominations have a polymer strip and micro printing, and notes $10 and higher have optically variable (color shifting) ink features.

Below, In 1960, cash was king and paper checks weren't far behind. There were no general-purpose credit cards, ATMs, or ACH (Automated Clearing House) items. There were $10,000 $5,000 and $1,000 currency last printed in 1945 and in circulation until 1969. The $10,000 bill below had a picture of Salmon P. Chase, Lincoln's Secretary of the Treasury and had series of 1928 and 1934. There was even a $100,000 bill, which was used only for transactions between Federal Reserve Banks.

Sometimes a Lawyer Always an Engineer – Looking Backward and Forward

Robert Saint-Aubin

Practicing law for 53 years I utilized the tools taught, learned, acquired at MIT. Observe, analyze, test, explain, observe, modify, formulate, test again. Find a solution, perhaps an optimum solution, that works for everyone.

MIT teaches us to analyze everything we observe, to look at all the data we have, then to select the data for use, to question and re-question every aspect of the structure. Be guided by GIGO; bad data leads to bad models, leads to bad results. Upon arrival at MIT, I rapidly learned everyone was smarter than me. After becoming a lawyer, I continued to believe that my adversaries were smarter than me. Therefore, I work harder, prepare more, and get done quicker. Never wait until the last hour to begin preparation.

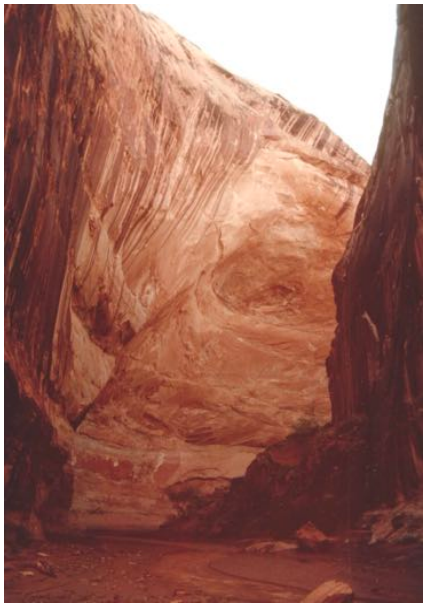
As in life, a continuing series of unconnected interrelated vignettes, MIT gave us the ability to deal simultaneously with multiple opposing matters. Is that proof of Heisenberg's Uncertainty Principle? From day one the MIT curriculum requires taking five unrelated subjects. The student must allocate time to prepare for each subject every other day. No way any normal 17-year-old product of American public schools could complete everything assigned. We had to learn to prioritize, to pick and choose, which we would complete, which we would deemphasize. That ability to make a choice may have been the Institute's most valuable lesson.

An Engineer

Copper mine waste lake adjacent to Tribal land

My retirement began in January 2020. For the past 20 years I represented a Native American Tribe in a dispute about contamination from an abandoned copper mine owned by an international oil company beside the Tribal Reservation. We settled the case. Why settle now? Because the "science" went to hell and the oil company put a significant amount of cash on the table. In presenting the settlement package to the Tribe, sitting in an auditorium filled with Tribal members, my friends, the Native Americans, I thought of MIT and what I now needed as the Tribe considered the settlement: *the Greek respect for moderation was a respect offered by immoderate passionate men toward political harmony*. I needed that political harmony from a properly impassioned people.

The pieces were in place.



How did I get from there to here? From then to now? My relationship with MIT started before 1960. Was it when I was 8 years old or in 8th grade? My parents took me to an MIT open house. In Building 2, I saw a demonstration of liquefaction of wet sand. QUICKSAND. The knowledge gleaned from that demonstration served me well some 20-plus years later when my wife Deanna stepped into quicksand the morning after being caught by a flash flood in Coyote Gulch or Hurricane Wash, while backpacking in Southern Utah. Actually, it's simple. One cannot drown in quicksand. The human body will always float in the denser mixture of water and sand. One must just move carefully and precisely from the slurpy, sucking wet zone to the non-liquified zone.

Waiting patch of quicksand, Hurricane Wash Southern Utah

In the 1950s, MIT maintained a meteorological lab on Colonel Green's estate at Round Hill, South Dartmouth, Massachusetts. This curious kid from New Bedford, an Eagle Scout on a bicycle, learned a lot from dedicated climate scientists chasing their instrument-laden high-altitude balloons around the private beach-front property. Those real mid-century climate scientists taught me that it is unlikely that we will ever be able to predict weather more than 10 days out. Fractals and chaos theory contribute too much to the instability and to the inability to predict the future. Cape Cod, Nantucket, and Martha's Vineyard provide natural testament to the scientific fact that climate change dates back at least 17,000 to 20,000 years. Melting retreating glaciers dropped their sand from their southern face, creating the Cape and the Islands.

The Chronology

The Massachusetts Years

I had a fascination with topology (non-linear non-numerical maps, Klein bottles, and Möbius strips), but a desire to be a Naval officer.

The beginning of the end arrived in 1959: I read, I studied, the United States Constitution. It made sense as a guiding principle. I learned that my previously unknown color blindness disqualified me for appointments to the US Naval Academy and the US Air Force Academy. MIT became the educational objective.

Fall of 1960, bamboo slide-rule on the belt, this Tech Tool began life in Burton House. I escaped by rowing on the Charles, totally uncoordinated but loved the red nylon parka. I really knew nothing about humanities. A few weeks into the term, Professor Harold Clark Kirk-

er gave us his Christmas break assignment, to write a theme based upon selected readings from the 3-foot stack of paperback Greek classics purchased at the Tech Coop.

The theme for the theme:

> *the Greek respect for moderation was a respect offered by immoderate passionate men toward political harmony*

What the hell did that mean? I have minimal memory and do not write well. How will I ever do that?

I wrote something that fortunately has been lost to humanity. Immoderate passionate? That's me.

Burton House

At a Washington's Birthday Burton House mixer I met a wonderful young lady from Virginia by way of Simmons College (now Simmons University). She thought I was wealthy. Sixty years later and I still have not set Deanna straight on that one. Deanna and I ended the year with an exchange of teddy bears. Turned out that those two bears and their progeny have been our family. She has been by my side from the beginning and still provides care and love!

After the mixer, we discovered the Burton House Social Committee, funded by the Institute to the tune of about 10 dollars per resident. There were 550 of us living in Burton. The social Committee received additional funding from the coin-operated Maytag laundry machines initially installed by the GI's previously housed in Burton during and after WWII. Maintained by Tech residents, and open to every college student in Boston, we had the only laundry machines in Greater Boston that worked.

Thermodynamics/heat transfer living at Lake Tahoe

In 10.12 Professor Merrill defined the future: *input equals output plus accumulation*. In 10.13 T.K. Sherwood added the second law of thermodynamics. No matter how hard you dream, you will never find free energy.

After sophomore year I became an engineering professional with a position as a chemical engineer for Allied Chemical in their acid plant at Claymont, Delaware. My first assignment, quite simple in fact: calculate the length of pipe necessary to cut off the gravity feed of a corrosive acid into a tank truck. I finished early afternoon. The calculation was correct and embarrassed the graduate chemical engineer who had unsuccessfully worked the problem for three months. The politics of engineering. Do I really want to earn my living doing this?

Process design. TK Sherwood. *How do I teach invention?* He answered the question by assigning the class to jointly design, at least three years before the discovery of oil at Prudhoe Bay, the Alaskan pipeline. Prescient? As an academic exercise, years later I followed the construction by Bechtel of the real Alaskan pipeline. The New York Times regularly reported construction progress and disasters. Bechtel followed our design plus/minus one pumping station. And as expected, the pipeline failed on startup due to the impossibility of achieving homeostasis with hot oil in the land of permafrost.

Ira Glazier's humanities course assigned me a paper on the British Corn Laws (1818 to 1846), which made me a believer in free trade. Free trade only exists as fair trade, a concept undone by unilateral tariffs, tariffs from which the United States still suffers.

After my Allied Chemical summer, I switched my major to Course XV. (The difference for me between a degree in Chemical Engineering and Management was one organic chemistry lab course.)

> Herb Goodwin: *An idea does not care who has it*
> Douglas McGregor: *The human side of enterprise*

One fall Saturday in 1963, as a lark, on the suggestion of a couple of friends, I took the LSATs. I'm not going to law school. You have to have a good memory to be a lawyer. Not me. I did very well on the test. The Law School at Penn accepted me overnight. I'm going to be a lawyer.

In the Sloan School I still needed two more engineering credits to graduate. Ok, try physical chemistry and unit operations. I'm on my way to graduation. Irwin Oppenheim of physical chemistry said *Robert, you must remember science is politics*. Truer words may have never been spoken at the Institute. With the unit operations final on the last day of finals period, with no other finals, I had lots of time, almost a month, to "learn" the subject. At the Coop I bought a textbook competitive to the one assigned. And I bought The Beatles' *Abbey Road*. I had completed none of the class assignments and about zeroed-out on the quizzes. All or nothing. Start at the beginning and read, adsorb, try to understand. My last engineering course. To synthesize understanding I created a 10-part test question that I could handle. If only . . . .

I took my teddy bear and the allowed materials to the exam room. It's going to be a long morning. Oh, my goodness. One question with 10 parts. Three hours to complete. All my Course X classmates moaned and groaned. An hour and 50 minutes later I packed up my teddy bear and all my stuff and walked out. My struggling classmates looked at me like they understood I was throwing in the towel. No. I had a numerical answer to each of the 10 parts. (No one ever gets numerical answers.) It was my question. I received a B in the course and was ready to go off to Penn and The Law School.

First, I needed to complete my thesis on *The Duty to Bargain in Good Faith.* Once long after, I started reading my thesis. Terrible! A classic example of burn before reading.

The Philadelphia Years

Notably, after small class education at the Institute, Penn Law classes had either 95 or 190 students. If you were called, the teacher intended to embarrass you. I am an engineer. No one embarrasses an engineer.

First summer of law school Deanna and I married. A worthwhile adventure. Love that lasts.

Saturday classes for me gave Deanna the opportunity to learn to cook like a French chef. Over the ensuing 55 years, her law school education proved more valuable than mine. In real life she was a medical editor. She still edits my work. And confirms applicable medical theories, especially during these Covid-19 months.

In a seminar on International Law, I was assigned to write *The Restatement of the Law of Neutrality*. Easy. There's no such law. Neutrals exist solely by the grace of the belligerents. Better run that by the professor before submitting the paper. I was convincing. The professor reluctantly accepted my insurrection.

After law school finally ended, I faced cram school and the bar exam. I'm still licensed in Philadelphia.

Employed Years

On my first day at work my mentor came into my office: *Robert, always remember to keep your sense of humor.* Thereafter, there has always been a teddy bear on my desk. My boss for 16 years always gave me guidance, space, respect, and the opportunity to climb out on limbs with my own cutting apparatus, and safety equipment, or lack thereof. And with Deanna, he taught me to write.

At the time I was hired as an attorney fresh from Law School in the Philadelphia Law Department of a Fortune 50 chemical company, the chemical industry may have been the least regulated industry in the country. They hired me because I had studied the new Uniform Commercial Code. Three years later, we had OSHA, EPA (formed by my law school classmates and other anti-business cohorts), NIOSH, Executive Orders, Affirmative Action, and the Equal Employment Opportunity Commission, as well as the Antitrust Division of the Department of Justice, and the Federal Trade Commission. Soon thereafter we would have age discrimination and Tribal Employment Rights Ordinances. And 50 similar, but not identical, parallel competing, turf-grabbing, state agencies. The company had 114 locations throughout the US. Before long we were the most regulated industry in the world. Regulatory compliance became another full-time job for me.

What the hell do I do in this job? Law school does not teach you how to practice law. Ask questions. Acquire information. Analyze data. Propose solutions. Test the solution. Revise revise revise. The importance of what we know. The importance of what we don't know. *The importance of what we don't know we don't know.* Economic consequences if we get it wrong. Every issue involved multi-millions of dollars.

As the new young elite-educated kid on the block, guess to whom each new alphabet agency problem was assigned?

I had no choice but to learn the appropriate law by reading the latest pronouncements in the New York Times (It used to be the unquestioned accurate newspaper of record in the United States), and CBS news in the evening. The chemical industry hosts spectacular disasters, some real, some imagined. Many of our facilities were opened in the late 1800s, or at least by the Great Depression. In case of catastrophe or disaster, my home number was on the emergency wallet card of every operating manager, among the first called. Safety of human life first. Protection of property second. Then, WHAT HAPPENED? Who is in charge? The business manager does not want to be, is incapable of being in charge. We must manage chaos and change to manage the response to catastrophic events. Somebody must talk to the press. If an official declines to talk, the press will interview the janitor.

A new plant addition implodes on start-up. *Saint-Aubin, find out what happened.* The contractors just happened to install the pump normally open for a start-up circuit that required normally closed. Yes, unit operations. Yes, stupidity. A Texas division of the company made the pump. End of investigation. No one provided the constructors with specific installation instructions. They installed it the way it came out of the box. No one bothered to check its state.

For breaks Deanna and I jumped into our blue '67 Mustang and toured the Atlantic coast. Over 15 years we covered the coast from Norfolk to Montreal. Before the Gaspé and Nova Scotia the Mustang was replaced with a Peugeot diesel.

Me, a Philadelphia Lawyer, working as a junior lawyer in the Philadelphia Law Department of a Fortune 50 international chemical company. In 1967, few companies had corporate law departments or general counsels. MIT hired its first in 2007. None hired lawyers fresh out of law school. They hired me because I had studied the Uniform Commercial Code which, state by state, had finally become the law of the land in every state except Louisiana. Little did we know how the future would twist and turn. In those parochial days you were not a Pennsylvania lawyer, but a Philadelphia lawyer; you could practice in only one county. Although parochial, with local counsel at my side, no state or federal agency or court ever required me to be specially admitted.

My main assignment continued to be commercial law. I drafted a request for proposal for demolition of a flood-destroyed facility containing significant valuable metal scrap. I did it by the book. All the correct *this is not a contract, rights reserved to reject*, *we will do business with whomever we want*. An unsuccessful bidder sued for breach of contract and violation of anti-trust laws. The jury ruled against us. The trial court removed the anti-trust treble damages. The plaintiff appealed to the Third Circuit Court of Appeals. The Third Circuit reversed the jury. *THERE WAS NO CONTRACT*. Personal vindication. The plaintiff counsel hired a famous Penn University Professor to put his name on their motion to the United States Supreme Court for *writ of certiorari*. We prevailed.

Lunch at the Philadelphia Union League with Charlie, a senior executive. *Can I ask you a personal question? Are you independently wealthy? What? Are you independently wealthy? No o o o. Still have MIT and Penn student loans and car payments and an unbelievable mortgage (those were the days). I've been watching you for the past year. You always make decisions on what you perceive as the ethically correct interests of the company, irrespective of the desires of "senior management," as though you do not need this job. Integrity. Never change, never stop.* I did not. He became a good friend.

Evelyn Wood taught me how to read at 5,000 words per minute, up a smite from the 150 wpm at the time I graduated from law school. In those pre-Zoom days, face-to-face meetings, especially with government agencies, were invaluable in achieving the desired result. After listening to us in California, in Wyoming, and other places, the meetings frequently concluded with the government agent saying *You came all the way from Philadelphia just to talk to us. Yes*. The ruling came in our favor. It meant lots of travel without much sightseeing. I made it to all 50 states.

I always thought about things, such as how do I make the best martini imaginable. I applied what I knew about the thermodynamics of ice, water, and alcohol, with a little hands-on experimenting to create the perfect martini. Using a mercury lab thermometer, I learned that it had to be precisely 28° F. Fill a stainless-steel cocktail shaker with freezer ice at 0° F. Pour in 4 oz. of vodka or gin, add a splash of your contaminant of choice, stir until the shaker frosts, and strain into a martini glass. Add olives, lemon twist, or cocktail onions. Make them one at a time. SIP one at a time.

In the mid 1970's the fax machine (invented in 1843) became ubiquitous - an anti-thinking machine. Before the presence of a fax machine in every office, a lawyer dictated a letter to his secretary. She typed the letter with carbons on an electric typewriter - an IBM Executive with proportional spacing. If you liked it, you signed it, or made corrections. After retyping (multiple times) it was signed and placed in the out basket. By the next day it would be in the mail and the day after delivered. The recipient followed the same process, so that on a good week you could have a response in a week. Then again repeat the process. The fax ended that. Dictate it, fax it, and expect a response by the afternoon; call if you didn't get the response. Email aggravates the disaster by orders of magnitude. I'm not a Luddite. I love technology. I love mechanical and electronic toys. I also love to contemplate, to think.

On December 21, 1982, Anne Gorsuch, head of President Reagan's EPA, named a company site on the banks of the Mississippi River in Fridley, Minnesota, as the initial Number One site on the National Priority List of CERCLA Superfund hazardous waste sites. The company said *Saint-Aubin, fix it.* We had the site cleaned-up on the following July 28th. We assembled a group of attorneys, engineers, geologists, hydrologists, contractors, consultants, and government personnel to find the source, path, and solution. The epitome of bad modeling and misuse of science contributed to naming the 84th worst site in Minnesota as the worst in the country. That it was Number One caused the company and the 5-plus state and federal agencies and two local governments to desire a speedy resolution. Another project with no budget. During that winter, this Philadelphia lawyer experienced 2 of the 3 worst Minneapolis snowstorms. The fun of business travel. EPA hired MITRE to find a way to decide which

of the 50 to 100,000 potentially hazardous waste sites to address first. The MITRE model used a formula that divided population by distance cubed. As our site was across the street from the intakes of the Minneapolis-Saint Paul waterworks, the divisor was a very very small number. We were Number One. We fixed the site. The negotiations were extended, excruciating, and difficult. EPA rejected every independent lab we proposed for analytic testing. In a passing comment outside the meeting room at a break, one of the US scientists said to me *Princeton. Princeton? Yes, Princeton.* We returned to the meeting. I said *ok, you have rejected every independent lab in the country. Can we use our R&D facility on US 1 in Princeton*? After some posturing, they agreed. The government believed that corporate chemical industry scientists have more integrity than the so-called independent labs.

We completed cleanup of the Number One hazardous waste site in the United States less than nine months after its designation.

The company had the Number One site, but also contributed hazardous waste to most of the litigated "public" sites. Setting the standard for multi-party sites, I negotiated many of the industry-wide settlements.

I learned that to solve what appeared to be complex problems, I needed a multi-disciplined *ad hoc* team. If someone in the new group was intelligent enough to recognize my brass rat, the ring would become an icebreaker, and I would be the *de facto* chair of the project for the duration.

Six or 7 years after passage of the 1964 Civil Rights Act, the Equal Employment Opportunity Commission and the plaintiffs' bar were up and running. We had a West Virginia plant that opened in 1930, still employing women initially hired during the depression. In their department the women had enjoyed continuous employment since being hired. The union contract protected seniority by department. Their lawyer filed two lawsuits in federal court. Alphabet soup, *Robert: handle it.* The labor relation guys said *not my job*. The Union was a co-defendant; *we'll let Robert fix it*. I found an in-house statistician to help develop an analytical model. We established that the case had nominal settlement value. The old honchos on the left coast (unbeknown to us) brought in a high-flying dork San Francisco lawyer who didn't need to talk to me. Their dork told super senior management to start negotiations north of $2 million.

No one bothered to tell me. I reached a settlement with the union and plaintiffs' counsel for $63,000 and change, which included attorney's fees. When I advised management, they said what about dork's $2 million? I had learned how to make deals. The named plaintiffs rejected the class action settlement. It was less than $1,000 for each of them. The US District Court Judge approved the settlement. What did I know? No one had done that before.

Nothing in the New York Times to guide us. Plaintiffs appealed to the Fourth Circuit Court of Appeals. The Circuit Court affirmed. We made law. A class action can be settled over the objection of all named plaintiffs. Plaintiffs filed a petition for a *writ of certiorari*. The US Supreme Court denied the *writ*, effectively affirming the district court. Now I'm a litigator, and I can write. I never heard from or of the dork attorney again.

Deanna and I decided to go backpacking Out West in the tradition of Ansel Adams, Edward Abbey, and Philip Hyde. Read about those adventures in *Chasing the Wind*.

While we were sinking in Utah quicksand, the chemical business's chief operating officer issued an all points edict. *No manager shall take a job action against any protected class member without clearing it with Robert.* Thanks for asking. Ombudsman. Compliance officer. Human resources had not yet been invented.

According to his application, a theocratic debater was hired as a lab technician. *Don't you read the applications?* When he filed his seventh human rights claim, I hired a black female civil rights attorney to represent us. She became a judge. I hired her husband. We won all 10 of the theocratic debaters cases and his appeals.

Upon my return from the Utah flash flood my boss said *I hope you like it out there*. Our phosphorous plant, located on a Native American Reservation, just received a letter from the Tribal counsel. Management built the plant on the reservation to avoid paying county taxes.

> ***"Dear Company. The Tribe has passed a TERO (Tribal Employment Rights Ordinance) under which we are entitled to have 100 percent Native American employment. Please contact me at your convenience."***

Ok. After again reading the Constitution, after again reading the '64 Civil Rights Act, I concluded that Congress actually authorized the demand. Tribal sovereignty. What a powerful concept. Time to negotiate, Robert. What a series of lessons*. OK, 85% of the employees are engineers. Give me 510 Native American chemical engineers and I will hire every one of them.* We reached an amicable resolution.

Another call from the Tribal counsel a few weeks later: *You have been underpaying royalties for the past thirty years. How much? Two to five million per year.* More negotiations, in which I learned when not to open my mouth. If the other side stops talking, you do not need to instantly respond. Pause. Let them follow up. Talking to break the silence will likely cost your side a lot. I practiced a different kind of law: problem-solving to a solution, (mostly) not briefs and arguments so that someone else decides. I worked best with a team of appropriate multi-disciplined players.

Early in my career an old California attorney transferred into our department. He was the smartest person ever educated (at another Ivy League law school). His specialty was tax exempt bonds to finance pollution control facilities. He ordered me to read the 400-page bond indenture overnight and carry his brief case to New York City. We sat in the conference room with all the bankers, accountants, and lawyers and their multi-tiers of seconds and assistants, all paid for by our company. They opened the bond book and said *we'll take a quick look at it before approving it and going to lunch*. On page two, I said *I don't understand this. Why is it here? It was used in the last deal we did. Take it out*. Page after page. No lunch or dinner. Late at night we cut it down to about 80 pages and took a very late train

back to Philadelphia. We did it that way because we always did it that way. Most of the time no one reads the nonsense passed from overpaid lawyers to not caring clients. Billable hours, not content, count.

I was still doing commercial law (almost on the side). The company hired a new group of young MBAs to revitalize moribund businesses such as swimming pool chemicals (chlorine). A fun team. Let's go to LA for dinner. The TWA plane home made two emergency landings. The flaps did not retract. They did not fix them. Swimming pool chemicals needed a spokesman. We hired Lloyd Bridges (*Sea Hunt*). A fun guy. Spend two weeks in February fifty miles out of San Juan Puerto Rico watching algae grow in a swimming pool. Attend lots of trade shows. I went to law school to avoid becoming a chemical salesman? The MBAs (none from Sloan) spent 95% of sales revenue on marketing that year. The project was deemed a success. We sold the business to a competitor. I learned everything about the chemistry of swimming pools. Drain and refill the pool. (I also learned everything about the chemistry of detergents. Change brands every time you purchase a new box or bottle of dishwasher soap. Love those Route One Princeton PhD scientists.)

On one of those rare days I was in my Philadelphia office I answered my phone. *This is Evel Knievel*. *Why did you stop shipping me my peroxide? What? Irish Ed the sales guy said you told him to cut me off. I've got a jump scheduled and you're putting me out of business*. (Nice of Irish Ed to warn me.) *I can come in and pick it up*. Investigate. The company made 97% hydrogen peroxide, also known as rocket fuel. A little more potent, and unstable, than the 3% peroxide available over the counter in drug stores. I had nothing to do with the shut-down of sales to Mr. Knievel. Irish Ed said the traffic department stopped him because the National Transportation Safety Board put limits on our ability to transport it. No problem (for us) if we let him pick his supply up at the plant door. Irish Ed handled it from there.

Is everyone a criminal? While I was having fun in the Wild West, the feds and enviro police were busy indicting the attorney in the office next to me for a West Virginia chemical spill (that happened to have been caused by a competitor). Acclimation to flying in corporate jets. Hard, nasty work reviewing millions of ancient documents in musty basements and interviewing hundreds of recalcitrant employees led me to a major change in my method of practicing law. After reviewing and producing to the government in response to grand jury subpoenas, thousands of pages of notes and memos that never should have been written or filed and saved, I simply stopped taking notes (except for my diary on travels and adventures).

It's not LA Law. Hundreds of professional employees to be wood-shedded before their grand jury appearances and debriefed after. *Always tell the truth. Do not speculate. Do not think you might know.* We employed every attorney in the local bar association (and a few in the local bars). The senior secretary: *oh, I burned all of those papers*.

The case was in West Virginia. Most of the government attorneys were also from Philadelphia. The Judge loved to have hearings on Friday afternoon, always ending them at about the time of the last flight out of the airport. As a matter of professional courtesy, we always offered the government attorneys empty seats on our private jet back home. Sorry. They

perceived a conflict. Missing the flight meant they did not arrive home until mid-afternoon Saturday. The company settled the case protecting the indicted employees.

The company had mining interests all over the country. We were members of every branch (including mine equipment) of the American Mining Congress except ferrous metals and copper. Coal, salt, soda ash (trona), phosphates, barium, lithium, coking coal, gold, silver, mercury. The New York attorney who had been doing mining law for 40 years retired. We had major gold plays in Nevada. I volunteered to take over the natural side of natural resources law (as distinguished from the environmental side).

My boss died and was replaced by someone who did not particularly like me. His words to Deanna: *Robert is the only one who takes every impossible assignment and solves it*. He had a couple of ideas. Send me and Deanna to Lake Tahoe for a month to take care of the company's Reno mining interests. I would have a company car, Deanna an Avis Cadillac. Three months later that became a similar 4-month assignment. Did I ever avoid a lot of crap assignments by not being in Philadelphia? On a trip from Reno/Tahoe to Carmel for a corporate law department meeting for all 4 law departments, we stopped at the ghost town in Bodie, CA, altitude 8379 feet. On June 6, 1984, I smoked my last cigarette. From up to 5 packs per day to quit. Cold turkey. Never wanted another smoke.

The company was Union Carbide's only domestic customer for methyl isocyanate (MIC), the Bhopal chemical. We had spilled some MIC in a neighboring school yard a few months back. They wanted me to go to upstate New York to negotiate our way out of the reopening of that case. *Sorry. I have a plane to catch.* I never returned.

Our Reno geologists discovered a world class gold body in central Nevada. In the late twentieth century a valuable ore deposit contained 0.15 ounces of gold per ton of ore. A classic geologist's response to a self-important executive's question how much waste will you produce per ton mined: *Exactly two thousand pounds.*

Serendipity. The geniuses from corporate headquarters in Chicago called a general meeting of all the Philadelphia-based executives to present a new corporate financial model based on work at the University of Chicago by Franco Modigliani, who had been an occult figure at Sloan during my MIT tenure, at about that time the Modigliani-Miller theorem earned Modigliani and Miller a Nobel Prize in Economics for essentially saying the value of an enterprise was equal to its discounted cash flow less cost of acquisition plus residual value. I was one of the few in the room who understood what they were trying to say. It was precisely the same thing I heard at Sloan in Building 52 from Modigliani's colleague, Zenon S. Zannetos. Really, it was simply input equals output plus accumulation. They received a Nobel Prize for that? No need for a computer, just some fingers and toes. Interest rates (internal rates of return) were 15 to 18%. Being on scene in Nevada to get those permits for the new gold mine would mean large amounts of return - $65,000 per day. Our relocation was approved. We went to Reno on another business trip and never came back. We were relocated.

The Reno Years

At this point I'm at a new place with a new program and a sense that I know what I am doing.

Start with first principles
Examine what you have
Define the problem
Collect the data/information
Think about what you know
Apply what you know or learn to the data
Analyze and calculate
Refine
Reach a solution

Figure out what's important; focus on what's important.

I celebrated the move Out West with a Coca-Cola red S-10 Chevy Blazer. A true off-road vehicle. Whether vacation or work, we toured every paved road, and most of the unpaved roads, in Nevada north of the Ward beehive ovens. I was now a focused mining lawyer, my principal assignment to get the new mine and processing facility fully permitted as soon as possible. From discovery of the gold and silver to the first pour from a $100 million plant took 34 months. Never before, never since, fully permitted. I became a mining industry heretic. We lined the tailings ponds to get the permits.

I took another bar exam and became a Nevada lawyer. It was a small club. My Nevada bar number is 909. The Nevada Supreme Court and the Social Security Administration corrected the spelling of our name to Saint-Aubin.

Shortly after start-up of the gold mine, the Reno mining manager received a call from a high school friend who happened to be the deputy US Attorney in charge of the Reno office. It had been reported that we were killing birds in violation of the federal Migratory Bird Treaty Act. We were a repeat offender. That one is going to be tough to fix. The lined tailings pond contained cyanide after leaching the micron gold out of the mined rock. What to do? Call Irish Ed to obtain 30 tank cars of peroxide. NOW. Peroxide will neutralize the cyanide. It made the government happy. Nobody around the table inquired about stoichiometric mixing. With perfect mixing 30 tank cars will neutralize the precise amount of cyanide in the pond. Simple chemistry. The head of the controlling federal agency lived across the street from me.

Serendipity prevailed. Reno, the Biggest Little City in the World, was a parochial small town. A PAC contribution to an unsuccessful Republican Senatorial candidate made me a recognized player. In 1980, Nevada had a population of 880,000. In 2020, it's over 3 million.

In 1988 the Rocky Mountain Mineral Law Foundation asked me to present a comprehensive paper on Nevada Mining law. I reviewed every published mining case to present *The Spirit of Gold - The Nevada Courts and the General Mining Law*. I was a published legal writer.

I had my first personal computer - a Compaq luggable huggable. A floppy disk drive and a hard drive. I had a Dictaphone. We used voice mail. Technology for a lawyer was moving ahead.

After 20 years with the company, we listed the gold operations as a new entity on the New York Stock Exchange. For me it was time to move on. I was invited to join a new Reno office of the second largest law firm in the state. A past and a future governor were partners. Senate Majority Leader Harry Reid had been a founder. I became managing partner.

Deanna asked *What do you do?* The answer became a published article *Quid pro Quo*. I make deals. Service on a jury and another published article in the Nevada bar journal. My methodology still comprises observation and analysis. Answering repeatedly what makes sense? Finding a consensus among multi-disciplined members of *ad hoc* teams. It continues to be non-linear chaos management. Persuasion. I never intend to do something stupid. There is no such thing as a stupid question (most of the time). I have always been non-linear in problem solving. Meet the client, meet the adversary, face to face.

While I toiled in the vineyards of law or trolled in the sea for clients, Deanna pursued art in multiple disciplines. She carved life-like birds painstakingly accurate to the number of feathers in the tail. She photographed nature as it should be photographed. Then she joined the Nevada Museum of Art as a Director and collection curator. Fund-raising and management and iconic buildings. She experimented with a cooperative art gallery with five other artists.

As managing partner of a statewide law firm, I had to be able to get away without getting away. We started in Nevada by living at Lake Tahoe. *Let's buy a Tahoe condo*. Unless there's 10 feet of snow, 40 minutes away. Engaged in mountain biking, golf, and cross-country skiing, at 7000 feet. Mountain biking on the spectacular Flume Trail from the Bonanza's Ponderosa Ranch, 14 miles south, 1400 feet above Lake Tahoe (6200 feet). Golf balls go farther at that altitude. Did not help me. I was the worst golfer of all time. But I loved it.

The President of the National Judicial College invited me to serve as *pro bono* general counsel. That meant I could contribute my funds and law firm funds to the College, from time to time provide legal advice to the president and board, attend board meetings, and attend functions, sometimes in exotic (at my own expense) places such as Jackson Hole, Wyoming. The NJC was loosely affiliated with the American Bar Association, which provided (but did not fund) the NJC pension plan. The ABA issued an edict mandating that the NJC board adopt specified changes in their plan, changes repugnant to the board. The College said no. The ABA's outside counsel sent us a 70-page opinion saying why under ERISA we had to do it. *Robert, fix-it*. I researched the question and found the ABA lawyers dead wrong through-

out their paper. Never be intimidated. The President forwarded my memo to the ABA. The ABA withdrew the mandated edict and provided a written apology to the NJC board.

I had a mining client who knew Securities Regulation D better than me. A Canadian who mostly stayed ahead of the SEC (and everyone else). In the fashion of most Ponzi schemes, he would buy out, at a premium, unhappy clients. One Monday morning his son showed up in my office. *Friday dad was arrested by immigration, IRS, treasury, Immigration, SEC, the FBI and the US attorney.* Guns, immigration, and money. It happened the day INS became ICE. After finding the best high crimes attorney in Reno, a former partner, I was out of it. I do not do that kind of criminal law. The following Wednesday at 5:00 pm the son and his girlfriend showed up in my office with 3 briefcases containing a million dollars in small bills. I told him I had no choice but to deposit the money in a bank trust account. After he was released from arrest the (now former) client left the country never to be seen again.

I represented a mining company taken over by Scientologists. For years we were on the sidelines of a battle between the mining company founder, the Scientologists, and a defamation suit against Time magazine (*The Cult of Scientology,* May 6, 1991).

I represented a state agency in a wrongful accounting matter. The Big Eight accounting firm settled for a respectable amount.

My all-time favorite legal writing - my client, a prominent individual, was t-boned by an uninsured motorist. My client had been in a coma for three weeks. The attorney for our insurance company offered to settle for $65,000. Not good enough. I called the attorney and told him they had to do better. While I was at lunch, he called my secretary and asked me to put it in writing. On my letterhead I wrote:

> *re prominent client*
> *Dear attorney:*
>
> *NO.*
>
> *very truly yours,*
> *rfs*

After my return from 3 weeks in Hawaii I spoke with the adjuster. He said his attorney did not understand my letter. The insurance company loved it. They asked if they could put a 2 in front of their offer. My client said send them a letter saying *yes*.

A friend had some relatives offering a fantastic investment opportunity for factoring of accounts receivable in the high-volume medical products industry. Known principals. Known product. Known financing. A real Ponzi scheme. I kept our friends out of jail. I lost our investment.

The California Years

We attended the wedding of the daughter of a friend and client at the Ritz Carlton Laguna Niguel in Southern California. Throughout the Reno years, whenever a cancellation, settlement, whatever, gave me a few free days, Deanna and I would drive to the coast and turn right or left. Quietly, unspoken, we were both looking for the place to retire. At the Ritz Carleton, Deanna said *this is where I want to live*. If you could live anywhere in the world, where would you go? We now live in the gated community next door to the Ritz Carlton within walking distance of the Pacific Ocean. Another bar exam.

Ritz-Carleton Laguna Niguel on bluff Strand Beach

A course by Pepperdine University's Straus Institute for Dispute Resolution. Something new. Mediation. Wait, it's not new. The entire thesis of Pepperdine's renown program builds on a little book taught at Sloan in the early sixties - Douglas McGregor's *The Human Side of Enterprise*. Change is always good, even when it's not change. Call up the Chief Justice of the Nevada Supreme Court and say *Bill, I want to be a Nevada Supreme Court Settlement Judge.* You could do that when your bar number is 909. Then call NASD and become an NASD (later FINRA) arbitrator. Dispute resolution. Irrationality rampant. The solution will always be better if designed by the combatants.

During 20 years of mediation - dispute resolution - problem-solving - not once did I ever use the word compromise. In the effort, we, I and the parties, searched for a resolution that worked for both sides, the classic win-win. We were not playing a zero-sum game. Consensus and collaboration work in dispute resolution. Sometimes.

Walking on the beach. A life-long objective. A life-long love. Presence in a cathedral greater than the churches of the Renaissance architects and builders. The freshman humanities courses become important.

The California practice was never full-time. An occasional client. A lot of homeowner association law. An occasional will and trust. Lots of time in Reno and Las Vegas, finishing stuff for old clients, mediating foreclosures, and mediating for the Nevada Supreme Court. And managing the Tribal claims against the copper company, theoretically on the same side as many of the government agents I used to oppose tooth and nail. Arbitrating for FINRA in LA and San Diego – I did not like the 3-hour 70-mile (each way) commute to LA.

My colleagues in the California Bar selected me as chair of the ADR Committees of the Business Law Section and the Litigation Section. *All you do is manipulate people to do something they don't want to do*. No one ever said it would be easy.

Looking Forward

Looking forward by again looking back. In the mid -1980s MIT with David Baltimore, the Whitehead Institute and the Broad Institute, added another focus to MIT's multi-disciplined advancement of thought. By entering the field, MIT became a technological giant of biomedicine. How our career paths might have changed had biomedicine happened during our era at the Institute?

Ordinarily I never advocate more laws. This exception proves the rule. One of the many broken parts of the American health care system has been the mis-applied so-called privacy laws. Oh, you can't have your wife's medical records because of privacy laws. In the vernacular, bull. Every insurance company has total access to every one of your private medical records. In boiler-plate adhesion contracts you signed on the last page of the terms of service of your application, you agreed to the release to them of all your medical records. Agree or no insurance. Every magistrate, judge, discovery commissioner, or arbitrator will

insist that your personal private medical records from birth to death be made available to the other side. Period.

Society needs to change this. We need a law governing access, allowing access. While not being made public, medical records must be accessible across platforms. We could start by requiring every medical record created be given to the patient, enabling some personal management of our own health history. Secret proprietary code in medical records systems must not be allowed. My pulmonary specialists at UCLA should have access to my local medical records here in Orange County and my historical medical records in Philadelphia, and vice versa. A doctor should never again say *I switched software suppliers and no longer have access to YOUR records.*

Reorganization of the Federal Government

Rather than making the District of Columbia an unconstitutional state, twenty-first century communications allows for dispersal of the Federal government to the people throughout the country. Return all populated DC land except the White House to the respective states. Reallocate the government employment throughout the country based upon federal taxes paid in each state.

Take the corrupting money of perpetual campaigns out of government by limiting Members of the House of Representatives to a single staggered 5-year term and Senators to a single staggered 10-year term. Prohibit all members of Congress from running for any office while serving their elected term. Go home before you run for your next position. Add 15-year terms for all judges and justices.

Require that all laws and programs apply equally to elected government representatives and no special benefits (including without limitation pensions and health care programs) be afforded to elected representatives.

Do not touch the brilliance of the Constitutional Framers in creating the wonderful electoral college. Finally, rewrite the tax code to about four pages eliminating all special privileges including so called charitable institutions (and deductions). Create multiple tax brackets sufficient to fund the necessary portion of the government. A variant of input equals output plus accumulation - taxable income equals all income less allowable costs of production as incurred. End arbitrary fictions like depreciation. Use the same set of books for taxes as used for shareholder reports.

Summary of Changes in the Legal World

Looking back a mere 22 years before our entering MIT, there were no Federal Rules of Civil Procedure (albeit there were precedents, rules of court, and customs); trial by ambush was the order of the day. Today's *cliché* (true) that no case ever again looks as good as it looked on the day it walked into your office was founded on that old order. Counsel for an aggrieved party filed a lawsuit. Counsel for the adversary began a highly orchestrated dance of arcane pleadings with unpronounceable Latin names to delay the day of reckoning, lead-

ing to a trial where for the first-time evidence was presented to the jury of peers for determination of the outcome.

The maturing of the federal rules (essentially adopted by the states as well) brought into the 21st century **DISCOVERY**. Simply, the parties must exchange all evidence (information), including, without limitation, evidence *likely* to lead to evidence introducible in court. Everything. You did not know what the other side had when you drafted the complaint. You do now.

I'm a Philadelphia lawyer, part of the last class of Philadelphia lawyers. In 1967, after passing the bar exam the Commonwealth of Pennsylvania only admitted new lawyers, resident of the state to the Pennsylvania appellate courts, and to the courts of a single county, in my case Philadelphia. **PERIOD.** When moving to Montgomery County, the adjoining county, I could not practice in my home county. Many other states had similar rules protecting the local bars. A year later the Pennsylvania Supreme Court changed the rule to allow Commonwealth wide practice. All attorney licensing was based upon residence. Eighteen years later I was able to sit for the Nevada bar exam *as a resident* because I had spent more of the preceding year in Nevada than anywhere else. By the time I took the exam, the US Supreme Court had abolished the residency requirements. Notwithstanding the full faith and credit, and the privileges and immunities clauses of the US Constitution law practices (and banking) were limited by state boundaries. It is a longtime past the time when national licensing should have been implemented.

Between 1960 and 1970 the number of lawyers in the US grew from about 250,000 to over 300,000. By 2019 the number reached over 1.3 million growing four times as fast as the population. What are the extra million lawyers doing? Conducting discovery, serving and answering interrogatories, analyzing data, reviewing document summaries, electronic discovery, no longer paper and pen. Ask for everything, look at a small sample then ask for more. And bill those hours by the minute.

Law was a profession. Lawyers worked with clients. Law firms were partnerships. A large law firm had fewer than 100 lawyers, one office, more secretaries than lawyers, typewriters, carbon paper, telephones (maybe with a detached speaker), conference rooms, libraries, teletype and telex (a few steps beyond morse code).

Then came paralegals. Mergers. Multi-state firms (but no multi-state practice without another bar exam or *pro hac vice* associated admitted local counsel). And the technology of the law. Xerox copying. IBM Selectric typewriters. IBM mag cards that remembered what was typed but you could not view in real time. Handheld Dictaphones enhanced the connection between the scrivener and the secretary. No more carbons. Xerox copies of everything.

In the mid-seventies McKinsey & Co selected me and Angel, my secretary, to beta test Exxon's prototype Vydec word processor, a large desk-sized computer with a green cathode ray screen. I was the most advanced law office in the world.

As the resident technologist, I was always a first or early adapter of new toys used in the practice of law including law libraries on CDs, WordPerfect, Lotus 123, Windows 95, PCs, laptops, notebooks, dot matrix, laser, and inkjet printers, flatbed and high-speed duplex scanners with optical character recognition, CD-ROMs, WIFI and the internet. My cell phone transformed from Motorola, Samsung, Nokia and then the wonderful computer in the hand the Palm Treo followed by the iPhone 4. I was addicted. The iPhone grew into multiple iPads (the daily battery life of one is shorter than my daily use). I transformed 100% to Apple electronics. A 27-inch iMac, an Apple chipped MacBook Air; An Apple Watch, an iPhone and all three sizes of the iPad.

Fax machines everywhere. The cost of telecommunications was falling. Printed law libraries were replaced by Lexis and Westlaw, then research on the internet.

Law firms became international, soon to have thousands of lawyers. Big business. PCs and Macs and laptops, all gobbled up by technologically unsophisticated lawyers, the younger generation prevailing. The end of collegiality. Competition for the sake of competition. Large firm associates, graduates of the best law schools, well paid, but required to work and bill 70 or more hours every week.

The advent of commercial jet transportation made a national practice, as an in-house corporate counsel, possible, corporate jets easier. Then the airline industry invented spokes and hubs, introducing immense useless delays. However, travel time was time away from the phone and away from interruptions, quality thinking time, while being tough on marital bliss.

C1978 EPA promulgated a hundred +/- pages of RCRA (Resource Recovery and Conservation Act amending the Solid Waste Disposal Act - the government being cute did not call it the land disposal of hazardous waste act which everyone could understand). The regs were applicable to 116 of our company US facilities. I had to make a presentation on the regs in San Francisco the next day. Fortunately, the company had given an Evelyn Wood speed reading course which enabled me to read the entire record while flying across the country. I still had time for my three martinis before landing. In that case, speed reading worked.

Inevitably specialization followed growth. Repetition. Doing the same thing over and over. Analysis without thought. The businification of a learned profession. Progress meant maintaining a book of business. Cannibalization resulting from regression to eat what you kill.

Until abolished in 1975 by the US Supreme Court every local county bar association published a minimum fee schedule controlling the fees of attorneys. That ended civility and professionalism. The bar answered with contingent fees for high reward recoveries and what started as the billable hour devolved into billable minutes. When do you think? When do you go to the restroom? Jimmy Carter furthered the downward spiral by abolishing the three-martini lunch. A government contracts colleague accused us natural resource lawyers of having too much fun.

Were those non-computer-generated time sheets great examples of fiction writing?

How many pages of legal periodicals and court opinions have been devoted to the reasonableness of attorney's fees?

As lawyers became more specialized, they became less learned. Litigators relied more and more on experts. If you are following the science, how do you end up with partisan "experts" on both sides of every question. The lawyer, using his preferred view of the "science" creates a "model" absolutely inevitably leading to his desired result. Then the expert witness testifies following the script written by the lawyer to lead the jury down his path. Advocates now try to substitute the judgment of their "expert" for the conclusions that should be in the mind and hands of the trier of facts, in the hands of the judge and jury.

The cost of discovery renders the cost of litigating moderate disputes ineffective. In 1925 Congress recognized that by enacting the Federal Arbitration Act, now much maligned by anti-corporate factions. Unfortunately, the American Arbitration Association has created an equally costly alternate universe. Building upon the truths of Douglas McGregor's *Human Side of Enterprise,* Harvard, Pepperdine, and others have nourished a workable solution - alternate dispute resolution - in the form of mediation (it may call for meditation but it's different). WHAT IS THE BEST ALTERNATIVE TO A NEGOTIATED AGREEMENT? **BATNA**

Near the turn of the millennium, I picked up the phone and called the Chief Justice of the Nevada Supreme Court. *Hey Bill. Heard you had a new program to wipe out the case backlog. Yes, its mediation. We call it the Settlement Judge program.* With that call I became a Settlement Judge, helping litigious and contentious parties find their own solution to their disputes, commuting to Las Vegas after moving to the Coast.

After passing the California bar exam, my third in 36 years, the professional transition to California required a number of changes in my law practice. No law office. No secretary. No partners, associates, or paralegals. No file room; no file cabinets. What do I do with the documents filling five five drawer file cabinets, documents I must keep for 7, 11 years, or to infinity? A high-speed desk top scanner. Twenty years later all those files remain findable on the hard drive of my current computer six iterations later. Not one document requested has not been found in less than three minutes. No secretary could ever find a 34 year old file in less than three minutes.

Throughout my career I ended with more friends among adversary counsel than among colleagues and clients. Does the attorney's duty to zealously represent his client mean beat the adversary and her counsel to oblivion, or does it mean zealously search for a solution, for resolution to the dispute?

Always Learning.

Last Thoughts

Because no one in California ever studied management, the second law of thermodynamics, or mathematics, I now drive an almost free Plug-in Prius Prime. The practice of law had passed from electric typewriters to word processor stations to desktop computers to laptops to notebooks to iPads. The phone descended from party line to private line to multi-line to brick sized portables to cell phones to iPhones. Are we better for the advances? Does instant communication beat careful reflection? In one important vital way it has. The young lady who would have become the personal secretary then is now a bright articulate engineer or attorney. Lawyering is an avocation where you continue to learn, and get better with each matter, with each passing year.

Mastering that bamboo slide-rule taught us a fundamental. Look at the data and our analysis. **DOES IT MAKE SENSE?**

We know that technology enables us to do a terrific job of analysis of data and of the past. After analyzing available information, we know what happened. We have the ability to explain it. From that analysis we can identify trends and directions. We cannot predict the future.

From day one I always operated above my pay grade. I had fun. I kept my sense of humor. Turns out that I do have a pretty good memory. Deanna provided grace and elegance. We retired with our heads held high. Figure it out. Non-linear, Eclectic, Impish, Iconoclastic, Immoderate, Passionate, Always an Engineer.

Peace love.

A spiritual place of peace - Mission San Juan Capistrano

Robert F. Saint-Aubin, SB ’64 Course 15, Industrial Management, University of Pennsylvania, the Law School, JD ‘67. Robert was employed as a corporate, environmental, natural resources lawyer for a major Philadelphia chemical company. He relocated to Reno, NV, entered private practice as a mining and natural resources attorney, and then again relocated to Monarch Beach, CA where he served as a neutral, including as a Settlement Judge for the Nevada Supreme Court. Robert and Deanna met at a Burton House freshman mixer and married during law school. They now walk on the beach.

Folding Money – One place where US technology is far behind

Joseph E. Boling

Getting Interested in Folding Money

I came to MIT as a graduate of a military dependents school at Itazuke Air Base, Japan, outside of Fukuoka. The school was at the "administrative annex," where housing and various support facilities were also located. The airstrip, a few miles away, is now the Hakata International Airport. The entire complex was turned over to the Japanese in 1972.

Two years ahead of me, Andy Humer had graduated and gone to MIT. I figured if one person coming out of Itazuke could make that leap, a second one could (we were graduating 10-15 seniors annually). The only classes in high school that interested me were science (not including math). My aptitude test said I should be a clerk, which was less appealing than anything else I had been exposed to.

I had never learned how to study in high school—my homework was always done in study hall or on the bus riding home (we lived off-base—Dad was a law enforcement special agent not allowed to live around or socialize with the non-law-enforcement personnel assigned to the base whom he might have to investigate some day). Not knowing how to study, and having had nothing beyond trigonometry in high school, I had a hard time with math classes, and it kept me from pursuing physics, which I thought was my principal interest. Later I decided I really should have been in the Sloan School, but that did not seem a viable option while I was on campus—engineering students who switched to business were looked down upon. So I moved over to Course III, metallurgy, in the materials science side (Course III-B). I really ended up majoring in ROTC. The transcript says III-B, but the grades show that Army military science was where I did my best work.

That led to a regular Army commission and a 28-year military career, first in Infantry (two years) followed by two years in Ordnance, and then a final branch transfer to the Adjutant General's Corps (administration and personnel management).

My first assignment after officer basic and airborne qualification was in Germany for three years. Sometime in 1965 I attended a coin and stamp show at Ramstein Air Base (maybe 40 miles down the autobahn from Worms, where I was stationed). I had been a stamp collector since about third grade. I stumbled on a table where the dealer had stacks of banknotes from the German 1923 hyperinflation, for 5¢ each. I looked at the amount of engraving you could put on a banknote compared to what would fit on a stamp and never went back to stamps. I soon was collecting all the different notes I could find in the junk stores, where there were literally bureau drawers full of them at the same attractive prices (including many from other European countries).

By 1967 I was also collecting US paper money. I discovered you could buy obsolete US notes (including the pre-1928 large-size, or "horse blanket" notes) for face value in German banks, as well as gold certificates, which had just been made legal for US citizens to hold again. When my infantry detail ended, I moved to Munich for my first job as an ordnance officer. The cashier at the Munich PX often had obsolete regular-size notes in his till (issues dating back to the 1920s and 30s), and I would stop in there to see what he had that I could buy at face value. One day he had two identical $20 bills from a series that I was still looking for. As I examined them carefully to see which I would buy ($20 was a considerable sum for a lieutenant), I realized one of them was a counterfeit—it lacked the red and blue silk threads that should have been in the paper. I pointed that out to the cashier, who was less than uninterested. When I asked about it the following week, he said he had deposited it in the bank, and nobody had raised an issue over it. I sure wished I could have afforded both pieces the preceding week.

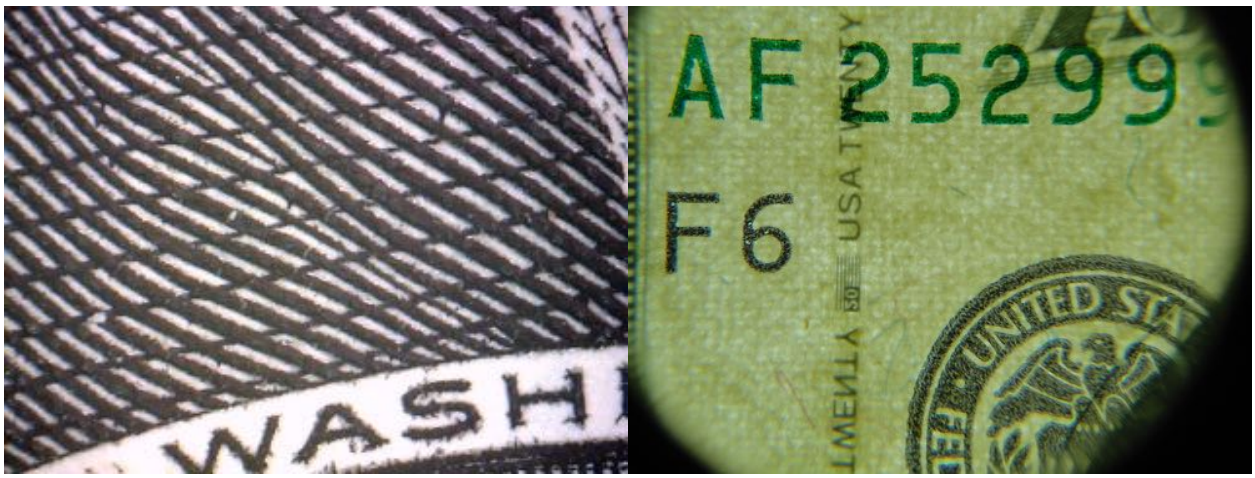
That was my second encounter with counterfeit money. Back in the 6th grade Dad had brought home a 5¢ military payment certificate that had been raised to 50¢ by clever drawing with a ball-point pen. I never saw it again—presumably, it ended up in an evidence file someplace. But those two experiences really raised my antennae. I began watching for publications about counterfeits and paying attention to what was in or on the notes to make them hard to replicate.

Over the next several years I became heavily involved in collecting paper money and coins of the world, eventually specializing in Japan. A friend who was collecting and writing about military payment certificates (many series were issued from 1946-1973) wanted to update the early books on Allied and Axis military currencies of World War II and recruited me to work on the Asian side of that. We published our first book in 1978. Fifteen years later we decided to go all out and cover all numismatic emissions related to WWII—paper, coins, medals, and war bonds. That 864-page book was published in 1995. While writing that, we uncovered the US counterfeiting of Japanese occupation currencies. The counterfeits were used by guerrillas working behind Japanese lines throughout Asia. This, of course, increased my interest in counterfeit notes.

When I started to sell off my Japanese collections, having bought all I could afford and having no place further to go with them, I kept back all the counterfeits I had collected, and genuine notes to match them (so students could see good and bad notes side by side). I then started to look for counterfeits of other nations, and other periods, and became aware of how far behind US notes are in the war against industrial-scale counterfeiting.

US Bank Note Technology

Until 1990 the US was still relying on only two security features in our notes—the printing done from engraved plates and the colored silk threads in the paper (by now no longer silk, but plastic).



$1 note - left a portion of Washington's lapel and right the imbedded threads.

The image to the left shows a portion of Washington's lapel on a $1 note, printed from an engraved plate. The ink stands up on the paper (check any denomination note in your wallet to see how that feels to the touch). The image to the right, shows three blue threads and one red thread in the paper (small and hard to see except for the blue thread in the black seal at lower right). The vertical strip will be described below.

Other nations were using watermarks, latent images (a very old security feature available only from engraved plates), see-through registration (part of an image on the face, the rest on the back, making a perfect image when viewed against a light), embedded plastic strips with text in them, micro-printing (hard for copiers to reproduce), multiple colors face and back, ultra-violet-reactive inks, security threads, optically variable ("color-changing") ink (OVI), holograms, and starting in 1988, polymer substrate with transparent windows, replacing paper.

The rationale for not keeping up with the Joneses was that the US notes were a worldwide store of value and changing them would confuse users. Counterfeiters could jump in with replicas that would not be recognized as replicas by long-time users of US notes. ("Oh, this is the new $50—haven't you seen one of these yet?") But about this time the "supernotes" began to appear—US $100 and $50 notes that were almost perfect reproductions, printed from engraved plates with the same kinds of presses that we use, on paper that looks just like ours. Something had to give.

Around 1989 patterns of magnetic and non-magnetic ink were introduced on the faces of most notes (used by bill readers to determine the denomination of the note). These were invisible to users, as both inks were black, but could be used by bill counters used by cash handlers to sense potentially counterfeit notes (manual examination would be needed for rejected notes, such as ones from older series). Both inks were printed on the same pass through the press. The Giori presses used by the Bureau of Engraving and Printing could print up to three different inks in one pass. So why were we not using that capability to print beautiful multi-color notes? We were using it for stamps.

In 1990 the US finally made a feeble effort to catch up—by using paper with an embedded polymer strip (also called a thread) that bore the note denomination in text that could be read with a back-light. That is the vertical strip in right half of the figure above, which was photographed on a light box. The threads were also reactive under UV light—a different color for each denomination.

$50 note - under UV illumination and showing the large-head style.

Shown above is a $50 note under UV illumination. Micro printing around the note portraits was introduced at the same time. These changes were made only on notes valued at $5 and higher (and the $5 and $10 notes with these features did not appear until 1993). To this day the $1 and $2 notes continue to use no security features beyond engraving and tiny colored threads scattered throughout the paper.

It was obvious that UV-reactive strips were not going to deter the hostile players who were copying our notes. In 1996 the first of the "large-head" notes was issued—the $100 note with Franklin's head moved to the left, a watermark placed in an unprinted "window" at the right, and the denomination "100" printed in OVI beneath the watermark. The shuffling of design elements was to introduce the watermark (an old but easy-to-confirm security feature), to get the portrait off the centerline (allowing it to stay undamaged longer—a good portrait is also a useful security feature) and to give the notes a fresh look. It was a good second step, but we were still far behind. The watermark could be simulated by printing in pale greasy ink that would make the paper translucent when held to a light, and the OVI could be simulated by mixing glitter in the ink. It did not change color, but it gave the correct visual impression that the security feature was present. The polymer strip with text could be replicated in several ways. When a counterfeiter puts all these false features into a note, it really does not matter that the note is lithographed rather than engraved—it looks convincing.

And yes, some overseas users were concerned. Most countries, when new note series are introduced, eventually retire the older series. They may still be redeemable at the central bank, but they can no longer be used in commerce. Canada just retired several series of ob-

solete notes this year, and the UK and Switzerland, as examples, have long stopped honoring older series a few years after they were replaced. I was treasurer of the International Bank Note Society when the 1996 $100 notes were introduced, and all of our Eastern European members suddenly wanted to pay dues in old cash, and for multiple years if possible. They did not want to risk getting caught with unusable notes if the previous series were demonetized (which the US has never done).

So far, so good, but we still had the most plain-looking notes on the planet. It took several years to get all the notes $5 and up changed to the large-head style (see the $50 note above), and the $5 never got the optically variable ink—too low a denomination for that expensive ink.

Near the end of series 1996 (next was 1999) the $20 large-head note introduced the use of infra-red-transparent ink on one section of the back. This was used by equipment that would read the pattern of the IR-transparent ink to determine the note's denomination. The other denominations followed, each with a different pattern. In ordinary light these patterns are invisible to users, so they add no security value unless the note is passed through a note counter that will kick out any note missing a pattern (which means that some older notes have to continue to be verified by eyeball in the banks). This capability replaced the use of magnetic ink patterns described previously—and was needed when the next phase of design progression occurred.

Eight years later (series 2004) the "colorized" notes began to be released—in all denominations $5 through $50. Because of manufacturing problems, the last of the colorized notes, the $100, did not appear until 2013. The colored backgrounds of these notes are printed separately by offset on different presses than used for the engraved portions. The color goes on first, since it is perfectly flat on the paper and would not print well over an engraved image, with its ink standing on the surface of the paper, causing a rough texture.

The colorized notes have both OVI and a device near the portrait in special metallic ink. It does not change color when wiggled but does have a distinctive look. But it displaced one of the black inks. Both the metallic ink and the OVI are printed from the same engraved plates as the main design, leaving only one more ink available for use. The Bureau chose to use magnetic ink on the full black plate, making the IR ink patterns on the backs essential for mechanical denomination determination. Since the $5 still does not use expensive OVI (or a metallic ink design feature), it continues to use magnetic patterns (it also has the IR feature on the back, which is used by note readers for the blind). And as always, by act of Congress, no changes have been made on the $1 and $2 notes.

The problems that delayed the release of the colorized $100s were related to the innovative feature in that note—the blue "Motion"® polymer strip in the paper (again also called a thread). This thread was developed by the company that has provided paper for our banknotes since the 19th century - Crane & Company in Dalton, Massachusetts.

$100 bill - showing a portion of the new thread.

The thread is wide and windowed (which means it is buried in the paper in some places and exposed in others) and has images that move around when the thread is tilted right and left or up and down. This is the most advanced feature to appear on US notes to date and is restricted to the $100 bill. The $100 note above, shows a portion of that new thread. The blurry images within the thread, which move when the note is tilted, are the number "100" and a Liberty Bell. But the thread adds thickness to the paper, over a much wider span than the thickness of the very narrow (and thinner) embedded threads used in other notes. The paper tended to crease when going through the press, and since the image was perfectly printed over the crease, the error could not be detected by the optical sensors that have replaced the platoons of note inspectors previously used. It would appear only when the note started to circulate, and the crease was pulled open by handling. Even manual inspection would not find the problem unless each sheet was tugged by an inspector, which was not part of the manual process and would slow production drastically. Eventually, adjustments to the press feed processes resolved the problem, but many millions of dollars worth of printed notes had to be shredded, and the introduction of the notes was delayed several years.

Well, where are we? We have a somewhat spiffy looking $100 note, and colorful notes in lower denominations, but next time you go overseas or can spend a few minutes at an airport currency exchange counter, look at what other nations have adopted. There are no end of proprietary optical effects (rolling, waving, and rotating in iridescent colors); all the features I mentioned in the introduction; "pearl" ink (transparent ink that a scanner or camera cannot see, but that reflects light when held at certain angles); transparent windows with embedded holograms that project images on the nearest wall when a laser pointer is aimed through them; images that, when activated with the proper cell phone app, will tell you whether the note is genuine; and much more. Printers like De La Rue have used some nations' notes as test beds for new features (Kazakhstan comes to mind, a relatively poor country with top-drawer banknotes).

It's time for our stodgy Treasury and Federal Reserve officials to get off the dime and move into the 21st century with US paper currency.

Joseph E. Boling, '64 Course 3, Metallurgy, spent 28 years in the Army, and is a currency collector and author.

Science and Technology

Left, The SpaceX Starship (SN15) taking off on a successful high altitude test flight in May 2021. In the six decades post Sputnik 1, satellites and space junk abound in Earth orbit, humans have visited the moon, robots have visited the planets and have left the solar system. The U.S. space program is now driven more by private industry than by the Federal Government.

Below, In 1957, the USSR shocked the world with the first successful launch and flight of a man-made orbital satellite. Many listened to the beeps on amateur radio or visually tracked the satellite with the aid of published trajectories. The event sparked a strong national response promoting math and science training and a furious push to develop a U.S. response, including the founding of ARPA and promoting launch competition among the Military Services.

The Weather

NEW YORK Herald Tribune

European Edition

PRICE PER COPY

PARIS, MONDAY, OCTOBER 7, 1957

U.S. Views Satellite as Russian Victory

Fights Flare In Warsaw for Fourth Night

By William J. Humphreys

Braves Nip Yanks, 7-5, In Tenth

Series Made 2-2 By 3-Run Rally

By Tommy Holmes

Russians Work on New One

It May Get Down With Instruments

By B. J. Cutler

This photograph, made from an altitude of 148 miles during recent rocket tests in the United States, provides background for artist's conception of the American man-made satellite in flight. Area in the background is of Southwestern United States and northern Mexico.

Soviet Satellite's Predicted Orbit

NORTH POLE

23-In. Sphere Looping World at 18,000 M.P.H.

Cold-War Effect Is Assayed

Symington Calls For Investigation

Editorial—Page 4

By Robert J. Donovan

Project Acorn:The Birth of the IBM Personal Computer

David Saul

Introduction

Personal Computer. The generic term has become a common part of our vocabulary. Toddlers to seniors understand what it means. But if you go back forty years, the concept of single-user computers was reserved for electronics hobbyists, academics, and popular science speculation.

What I attempt to do in this set of historical remembrances is to take you back to 1981 and the introduction of the IBM Personal Computer. Personal computing was inevitable given the progress being made in microprocessors, solid-state memory, and software. But IBM gave legitimacy to the PC that hastened its acceptance. I played a small part in IBM's development of the first PC. I want to thank our classmate, Bob Gray, for providing his personal perspective on personal computing in academia in the late 1970s and his specific insights on CP/M, the most serious operating system for early microprocessors.

A bit of background is to understand how I was in the right place at the right time. Specifically, why was I a Project Manager in IBM's Cambridge Scientific Center as 1981 began and how did the Center become part of Project Acorn, the initial code name for the IBM Personal Computer?

I began work at IBM in 1965 as a Systems Engineer in its office just outside Harvard Square that supported federal government customers. As described in my earlier essay in our first Class compendium, I worked with the NASA Center in Technology Square on the Apollo ground guidance computer, MIT's Instrumentation Lab (now Draper), Air Force Cambridge Research Labs at Hansom Field and MITRE. While supporting MITRE I had my first experience programming IBM's recently announced System/360 computer. Prior to that announcement, IBM had a separate 36-bit word-based scientific computer series starting with the 701 and evolving to the 7094. For example, MIT had an IBM 7094 in Building 26 at the time of our graduation. MITRE had one of a very few Stretch computers which was a supercomputer version of the 7000 series. Since computers of the time did not have separate input/output processors they were slowed to a crawl when they had to read input, typically punched cards, or print to paper. Stretch speeded up I/O by spooling its input to magnetic tape and sending its output to magnetic tape. An IBM 1401 character-based business computer provided offline card input to tape as well as tape to paper printing. MITRE replaced their 1401 with one of the first System/360 Model 30 computers in the Boston area. Rather than writing a completely new spooler program I took advantage of the 1400 series emulation that came with System/360 and I only had to provide a shell in

360 Assembler which called the emulator with the correct parameters. Fifteen years later the IBM Asynchronous Communications program for the IBM Personal Computer used a similar architecture.

I moved from that position to a District systems-support role at IBM on Boylston Street in Boston. The District office provided second-level software assistance to customers in New England, upstate New York, and most of Connecticut. Our job was aptly described by a fellow MIT alumni co-worker, George McQuilken, as "birdmen". We flew in to the customer site, dropped a load of s**t, and flew out. I became a regular on Mohawk airlines for Buffalo and Rochester customers. I also put many miles on my car driving to southern Connecticut, except when the Arab oil embargo forced me to use the train.

In 1977 I got my first management job at IBM's Cambridge Scientific Center in Technology Square. CSC had two non-contiguous floors at 545 Technology Square. Most of the remainder of the building was occupied by MIT's Laboratory for Computer Science (LCS). Cambridge was one of three domestic Scientific Centers and others globally that engaged in advanced technology projects. We were the interface between research and development and were deliberately located adjacent to leading computer science universities. Cambridge is best known for its invention of the Virtual Machine, the extension of virtualization to an entire environment. In conjunction with the Palo Alto Scientific Center, Cambridge had added virtual memory hardware to an IBM System/360 Model 40, creating CP40. Later that prototype was productized into CP/67 and its operating system, CMS (Cambridge Monitor System). CP/67 was fortunate for IBM as the core virtual memory software, TSS (Time Sharing System) was mired in delays and performance issues. When the System/370 was announced VM/370 became a standard product and moved to a separate site in Burlington, MA. A historical footnote is that several of the CMS developers were recruited by DEC and you can see their hand in the development of VMS.

The projects I managed at the Cambridge Scientific Center when I arrived were mainframe oriented, which was the core of IBM's business. The minicomputer was just starting to eat away at the lower end of IBM's world with DEC's PDP being the most prominent inroad. Others had also cloned the IBM mainframe with former IBM architect, Gene Amdahl, building a high-end machine. I also worked on early networking projects which predated the Internet. Networking projects needed partners to communicate with and universities were the ideal collaborators. I managed the BITNET networking project with Grey Freeman at the Yale Computer Center and Ira Fuchs at CUNY.

One of my mentors in Cambridge was resident IBM Fellow, Nat Rochester. Nat had been one of the designers of IBM's first computers, the 701. In addition to telling us anecdotes about those early days, Nat could always be relied on for practical advice on a project. He was also a bit eccentric. Nat liked to drive with no shoes on. He said it gave him better feel

for the pedals. I remember the day Nat forgot to bring his shoes with him and spent the entire day walking barefoot around the Center. Nat died in 2001 and his memorial service in Duxbury attracted a crowd that overwhelmed traffic in that small seaside town with so many friends and colleagues wanting to pay tribute to him.

Another project I worked on turned out to be one that paved my path to the PC. When IBM introduced System 360 it also introduced the 8-bit byte and its encoding, EBCDIC. The rest of world continued, for the most part, with ASCII coding for characters. IBM did not compete at the low-end of the terminal market where Teletypes set the standard. Others were building CRT screen terminals that used the ASCII standard. IBM Japan needed a product and had developed the 3101 CRT terminal. To validate the 3101 in the United States an IBM location was needed with ASCII expertise and Cambridge was picked based on our university networking experience. We were able to validate the 3101 and it went on to some success, primarily outside of the US.

Personal Computers Begin to Emerge

Personal computers were starting to emerge at the time. Radio Shack's TRS-80, Commodore 64 and the Apple II computer were most popular with hobbyists. They were crude by today's standards with cassette tape for storage and upper/lower case keyboards optional. But they had also started to gain traction with academics who began to use them for scientific calculations, avoiding the delays from mainframe batch computers. Classmate Bob Gray was one of those pioneers. Here is what Bob has to say about those early days:

> ***"In 1978 I purchased a Cromemco System 3, a Z80-based machine which ran CDOS (Cromemco DOS, one of the many CP/M imitators of the time). My home office was in a tiny rural town (La Honda, perhaps 500 people then, in unincorporated San Mateo County). I needed real computing power, including a decent word processor (Emacs and the WYSIWYG WordStar ran on CP/M and its imitators) as well as Basic and Fortran 4 (also great on CP/M). Modems then were too slow for me to work remotely from home (and the networks of the time too unreliable), so I needed a self-contained system, often exchanged data with the Stanford computers using 8-inch floppy disks and used the modem only for email. That machine cost me nearly $4K and weighed over 70 lbs. But it allowed me to do serious Fortran programming and then pass on the successes to graduate students who redid things in C or C++."***
>
> ***"By May 1978 I submitted a paper (published in January 1980) with two students to an IEEE Transactions with examples and preliminary results developed at home in Basic on the Cromemco System 3 (acknowledged in the paper) with careful expanded simulations obtained on a PDP 11/34 at Stanford. Personal/home computers running CP/M or an imitation were far from being for hobbyists alone. I and several colleagues were actively using them for statistical signal processing research by 1978. Another virtue of CP/M was that the early versions of LaTeX typesetting applications (combining Knuth's Tex with Lamport's macros) were quickly available for CP/M and hence for its imitators. I used the System 3 extensively until the early 1990s when I replaced it with a SUN Unix system, which Stanford paid for. I never owned a PC running MSDOS."***

Recognizing the business potential, IBM started a project in its Raleigh, North Carolina plant to build an Apple II clone, called the 3101P. It used the 3101 keyboard and screen with a modified chassis to hold adapter cards. No software would have to be written for the new product as it could reuse anything written for Apple. Given our work with the 3101, several of us flew down to Raleigh and met with the 3101P developers. We asked them what distinguished their product from Apple, and they were hard pressed to come up an answer other than that their chassis was easier to insert adapter cards into and they had a better keyboard. Assuming the price would have been higher; we did not see the 3101P as a winner. What was the alternative?

TRS -80

Apple II

Every year our Cambridge Scientific Center head, Dick MacKinnon, would hold a kickoff meeting in January to celebrate the accomplishments of the previous year and brainstorm about the year ahead. In January 1981 we were offsite at a local hotel. One of the stalwarts of our Center was Fritz Giesin. Fritz was a former IBM Customer Engineer with experience maintaining hardware. More than that, Fritz was the person you went to if you needed something built. He was the ultimate tinkerer. For his 1980 Christmas holiday, Fritz had taken his family to Boca Raton, Florida. Never one to relax, Fritz had stopped by the IBM plant to visit with old friends. While there, he heard about Project Acorn, a "skunk works" project to build a personal computer. Fritz described to us what he knew about Acorn and asked whether the Center wanted to get involved. Of course, we did. Our experience with the 3101 was our entry. It turned out that being in Cambridge gave us another entry that we did not realize at the time.

Project Acorn

The IBM Personal Computer would never have existed without the creativity, salesmanship, drive, and persistence of one man – Don Estridge. He was the force behind Project Acorn and convinced IBM's then chairman, Frank Cary, that IBM needed to innovate rather than copy. I only met Don once and it was after the work I describe below. The three US Scientific Centers in Cambridge, Palo Alto and Los Angeles would gather several times a year at an IBM laboratory or development site for a symposium. In late 1981 we went to

Toronto where, upon introduction, Don Estridge commented that he had already seen me on the IBM PC announcement video. At that meeting I sensed the force of his personality and why he earned the title of "Father of the IBM Personal Computer". IBM's future PC struggles might have been lessened if Don Estridge had not been tragically killed in a private airplane crash in 1985. Anecdotally, going through Canadian customs and immigration, Nat Rochester had his floppy disks confiscated as undeclared business goods. The disks contained Nat's presentation slides, so he had to improvise during the meeting.
Acorn was based on an Intel 8088 chip rather than the Motorola 6800 that Apple used. We were told by the Acorn architects that they chose to use the 8088 chips, a variant of Intel's 8080 with a smaller data path, primarily due to cost. That choice meant that new software would have to be written from scratch – operating system, programming languages, applications, etc. Developing the PC hardware could borrow from other parts of IBM like keyboards and monitors, but internally developed software had never been a historical IBM strength. The solution was to go outside for everything. One of the first software contracts was with a Washington state startup, Microsoft, for a BASIC interpreter which would be the primary programming language. Other contracts were let with outside companies for accounting software from Peachtree and a word processor, WordStar. The Center saw an opportunity for us to contribute communications software, which was not part of the initial plan.

Software

We assumed that the first choice for an operating system would be CP/M, the first successful operating system for microprocessors, invented by Gary Kildall and sold by his company, Digital Research of Pacific Grove, California. We were told that the IBM negotiators were not able to reach a satisfactory deal for CP/M with DRI during their initial visit, so IBM turned again to Microsoft with a request for a suitable operating system. Microsoft then purchased a CP/M-like operating system from Seattle Computer Products and transformed it into MSDOS, which they provided to IBM. Our software development was not dependent on the choice of operating system. Following an agreement with Digital Research, early IBM PCs offered customers a choice of which of the two operating systems they wished to purchase, with MSDOS being one-sixth the price of CP/M.

The "killer application" for all PCs turned out to be the spreadsheet. Another startup in Cambridge, Software Arts, was developing VisiCalc. Originally developed for Apple by Dan Bricklin and Bob Frankston, VisiCalc was the prototype for all of today's spreadsheet products that have transformed data manipulation. Later at Lotus (acquired by IBM), Bob developed Lotus Express before moving to Microsoft. After many years I reconnected with Bob Frankston at the Boston CTO Club. He remains an active contributor to the IEEE and a seminal thinker on multiple topics.

The original IBM Personal Computer had hardware communications adapter cards for both binary synchronous communications and asynchronous communications but no plans for software to drive them. That provided an opening for a Scientific Center project. We volunteered to write asynchronous communications support that would allow the IBM PC to operate over telephone lines to an IBM mainframe, minicomputer, etc. And we committed to finishing in time to be included for the mid-year product announcement. The Acorn

software manager, H. L. "Sparky" Sparks, was dubious but agreed. He did not think we would make it. We may not have but the announcement slipping until late summer gave us more time.

We needed a prototype IBM PC to test with and they were in truly short supply. One could not be procured for us. The solution was due to our proximity to Software Arts in Central Square. Shipments to their shared space were not secure. The solution was when the latest version of PC hardware was produced it was sent to our secure IBM location. Fritz would then hand deliver it to Software Arts and take the previous hardware back to our Technology Square facility to use for software development. The oldest machine would be sent back to Boca. The PC prototype was locked in a windowless room with two tables and a few chairs. Only I and the two developers had keys. My hardware contribution was to neatly print characters on stickers which were placed on the keyboard. The prototype keyboard had come from an IBM word processor and was EBCIC instead of ASCII. Never underestimate the importance of taking an engineering drawing course.

Networking

Modems were not yet available to connect the asynchronous adapter to a phone line, so we used an acoustic coupler operating at 300 bits per second. Later 2400 bps modems seemed lightning fast to us.

Asynchronous Communications Support was developed by Frank Bequaert and Charlie Salisbury (MIT Class of 1964). The software emulated an ASCII terminal. To speed development, Frank wrote most of the software using the native BASIC interpreter and Charlie wrote an Assembler driver for the adapter card, being called and interrupting when needed. They had to limit features as the Boca Raton management insisted that the program fit in the default 64K memory. We did produce a Version 2 for 128K with those additional features before the end of the year.

At some point the Acorn code name was dropped and Chess became the new label. There was also a Checkers project which became the ill-fated PC Jr. Plans were being made for selling the PC in IBM stores as well as Sears, distribution channels entirely new to IBM. One of the stores opened, briefly, across from the Burlington Mall. After much discussion it was decided that the PC would also be sold by IBM's Data Processing Division which normally marketed mainframes et al. DPD VP Dave Hanna was an early supporter of integrating the PC with IBM's other products.

I became a regular traveler to Boca Raton, Florida to meet with the Acorn software management. The Acorn group was housed in rental space away from the main IBM development site which helped to maintain its confidentiality. The building abutted the railway tracks, and, due to the noise, we would have to pause meetings with Sparky Sparks, in his single-pane windowed conference room whenever a freight train would pass by. He later left IBM for newly founded Compaq as vice president of sales and service.

PC Announcement Day

As PC announcement day neared, we were finishing up our testing and documentation. The Data Processing Division realized they needed some announcement material to educate their sales force. A professional video would be produced with DPD President, George Conrades, taking the lead role. Earlier I had demonstrated our Asynchronous Communications Support to him on a visit to Cambridge. We had connected to the New York Stock Exchange over a dialup line and were receiving stock prices, looking like a Teletype. I had to-convince Conrades that we were doing this in real time and had not pre-recorded the data feed. When the time came to record the announcement video I was selected to act as the PC user. We filmed in our locked room with me sitting at the PC and describing the uses to which it could be put. I had a brief talk to memorize. Mostly I remember having them apply stage makeup so I would appear human on the video. Thankfully, I bore no resemblance to Charlie Chaplin who the IBM advertising agency chose as its silent campaign spokesman. Years later I met George Conrades when he was CEO of BBN in Cambridge and reminded him of our shared video past. He did not seem to remember me.

Shortly after the PC announcement, IBM had one of its quarterly mainframe users' meetings, SHARE, at the Palmer House hotel in Chicago. Headquarters DP marketing people came up with the idea of shipping our prototype PC to the hotel and have me give a PC introduction "birds of a feather" session to a small group. We were added to the schedule but the day before the session our prototype was seized by security guards sent to our hotel room by IBM. Our development PC was not Underwriters Laboratory certified and could not be shown in public. We were told a certified model would arrive that night. After midnight I drove to O'Hare Airport and I met an engineer from Boca Raton. We took the boxes off the luggage conveyor, piled them into the rental car and drove back to the hotel. We spent the rest of the night assembling the two PCs, under his guidance. It was the first time I had ever inserted memory chips into a circuit board. Fortunately, I did not bend any of the pins. I also had to install the 5.5-inch floppy disk drive in its bay which required cantilevering the PC over a table and inserting a screw from underneath. An early engineering change with the production model PC changed that procedure to a safer one, inserting screws from the side.

The next morning, I set the PC up on a table in front of a small hotel meeting room. When we opened the door the entire hallway outside was filled with people who wanted to get in. I had to repeat my presentation on overhead transparencies (no PowerPoint yet) to larger and larger meeting rooms for the entire day. The only software I had to demonstrate was a program that drew random colored lines on a TV monitor and a BASIC program that calculated payments, given amount, term and simple interest. IBM did not yet have its own color monitor available. The SHARE membership presentations were followed by a late-night trip to Lake Geneva, Wisconsin, to present to the SHARE Board of Directors after their din-

ner. After a heavy meal and much wine, the Board did not show as much interest as their members had.

On August 12, 1981 IBM announced the model 5150, IBM Personal Computer. The only piece of IBM internally developed software included in that announcement was Asynchronous Communications Support. I was and continue to be proud of the work that our team did in 1981 to make that happen. Like many of the accomplishments of the Cambridge Scientific Center during that period, our Personal Computer project would not have happened without the leadership of Dick MacKinnon and his ability to see how technology could be applied to relevant problems.

With the announcement IBM had made provisions for an employee Personal Computer purchase program and our family received its first home computer later that year. It had two 5.5-inch floppy drives, a monochrome monitor, and an Epson dot matrix printer. Disk hard drives did not come along until the XT model in early 1983. Our first role-playing game was Zork, entirely text based. We soon purchased enhancements from a start-up mail order company in New Hampshire, PC Connection. They are still in business and an early example of the huge industry that has prospered from the personal computer.

Building on this first terminal communications program from Cambridge, in 1982 staff member Jim Perchik developed a full featured terminal communications program, 3101 Emulation Program, with full-screen capabilities as well as the ability to emulate other manufacturers Teletype compatible devices. 3101 Emulation had the distinction of having zero bugs reported during its two-year lifespan.

As a postscript, in 1992 IBM closed all three remaining domestic Scientific Centers as a cost cutting measure. That closure ended their twenty-eight years of advanced technology contributions to computer science. Ironically, in 1989 the IBM Systems Journal (Volume 28; Issue 4) had published "History and Contributions of the IBM Scientific Centers", an entire issue dedicated to the innovative work done in their twenty-five-year history. I was one of the guest editors on that issue.

David Saul '64 Course 16, Aeronautics and Astronautics, his first job after graduating from MIT in 1965 was with IBM's Federal Systems office in Cambridge. His first management position was with IBM's Cambridge Scientific Center, where he oversaw advanced technology computer projects in virtualization, multiprocessing and networking. In 1981, his group developed IBM's first software product that allowed the IBM Personal Computer to communicate over telephone lines to mainframes. In 1993, he joined State Street and applied his computer skills to financial services. He was State Street's Chief Scientist, where he focused on applying innovation to their business.

Big Data and Small: A Statistician's View

Stephen Portnoy

I entered MIT as a budding mathematician. My initial interests included physics, but after getting a couple of C's in the first year course for Physics and Math majors, I switched to the general version (B's, with much less work and stress), and concentrated mainly on more abstract math. However, by my junior year I was beginning to look again at math applications, especially after courses in Artificial Intelligence and Operations Research piqued my interest. In my senior year, I took a great course in basic mathematical statistics from Professor Harold Freeman from the Economics Department. From there I went on to Stanford (helped greatly by the recommendation from Professor Freeman) for a Ph.D. in Statistics. After a 5 year stint at Harvard, I spent the remainder of my academic career at University of Illinois, where I continue as an Emeritus Professor. Four years ago I moved to Oregon to be near my daughter's family (especially my youngest grandson). But I continue to do research and some student mentoring through an adjunct appointment at Portland State University.

I remember my time at MIT with great fondness, especially since MIT is the source of my two greatest loves: statistics, and much more exuberantly, my wife, Esther, whom I met at the MIT Science Fiction Club in 1963. After the meeting, many of the attendees walked up to Central Square for a pizza dinner. Esther and I, both avid hikers, found ourselves walking faster and separating from the others. Fifty-seven years later, we still enjoy hiking, especially in the nearby hills and mountains of Oregon.

The Alps

Academic life provided a serious advantage: the ability to work with colleagues from all over the world. International conferences gave ample opportunity for travel, and when traveling we almost always try to take a side trip to scenic areas where we can do some extensive hiking. Visits included sabbaticals in Australia (where in one 6-month period we did sufficient hiking to have climbed from the coast to the top of Mt. Everest, twice!) and numerous trips to Europe, where we hiked in the Alps (see photo), the Tatras in northern Slovakia, the Lake District in England, and on Greek Islands, among others.

Statistical Career

My career as an academic statistician has been especially rewarding, both in terms of research and teaching. I have special fondness for the Ph.D students I advised; working with bright and eager minds tends to keep one young at heart. My research activities began with extensions of my thesis work on mathematical statistics. As my career developed, I had ample opportunity to work with colleagues developing innovative statistical methodologies, to engage in statistical consulting, and also to work on a number of collaborative projects with scientists and scholars in a very wide range of fields: from biological sciences (especially ecology), social sciences (especially economics), and other sciences to linguistic studies of the Hebrew Bible. This has given me a broad perspective on statistics, and a great deal of sheer joy.

My collaborative work on the Hebrew Bible has been especially rewarding, as this is an area where the application of statistics is far from clear. This work generally concerns analysis of word frequencies, to which I recently introduced the analysis of the gaps between specific words. The aim is to distinguish possible differences in sources (or authorship), especially differentiating between early and late Biblical Hebrew. A major question is what one can do statistically when there is no agreement (or data) on sources, dating, or authors. Basically, we look at the appearance of putative markers of source or dating and ask whether or not the data for the marker could have been generated at random. The conclusions are that for some markers, the probability that they appeared "at random" is very small, but other markers are not at all unlikely under models for random appearance and thus not likely to be useful.

Big Data, a Statisticians' Perspective

One of the hottest topics of modern data analysis concerns what is called Big Data, or Data Analytics. I'll address this issue from the perspective of a statistician, beginning by a brief discussion of statistical science. This is the systematic study of comparative properties of procedures for analyzing data. Note that this is NOT data analysis. The analysis of data should only be done by those who know how data was taken, understand what was measured, and realize how the measurements should relate. In this sense, neither the statistician (nor the computer scientist) have any business drawing conclusions from data analysis unless they have independent scientific or scholarly expertise underlying the collection and measurement of the data.

In almost all cases where data is taken, the scientists or scholars taking the data believe certain relationships among the data should hold. In fact, such relationships almost never hold exactly; any data set contains errors and discrepancies (errors of measurement, sampling variation, etc.). Such problems date back to the earliest days of modern science: Galileo and other 17th century astronomers clearly recognized that the observed angles of observation of stars and planets would vary, even when taken by the same observer and the same time. Errors of measurement were quite evident whenever one tried to use the measurements to fit elliptical orbits.

Statisticians have tried to quantify such variability by positing explicit families of probabilistic processes as the source of the discrepancy. For example, since Gauss and Legendre around 1800, much data was assumed to follow the "bell-shaped" curve, that is, the data have a Normal distribution with the mean being the parameter of interest and an (unknown) standard deviation. This led to simple least squares methods that allowed statistical analysis of relatively small data sets in the absence of high-speed means of computation. In fact, Galileo had earlier suggested methods minimizing absolute errors, avoiding the unnatural squaring of errors. However, efficient computation for such methods was not available until the computer age. Interestingly, one of my contributions to the field was to show that with probability tending to one, minimizing absolute errors was faster computationally than minimizing squares of errors in certain common large sample problems.

Big Data, or Data Analytics, may be distinguished from statistical science by the tendency to avoid specific families of models for the data. It focuses on the study of methods for finding "structure" or "features" in large often somewhat amorphous data sets. It emphasizes algorithms (or "black boxes") to be applied to the data. These have been generally developed by computer scientists, though statisticians have also played a role. These algorithms go by a number of somewhat fanciful names: neural nets, support vector machines, random forests, wavelets, bagging-boosting, and many, many others. They often come with extravagant claims, the epitome being: with Big Data determining all relationships, science is no longer needed. Are our MIT degrees dinosaurs about to go extinct when hit by the Big Data asteroid?

In fact, a large number of critiques have arisen from both computer scientists and statisticians including:

(1) bias: If the observed data differ systematically from the population of interest, the results of any analysis can not be generalized beyond the data. Almost all observational data sets have some bias, often much more than realized; and if relationships change in time in ways that cannot be well-modeled, the results will again fail to provide appropriate conclusions for the present or future. Furthermore, almost all non-randomized methods of taking a sample are subject to bias, making the observed data unrepresentative of the population of interest. Basically, since Big Data methods focus on a single data set, generalization beyond this set requires some scientific (or scholarly) body of knowledge to provide a basis for such extrapolation. 2016 and 2020 election polls provide ample evidence of the ubiquity of bias.

(2) lack of quantification of variability: There are two sources of variability in data: variation among the individuals sampled, and variation in measurements (measurement error). By imposing probability models, statistical methodology provides a well-developed and well-tested approach to assessing such variation in ways that allow generalization beyond the given data. Of course, this requires that the assumptions underlying the models hold, at least to adequate approximation; but this can often be reasonably justified by substantive scientific expertise. There are good methods for assessing variability within the data, but, again, it is generalization beyond the data that is critical both scientifically and practically. Can assessment of variability be done without statistical models? Fundamentally, the answer is no! Without some assumptions it seems impossible to know that the next data one sees will have the same structure as the data set just analyzed; and the assumptions must be very much stronger if the data was not taken as a random sample from the population of interest. Note that computational "black boxes" do not address the problem. Each black box searches for specific types of features, and thus indirectly assumes some form of a model for the data. One advantage of the statistical approach is that it makes the assumptions explicit.

(3) inadequate attention to measurement error and the meaning of the data: The observed data is often only roughly related to the questions of interest. For example, voting polls seek to select a sample from a population of potential voters and ask what fraction favor a given candidate. The result of interest, however, is what fraction of the voters actually vote for the candidate. That these fractions may differ significantly was clear in the 2020 presidential election. This further emphasizes the need for the analysis to involve scientists or scholars with substantive knowledge of where the data arose and what they mean.

In fact the strongest criticism concerns claims of success for Big Data methods. There is ample evidence that results suggested by application of a Big Data methods often fail to hold up in subsequent studies. Let me quote a study found at: https://www.datasciencepm.com/project-failures/

"Only 27% of big data projects are regarded as successful"

"Only 13% of organizations have achieved full-scale production for their
Big Data implementations"

"Only 8% of the big data projects are regarded as VERY successful"

An example of Big Data failures may be informative. An early "classical" failure concerns a study of a large sample of customers who shopped at a supermarket chain. The analysis found an unusually large correlation between the purchase of milk and the purchase of diapers resulting in a recommendation to move the diapers nearer to the milk. Not surprisingly, this correlation disappeared in future studies. Basically, the initial study paid insufficient attention to the fact that a huge number of correlations were computed, and some were bound to be very large just due to (random) variation in the sample. Even when there is collaboration among scientists, computer experts, and statisticians, it is still quite com-

mon for the main results of the analysis to be valuable only in pointing to future research directions.

Is there a general principle underlying the problem? In addition to the criticisms above, the analysis raises one fundamental issue: there are far too many possible structures. A structure could be given by any partition of the data into subsets followed by any collection of models within each subset. For a large data set, the number of partitions quickly exceeds the number of electrons in the universe. Unless very serious restrictions are imposed on the kinds of structures to be considered, it is impossible to examine even a minuscule proportion of cases. Essentially, each of the black boxes of Big Data imposes very strong restrictions on the structures to be found. Whether or not these restrictions are appropriate requires scholarly knowledge beyond the data itself.

Small Data

My journey from MIT to the present has been filled with challenging mountains of many sorts to climb. Notwithstanding the slips that occurred along the way, the climbs have almost always been extremely enjoyable. Some of the most fun I have had recently concerning problems in statistics is the case of small data. One recent example concerns inference on the mean of a Normal population. Generally, the statistician addresses this problem by taking a sample, computing the sample mean and standard deviation, and presenting a 95% confidence interval. This is the interval of the sample mean plus or minus (approximately) twice the standard deviation; and it is claimed to contain the unknown population mean with “confidence" .95; that is, the probability that the random interval covered the mean was .95. Around 1960, my thesis advisor (and others) realized that one could obtain a confidence interval for the mean of a Normal population with only one observation (which would not permit estimation of the population standard deviation). Basically, the observation plus or minus about 20 times the absolute value of the observation will cover the population mean with probability at least .95 no matter what the values of the true population mean and standard deviation. Recently, I considered the question of comparing confidence intervals based on a single observation and obtaining the optimal one. I developed a legitimate confidence interval with strictly smaller length than those suggested earlier. I also extended the idea to the case of having single observations on a large number of possibly correlated Normal populations, thus touching Big Data.

A second example of inference with a single observation concerns the two-envelope problem. This problem was suggested to me by a mathematician, Jim Stein, who had read my confidence interval paper and wondered if I had any insights into work he and colleague were doing on the two-envelope problem. The problem concerns the following paradox. You and another person are each presented with an envelope (at random). You are told that one envelope contains Z dollars, and the other 2Z. You get to look at your envelope and then may either take what you observe or switch envelopes and take whatever is in the switched envelope. Having observed X, you (and your opponent) reason as follows: either I keep X, or I get an envelope with the amounts (1/2)X or 2X, each with probability 1/2. The expected payoff if you switch is (5/4) X, and so you should switch. The paradox is that both you and your opponent reason that you should switch. The resolution is that, while the un-

conditional probability of getting each envelope is 1/2, the conditional probability given your observation, X, is not 1/2. For example, given that each envelope contains a positive integer number of dollars, an observation of X = 1 ensures that the other envelope contains 2 dollars.

It turns out that if the envelopes contain any pair of random values that are bounded by a known constant (say, B), there is a procedure for selecting the bigger value with probability greater than 1/2: take a uniform random number, U, in [0;B], and keep your envelope if X > U and switch if X < U. This was already known in simple versions of the problem, but it was a good bit of fun for me to develop a mathematical theory giving precise conditions on when the procedure above is optimal and when it isn't.

Concluding Remarks

One prerogative of age is the chance to look back and offer words of wisdom to the future. My wife and I look back with a profound appreciation of what has provided the support for our journey: our parents, our educations, our friends and colleagues, and our mutual love for each other. At a famous British University, each member of the faculty greets each graduating student with the words: "I wish you joy". And so I conclude by extending this wish to all.

Stephen Portnoy '64 Course 18, Mathematics; PhD. Stanford, Statistics '69. Career: Asst. Prof., Harvard, 1969-1974; Prof., University of Illinois and Urbana-Champaign, 1974 - present; Adjunct Prof., Portland State University, 2017 - present. Professional Recognition: Fellow, American Association for the Advancement of Science; Fellow, American Statistical Association; Fellow, Institute of Mathematical Statistics; Editor: Journal of the American Statistical Association: 2005-2008; Francqui Professorship, Université Libre de Bruxelles, 2005. An academic career spanning nearly 60 years has afforded ample opportunity for teaching, directing thesis research (13 Statistics Ph.D.'s and as a second thesis advisor for 10 Ph.D.'s in applied areas), serving in academic and professional administration, and working on statistical theory, methodology, and applications (over 100 publications, mostly with collaborators in Statistics and Applied areas). Steve married Esther, who he met at the MIT Science Fiction Club, and raised two children: Rachel, who now lives with her husband and son nearby in Hillsboro Oregon, and Gerald, who died in 2004 of complications of Multiple Sclerosis leaving 3 children, now adults, two of whom live near Chicago and one in Houston.

Revolution in Telecommunications 1964-2020

Larry Hendrickson

The telecommunications industry changed radically in the years since 1964, probably more than most industries, and maybe more than any other. Immense technological change added new products and services, and with new competition melded industries together. In addition, the telecom industry has been restructured radically, its major players changed, and its relationship with government redesigned. The business model is different. The view society holds of the services offered by the industry has gone from a luxury affordable only by a few to a necessity needed by all and then to an inexpensive vehicle for idle pastimes used by most. Few businesses have been through such change. This story is about the changes in the industry and my participation in some of those changes.

My Advantageous Start

I happened to participate in several of these major changes throughout my 37-year career in the industry from 1964 through 2001. My MIT degree got me started in an advantageous spot with AT&T and gave me boosts along the way. I was not cut out to be an engineer and did not want to be. I saw in my father's work as a general manager of a mid-size manufacturer that businessmen had little understanding of the potential for computers and communications to alter their businesses. I worked with my advisor, Don Carroll, on his way to becoming dean of Wharton, to develop a prototype "systems management" minor to fulfill the technology requirement for a Course 15 degree.

That education got me a position as operations manager of the central data processing center for AT&T Long Lines, the operating company providing interstate telecom services. I took advantage of that position to visit all my "clients" to learn what their applications did for them. AT&T tried to be on the leading edge of management systems and methods. So the applications being addressed by computers were advanced for the time. It was a superb education in how the company operated, how money flowed, and how regulation worked.

As I moved from department to department in Long Lines' management development process, I gained in understanding network technologies, network design and expansion, business cases, and capital investment decisions. A time in Division of Revenue gave me understanding of that process central to the finances of the industry. All of that gave me an unusual breadth of understanding that led to assignments in regulatory and antitrust cases and

strategic planning. It was in those latter assignments that I participated in the major changes that took place in the regulation and structure of the business and the industry.

The Break from Rotary Telephones

Remember the black dial telephone on the wall in most of our living quarters at MIT? A clunky monster, a painful wait for that dial return for the next number. Then the connection took 15 seconds as mechanical switches sequentially clunked into place. Voices were weak and distant, lines were noisy and disconnects not infrequent. Calls to some small towns and many foreign countries still required human operators, plugging cables in switchboards.

The wristwatch that we now ask, not dial, connects instantly across country and the world. We don't just talk to people, we see them. In high resolution motion and color. We see stock market quotes, news stories, photos, play music, track exercise, get the weather, and much more. Communications can be combined with computation from simple calculations to calling up elaborate modeling and analysis. We buy merchandize or stocks, cars or houses. Communications move from the watch to phone in a pocket to a laptop to a desktop to a car dashboard to a television without interruption. The telecommunications industry, the data processing industry, the electronic content industries, the home, business and industrial controls industries, and many others are still distinguishable. But they overlap and integrate far more than any of us anticipated. Certainly no one was imagining a "today" back in 1964.

All of this change in the telecom industry required massive changes in technology produced by progress in many different fields of science. Materials, astronautics, launch rockets and fuels, computation, data storage, data transmission, signal processing, and many more. That happened in most other industries as well. In telecommunications, it changed the fundamental operation of the industry and its relationship to society.

Many would say the door that opened to allow this massive change was the 1984 breakup of AT&T. Actually AT&T's Bell Laboratories was the creator of many of the products, technologies and underlying sciences that led to the change. In another country the company would have adapted to the change in national goals without being broken up. All other advanced countries adapted to competition by privatizing their telecom "ministry" and set-

ting up the rules that allowed competition. Our society in the 1970s wanted to end monopoly power, not regulate it to achieve competition. A discussion that should be repeated today.

Advancing Technology

The technology of AT&T was changing rapidly in 1964. Most of the existing facilities were not much different than what existed 30 years before, before the war and before the Great Depression. The technologies developed during the war were moving into widespread use during the fifties and new tech was coming in the sixties. In 1964 95% of homes had at least one black dial telephone set. New phones were coming but replacing 95% is a big job. All those phones were connected mostly by copper wire cables strung between poles. Again a huge job to replace all that.

In 1964 AT&T was growing very fast. Expanding its network and hiring a lot of people. Our population was growing, incomes were rising, our economy was expanding, and calling prices were falling all of which were driving fast growth in calling, revenues and profits. AT&T was busily creating a hardened backbone of coaxial cable connecting all major cities and all major military bases, cables 4 feet underground connecting switching/multiplexing buildings 40 feet underground. Sufficient to withstand a direct nuclear blast by the weapons of the time. That backbone network had enormous capacity for the time. It supplemented the point-to-point microwave system that had been installed in the 1940s and

1950s. The capacities of both radio and cable technologies were being expanded by solid state multiplexing systems. The old wire cable systems were being retired from the long-distance network. The technologies of coaxial cable and solid state frequency division multiplexing allowed for the bundling of thousands of voice channels. The bundles were being expanded with each generation of multiplexing. Ocean wire cables were being replaced by coaxial cables as well and their capacity expanded rapidly. Switching transitioned to electronic although still analog and space division.

Satellite

Two years before I started with AT&T, the company had implemented the first private commercial satellite telecommunications system. Launch technology was not sufficient to achieve a geostationary orbit. The AT&T earth stations had to rotate to track the satellites as they passed overhead at 600 miles altitude. Transmitters and receivers in the satellites were low powered, limited by early solar panel efficacy and transceiver weight. The ground antennae were huge horns rotating on what essentially were railroad tracks. The capacity of the satellite was one TV channel or several hundred voice channels. It was intended as an experiment to demonstrate the technology and start the development process. In 1965 other companies achieved a geostationary orbit, 22,000 miles from earth so terrestrial antennas could be fixed. Station keeping technology improved greatly over time resulting in fleets of satellites staying close enough to appear as one to an earth antenna. Even a 2 foot house antenna. That allowed up to 800 TV channels. Massive.

Data

Demand for computer to computer communications was growing. The Bell System offered a data modem that handled conversion of digital data to the analog signals carried by the telecom network. Those modems handled 100 bits per second. About four times the rate of a good manual telegraph operator in the Civil War 100 years before. But there was a huge demand for those data modems. Those of us in operations started acquiring them any way we could and squirreling them away to be able to respond to customer orders.

One of our most advanced data communications technologies in 1964 was an experimental data line offering 50 Kb/s. Very unstable. But allowed us to transmit the data from a mag tape to a mag tape in another data center about 20 miles away - given enough time. That was the threshold of data communication technology at the time.

Today data communication speeds are in gigabits per second and a UK laboratory has demonstrated 178 terabits per second. With vast improvements in coding, the actual difference in content transmitted between 1964 and today is many times higher.

Videophone

In 1964, AT&T was completing a yearlong trial of a desk top video phone service. Three large US corporations had videophones on the desks of their senior executives. At the end of the trial, all three of those companies and many others said they would buy the service. A massive investment was made in network capacity. But when the service was launched and the prices were announced there were no orders. A huge market bust. Even worse than the Edsel. Maybe if AT&T had offered the service at rates the market would have accepted (and assuming the regulators would have approved a loss-making service) the world would have had person to person video calling many years earlier than eventually happened. The problem was the analog transmission took too much bandwidth.

Conversion to Digital

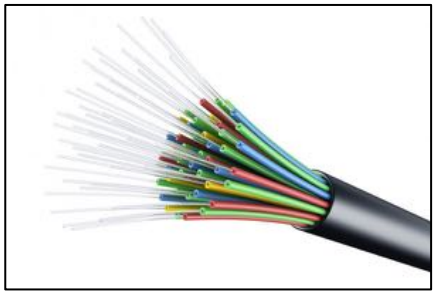
In 1978 AT&T decided to convert its entire long-distance network from analog to digital. Voice calls still were carried more efficiently over analog facilities. But it was apparent that data transmission was growing far faster than voice. Eventually most originating traffic would be in digital form. All multiplexing equipment had to be replaced with time division multiplexing in every network node and terminal. The cost was massive and took a long time. Conversion to digital was a real forward thinking move that paid off over time.

Cellular

In 1983 the Bell System started cellular telephone service. Mobile telephony had been around for over 50 years. But base stations were few and far between, car phones were heavy and bulky and service was poor. The idea of cellular transceivers in a cell grid was conceived by an FCC engineer in 1947 who was trying to find a way to reuse the small amount of bandwidth allocated to mobile telephony. By 1973 the Bell System had obtained approval to implement a network design to provide the service. Those in network planning were convinced that cellular radio could replace the local wirelines. That may turn out to be true. Ten years after 1973 all the components required, from radio systems, antenna systems, switching systems, and telephones had been designed, manufactured, installed and tested. The telephones were the size and almost the weight of bricks. The service was slow, noisy, unreliable and expensive but hugely popular. Most involved with the cellular industry thought that the technology would top out at about 3% of the population. It exceeded that many, many times over. Today even young kids have cellphones.

Optic Fiber

At about the same time that cellular was introduced, optic fiber, otherwise known as glass fiber wave guide, was being introduced in long haul networks. Conceptualized in the 1930s, prototyped in 1952 and proven in application in 1970, optic fiber offered orders of magnitude increases in bandwidth. As an example, if a single hair thin fiber were strung to all 4,000 cinemas in the US, that fiber could carry simultaneous transmissions of 4,000 different high-definition wide screen films. An immensely powerful and game changing technological change. A number of new companies entered the industry just offering optic fiber cable service, building upon some established advantage such as a railroad right of way or power lines. New companies with connections to maritime resources offered ocean cables. Far more competition than was sustainable. Another massive capital destruction. But very rapid change for the industry.



Competition and Regulation - A Volatile Mix

The telecom industry was a highly regulated geographic monopoly in 1964. This came about early in the twentieth century because of network economic effects. The more subscribers that were connected to one network, absent interconnection with other networks, the more valuable the company's offering became. Same as the social media companies today. After a consent decree with the DOJ in 1925, AT&T and its subsidiary companies, the Bell System, provided service to about 80% of US households and businesses. 6,000 other companies had local monopolies of their own serving the remaining 20%. All were regulated by state commissions that controlled prices of services provided within the states. The FCC regulated the services between states that were provided by AT&T.

Regulation was intense including product offerings, prices and terms, service quality, and accounting principles. The FCC took seriously its charge to create the same efficiency as would be achieved by competition. The industry was regulated as a common carrier required to offer all services under public tariffs without discrimination among customers. In return for agreeing not to expand geographically, the FCC prohibited others from providing services in competition with AT&T and the Bell Companies. The state regulators did the same for the companies they regulated.

Revenues for interstate long distance calling were divided among the companies in the industry in proportion to the portion of their costs attributed to these calls thereby equalizing the profit each made on their invested capital. Similar principles were used to divide intrastate revenues among the Bell Companies and the smaller connecting companies.

Because costs were falling faster in long distance telephony facilities than in local facilities, the rates of long distance were falling, and local rates were rising. For many years it was agreed between state and federal regulators that accounted costs would continue to be shifted to "interstate" to reduce the pressure to increase local rates. As a result, by 1964 long distance rates were on the order of 30 times higher than direct costs. This of course

led to a lot of pressure by potential competitors and large customers to allow competitors to enter the industry.

Private Microwave

The first competition started in 1958 with FCC approval for corporate customers to connect their locations with privately owned microwave radio systems. AT&T had responded to this initiative with a rate plan that offered competitive rates for a "bulk" private line service. AT&T did not construct separate facilities. They created a virtual private network within the common network. That prompted an investigation of costs by the FCC since the offering appeared to be discriminatory favoring big customers. A violation of the common carrier principle. This case went on for many years during which AT&T's ability to compete with private microwave suppliers was hampered.

Satellite Competitors

In 1967 the FCC decided to prohibit AT&T from further development of satellite transmission. Instead, the FCC granted licenses to most other companies applying for them. The aerospace companies all jumped in, as did many of the computer companies including IBM and GE. Suddenly AT&T had serious competition in a large and important market segment. The satellite operators tried to offer private line service for voice and data, but were unsuc-

cessful because of the costs of connecting facilities leased from local carriers. They did succeed highly in offering TV broadcasting service. The satellites were ideal for broadcasting. One TV transponder could serve a broadcaster's local TV stations over the entire country, and a local satellite transmitter at a sports, news or concert event could reach a broadcast network's home studio in one hop. This was truly a revolution.
Another aspect of the revolution was the discovery that customers did not actually want to pay for the level of service AT&T provided. The broadcast networks had constantly demanded higher and higher reliability. AT&T had achieved great redundancy in its network, even in the connections to a local stadium, concert or athletic game. Yet the satellite carriers quickly gained nearly 100% market share in serving the TV broadcasters in spite of a much lower record of reliability. Given a choice the TV networks opted for the lower prices, an early and good lesson for AT&T in a new world of competition.

That drop in broadcasting cost and the explosion of available channels resulted in a complete restructuring of the broadcast industry. Many new broadcasters, many new channels, many small groups with special interests were served. A great set up to fill the future Internet with content.

We are seeing the same decisions played out today as broadcaster video signals pixilate and audio breaks up. The broadcasters are putting their programming on the Internet at even lower costs than the satellite broadcasters. DirectTV and Dish, the two largest satellite broadcasting operators are losing business.

Terrestrial Microwave Competitors

In the early 1970s, a number of competitors in addition to the satellite carriers were providing long distance services. They used point to point radio relay facilities from city to city. MCI broke the ice with a radio route from Chicago to St Louis. Those terrestrial carriers and the satellite carriers would then obtain local connecting "private line" facilities from the local telephone companies. Their market was limited to those customers large enough to need dedicated intercity private lines. There were not enough of those for any of the new carriers to be successful. The competitors then demanded that they get access to the local switched networks of the telephone companies. They would then be able to compete call by call rather than line by line. Most local network service was billed at a monthly flat rate heavily subsidized by cost shifting to the long-distance service. So interconnection would heavily subsidize the competitors. When the FCC decided to order interconnection AT&T vowed to fight for fair rules. In 1974 the AT&T chairman told his assembled executives that the company was going to fight this unfair regime and would not accept competition on those terms. The justice department of the US immediately launched an antitrust case. At the same time, the FCC launched an investigation into the options for competition in the telecom industry.

The Canary in the Coal Mine - Undermining Division of Revenues

In a very consequential decision in 1973 the FCC authorized General Telephone (GTE) to construct a satellite system and use it for interstate calls. GTE operated a number of smaller monopoly telephone companies scattered across the country. They connected each of those to the local Bell Company and share revenue from long distance calling through the division of revenue process. By connecting their scattered territories, GTE could carry calls not only between customers they served, but by switching through their locations they could carry calls between any customers. They were part of the division of revenue process unlike competitors like MCI. Because the satellite facilities cost more than AT&T's network, AT&T ended up subsidizing the satellite by sharing revenues based on costs. The division of revenue process would not survive. With my experience studying satellite competitors as well as division of revenues, I was asked to calculate the costs this decision imposed on the AT&T customers. I presented this study and defended it with the FCC staff. The decision was a political one and the study did not matter.

Cellular Competition

Cellular was a technological revolution executed by a new set of companies with new approaches to customers. The FCC allowed competitors to start from the beginning in 1983 granting a competing license for each Bell or other telco license. All the network operators allowed resellers to buy bulk calls on their networks. Additional network competitors were allowed to enter as regulators came to general agreement that four networks were required for effective competition. Cellular prices were high for both phones and calls. Cellular was not yet a threat to the wireline business. That comes later.

Culture Change

Through the mid to late 1970s AT&T underwent a concerted effort to change its management culture. When I joined in 1964 the culture was very comfortable to me with my MIT education. It was collaborative and based on analysis and data. Decisions were based on a very long-term view of what was good for share owners, customers, employees, and other stakeholders. In 1974, the AT&T Chairman, John DeButts, brought in a senior executive from IBM, Arch McGill. Arch was asked to make the company "competitive." He brought in hundreds of managers and executives from highly competitive industries. We "Bell Heads" thought they were just showmen and women with extremely short-term views. Interested in change for change's sake and interested mostly in self-promotion. But most of us adapted. The nature of the company changed. Profits and cash flow became the predominant goal. The view of the future was shortened considerably.

Those 6,000 smaller telephone companies were being consolidated rapidly. The same thing was happening in their management. Acquisitions were leveraged and cash flow was very important. The culture changed throughout the industry.

In 1982 I took three months to attend Harvard Business School for an Advanced Management Certificate. This gave me a great extension of personal network and friends to this day. And a reorientation from my "systems analysis" view of the world from MIT to a people relationships analysis. I then understood what I heard in an entrepreneurship seminar in 1964 with then Dean of the Sloan school, Howard Johnson, and his counterpart from

Harvard Business School. The two deans were asked to state the goals of their respective schools. Johnson said the goal of the Sloan school was to teach the art and science of management with understanding of all modern tools of analysis and decision making and an ability to learn constantly the new ones as they are developed. The HBS dean said his goal was to "instill a rat-like cunning and an insatiable desire to win." I was very fortunate to have learned from both institutions.

The Bell Breakup

In 1975 I joined a group in NYC assigned to win the regulatory reform case brought by the FCC at the same time the DOJ had started the antitrust case. Our group provided material for filing with the FCC and with the antitrust court. I had a considerable budget to hire economists and analysts, the best in the country. I learned a great deal about the economic theories of natural monopoly, economics of vertical integration, economies of scale, and scope and the economic theory of regulation to deal with free market failures. All of this drove the studies I managed and the briefs we filed. I came to understand the theory of how AT&T had related to society, how that theory was being undermined, and how the political process was working to change the industry.

I spent many hours in DC meeting with government officials, staffs of Congressional committees and government contractors. The Bell Laboratories team of economists did excellent research on economics of natural monopolies and economies of scale and scope. Together we made presentations to government officials. We were advancing economic knowledge but at the same time losing out to political forces.

It was very clear that the FCC, the White House Office of Communications, and the Communications Committees of both houses of Congress were united in wanting the telecom industry to become competitive. Many in government were determined to reduce the size of AT&T for the sake of getting rid of large companies. They told me so. The Bell System was a major contributor to the campaigns of most politicians, national, state, and local. And Bell System managers were required to volunteer to serve in their communities as did many non-management employees. The Bell System was highly regarded by the public and had a lot of loyalty with voters and therefore political power. The antitrust case and the regulatory reform case both moved slowly and legislation even slower. But they were moving inexorably toward a major change contrary to the interests of the company.

In 1979 I was appointed Director - Strategic Planning in a new strategic planning group serving the office of the chairman of AT&T. I continued to do lobbying in DC and state capitals but worked on strategic threats and direction and advised the senior management team. The primary threat to the business was the anti-trust case against it. Competition was growing but regulation and the internal cross subsidies in the system were eating away at the foundations of the business. Changing those cross subsidies would require agreement of 50 state utility commissions, the FCC and the Congress.

In 1980, I was visited by a group representing the Business Roundtable, an organization of the largest corporations in America. They asked me if it was in AT&T's strategic plan to offer service to customers. After getting over my shock, I said that it always was AT&T's

strategy and purpose in life to serve the public. They said they did not mean service to the public. They meant service to individual customers, meaning providing customization of services and prices. Completely different than the common carrier concept offering services by tariff. AT&T was on its way to doing that if regulation would allow. We faced a huge change in mentality as well as law and product offerings.

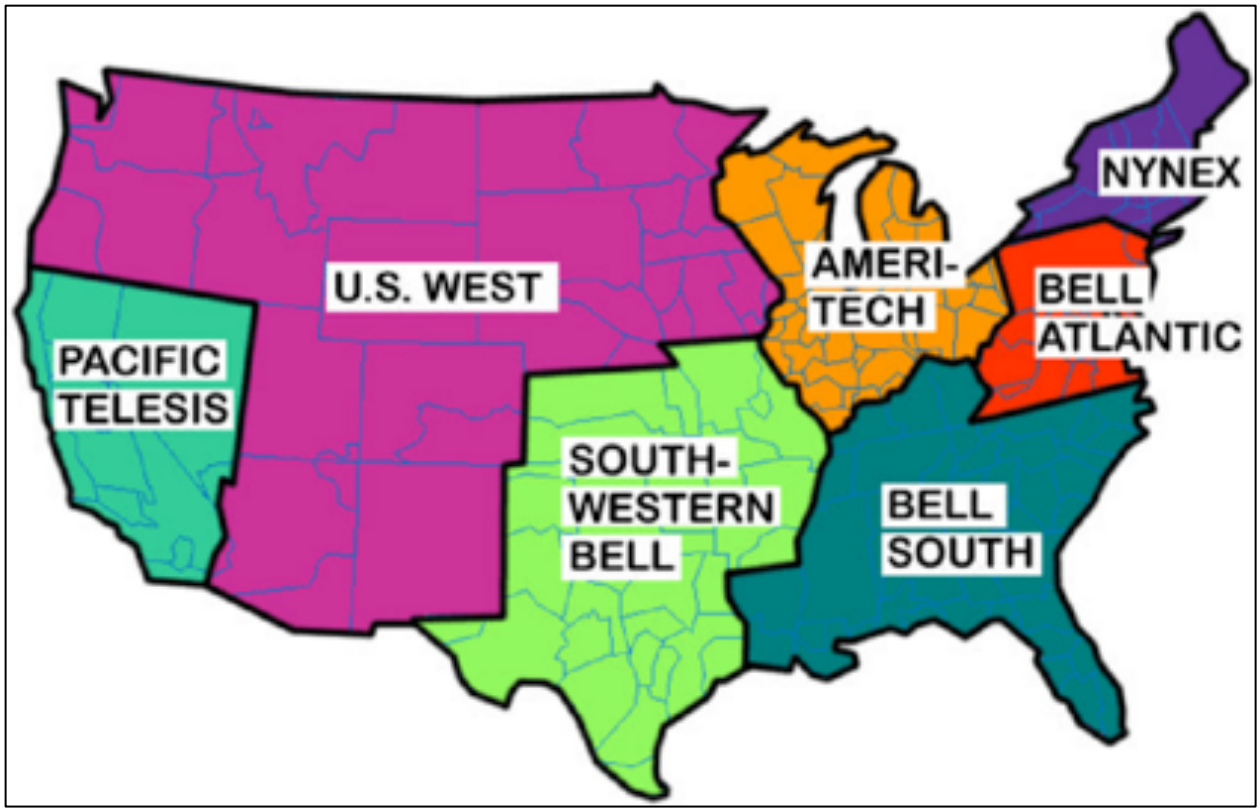
In a meeting I had with a group of FCC staff, one of them suggested that AT&T consider establishing a schedule of access charges that could be charged to competitors wanting to interconnect with local networks. The access charges could create the equivalent contribution to local costs as then provided by AT&T's own long-distance service. A simple and brilliant solution. He also suggested a monthly fixed "access" charge to be added to the bill of residential customers replacing the contribution long distance calling made toward the local line costs. Another simple ingenious solution. I took those ideas back to the senior management at AT&T and with help from the whole strategic planning group wrote an extensive proposal backed by an economic model of the profits of the business if it did not solve this problem. The access charge suggestions became the solution. Not only for the Bell System but for all the privatized former monopolies providing telecom services around the world. Since most local service was charged on a monthly rate, we could not recover all the monthly revenues with per call charges. We needed a monthly rate. About one third of the costs of local facilities, the local lines to homes and businesses and the telephones themselves, had been transferred by accounting rules to interstate calls, about $7 per month in the early 1980s. So that became the monthly interstate access charge that showed up on all residential bills payable whether they made any interstate calls or not. A charge to be reduced to zero over time as costs were reallocated. A sea change in the regulatory principles in effect for 50 years; and changed in a decade. And an opening of the door to regulation that allowed relatively level competition and open entry in the industry.

In 1982 I was given an assignment from the chairman to outline a way the network could be divided between interregional and local in a way that would satisfy the Justice Department, the FCC and our opponents in Congress. I was given a weekend. The three page outline I delivered eventually was fleshed out by a huge task force and implemented as the way the Bell System was divided into AT&T and the seven "Baby Bells." The breakup took two years of hard work of planning, negotiations and rearrangement of facilities, jobs and organization. A massive expenditure undertaken only in the US. No other country did this to their leading telecom provider. For a brief time I chaired an interdepartmental committee integrating and working out conflicts in the departmental plans for the breakup. As tangled as a plate of spaghetti I said to the Wall Street Journal.

A delegation from the Japanese telecom ministry visited me for an explanation of what we were doing in breaking up the company. As I was going through the explanation of how we were rearranging the network, they just kept asking "why?"

The breakup of AT&T was executed on January 1, 1984. The Bell System was no more. Almost everyone had some change in positions as well as companies. I became the Director of Market Strategy for the new American Bell division of AT&T. We had established separate organizations for regulated and unregulated activities with procedures to make interac-

tions with the regulated division the same with competing companies as with unregulated affiliates.



In early 1985, I was asked to co-chair a task force reporting to the chairman to resolve how the regulated and the unregulated parts of AT&T could work together and still provide the operating and accounting transparency to assure the government overseers of "fair" competition. I mention this project mostly because what came out of it was the most important development of my life. One of the task force members was a very bright, outspoken and extremely creative woman to whom I was instantly attracted. Early in the task force work, as we all were beating our gums establishing a power hierarchy, Betsy rolled a goose egg, a real goose egg from her farm, covered in goose shit, down the center of the conference table with 14 participants on the two sides while saying that "This is what this committee is laying at the rate we are going." It had the desired effect. I married her.

One of my contentions as a strategic planner turned out to be correct: the natural monopoly existed only in the networks connecting homes and small businesses to community switching centers. Everything else was subject to sustainable, open and free market competition. Long distance calls in my view were a commodity that could not be differentiated from the competition except on price. That view was opposed by all of my marketing education and marketing peers, but it proved to be true. No long-distance competitor remains. All were acquired by telephone companies with local operations. The fundamental problem is the cost of laying lines to buildings using city streets or country roads. Economically affordable only if all the buildings are on the same network. Wireless however changes the game.

Changing Prices and Social Meaning

Back in 1964 those long-distance calls to our parents cost a relative fortune. A five minute call = ten beers. Calls overseas were enormously expensive, especially to developing nations. Only the rich used the phone. Today, one call anywhere including video has a cost near zero. Not even the deposit on one bottle of beer.

Evening and night rates had been introduced in the late 60s and early 70's. Someone like me with parents and friends halfway across the country lowered our long-distance phone bill from over $100 per month to half that. But daytime long distance was still expensive. Remember calling from a hotel room. Spending time doing business from a hotel room resulted in long distance charges on the hotel bill that often exceeded the cost of a suite.

Today we spend hours on connections to content libraries, gabbing with friends or playing games. Our Internet connections are $50 to $100 per month and our cellphone bills are $35 to $50 for most. This for hours of use per day and providing thousands of times more content.

Those of us so inclined now play hours of video games with opponents around the world. Or watch hours of movies and video clips. Many spend hours exchanging messages with friends and relatives and with people we've never met, even movie stars and political leaders. Many of us rely on telecommunications not just as a necessity in life and doing business, but as a source of hours of entertainment.

The result has been a series of changes repeated over time. New industries and products emerge, others disappear, some loose their dominance and survive in niches, while others reinvent themselves to prosper and grow. Remember these?

All of the devices have undergone significant change.

Cincinnati Bell - Cellular Industry Billing

In 1986 I left AT&T to become President of a subsidiary of Cincinnati Bell that was doing billing for new cellular telephone companies (cellcos.) The cellco subsidiaries of existing telephone companies needed billing systems specialized to the needs of cellular services. Cincinnati Bell did a crash development of a new cellular service billing system. It was offered to all the Bell Companies and most took it up, some buying the software and maintenance services, others buying the billing processing service. A Chicago startup company had also done a crash development and was serving most of the non-Bell competitors with a billing service. In June 1986 Cincinnati Bell acquired that Chicago company and I was asked to become president of a group consisting of those two units. With two more acquisitions in 1987 we were then doing the billing for 75% of cellular customers in North America including the US, Canada and Mexico. The industry was growing incredibly fast and always faster than the most optimistic forecast. We were having IBM install added disk drive capacity every week and a new mainframe every few months. We had 40 different cellcos as customers. Each of our customers had their own ideas on rate plans, sales commission plans, customer data mining and every other variation of billing and billing data that can be imagined. We were doing over 1,000 software change requests per week. Talk about creative destruction! It was chaotic but hugely successful for everyone

Cellular telephone companies were started by groups of physicians, groups of lawyers, and investors of all types. Ex Bell System employees were in high demand for management and technicians. It was incredibly fast changing. Companies were being acquired and sold at a fast pace. Computer technology, both software and hardware were changing fast as well. Higher level languages allowed faster replacement of software. Mini-computers lowered the cost. Our customers demanded and we delivered an entirely new billing system just three years after the initial one. We also provided assistance to some customers who reached maximum capacity of their switching systems by offloading some functions on to our computers. Another industry crossover.

Long Distance Resale

I moved on to another job in 1988, President of Cincinnati Bell Long Distance. We were a "reseller" of long-distance telephone service. Buying telephone calling under large volume contracts, having customers use local networks to call in to our switches and then routing their calls over the lowest cost long distance facilities. We purchased from AT&T and other long-distance carriers and at the same time competed against them. Another aspect of the emerging industry to learn. These "retailers" started in telecoms in 1973 with the FCC order mandating interconnection allowing resellers to connect to established telephone companies. By 1988 the resellers were well established and the business models functioning well. Our goal at Cincinnati Bell Long Distance was to "roll up" smaller resellers the way McCaw had rolled up cellular companies and Staples had rolled up local business supply stores. We started going downriver from Cincinnati to Louisville as well as to the adjacent state of Indiana. We did not move fast enough. Worldcom and others were winners at that game but then losers as the industry consolidated later.

Repeat in Europe

In 1989 I was asked to go to Europe to create a business for Cincinnati Bell Information Systems. The European countries all were privatizing their telecom ministries and at the same time authorizing competing telecom companies. Both types of companies needed new IT systems and services to provide competitive level telecom services. Within three years we had established partnerships with local IT businesses to provide in country support and were implementing $150 million in IT projects. The industry was essentially the same as in the US with both regulators and company management closely following the lessons learned in the US. A big difference was cultural. The biggest difference was in finance. European banks were reluctant to invest in startups. Most financing came from the US. Also the Europeans would not trust their customer data to a third-party processor, especially a foreign company. We were able to sell our software, but not our processing services. There were many other cultural lessons of course which we learned as we worked with partners, customers and suppliers.

Betsy and I adapted well and loved living in Europe. Wanting to stay there, in 1993 I joined a Dutch consultancy in Utrecht, NL. Betsy was recruited by Anderson Consulting, now Accenture, as Associate Partner. I was the first "foreign" member in a Dutch firm of 35 associates. Within five years DDV had expanded to 175 associates from 11 countries doing business in 14 different languages and all over Europe. Those five years were a phenomenal experience in learning to work with different cultures of employees and clients. Our firm advised some of the former ministries and many of the startups. Some of the startups were subsidiaries of power companies with facilities created by wrapping optic fiber around power lines. Another cultural challenge was getting a very old utility company to give sufficient freedom to a start up in a highly competitive market. It was even more interesting when the utility was in Central Europe and still staffed by former Communist apparatchiks. We advised on technologies, network design, regulation, competitive marketing, product offerings, business planning and other experience we brought from the US.

The telecom industry of course had been global from the 1920's. But that involved national companies connecting their lines to make international calls. In the 1990's the industry became global. All the Bell Companies and AT&T made investments in other countries. Ex Bell System employees were in demand everywhere. Telecom employees from other countries got jobs in the US to aid in management of investments in their home countries. Money and people flowed in all directions.

One of my Dutch consultancy clients was the satellite TV broadcaster SES, known by the trade name ASTRA. Located in Luxembourg, they served 95% of the 350 million people in Europe as well as the Middle East and northern Africa. I served as the Director of Strategic Planning for three years as the company worked to transition from an extremely profitable TV broadcaster to an interactive communications company. We learned to watch the eyeball time of people watching TV vs. watching content on the Internet. We could see the trend. We had to get some of that Internet demand moved to the satellites. The company did accomplish that. It is still immensely profitable.

Dot Com Madness

The Dutch consulting company was sold in 1998. In my last year with that company, I was contracted and then later hired to be the Chief Technology Officer of a startup telecom business called Versatel, NV located in Amsterdam. I got direct experience in the "wild west" days of getting financing for an Internet involved start up. The business had been started by two Americans in Amsterdam as a reseller of long-distance using experience from the US. They had established a relationship with a partner of Lehman in Amsterdam. We agreed the business should build a network. Lehman assisted in selling junk bonds for financing an optic fiber network. I led the network development and the implementation of IT systems. In spring 1998 there were five of us partners who with Lehman raised $250 million in a whirlwind road show. We immediately started building. True start up experience, working on card tables and folding chairs. Everything on the cheap except the network. On July 1, 1999 we turned up optic fiber service in the Netherlands. An instant success. It was the height of the dot com boom. We planned a three year network capacity for voice circuits and 1.5 mbs data lines. Within 30 days our network capacity was sold out with most customers leasing 6.2mbs lines. In October we did a second offering of junk bonds and took in $150 million. The next July 2000, after surviving the terrors of Y2K without a hitch, we did an IPO and raised $800 million. We were still bringing in only about $10,000 per month in revenue and losing about $100,000 a month. By late 2000 our market cap was $6 billion. The magic of the dot com era! We had grown from a handful of employees to 1,800 in a year. We were winning awards for our service quality and customer satisfaction, and also our advertising and corporate communications. We were winning court cases against the former telecom ministry for interconnection rights and competition abuses. All good stuff. All replays of what happened in the States. All the same overturning of norms in the way the industry worked and the way it related to customers.

That company made the decision in 2001 to enter the TV streaming business. For example, Versatel contracted with the Dutch football league (soccer) to handle all of its electronic communication - TV, Internet, DVDs, news releases, all media. They went on to acquire many other clients for content distribution. The company was still a telecommunications company but had also become a content distribution company.

We had placed 95 pair optic fiber cables in the first of four conduits in our network. The monopoly telcos had 2 or 4 pairs. We saw trenches in which we and four other competitors were placing four conduits each and each was blowing in 95 pair cables. Massive overbuilding. Yet as the Internet exploded that capacity eventually was used.

Like all other dot com businesses, the crash happened fast. After Christmas 2001 sales via Internet fell short of expectations, the dot coms crashed. Versatel's stock went from $80 to $10 in a few weeks. Eventually down to $0.29. Unlike may others, Versatel survived and is still in business. And financed our retirement.

Retirement to the Rockies

Betsy and I left Europe in 2001 retiring to Vail, CO. We concentrated on learning how to ski well, hike, bike, ATV, snowmobile, ride our horses, drive our H1 Hummer and otherwise do

nothing slowly. We bought land in the Flat Top Mountain wilderness at 9,500 ft. altitude, 11 miles from a paved road, built a log home and learned life in very remote and high Colorado in addition to our home in Vail. To stay in touch, we experimented with the early days of Internet access by satellite. Expensive, clunky, unstable but kept us in touch as the Internet grew. I consulted for four years but then abandoned that as the security provisions of air travel became more and more arduous. I became a student of the industry rather than a participant.

Status of the Industry - 2020

I note that today, the trends in the industry have advanced quite far from where I left it 20 years ago and a night and day difference from 1964. The natural monopoly of the telephone wires in the streets has been replaced by the cable TV companies and they are slowly replacing their coaxial cable in the streets with optic fiber. Not only is it very costly to lay small capacity cables it is also extremely expensive to deal with cities on permits, regulations, oversight and payoffs required to put those lines in the streets and to maintain them. The telcos tried to replace their wires with optic fiber but found it was nearly impossible both economically and politically. The telcos bought cable companies and tried to put telephony services on the same networks as TV distribution. But they did that too early and the technology did not support the goal. Now the cable companies are entrenched and are providing telecom and Internet as well as TV broadcasting. The wireline telecom companies are going out of that business. Slowly but definitely.

We now live in Santa Barbara, CA. The telephone wires to our home lie unused as are most in the city and many around the world. The cable companies, having provided Internet connectivity, are seeing their TV broadcasting businesses taken over by TV streaming services provided over their internet connections. Rates for internet access are high in the US and the cable companies are quite profitable like most monopolies. As in so many other industries, the Internet is forcing a reduction in TV broadcasting revenue of an order of magnitude. Other industries such as the music business have found that after a tough transition, they have exceeded previous revenues and growth rates by providing many new products at much lower prices but far higher volume. Cable TV is now experiencing the same transition. AT&T, which bought DirectTV, is now looking to sell the business. But the cable businesses as local monopolies with light regulation are doing very well financially.

Today we pay under $100 per month for cell service for the two of us. We use that service for several hours every day. Routinely we make video calls to friends all over the country and to Europe. Calls that were very costly 20 years ago even without video. Now we think nothing of chatting with friends in Europe for an hour. The price is covered in our monthly subscription. Is there any other industry where such an extreme change has occurred?

The tightly regulated “common carrier” has been left behind with the assumption that competition is sufficient to make prices, quality and terms reasonable and fair. The common carrier principle of non-discriminatory pricing has been retained and by law extended

to the Internet. The industry participants and the major customers are now questioning this principle. There is considerable pressure to allow pricing to be customized.

Yet we do not have effective competition. We are left today with a small number of very large, highly profitable and politically powerful cable operators and just two very large, highly profitable and politically powerful telecom companies. Prices for telecom services in the US are higher than they are in most other countries. Services are not as good by a number of measures. The goal of achieving a competitive industry that was so important forty years ago has not been achieved. This should become a political issue. Apparently, few Americans are aware of the issue and Washington politicians are well supported by industry lobbyists.

The Future

Coming right along is the transition to 5G cellular service. Using much higher frequency and wider bandwidth, the service offers the promise of providing the same services as the cable TV operators. Covering all the needs and demands of data services and content distribution as well as voice and video communications services. With capacity and speeds for as yet unheard of connections to the Internet of Things. A replacement for the cable networks is already in sight. The dream we had in 1973 could come true. The facility that connects the customer remains the controlling factor in the economics of the industry. Watch this space. The new 5G technology is an existential threat to the cable companies for an end link to customers.

Another wireless technology is currently in the news: low earth orbit small satellites. Able to be lifted by smaller, cheaper rockets, these very small and far less expensive satellites could blanket the earth and provide a global antenna/repeater in the sky. This concept has been around for 50 years and has been tried a couple of times. Maybe this time the technologies will have advanced enough to make it a winner. The vast areas of the earth that lack telecommunications would certainly benefit.

The common carrier principle is unlikely to survive. Too many huge players like Google, Amazon, et al. have the ability to build the facilities they need. The legislation governing the Internet will be modified to allow normal commercial pricing and to allow normal commercial liabilities. The alternative is to allow the competitors to AT&T and Verizon to cream skim them until they are financially weak. I think they are politically strong enough to avoid that outcome. They will remain as the dominant providers of cellular service connecting end customers and the dominant intercity network operators. The losers will be the cable operators.

A final question mark on the future is the development of industry standards. For over 100 years, AT&T dominated the setting of standards for the global telecom industry. That dominance ended after the breakup of AT&T. The influences over standards was scattered. Today the Chinese are challenging who influences standards. Such things as privacy could be

at risk as well as Western manufacturers profits if specifications for rare materials the Chinese control become the standards.

The industry is still changing fast.

Lester "Larry" Hendrickson '64 Course 15, Industrial Management, grew up in Illinois small towns attending public schools. After MIT he was with AT&T in NYC and Framingham, MA, 1964 – 1986 in executive positions managing all aspects of AT&Ts business, putting him in the forefront of the reorganization of telecommunications concurrent with the breakup of AT&T. He then moved to Cincinnati Bell as president of a number of subsidiaries until 1990. From 1990 until retirement in 1998 he established a number of European telecommunications business as an executive and consultant. He and Betsy retired to Vail, CO with their family of two horses, three dogs and a parrot. They now live full time in Santa Barbara CA with three dogs, no horses and the parrot, sailing, hiking, biking, and enjoying CA sunshine, ocean, and mountains with great neighbors and friends. neighbors and friends.

Adventures in the Arctic

John Meriwether

Introduction

The word "Technology" is found in the name of our institution where we all spent four years getting an excellent education while having our limits pushed in a continual test of our capabilities. Certainly, I found life at MIT quite challenging but also exhilarating. However, I did not particularly appreciate the importance of the word "Technology" for a career path. Wikipedia defines technology:

> ***Technology*** *is the sum of techniques, skills, methods, and processes used in the production of goods or services or in the accomplishment of objectives, such as scientific investigation.*

Clearly then, change in technology with time can easily happen as the integral of changes in "techniques, skills, methods, and processes" that come about as time progresses. We are all aware of how innovations in technology come about as a result of breakthroughs achieved by insurgence of new ideas based on science imbued with quality engineering.

Since the start of the industrial revolution 300 years ago in the UK with the introduction of steam engines and coal as the energy source, technology has advanced by leaps and bounds. This path has not been a straight-line pathway but many sudden upward discontinuities when some breakthrough or invention took place. My scientific research in space physics as an experimentalist was highly affected by advances in technology.

In my senior year I chose to become an experimentalist in space physics after Prof. Irwin Oppenheim responded to my question about what should one consider in choosing a career path in experimental or theoretical physics. He remarked that to be a good theorist, one needed to be really clever and smart. On the other hand, to be a good experimentalist, care, attention to detail and the level of energy invested become the highlights. I did not think that I was particularly clever or smart, but I was willing to put in considerable dedication to my efforts, especially with my passion for science. I did find satisfaction in doing experimental work, especially in aeronomy and space physics as this area has a romance attached that is undeniable – the optical aurora is one of the most dazzling wonders of the universe to behold.

I chose MIT because of the diffusion of awareness filtered by family commentary. The husband of my great aunt an MIT mechanical engineer during WWI, left in 1917 to join the WWI war effort through his work at the Wright Aeronautical Company on the design and construction of air-cooled aircraft engines. My grandfather was the President of that company at that time. It is a family story that my grandmother introduced her youngest sister to Uncle Jack one fine summer day. That afternoon outing led to their engagement and marriage. When I was in the 8th grade, I heard from my parents the story of Uncle Jack Mead

and his contributions to the WWII war effort. This aroused my curiosity about MIT to the point that I wrote to MIT requesting a copy of the course catalog. What I saw about MIT classes in that hefty document whetted my interest immensely and convinced me to select MIT. It also helped that in 1958 Norbert Weiner published his memoirs "I am a Mathematician" in which he wrote about his life while being a professor at MIT. From that I knew MIT would be a special place.

My senior thesis at MIT and my graduate work at the University of Maryland taught me the fundamentals of atomic and molecular spectroscopy. Thus, it was natural for me to become attracted to the idea of using a high-resolution interferometer to observe the dynamical properties of the upper atmosphere. My efforts as an experimentalist evolved over the years as the technology of the application of the Fabry-Perot interferometer instrument to obtain ground-based Doppler shifts and Doppler broadening measurements changed since the beginning days of 1971.

I had never really thought about the meaning of technology in a personal sense as to how advances in technology over the years might end up having a strong impact upon me and my career aspirations. What were the advances? As applied to the Fabry Perot Interferometer (FPI) instrument that I ended up installing in many locations around the world, the convergence of the new technologies brought to birth as a result of the major advances in mini-computers, imaging cameras, and the internet aided my science studies enormously. The first provided the basis for remote operations, the second for the remarkable improvement seen in the FPI sensitivity to measure accurately upper atmosphere winds and temperatures, and the third allowed for the remote transfer of data as well as remote intervention in data acquisition. Why so many locations? In studying the aeronomy of the upper atmosphere, one has to go where the phenomenon exists, whether the polar region, the auroral region, mid-latitudes, or the equatorial region. The dynamics of the thermosphere (the atmosphere in the range of 150 to 600 km) differ because the admixture of forcing functions changes with latitude.

At MIT we were hearing numerous comments about how computing by machines might make so much of a difference to what we could achieve in doing calculations. I remember seeing on a TV quiz show in 1958 how the Univac machine was used to keep track of the presidential elections or store answers to quiz questions. However, I never took this seriously enough to want to spend time taking MIT computer classes. I had my interest set upon doing chemistry and then physics after my sophomore year. In my senior year I ended up deciding to major in chemical physics in graduate school. Prof. Amdur and Prof. Thorsen, both MIT chemistry professors, had advised against taking computer programming classes. They both thought that this material could be learned easily on one own. Indeed, in doing my graduate research I needed to develop graphics associated with my measurements of auroral intensity variations as plotted as a function of time. Thus, I was motivated to learn the Fortran IV language. Fortran is not a very handy language for graphics, so I ended up some years later migrating into the use of IDL (Interactive Data Language) which is quite a bit more sophisticated for managing arrays to plot whether in simple form or in 3-D color view of content.

At the University of Michigan in the fall of 1971 to start a postdoctoral appointment with Dr. Paul Hays, an assistant professor in the High Altitude Research Laboratory, I did not know then how much of an adventure our friendship and my research affiliation with him and his group ultimately represents. I found Paul to be a wonderful mentor and inspirational about doing experimental space science, especially with the Fabry-Perot. Previously as a postdoctoral fellow at the NASA Goddard Space Flight Center I participated in studies of auroral dynamics of the thermosphere region. The approach we used featured the use of rocket-borne chemical releases to obtain electric fields and neutral wind measurements by tracking from several camera stations the motions of ion and neutral clouds against the background of stars and using triangulation to determine speeds and directions from the successive positions observed. The plasma associated with the barium ion clouds is only able to move along geomagnetic field lines unless there is an electric field that enables ExB drift of the plasma across these lines.

We had a poor understanding of the behavior of the plasma within the auroral zone. Ultimately, we learned that in the evening sector, the ionospheric plasma tended to move toward the Sun, a westward flow at 18 hrs local time and a eastward flow at 06 hrs local time. In the morning sector the plasma again moves toward the Sun so that at 06 hrs the flow is eastward. The neutral wind generally follows the plasma flow in the evening, i.e., Sunward, but in the morning the flow tends to be southward with possibly a weak westward component. The neutral wind is highly influenced by the plasma motion because momentum transfer from the moving ions to the atmosphere atoms and molecules by collisions speeds up or retard the motions of the neutral constituents. This mechanism became known as "ion drag". In the morning hours the ionospheric plasma density is low, so the ion drag is much less effective.

While rather interesting, I had much to learn about the field of aeronomy and space physics. Moreover, we did not understand the geospace system, especially in the polar region. What was also quite exciting about working with Jim Heppner and his group at the Goddard Space Flight Center from the experimental standpoint was in part that the project meant travel to the Far North such that I ended up at the Bar Main Dew line site located just off Barter Island at a location now known as Kaktovik. We flew from Fairbanks to Bar Main and after staying over a day I went on to Bar 1, a five-man DEW radar site located in Canada just inside the Alaska-Canada border. Though the trip was simply 100 miles and so, about a 45-minute flight, it was a transition from the Alaskan time zone to the Canadian time zone which was governed by the time zone 4 hours to the east so that all DEW sites within Canada followed the same clock. This difference of 4 hours made for some weird experiences. On the return we left Bar 1 after lunch and arrived at Bar Main before lunchtime.

Using rockets to observe the auroral dynamics is expensive. Moreover, the neutral atmosphere dynamics at lower latitudes were also of considerable interest. Thus, the Fabry-Perot interferometer (FPI) entered into the aeronomy picture because it was an instrument capable of measuring Doppler shifts and Doppler broadening (which is proportional to the square root of temperature). Paul Hays and a Michigan colleague Andy had decided to build and develop such an instrument. The fabrication of such an etalon required a great deal of painstaking polishing to achieve the extreme flatness required for the high-resolution ap-

plication to observe the lineshape of the atomic emission of oxygen at 630.0303 nm. A 100 ms-1 Doppler shift represents a wavelength shift of 0.00002 nm which is extremely small. What makes the measurement doable is the sharpness of the 630-nm spectral profile line, which tends to be Gaussian, so that a slight shift shows up as a considerable difference in the two half-peak signals. To get enough aperture area so to collect enough photons to get a reasonable result, it was necessary to push the state of the art in fabricating large-sized etalon plates. Paul and his colleague purchased at an enormous expense a set of plates 15 cm in diameter, much larger than the more typical sizes of 3 to 5 cm intended for laboratory applications. The plates were polished to a flatness of lambda/200, the scale of the surface roughness was typically 3 to 5 nm.

The Michigan FPI System - Engineering Design Details

To build the instrument Paul and his engineering staff followed the basic design that had been published in the literature in the late 60s. Five major components constitute the instrument: the pointing head, the FPI etalon chamber, the objective lens, a 630-nm interference filter (0.5 nm spectral width) and the detector.

An example of the 15 cm set of etalon plates similar to that utilized in the Michigan Alaskan FPI observations. Typical market value for this etalon plate assembly is $100,000. The gap for this Arequipa, Peru FPI instrument was 1 cm set by using three 1 cm thick glass spacers. The thermal chamber mount for this etalon assembly is shown in the center. Three knobs are used to adjust the pressure exacted by stiff springs onto the etalon spacers to adjust the parallism of the reflective polished surfaces of the inner side of each etalon plate. The etalon housing is seen on the far left.

Getting the full spectral measurements across the line profile of the 630-nm emission could be done by three methods: imaging the interference ring pattern, changing the gap between the plates using piezoelectric spacers, or by changing the index of refraction of the gas within the two etalon plates by simply increasing the pressure of the gas inside the sealed etalon chamber using a flow of gas from a needle valve. The technology of the time required a photographic plate as the detector for the first approach, which was not optimal due to the poor quantum efficiency of film. The other two methods used a photomultiplier for the detector. The approach used by UM was the pressure scanning version of the FPI as this avoided the need to control the piezoelectric scanning with precise stability. This last approach requires the application of a variable ramp of high voltage to the piezoelectric spacer material.

Thus, the combination of a photomultiplier detector (model number FW-130 selected for low noise at the cooler temperature of -20° C), an objective lens (required to create the ring interference pattern), and the etalon together with a double axis motorized mirror system allowed the nightglow observations be made in whatever direction selected by the mirror stepping motor electronics, directions typically north, south for the meridional wind component and east, west for the zonal component. The zenith direction was also necessary to get a measurement that is nominally a zero wind reference. The Doppler shift is then simply the difference in the peak positions for the 630-nm spectral profile for any one off-zenith direction relative to the peak position for the zenith direction. These five directions are the normal scan strategy to be followed to determine the zonal and meridional components of the thermospheric wind vector. Plotting these Doppler shifts as a function of time indicates how the thermospheric wind vector changes in speed and direction during the night.

Calibration of the FPI instrumental line shape was carried out with the use of a HeNe laser which has an emission line at 632.8 nm that is very narrow. The neon line at 630.28 wavelength emitted by a hollow cathode lamp was also used to track the FPI stability during the night as the Doppler reference shifts as a result of room temperature changes.

The FPI system in use at UM was quite robust for the electronics of the early 70s. Commercial products were generally quite reliable and considerably cheaper than building the equivalent in house at UM. A pressure transducer generated a DC voltage that was proportional to the pressure. A Hewlett Packard (HP) scaler-timer counted the pulses from the phototube pre-amp and a HP digital to analog convertor produced a voltage signal within a range of 0 to 10 V. A XY plotter plotted counts versus pressure by using these two voltages to generate an analog graphic of the variation of the FPI signal across the 630-nm spectrum as a function of pressure (which is proportional to the etalon gas density). Modulation of the etalon gas density results in a change in the interference pattern with the rings getting larger with a decrease in pressure.

Two racks of electronics and numerous cables were required to house all of these electronic components of the FPI instrument as well as that of a tilting filter photometer. I got to know this hardware rather intimately as I had to take the system apart and reassemble it several times while I was working with Paul and his group. I learned how important it was to try your best to keep the cabling layout as simple as possible and doing the utmost to use

nylon ties to bundle the cables to minimize the amount of confusion as to where cables need to go. Labeling the two ends of each cable was of great importance as many cables were quite similar in appearance.

Once the etalon reached the pressure of a few psi, the pressure is released by a manual vent. One order of the 630-nm spectrum was 1.7 psi of pure N2, and the scan was extended to get two orders. Upon the completion of a pressure scan followed by the venting to release the gas, the mirror director electronics was commanded by push buttons to move to the next direction desired. Obviously, operations involving the FPI of this design required personnel staffing. This meant continual attention throughout the night to get one night of observations. Paul had managed to upgrade his instrument electronics to include magnetic tape recording with a 7 track 556 bpi tape drive that recorded 72 characters of ascii information upon the close of each integration period on the HP scaler. Just before my arrival the FPI data were being recorded on paper tape which required continual attention to avoid the tape punch from clogging.

Thus, it was in the beginning of September1971 that I started studying the FPI technique learning the details of how the instrument worked. Paul's engineering staff had generated an impressive set of schematics collecting all of the system information whether mechanical, optical, or electrical into one set of bound blueprints. The Michigan Airglow Observatory (MAO) was a 40-foot-long semi-trailer that had been refurbished to set up a three-room portable observatory. A four-channel tilting filter photometer was installed from the ceiling in the control room. This instrument provided contextual information regarding the nightglow or auroral intensity distribution. Its observations were needed to normalize the FPI fringe profile to avoid distortion caused by 630-nm intensity variations.

Each of the three rooms had mounting to support the installation of a 40-inch diameter clear plastic dome. Heated air circulated within each dome to keep the dome clear of any fogging. The middle room was the FPI darkroom housing the FPI optics on the equivalence of an optical bench that was supported by jacks firmly mounted onto the ground surface below. After integrating all of the instrumental components into this trailer and running it in observational mode for a few clear nights of nightglow operations from the UM North Campus, it was shipped to Alaska via flat bed truck to Seattle. From there it was sent to Anchorage by ferry where it was transferred to a freight train for shipment to Fairbanks. I went to Alaska in late September 1971, with an engineer who had been working with Paul for several years. He was the FPI Alaskan project manager and led the team of students that did the work to pack and ship the trailer before my arrival.

Once we were in Fairbanks, we had to decide where to locate the MAO trailer. One choice was Ester Dome, which is a hill of considerable elevation located about 4-5 miles to the west of Fairbanks lying a few hundred feet above the valley floor. At this location the Geophysical Institute had constructed their auroral observatory about one hundred meters above a ski lodge that did not last long as the slope was not that interesting or challenging. Getting to the top of the Ester Dome hill was at times demanding because the access road was quite often icy and slippery after any snowfall. The alternative site was the Poker Flat rocket range located 40 miles to the northeast of Fairbanks, but this required an hour-long

drive, not a practical choice. This location was where the Chatanika incoherent scatter radar was just commissioned and in retrospect, perhaps we should have taken a harder look at going out to Poker Flat.

The Rigors of Auroral Data Collection in the Alaskan Winter 1972 & later

The design details of the FPI instrument fielded in 1971 are a baseline description of the technology of the times. Operating the FPI single-handed in the 1971-1972 winter was quite demanding. The nightly temperature in January or February was typically -30 to -40 F, and these low temperature extremes last for many days. Automobile travel was somewhat hazardous especially with ice fog making the visibility ahead of you on the highway limited. Also, when the tires are flattened by the cold, a worrisome thump-thump noise can be heard but thankfully it faded as the tires warmed. I used a station wagon rented from the Government GSA motor pool. Unfortunately, this vehicle needed considerable maintenance after the severe wear and tear of the Alaskan winter upon motor vehicles. The gas gauge meter did not work under cold conditions. This led to circumstances that one morning after a long night observing, I could not start the vehicle because it was out of gas.

The Michigan semi-trailer located on the east side of the Ester Dome auroral observatory managed by University of Alaska at Fairbanks. The plywood structure was a wanagan built to house tools and Arctic parkas. The wooden structure in front of the front axle was installed to help secure the trailer against the effects of high winds.

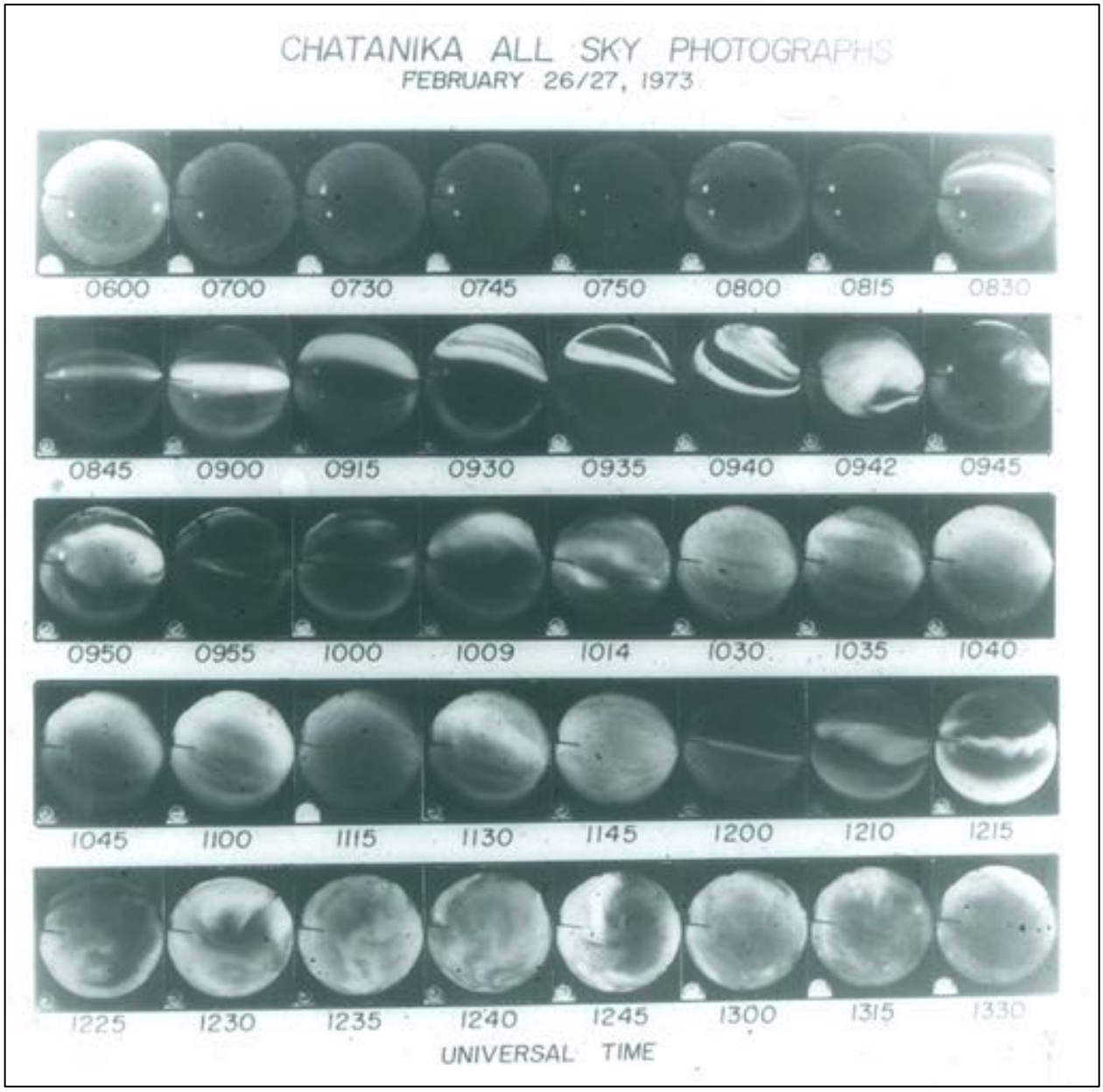
The skies were dark enough to allow observations between 5:30 pm and dawn at 5:30 to 6:00 am. When I started observing in the early evening, there might be only a faint sign of aurora along the far north horizon. As time went on, for active geomagnetic conditions, the aurora brightens and moves southward while appearing in the form of an elongated arc hanging stationary overhead or off to the north. This arc is reasonably bright such that I could see in place of a grayish white the green color of the oxygen line emission at 557.7 nm. Occasionally, I could also see signs of a faint whitish arc off to the south of the zenith. This grayish diffuse display indicated a proton aurora meaning that the light was generated by incoming proton particle precipitation generating bluish light through the excitation of the hydrogen beta emission at 486.1 nm. Some green line emission is created as well. Following local midnight, the aurora generally become much brighter with this behavior coinciding with a negative bay in the magnetometer H component indicating the passage of current within the auroral electrojet. This phase of the auroral display is called the "midnight breakup" as the homogenous character of the auroral fades into a display with many arc segments and patches. These aurora forms become very active with bursts of bright areas appearing along the auroral arcs with tremendous fluctuations.

Following the breakup period, the sky region overhead filled with glowing patches that pulsated with a cycle of a few seconds. It was quite spectacular to see the irregular edges of a pulsating patch fade and reappear with hardly any change in the shape. This activity goes on for 30 minutes to an hour. Eventually all of the auroral emissions disappear. During the height of the breakup the color of the auroral forms takes on different colors of deep red to orange. Often, on the top side of auroral form a broad arc border marks the emission of the oxygen red line 630-nm generated by rather soft electron precipitation.

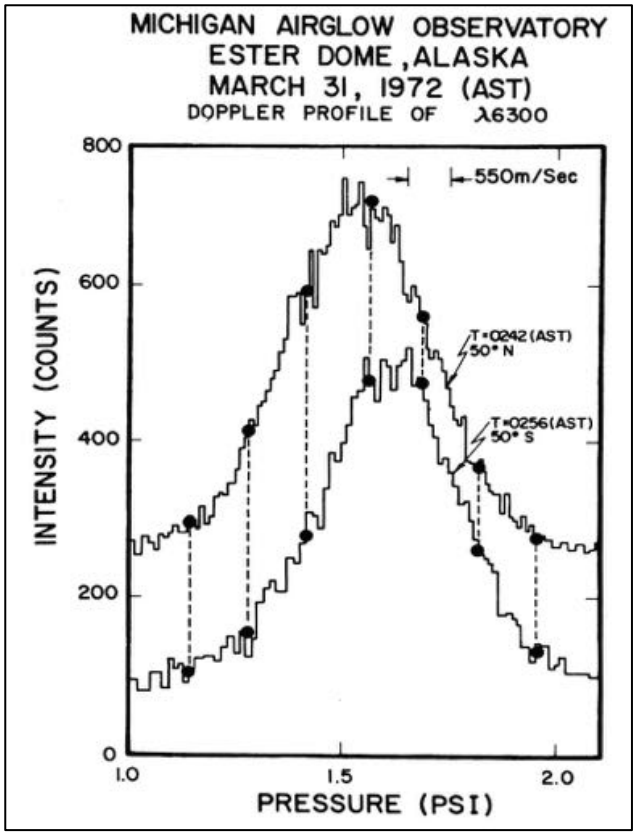
I had taken several graduate courses in molecular spectroscopy, so I was familiar with the molecular band systems for N2, N2+, and O2 that generated these colors. The second brightest auroral emission is that of 427.8 nm, which is the 0-1 vibrational transition of the first negative molecular band system of N2+. The aurora with an upper red border attached to the auroral form is emitting the red line, 630-nm emission of atomic oxygen. There are also periods during the height of the breakup period that aurora with a bright lower border of pink and red might be seen. These auroral forms are generated by auroral electrons with energies in excess of 20-30 kev which penetrates deeper into the atmosphere and generates red nitrogen molecular emissions (known as the 1st Positive system). Blue colors mixed with the pink and red emissions are generated by ionized molecular nitrogen bands at 361nm and 428 nm wavelengths. Soft electron particle precipitation generally just produces the red 630-nm emission.

Most nights feature only one auroral breakup, called an auroral substorm. On rather active occasions when a geomagnetic storm caused by the passage of a corona mass ejection (CME) of plasma through the Earth's magnetosphere was taking place, there might be several substorm events. Each one featured a strong negative bay in the magnetometer trace. The finest moments to observe the aurora come rather late in the night. Because my job running the FPI operations involved so much manual intervention, I could only pop outside every once in a while, to take a quick look as to what was going on. However, I did get to see these visual highlights for a minute or two before I had to dart back into the trailer to

continue FPI operations. Because each spectral scan was associated with two peaks on the X-Y plotter, which defined the width of a fringe, I called this period of data collection "auroral fringing". Because there was so much 630 nm signal in aurora, one fringe might take only two or three minutes. This is very much unlike that required to get a good nightglow fringe, of the order of 30 to 45 minutes for a decent signal for both peaks. Thus, I was quite busy venting the FPI pressure scan, setting up the XY plotter with graphic paper, moving the mirror system to a new direction, setting the integration period on the HP scaler-timer, and watching the tape drive to make sure that all the data is being recorded.



Collection of all sky photographic images of the aurora for the night of 26/27 February, 1973 illustrating an example of extended auroral activity throughout the night.



Detected FPI signal (counts) of the observed 630-nm Doppler profile plotted against pressure which is linearly proportional to wavelength. The interval of 1.7 psi is equivalent to a 0.0198 nm interval between FPI orders at 630 nm for a spacer gap of 1.0 cm. The two fringes show a Doppler shift equivalent to a meridional southward component of the thermospheric wind vector of about 300 ms-1. Each fringe required about 15 minutes of integration for data collection. The broadening of the 630-nm spectral profile relative to the laser spectral width is ~a factor of two and corresponds to an upper atmosphere temperature of ~1000 K.

The various aspects of the auroral activity that I have alluded to all have space physics explanations. For example, the pulsating aurora is a result of precipitating energetic electrons that are of order of 10 to 30 kev (an energy unit that represents a thousand electron volts). These electrons pass to and fro along the geomagnetic field line cycling between the conjugate point in the opposite hemisphere and the region overhead. It has been fascinating to read about how aeronomers and space physics scientists have struggled over the years to explain these phenomena. Even now in the age of supercomputers and extensive knowledge of the geospace system, there remain many questions that have yet to be answered.

Early in my observation efforts I realized I needed to listen to music to keep my mind occupied while engaged in the tasks. I was a big fan of classical and folk music. Beethoven, Mozart, Haydn, and Schubert were the key composers for me. There was nothing like the experience and thrill of listening at 2 or 3 am to Beethoven 7th symphony approaching the finale at a rather loud sound level at a time that I knew the aurora was gushing forth with a really bright display overhead. Joan Baez and Judy Collins were my folk singer favorites; I had a large tape collection featuring their songs. I also included the Beatles in my playlist selections. It was only later that my collection expanded to include Bob Dylan and Peter, Paul, and Mary. It was quite a thrill to be up on Ester Dome alone doing these wind measurements of auroral dynamics.

I also spent a great deal of time writing letters home to my girl friend, Erika, who in August 1973 became my wife. I think she might have been quite attracted to me in part because of the various tales of life in Alaska that I wrote about in my letters, generally three to five a week.

Midway through March, Paul and I talked about how much longer to operate the FPI. There were several upgrades that he had been considering but needed to have the hardware relocated to Ann Arbor. In early April 1972, I packed all of the electronics and the FPI optics into shipping boxes and arranged for everything to be shipped back. It was a weird experience in that I was still on a nighttime schedule. Thus, I found myself up on Ester Dome at 2 am packing but it was quite bright as the length of the day and twilights approached 22 hrs.

During the summer I set up the FPI in Michigan at Paul's laboratory where there was an airglow observatory. This meant putting together the various optical and electronic hardware components including all of the cabling. Paul wanted to eliminate the needle value that was used to generate increasing pressure within the FPI etalon plates. Because of the adiabatic cooling that was generated each time that the application of the vent valve released the etalon gas, the FPI fringe shifted as a result of the induced temperature change. Although there was time for recovery in the few seconds that it took me to move the pointing head to a new direction as well as setting up the XY plotter with a new sheet of graphics paper, Paul was rightly concerned that this effect might be a source of systematic error. He and Will Hanson, a mechanical engineer that designed the mechanical layout of the FPI instrument, came up with an approach centering upon the use of a stepping motor that drove a piston back and forth within a cylindrical chamber. Thus, the pressure scan takes place for both directions of increasing and decreasing pressures. Averaging the signals observed in both directions balanced the adiabatic heating (increasing pressure) and adiabatic cooling (decreasing pressure) effects.

An electronic engineer, Jim Cutler, designed the stepping motor controller so that the lower and upper limits of the stepping range over the spectral profile could be defined in terms of the number of steps relative to the lower end of the stepping range defined by a limit switch. Also, to be specified by thumb dial switches was the value of delta, the number of steps between spectral positions, to achieve a linear scan across the profile. One sets up these settings and then the pressure stepper operates as long as the go switch was active. At the end of each integration period, a pulse from the HP scaler-timer provides the trigger necessary for the tape recorder to record all of the values.

I asked Jim whether a similar controller could be designed to run the pointing head so as not necessary for the operator to exercise this function. Jim said, yes, it is be possible to design such a device, but he did not advise doing so. This was really a job for a computer. He was very adamant in spite of the fact that it required a major reconfiguration of the system to implement the interfaces of the computer with various hardware components. The interface between the computer and the stepping motor electronics for each stepping motor needed to be developed. Similarly, the analog readings from the azimuth and zenith sensors needed to be digitized for the computer to be aware of the mirror system pointing direction. The list of the necessary changes was long and the resources for such modifications were limited so I was resigned to spending my second winter in Alaska running the FPI. My job should be less taxing though as I did not have to worry about venting the pressure scan or setting up the plotter graphics.

The question came up then as to how we should manage the next trip to Alaska. Renting a vehicle in Fairbanks was rather expensive. There was also the need to get all the electronics back to Alaska. Paul had a graduate student, Gary, who had finished taking classes and was finishing up the construction of a new optical instrument designed to observe the 732.0 nm emission of O+ by rotating an interference filter across a spiral aperture which was equivalent to scanning the O+ spectral profile in low resolution. No Doppler shift could be measured but the intensity of the signal could be determined. The aim of his PhD dissertation was to apply this instrument in the guest observatory room in the UM trailer located at Ester Dome under a pointing head that allows Gary to observe the aurora forms in any direction of interest. Slow meridian scans across the arcs would observe this emission appearing on the upper edge of the aurora arc as emission lower in altitude was generally not possible as the excited state of O+ involved in this emission is quenched by collisions with neutral constituents.

Gary and I drove a UM van across the country along I90 to Seattle where we boarded the ferry to take the Inland Passage to Haines Junction near Skagway. This vessel stopped at various Alaskan towns along the way including Juneau and Ketchikan. We formulated this idea in the late fall of October as Paul had decided to broaden the scope of this project to include a third person, Ashley, a graduate student at York University working with a colleague of Paul named Gordon, one of the foremost aeronomers in Canada. Ashley and Gordon built a Michaelson interferometer they wanted to try out observing auroral displays. This instrument was similar in purpose to the FPI, capable of measuring Doppler shifts and Doppler broadening but using a different approach also based on optical interferometry.

Paul was able to reserve the use of a UM van for four months from January to April 1973. Obviously, the idea of driving this van to the north in the midst of winter gave one pause. We had the van prepared for the immersion in Alaskan winter conditions with a plug-in heater to keep the oil sump warm as well as a heater for the battery. We had the engine coolant flushed and replenished with antifreeze to help cope with the very low temperatures that we were expecting. The van itself was in good shape with new tires. We thought we were in good shape.

After the holidays we met in Ann Arbor and packed the van with the FPI equipment as well as the scanning spectrometer instrument that Gary and Paul had constructed. The Canadian equipment had been shipped to Alaska separately. On a Sunday January 7 we loaded up the van with our baggage and headed off along I94 toward Chicago. It took four days to get across the country passing through Wisconsin, Minnesota, North Dakota, Montana, and Idaho before finally arriving in Seattle, a journey of about 35 hours driving and 2400 miles. Our ferry reservations had been made for departure on Friday of that week and we arrived midday on Thursday. We found a place to stay in the outer part of Seattle and did a bit of walking around the city. Friday morning, we headed toward the ferry terminal and boarded the vessel after lunch and our trip started late that afternoon. The ferry journey was quite scenic though the weather was generally cloudy and chilly. I found myself having trouble staying in one place even though I might be watching pretty Alaskan scenery passing by.

We arrived in Haines on Sunday after stopping at Ketchikan and Juneau. We stayed overnight at a downtown hotel and joined a caravan of cars that had been organized to drive along AK 3 through the mountains and Tatshenshini-Alsek Provincial Park toward Haines Junction, a morning drive. There had been quite a bit of snow over the weekend but at the time of our passing through, the road had been cleared by snowplows. We had lunch at Watson Lake and turned onto the Alcan Highway, AK 1, which was the historic gravel road famously constructed in WWII. A fair bit of traffic was passing through even in the midst of winter because commercial supplies of pipeline materials as well as diesel fuel were being shipped to Alaska to help with the construction of the Alaskan oil pipeline. The traction was pretty good because the road was graded by a grader every once in a while, evening out the permafrost heaves. This was an advantage of a gravel surface that it could be treated to eliminate potholes and road surface disruptions.

We were heading for a motel at Beaver Creek located at the border with the Canadian Yukon Territory. We left the caravan of vehicles behind. About 6 pm we stopped to refuel and only then did we notice how cold it had gotten, perhaps -50 F° or so. The gas gauge on the pump did not reset. This meant that to figure out how much we needed to pay, we had to record what the meter indicated and then go ahead with pumping gas into our van. We moved on from this and about an hour later, we began to experience difficulty. I noticed that the front windshield was becoming foggy and the seeing was getting to be difficult. Gary started wiping the windshield clear of the condensation. I was doing my best to keep the van going but I had to let up on the gas pedal to navigate across a bridge. It was then that the engine started to quit in spite of my efforts to keep the engine going. Eventually, a few hundred yards past the bridge I had to pull over to the side of the road. In spite of my efforts or Gary, we could not get the engine running again. Studying the map using the mileage post reading we knew we were close to our destination of the motel. Looking ahead along the road, in fact, we could see the glow of lights just around the bend. The three of us immediately went to the back of the van to put on our bunny boots, leggings, and our parkas. Once outfitted for the very low temperatures we started our trek toward the light. I was carrying a box that had been packed with the FPI optics. No way I was going to leave that package behind and let it become cold-soaked in extremely low temperatures.

Sure enough, our motel was just about 300 yards walk along the road. When we arrived, the proprietor was surprised we travelled in such cold temperatures. He told us that he could take us in, but we needed to avoid flushing the toilets because he had closed the pipe connections to the sewer tank to avoid the risk of water freezing within the pipes. We went to bed right away with all of our winter gear on because the cabins were not heated when we arrived. I was able to get a night sleep though it was rather fitful. Needless to say, we were thankful that our adventure had a good ending.

The next morning, we met with the innkeeper and his family. He and his wife and their two kids had been living there at Beaver Creek for several years. We commented on how isolated their B&B place was, but they noted that there is always quite a bit of traffic along the Alcan Highway. His wife cooked us breakfast of eggs sunny side up and toast, which we very much enjoyed. Then Gary and our host walked down the road to our vehicle with the

innkeeper carrying a blowtorch. He applied this flame carefully to both the engine block and radiator to gradually warm both so that the engine could be started.

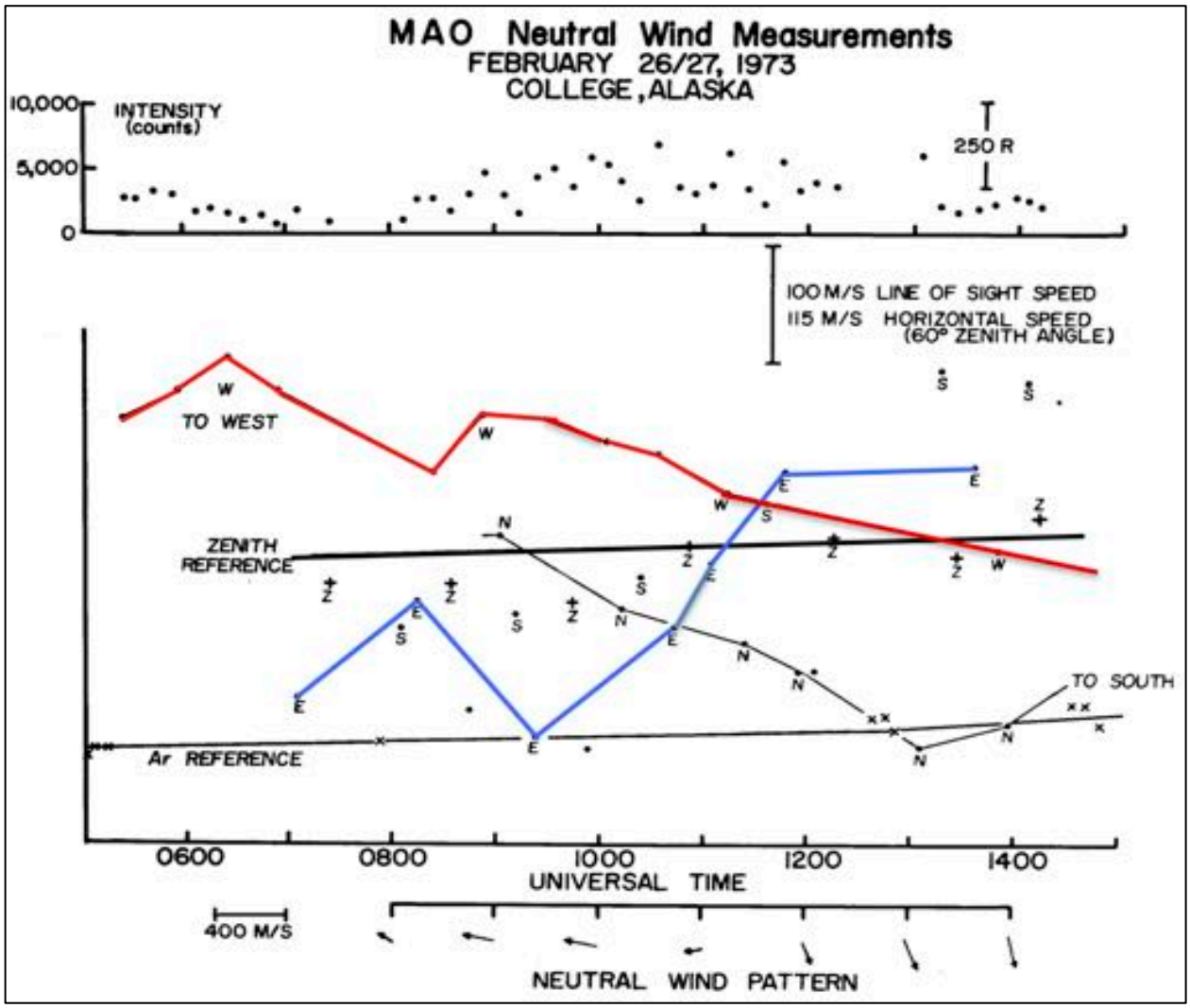
As to why we had suffered this mishap in spite of the several precautions that we had undertaken to prepare for our journey into Alaska, we had overlooked a fundamental requirement to protect the radiator against the wind chill caused by our speed along the highway against the chilly air ahead of us. A piece of cardboard inserted in front of the radiator intake was sufficient to keep the incoming cold air from freezing the coolant. Even though we had the right mix of antifreeze and water in the radiator, the flow of very cold air at 50 mph is capable of freezing the engine coolant. This was the explanation for our problem as to why the engine quit. We found this experience rather daunting, and it all meant that we needed to be careful with our activities. The obvious lesson: experiencing the Alaskan winter can have serious consequences unless one is careful.

After the stopover at Beaver Creek, we continued on to the Alaskan border with the Canadian province of the Yukon Territory, where we encountered the Custom officials who were taken back at our mission to bring along a whole van loaded with electronics through a corner of Canada. It took several hours of back-and-forth conversations to get the OK to go ahead. We had called ahead before our trip started to check that passing through Canada with scientific equipment was permissible, and we thought we did have that OK. However, the officials at the border were telling us that we needed to put the equipment into bond delaying our trip for some time. We ended up getting Paul and the National Science Foundation aeronomy program office in Washington Involved before we finally convinced the officials that we were indeed legit scientists bullheaded enough to take on such a mission during the coldest month of the year. The Custom officials relented. We continued on and spent the night at Delta Junction making sure that our van was plugged in. The temperature was still quite cold, -50s or so, and there was hardly any traffic on the highway. The next day we arrived in the east end of Fairbanks within a trail of ice fog along the highway. This ice fog is a result of the moisture in exhaust smoke condensing so straight-forward physics. Still, it is a strange sight to see how the ice fog shrouds the road surface but being located in the van driver seat you are several feet above the worst of the fog where the visibility is sufficient for careful driving being ready to slam on the brakes should something emerge from the fog trail ahead.

After two weeks of hard work, I got the FPI set up in the Michigan trailer while Gary and Ashley got their two instruments working. Paul and then later Andy came up from Michigan in mid-February and spent several weeks helping to observe. The effort was brutal as the temperatures remained in the low -40s from day to day. Such temperatures are rather rare nowadays. Nevertheless, we got excellent data in this effort as the skies were clear throughout and the aurora was quite active and lively. January in Fairbanks is really a glorious time as there is so much optical phenomena going on: mirages, sundogs, and the solar pillar.

The pressure stepper worked out well providing a more stable FPI instrument for observations. It was a bit disconcerting that the zenith measurements did not seem to be as stable as we had thought to see with some indication of Doppler shifts suggesting vertical wind

events of significant magnitude (>25-40 ms-1) were common. This left us baffled and we tried to check through the instrument to see where a systematic error might have been possible. It turned out that auroral activity can indeed generate significant localized areas of upwelling due to the heating caused by energetic particle impacts or by electric fields. This result was not appreciated until several decades had past by when other instruments and other investigators had seen the same thing.



Observations of thermospheric winds obtained on February 26/27, 1973. The zenith reference (zero Doppler shift) is taken to be the black line plotted as the best fit for the zenith points (z) marked on this plot. The points marked E, W, S and N represent observations made to the east and west and to the south and north directions to determine the zonal and meridional components of the thermospheric wind vector, respectively. The Doppler shifts determined by the differences of fringe peak positions relative to the zenith reference line are used to formulate the variation of the wind vector during the night as shown here by the hourly progression of the wind vectors. Typically, for an active auroral night the thermospheric wind would be westward until after geomagnetic midnight (typically, 11 UT) when the wind vector shifts toward the southward direction.

I had several adventures relating to driving up the hill to the observatory at Ester Dome. In March due to the occasional thaws the road melts in the daytime but freezes at night. This meant driving could be treacherous. One night I was returning mid-evening because the skies had clouded over. I was thinking that I needed to be careful but was still surprised when I came over a hill to find several vehicles parked at the side of the road. Apparently, they had suffered from the icy surface and slid into the ditch. I stepped on the brakes but overdid this pumping of the brakes which put the van into a spin in which I ended up in the ditch. There was no harm done and the people ahead of me came to help me push the van back onto the road.

In mid-April I had to pack for a return to Ann Arbor the same way that I came via the Alcan Highway. My two colleagues had already packed, shipped their instruments back home, and left by an airline flight. Paul was concerned about my returning alone, but the Geophysical Institute machine shop supervisor had an adopted son that wanted to spend some time in Seattle. It was perfect for this boy, a teenager 17 years old, to come with me down to Haines Junction where I got back on the Inland Ferry to head down to Seattle.

It was a beautiful drive through the mountains enroute to Haines. The slopes were often quite clear as the wind blew off any loose snow. It is really quite impressive to see what looks to be an endless landscape of hills and mountains without any signs of humanity. I saw quite a number of bullhorn sheep and once, as we came over a rise in the road, we were surprised to find a moose in the middle enjoying a break in her wandering southward for the spring pastures. She was a sizable animal, so I decided to simply be patient and waited. Eventually she moved on. The weather was quite a bit warmer in April than in January and we had no problems finishing the trip south to Haines Junction. We met the ferry with an evening departure and from then on, the ferry ride was comfortable. I had the problem of not being able to sit continuously in one place just watching the scenery go by. After being in one place for an hour, I had this urge to move on to another location, whether the cafeteria for a cup of coffee, the top deck to watch the scenery, or to my room to continue reading. The deck outside was very windy and quite chilly.

Enter the Mini-computer

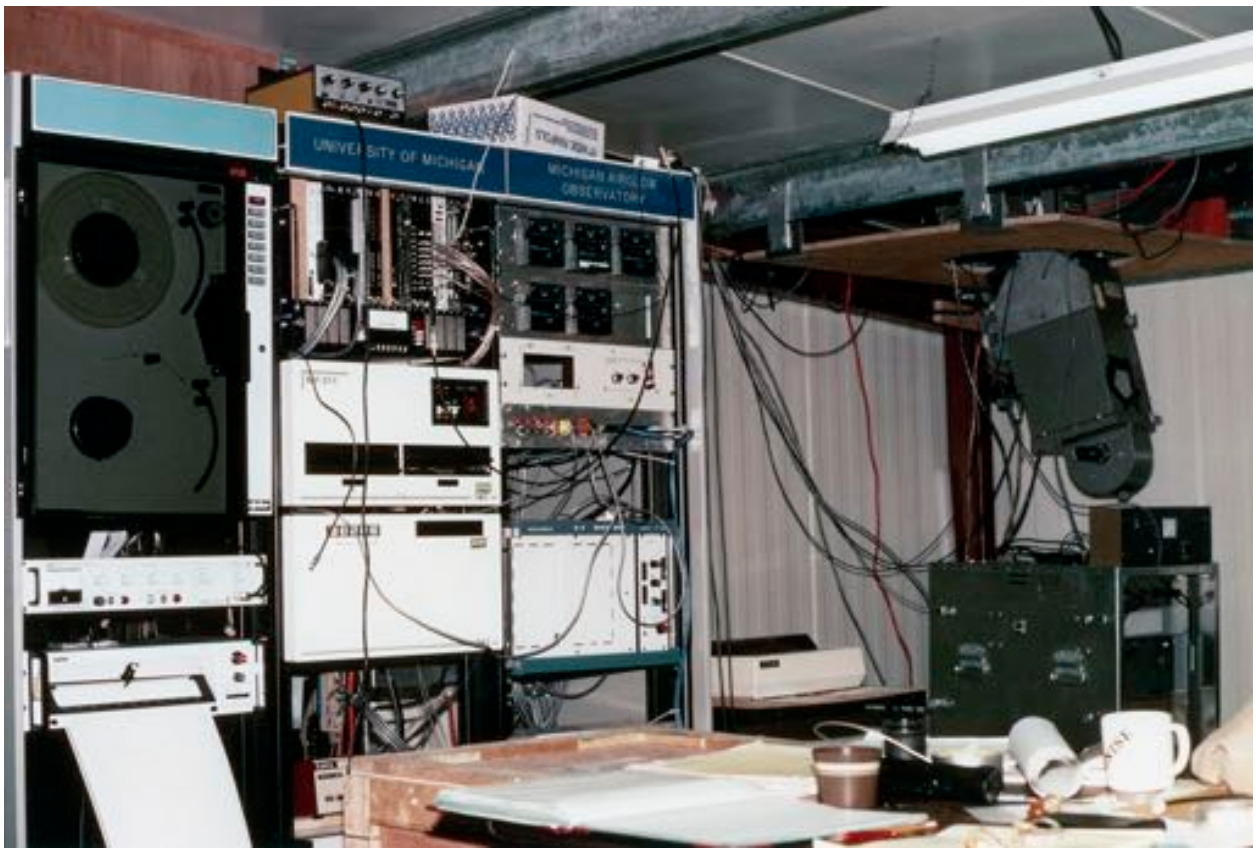
So, this was my introduction to the Fabry-Perot interferometer experiment early on in my career – no computer, no internet, and the need for manual operations all through the night. There must be a way of avoiding this requirement for an operator.

The results of the measurements of thermospheric winds and temperatures were of considerable interest to the modelers of upper atmosphere dynamics, and they wanted more data regarding the responses to space weather drivers such as geomagnetic disturbances, increased solar activity, and atmospheric tidal waves. Having a much larger database allows the development to get the averaged wind and temperature variations from month to month within a year and from year to year within a solar cycle interval of 5-6 years, the period from solar minimum to solar maximum.

What was also clear was that these observing operations had to be automated, which meant that a mini-computer must be incorporated as part of the instrumental design. (I well remember the experience of watching and playing SpaceWar at MIT in Building 20 one summer on the console of what was the PDP-1 that took up a roomful of space.) In the early 70s what was available within the Space Physics Research Laboratory at UM was the PDP-8 mini-computer that ran off paper tape. This was superseded in the late 70s by the PDP-23 which was based upon a floppy disk drive and then later, a 5 MB hard disk drive. When I returned to UM from my work at Arecibo Observatory as a research associate, I became a research scientist at the Space Physics Research Laboratory (SPRL), located on the North Campus across the street from the High Altitude Laboratory where I had previously worked. I inherited from Paul the hardware apparatus that he and his group had developed in the early 70s that I had operated in Alaska. Paul was busy with the task of building for NASA the Dynamics Explorer FPI that was designed to measure the thermospheric winds and temperatures from space as part of a suite of instruments that made up this satellite payload. In essence he was trying to transform what for ground-based measurements represented a trailer van of electronics and hardware into a 15 kg gadget mounted on a spinning satellite.

The National Science Foundation had agreed to Paul's request for a supplement to his award to cover the expense of adding a computer with the capability of operating the FPI automatically from night to night. This meant that I had the resources to cover the expense of purchasing a PDP-23 so this was a major opportunity. We considered other mini-computers such as Data General, but the Digital Equipment Corporation had a strong reputation of selling a mini-computer that was well-engineered and robust. PCs did not exist at the time, and we did not really consider alternatives such as Hewlett Packard because the in house experience with the DEC PDP-8 had been so positive that we were naturally inclined to go with the PDP-23 new generation of computers based upon the 16 bit architecture of the microprocessor, which was much faster than the 8 bit structure of the PDP-8 chip. Moreover, the SPRL laboratory experience in using the DEC hardware meant that there were available as part of the SPRL institutional memory software computer code that I could take advantage of. One example was the compiler I needed for producing machine language code from the Fortran level language that I was using to write the FPI data taking programs.

The SPRL laboratory engineers had also considerable experience in using the CAMAC hardware that represented at the time a robust approach to the problem of interfacing the computer CPU with the experimental parameters. Examples include a CAMAC module to provide the source of stepping motor pulse trains to operate the FPI mirror system or the FPI pressure stepper, an A to D CAMAC module to sample with sufficient precision the pressure reading from the FPI etalon chamber or the analog voltages from the potentiometers that were used to measure the azimuth position or the zenith position of the azimuth or zenith mirrors, and the multi-channel pulse counters to count the pulse signals from the multi-channel detector. Among the many new design features of Paul's satellite FPI was the imaging detector that ITT had designed to achieve the equivalent of 12 separate photomultipliers, each observing signals associated with a segment of the spectral profile that represented the circular interferogram produced by the etalon.



Electronics required for the automatous operations of the MAO Greenland Sondrestrom FPI observatory. The nine-track tape drive is seen in the upper left, the CAMAC crate and modules are seen in the central top region and the PDP mini-computer and hard disk drive are located below this. This assembly is representative of early 1980s technology involving the PDP-23 minicomputer.

I had my hands full in writing the Fortran code for the upgraded FPI computer-driven system. There was the limitation associated with the PDP-23 computer memory of 64 kilobytes. There was also the need to figure out automatically when to start nighttime observations and when to quit. I chose the observing start and end times at which the Sun was below the horizon by 8 degrees. This turned out to be possible because there was a SPRL Fortran program that did this ephermeris calculation of the evening and morning times for this solar depression angle. I could put all this information into an ascii file and have the computer look up the appropriate startup and shutdown times for each night.

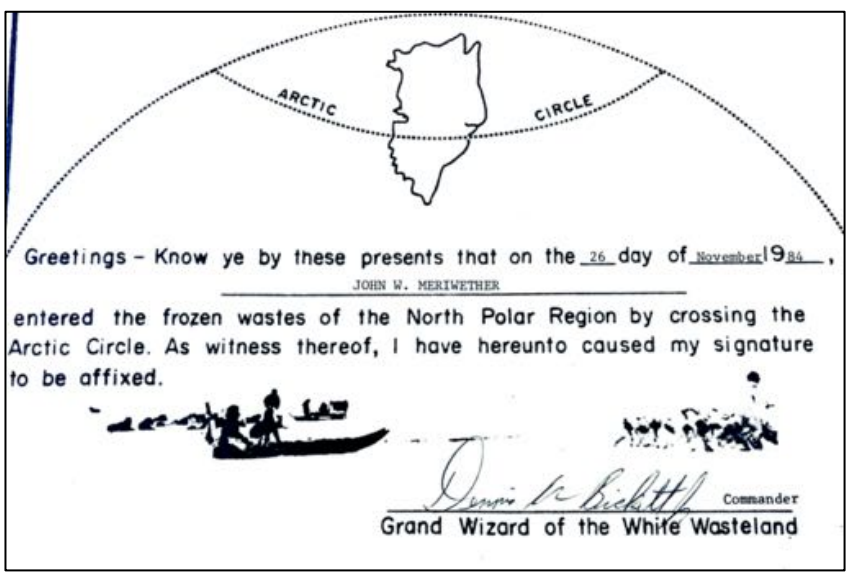
Moving the double axis mirror system was straight-forward as Sly-Syn stepping motors were used to move both mirrors. The computer commands a CAMAC pulse-train generator to send a series of pulses to the motor translator module which converted the digital pulse train into current pulses that drove the stepping motor. Potentiometers gave the data taking program feedback as to where the mirrors were pointing. FPI spectra were written out to the disk along with related auxiliary information. Clearly, 8-inch floppy disks of 500 kilobytes capacity are not be adequate for the job so I brought a hard disk drive of 5 megabytes. There was still required a means of data storage, so I brought a 9-track tape drive. All

this taken together represented an expensive system. On the other hand, the information acquired was unique and invaluable to space physics at the time.

Once I had the bugs worked out for automatic observing, the question came up of what to do with such an instrument. It was at this time (1980) that NSF announced a relocation of an incoherent scatter radar to be relocated from Chatanika, AK to Sondrestrom, Greenland. The idea was to relocate the radar to a location where polar cap observations of the plasma poleward of the auroral zone as well as southward toward the vicinity of the auroral zone could be achieved. It was my idea that the science studies relating to measuring the plasma drift by radar should also include simultaneous measurements of the neutral atmosphere flow of air. The process of ion drag compels the air to move in the direction of the plasma flow, so it made sense to study the dynamics of both plasma and neutral flows together. I submitted to NSF a proposal pointing to the success I had achieved with the Michigan automated FPI and suggesting the construction of a new instrument to be installed at the radar facility location. This proposal was successful so soon I found myself on a Air Force C-141 flight that went from McQuire AFB in New Jersey to the Sondrestrom AFB located in southwestern Greenland. The radar site had been picked to be within a small valley that served to shield the radar antenna from ground clutter. Although my project was somewhat expensive, it turned out that the fluctuations of the Danish conversion ratio to US dollars were such that SRI International, the radar PI, did not have to spend any extra funds to build an addon to their building to provide an optical observatory space for the FPI installation. With the help of two engineers from SPRL I was able to get the FPI installed and operational toward the end of February 1983. The system did prove capable of automatic operations and successfully collected data for a number of weeks until it became too bright in mid-April.

The success of this project led to another project that was to install a FPI in a trailer located at Thule Air Base in Greenland. This instrument was funded by the Air Force and proved to be successful as well in spite of the far distances required to travel from McQuire to Thule in a C-141. I had to get equipment up to the Greenland site; shipping to Thule was problematic, especially if time was limited. Taking it with me as personal baggage seemed to be the best way. However, I had the problem of getting the boxes from the New Jersey Newark airline baggage area to the McQuire AFB terminal. A taxi did not have enough cargo space. In previous trips I noticed a limousine service at the far end of the Newark terminal. I made a reservation for one, getting everything into the limo along with my technician and our luggage. Imagine the reaction of the military guard at the entrance to McQuire AFB to have me show up with my military travel orders in hand. The guard was quite taken back with surprise but how else was I going to be able to get my equipment to Thule AFB, especially in mid-winter?

The FPI trailer located at the harbor of the Thule Air Base. Seen in the background is an interesting sandstone outcrop smoothed flat by Greenland glaciers in ancient geological times. The concrete bar was mounted onto the trailer along with restraining cabling to anchor the trailer against the stiff winter winds that occasionally developed along the Greenland coastal region. Each spring a golf tournament is held on a 9 hole course set up on top of the bluff.



ARCTIC CIRCLE

Greetings – Know ye by these presents that on the 26 day of November 1984,

JOHN W. MERIWETHER

entered the frozen wastes of the North Polar Region by crossing the Arctic Circle. As witness thereof, I have hereunto caused my signature to be affixed.

Commander

Grand Wizard of the White Wasteland

Affidavit of passage into the High Arctic region, November 26, 1984.

In the same year I modified an existing FPI that was operated by a MIT alumnus colleague to achieve automated operations. This instrument ended up in southern Peru at Arequipa. Its purpose was to observe equatorial thermospheric winds and temperatures which it did with moderate success during the times of clear skies from April to September. The rest of the year was lost because the skies became continuously cloudy due to the equatorial cloud belt that migrates south from the equator during the local summer. It took a number of years but finally, in the mid-90s I got the monthly climatology data that I had originally set out to achieve.

Enter the PC Revolution

It became clear that the heyday of mini-computer technology was past, and the PC revolution was upon us. The PC was quite attractive to me because of the 32-bit architecture as opposed to the 16-bit limit of the PDP-23. My writing of the data taking code for the PDP-23 had become severely hampered by the memory limitation of 64 K words as I tried to get the software to do more tasks in managing the FPI data acquisition. Switching to the PC platform was something I should think about doing sooner rather than later. However, it was a big job because the software required extensive modifications, not just in the data acquisition software but also in the data analysis.

The switch became even more attractive, though, when I looked at upgrading the detector to move away from a photomultiplier (PMT) to a CCD camera. There were several advantages supporting this switch. One is that the quantum efficiency of the cathode surface of the bare CCD camera is much higher than that of the PMT, i.e., 90% rather than 10%. Second is the fact that an imaging system such as a CCD camera means the sky signals are collected simultaneously across the whole range of input angles between two interference orders (rings) rather than only a small fraction of the interference ring that is allowed to pass through an aperture. And then, there was the fact that multiple orders (rings) could be imaged simultaneously rather than just the innermost one. Taking all these advantages together meant an increase in FPI sensitivity by about a factor of 300 or so. Using a four-stage thermoelectric cooler reduced the dark noise to essentially nothing. Achieving this conversion answers my dream – a perfect detector.

I researched the CCD cameras available on the market and thought that the Andor CCD camera made by an Irish company located in Belfast was attractive. The sales engineer that I talked to was supportive and helpful with information. I wrote a proposal to NSF and got a supplement to my Peru award that gave me the funds that I needed to purchase a camera for a tryout. The camera was expensive, about $25,000, but the expense was worthwhile given the huge improvement in sensitivity that I expected to get.

Looking at the software issues involved in switching to the CCD camera detector was daunting as it meant facing up to the hurdles associated with Windows software. It was right at this time that I renewed my friendship with Peter Sherwood and his wife Bonnie at the 2004 class reunion. Peter had started his own company to develop software for clients, and so, I mentioned my challenge in regard to learning how to program Windows to work with the Andor camera. Peter volunteered his services, and I was sensible enough to accept. Initially, I was hesitant to do so partly because I had the attitude that I should be able to manage this challenge on my own. But then, later, I realized that Peter was offering to be part of my team. I had enough to do in regard to the data analysis issues and writing up the science of the measurements that I wanted to take that I could not really afford to drill down into Windows programming issues when Peter was clearly an expert and willing to help. This is an example of the transition that has taken place over the past three decades in most science fields in which teamwork can become more important than the individual initiative in achieving results. It is rather difficult nowadays for a scientist to master all of the

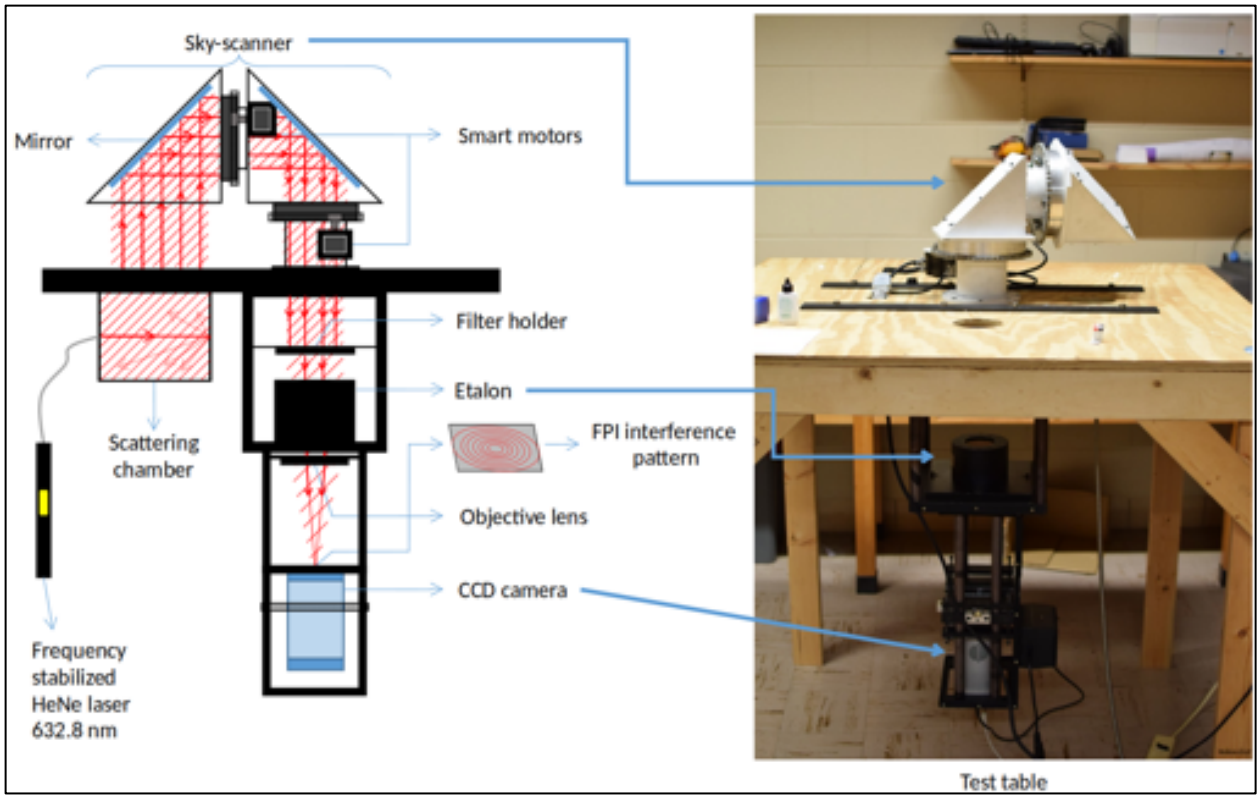
skills necessary to achieve an instrument operating at the cutting edge of modern technology.

Our partnership became a wonderful experience involving many emails. Early on we developed a plan based upon four modules: Master, Observatory, Camera, and Analyze. This package was designated as A3O based upon the acronym that my Peruvian colleague and MIT alumnus (Class of 1944) Fred Biondi came up with Arequipa Automatic Airglow Observatory. From its name Master was the dominant module and provided instructions to the other three modules. It sent messages as needed and received back data and status markers. Observatory did the work of moving the mirrors, collecting analog samples of pressure and temperature, and managing the FPI shutter function (whether light is admitted to the etalon or not, and whether HeNe laser light passed into the etalon). Camera operated the Andor camera passing forward the exposure time and collecting the imaging data at the close of the camera exposure. It also controlled the camera temperature to cool the CCD chip to minimize the dark count during operations. Analyze presented the image to the monitor for display, and also did the summing of the image data around the ring center to achieve a one-dimensional display of the interference spectrum. It also provided the means for simulating the FPI interference pattern depending upon the input parameters of spacer gap, etalon diameter, exposure time, dark noise level, and 630-nm source signals. Master communicated with each of the modules in an interrupt mode that allowed Master to deal with any issue that came to continue the sequence of observations.

Control files were used to provide to the PC all the input parameters required to set up the observatory data taking. There was one for each module except Master. ObservatoryControlFile included the latitude and longitude information necessary for ephermeris calculations of sunset and sunrise. Master also calculated the direction toward the Moon so to enable a strategy of avoiding data taking in the direction toward the Moon which made the FPI background continuum too bright for quality measurements of Doppler shifts and Doppler broadening.

I came to learn much more about the culture of programming professional software, especially in regard to how precise one needed to be to begin a project with careful specifications, and also how important it was to document results of any computer error. Peter was always very helpful and patient, especially during the moments that I was in the field, and something unexpected turned up causing the programs not to work as expected.

The replacement of the PMT with the CCD camera proved to be a major breakthrough that was made possible not only by the advance in the technology of the camera but also the capability of the PC in regard to memory and speed. I remember in 2000 visiting a colleague who was trying out a CCD camera with his FPI instrument. I saw then that the limitations in CPU memory and speed in his PC were clearly hampering his efforts to analyze the image to extract Doppler shift and Doppler broadening. Still, I was motivated enough to want to learn more about this camera technology. I expected Moore Law to soon mean that the PC computer memory and speed could be easily capable of matching my requirements.



Modern version of the Fabry-Perot interferometer. The instrument frame is mounted to the test table top with the double axis SkyScanner mounted onto the test table top. The instrumental schematic shown on the left illustrates the major components of the instrument including the CCD camera, etalon chamber, filter, and SkyScanner. For the laser calibration the SkyScanner is directed to look down into the scattering chamber and a shutter mounted on the laser head opens to pass the HeNe stabilized-laser light into the scattering chamber through a fiber optics cable. Figure taken from the PhD dissertation submitted by Dr. Rafael Mesquita (2021).

It was about this time in 2001 I purchased an all-sky imaging system fitted out with a CCD camera. This decision gave me a start and allowed me to gain some experience in using the CCD camera. Unfortunately, my Clemson observatory was raided by thieves that cut a hole in the fence and broke into my trailer. They swiped the imaging system and computer and even took the dome. There was a silver lining, though. This loss was covered by Clemson University insurance, and I invested the proceeds in buying a small FPI from the Michigan company that Paul Hays had organized. This instrument deserved to have a name and after spending two hours debating possible names, one of us came up with MiniME, so perfect because the name acknowledged the miniaturized nature of the instrument which proved to be quite adequate for observing winds and temperatures but very handy for lugging around the world.

From the beginning the computer memory was quite adequate but as the four A3O modules became more complex, the extent of memory required increased considerably. However, the PC technology always moved ahead faster than my computing demands, and I never had any issues due to PC shortcomings. One could say that my choosing to wait until the early years of the decade after 2000 was insightful but I had no real idea that the PC

technology could continue to improve as it did. I just kept on pressing the pedal as it were but with the continual sequence of hardware upgrades of the PC computer platform over the years, I never came up to any barrier in regard to CPU speed and core memory as I had experienced with mini-computer technology.

Peter and I kept on improving the A3O software with the back and forth engagement via email. The software he wrote proved to be quite robust while remaining reasonably small in taking up computer core memory. One might ask the question, why not use the commercial software such as LabView that supposedly offer simple-minded pathways toward achieving data acquisition. The response from Peter was that the demands upon the computer CPU speed and memory are quite a bit more severe and difficult to support. I chose to listen and accept his advice as I knew Peter to be much more knowledgeable about Windows real time computing than I was in spite of my many years of using the DEC mini-computer technology during the 80s and 90s.

The remainder of this story is interesting in that the strong community interest in collecting these measurements of upper atmosphere winds sustained my research for the past several decades. I was open to collaboration with colleagues and with Peter's consent and support I shared the software programs with other colleagues, which led to delightful experiences in doing so. My colleagues and I started new FPI observatories in Argentina, Brazil, Ethiopia, Morocco, Peru, South Africa, and Alaska. A Brazilian feast in Sao Paulo. A FPI at the Bahil Dar University, Ethiopia, that was guarded by an armed guard bearing an AK47. A long trip to Hermanes, South Africa to talk about FPI results and plans for locating a FPI at the Sutherland Astronomical Observatory, SA. An overnight trip to San Juan in Argentina to visit the El Leoncito astronomical observatory in the Andes near the western coast. And then I had a great opportunity to revisit Alaska after some four decades.

Modern version of the FPI instrument that is about 200 times more sensitive than the MAO 1973 interferometer. This particular observatory is located in the Nazca region about 100 km south of Lima, Peru. Internet access was available with a wireless router connection. The CCD camera and the FPI etalon are located at the bottom and center (blue thermal jacket) of the FPI frame. The SkyScanner is located in the dome area. Figure provided by Dr. Luis Navarro from his PhD dissertation (2019).

Return to Alaska in 2009

During the 90s it finally became possible to build a new advanced incoherent scatter radar. This instrument was to be located at Resolute, Canada just 1200 km or so from the North Pole. The reason for such a location choice was that the aeronomy community thought that studying and learning about the space physics phenomena, which was now being called "space weather", at the high latitudes within the central polar cap region would be highly rewarding in regard to transformative new science. The idea was to recognize that the electrodynamics of the polar region and the magnetosphere that was connected to the polar regions along geomagnetic field lines was all part of what we might call the "geospace system". This approach recognized that no longer could the space physics phenomena be studied piecemeal. A holistic approach to space physics studies was now necessary to achieve a deep physical understanding of the myriad number of processes operating simultaneously. The new measurements were expected to supplement in major ways our understanding of the electrodynamics of the aurora and the convective forcing of plasma across the polar cap and toward the Sun in the evening and morning sectors.

Funding such an instrument was estimated then to be about $60,000,000 and normally, finding the money to support such an expense is difficult to achieve politically within NSF unless there was manifested strong support. The leaders of the geospace program at NSF thought that they had everything set up within the aeronomy community and within NSF to go forward with this plan for the construction of what was to be called the "Polar Cap Observatory". Unfortunately, there was one problem, and that was Senator Stevens from the state of Alaska. He thought it was outrageous for NSF to spend this amount of money to put such an instrument at a location such as Resolute outside of the US boundary. He thought that Fairbanks, Alaska was a perfectly good place for such a facility. As a result of his opposition, in spite of all the efforts that had gone into selling this plan, the PCO project was canceled.

Eventually though, the NSF geospace program officers had an inspiration. Let us call this project *the relocatable ISR* with the plan that the instrument stays put in one location for a number of years and then be moved to another location. The natural starting point is Fairbanks, Alaska at the location of the Poker Flat Rocket range. The new ISR instrument featured cutting-edge solid-state radar technology which meant among other attributes including the capability of continuous unattended operations. The beam forming capability of this radar meant that it is able to observe multiple directions almost simultaneously with millisecond intervals. The name reflects this capability as "Advanced modular incoherent scatter radar", i.e., AMISR. The combination of the AMISR radar, optical instruments at the range, as well as the ability to fly instrumented and chemical release rockets into aurora would really be a powerful means for studying at an advanced level the electrodynamics of the aurora. This plan also included funding to support the construction of another AMISR radar installed at Resolute, achieving what the aeronomy community originally wanted while satisfying the desire of Senator Stevens for Alaska to continue to be at the forefront of space science studies.

Along with this plan for building up a cluster of instruments at the rocket range, NSF wanted to provide PIs the opportunity to bring to Poker Flat new instruments that provide observations complementing the plasma profile measurements of electron density, electron and ion temperatures as well as measuring convective flows of the plasma. Thus, toward the end of the decade in 2008, NSF announced an opportunity to propose additional instruments to measure parameters that complement the plasma physics measurements produced by the Poker Flat ISR facility. Neutral winds and temperatures were obvious physical variables for a winning proposal.

This to me was a wonderful opportunity to return to Alaska to continue the studies on auroral electrodynamics that I had started in the early 70s. After thinking about what I might undertake, I decided a network of three FPIs to be the core of my proposal with each one being a copy of MiniME which at this time I had spent quite a bit of time working with by running the instrument at Arecibo Observatory. The aperture of 4 cm was small, but the imaging detector made the sensitivity be quite respectable and sufficient to observe the 630-nm nightglow. Auroral signals make the wind and temperature errors quite small, and in fact, these errors turned out to be about 2 ms-1 and 5-6 K for a camera exposure of 120 s.

It turned out that the funding that I was able to get from NSF as part of the AMISR solicitation was inadequate for me to start from scratch with three new copies of MiniME. Instead, I was able to convince NSF to provide funding to refurbish two FPIs and use the MiniME that I had. One of the FPIs came to me from the University of Saskatoon through the help of a colleague that I knew from our work in running the Arecibo Observatory airglow facility in the 70s. The other FPI came to me from a wonderful friend and colleague at the Utah State University who no longer had anyone interested in using that instrument. I had met this person, a Harvard graduate in Alaska in the first year of my work with MAO, and we had hit it off very well. He wanted to observe the 630-nm nightglow for very quiet nights in Alaska to observe the nightglow effects of electrons arriving overhead of Alaska along flux tubes from the conjugate hemisphere. This project proved to be quite successful.

In both cases I replaced the detector for each FPI to be refurbished with an Andor CCD camera. The etalon size was bigger so that was a bit of an advantage. However, it took several years to fully complete the upgrade of the instrument to observe multiple rings of the FPI interference pattern (bull eye circles). I chose to locate these three FPIs at Poker Flat, at the Geophysical Institute Observatory at Ft. Yukon, and in a small observatory meant for a magnetometer adjacent to the airport runway at Eagle. Ft. Yukon is located toward the north of Fairbanks and north of the Alaskan Range. Eagle is found on the US side of the Yukon River at the border with Canada. The separations from one station to another are about 250 km. allowing me to get decent Doppler shift measurements into a volume of space that is common to all three look directions. This allows me to use the observed Doppler shifts for all three directions to compose a thermospheric wind vector – 8.01 physics- for each spot. In the observing that I undertook I chose a strategy of observing toward four successive spots within this region bounded by these three locations so that the SkyScanners for each of these FPIs commanded by the computer to move in succession from one spot to another. This proved to be a great strategy as one of our findings from this project was that

the auroral thermosphere was populated with numerous wave structures that continually passed overhead. With this observing approach we could measure the speed and direction of these waves.

For me to be able to coordinate these observing operations as described for these three FPIs, I needed to have access in a remote sense. Fortunately, the internet technology had arrived in Alaska. The internet to Ft. Yukon was a bit slow but was based upon microwave transmission of signals from the Ft. Yukon observatory to a repeater located in the Alaskan Range which in turn transmitted (or received) to the Geophysical Institute in Fairbanks. The internet to Eagle was also slow because it depended upon a satellite link which did not have a very wide bandwidth. Still, the speed for these stations was fast enough to allow me to communicate with the desktop of each observatory computer. Thus, I could change exposure times and pointing directions by editing files. It was possible to watch the data taking in real time whenever I logged onto the site.

Peter wrote a new module called Communicate that allowed me to arrange for the images to be downloaded to a server automatically at the close of the data taking for each night. I then download these images from this server to my computer for data analysis using my IDL programs. This was all a bit clumsy but still much better than having to go to the site to copy the data files off the computer. I eventually used the program TeamView for this purpose of remote observing as this program proved to be robust and multi-functional in that I could upload new software or download data images or log files that we used for documentation of the data taking each night. For the network of five FPIs that we later established in the mid-West that we called NATION (North American Thermosphere Ionosphere Observing Network), we improved the communications so that not only were the images automatically transferred to a server but once there they were analyzed. This meant that each morning I could be looking over the results of the previous night while drinking my morning coffee.

Because I was teaching at Clemson University, I could not spare much time away from classes. When we heard from my Alaskan colleague that the shipment of FPI equipment had arrived, divided up into three pallets, a student and an engineer from the Physics Department machine shop and I made plans to travel to Fairbanks. This was in October of 2009 in the fall season before the really low temperatures of Alaskan winters. Each of the three pallets was loaded with three or four crates containing the FPI equipment and a set of tools as well as a dome with the right diameter to fit to the hole in the roof of the observatory building at Ft. Yukon or at Eagle.

Once we arrived in Alaska, we met with my colleague associated with the Geophysical Institute of the University of Alaska at Fairbanks and went out to Poker Flat where the cargo for the FPI to be located at Poker Flat was already situated. We immediately went to work with unpacking and installing the FPI frame and the other parts of the instrument under a large sized dome. We had lunch nearby at the Chatanika Lounge, a bar well known for nighttime festivities. When we left that evening to get supper and then to bed, we had the instrument in place ready for first light. The next day we went to the airport with the FPI shipment intended for Ft. Yukon and took a flight north on the Wright Air Service, providing cargo and

passenger service to remote communities which in the winter were otherwise completely isolated from civilization. We stayed at the AF radar base located to the west of town where the GI had an agreement to locate a trailer fitted out with three domes. This observatory was well insulated against the Arctic cold of extremely low temperatures. Our FPI went into one of the three rooms and was located under a large plastic dome. Again, installation went forward rather quickly, and we left after two days of continual effort. I was able to get first light with this instrument much to my satisfaction. Once we returned to Fairbanks, we were off to Eagle using the Everts Air Service. Here we rented a rather decrepit truck provided by the people at the Eagle General Store. During the winter there was no eatery place to patronize so we had brought along some food to go with some items purchased at the general store. Again, the setup went rather quickly and within a day I was collecting images.

Discovery Science Results

The results that emerged from this 21st century series of observations were quite interesting. In the FPI world to measure a Doppler shift, one needs a Doppler reference. In radio science, a Doppler reference is provided by a local oscillator set for a certain frequency. In the case of a radar, the frequency of the radar echo received is compared with this frequency, and whatever frequency difference is seen is taken to be a Doppler shift that might be used to infer the speed of the target generating the echo. A positive frequency shift means that the target is moving toward you, and a negative shift that the target is moving away. In the case of the FPI, though, because we are dealing in the spectral domain, i.e., wavelength, a shift of the 630-nm spectral profile emission to longer wavelength, i.e., toward the red, would be taken to say that the air is moving away from us. Vice versa, a blue shift (i.e., toward higher frequency, shorter wavelength) means that the air is moving toward us.

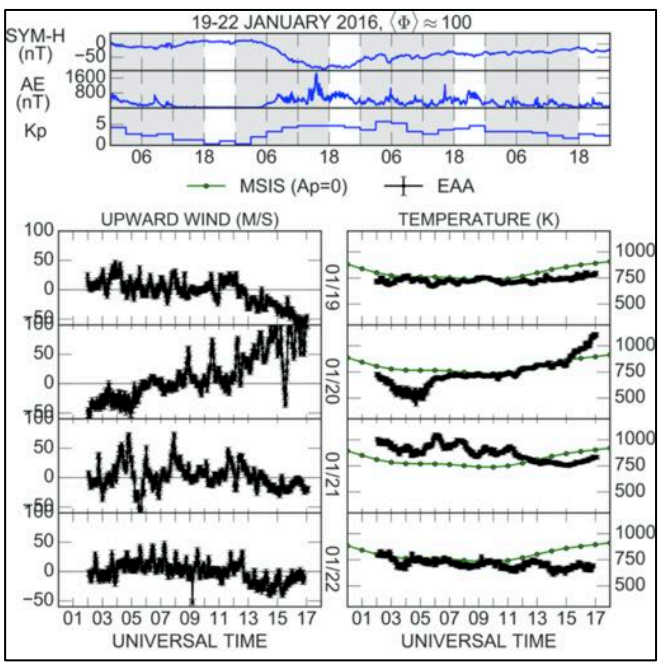
Unfortunately, the local Doppler reference needed for thermospheric wind measurements is not available. Because the upper state of the O emission is metastable, it is simply too difficult to make an atomic oxygen laboratory source that emits at the 630.0303 wavelength – the lifetime of the oxygen atomic species is about 110 seconds and so, at 250 km, this state is generally destroyed by collisions before emission can occur. Consequently, the state is thermalized and observing the Doppler width does provide a temperature measurement. For Doppler shift measurements, the peak position of the FPI spectral profile seen in the zenith direction is taken to be the Doppler zero. Why is this assumption valid? Well, thermospheric winds are believed to be driven in the horizontal direction with zonal and meridional components but generally, no vertical wind speed greater than 2 or 3 ms-1. There is so much bulk air within the 630-nm viewing volume that needs to be moved to see any significant vertical motion.

At low latitudes this assumption generally has worked out well. However, in the auroral region, is this the case with particle precipitation depositing a considerable amount of energy? Or with the significant energy source provided by Joule heating arising from the frictional drag of fast-moving ions colliding with the neutrals in the thermosphere region? Our Alaskan results obtained in 1973 as sporadic as they were due to the weak FPI sensitivity did suggest that the auroral vertical wind observations demonstrated strange behavior. I

remember Paul and I undertaking tests such as removing the plastic dome thinking that reflection of light within the dome introducing scattering might have something to do with the strange results. But no, the effect was quite real, and we were simply refusing to face the reality.

This example illustrates the dilemma that experimentalists quite often face in examining the results obtained subsequent to the application of an instrument. Are these results real or possibly a result of an artifact? What I have learned from all the years of experimental space physics work with ground-based optical instruments is that one has to understand well how the instrument works before trusting the results and what these results might signify. You are always asking yourself can I explain this as a result of scattered light? Or could it be a result of leakage through the interference filter outside of the spectral pass-band? Or, or, or, the list goes on. Thus, oftentimes, it takes considerable courage to publish your findings, especially if the correct interpretation to achieve an explanation requires quite a bit of theoretical insight that you might not be able to apply.

What we later found using the upgraded FPI instrument for each of these three stations in central Alaska was that the auroral thermosphere region is populated by very active wave disturbances, especially so for active geomagnetic times. A figure is attached to show an example of such results in comparison with the early results. Such waves were totally un-expected but in retrospect the idea of such waves should not be surprising. The local depo-sition of energy within auroral forms through auroral particle influx or through electric fields interaction with the auroral plasma can indeed produce enough energy deposition to cause an atmospheric response of adiabatic expansion producing upward vertical winds.



Vertical winds, temperatures, and auroral intensities measured at Eagle, AK for four nights, 19-22 January 2016. Error bars are typically ±3-5 ms-1 and ±10-15 K for the vertical winds and temperatures, respectively, for a two-minute exposure. Associated with the heating event on 20 March between 13 and 15 UT is a period of a strong upwelling of the thermospheric air with speeds as high as 50 to 100 ms-1. This period is associated with the peak geomagnetic storm disturbance as demonstrated by the increase in the planetary magnetic index (Kp) to 5 as well as the increase seen in the AE index (a linear measure of high latitude geomagnetic activity). Typical of such geomagnetic storm disturbances is a negative deviation of the horizontal component of the Earth's geomagnetic field, which is presented in the top panel.

The results from the application of general circulation modeling for what seemed appropriate input parameters suggested at best upward winds of just a few ms-1. In practice in addition to the active wave disturbances, we were seeing upward vertical wind results as large as 100 ms-1 for a sustained period of an hour or so. These periods of sustained upwelling of air coincided with bright 630-nm auroral intensity enhancements caused by soft energy particles with energies less than 1 kev. Such particles are all absorbed by collisions within the atmosphere for heights above 200 km. These results of strong upward vertical winds represent to me an example of discovery science, something totally unexpected beforehand.

This discovery would not have happened had it not been for the advances in technology over some 50 years as described in this essay. Although perhaps now the insight is not so hard to understand, but for a very long time among my aeronomy colleagues, there was an embedded bias against the idea of strong vertical winds in the thermosphere region. This was even the case even when we had composition measurements obtained by a satellite such as the Dynamic Explorer that flew in 1981 showing a strong upwelling increase of the molecular content of the air at 400 km. The only way this could happen was through upward vertical winds moving the O2 and N2 molecules into the higher atmosphere regions.

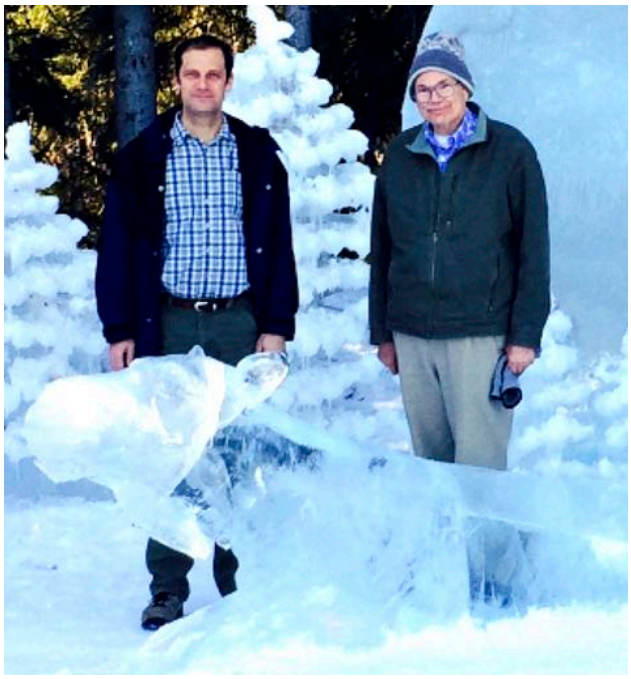
Another example of discovery science that came about as a result of the enhanced sensitivity of the FPI was that for mid-latitude locations a detection for about one-third of the time found a nighttime double maximum temperature structure with two thermal peaks showing temperature increases as much as 100 K above the nominal 700 K background. This structure showed the two peaks separated by about six hours. In contrast to this behavior, at lower latitudes such as that of Arecibo Observatory, there is almost always a single peak at a time just past midnight. This feature became known as the midnight temperature maximum. At higher latitudes previous to the use of the CCD camera for the FPI instrument observations no signs of this double peak structure have been seen. This lack of any successful detection was a result of the poor quality of the FPI data due to the small number of data points per night and the much weaker sensitivity of the FPI instrument deployed for these measurements. Why is this structure seen for nighttime temperatures? It happens that the Sun generates tidal waves as it passes over the atmosphere during the day heating the stratosphere region as a result of ozone and water vapor absorption of solar radiation. These waves have significant thermal amplitudes that propagate to the higher altitudes of the thermosphere. At low latitudes these waves tend to be dominated by the semi-diurnal tide. At higher latitudes additional tidal wave harmonics come into play causing the incidental occurrence of two temperature peaks in the nighttime temperature data.

Closing Thoughts

Over the years my research has focused upon the wind and temperature dynamics of atmosphere regions for those layers above 80 km such as the mesosphere and lower thermosphere (80 to 105 km) or above 200 km for the thermosphere. As this essay has illustrated, it has taken a degree of passion on my part mixed with drive and dedication to achieve all this. I had a passion for hardware and instruments from the beginning in graduate school and MIT days. I remember how much I enjoyed the class of analytical chemistry 5.091 in

my senior year, where we dealt with a variety of instruments including the spectrophotometer and gas chromatograph.

However, one of the things I learned as an early career scientist was that any funding proposal submitted to get research funding must focus upon the science rather than the instrument that one might use to make the measurement of the science data. Although I might be quite keen to write about the instrument, especially one that to my mind is as elegant as the FPI, this information is not what is of interest to my space physics colleagues. If I wanted to get their blessings regarding my research goals and consequently, good proposal reviews, I needed to be convincing and explain clearly why the science that I do was important and potentially transformative. Once I have presented these goals and laid out a research plan that shows a clear path toward closure, i.e., actually achieving the success imagined, only then is it OK to describe the instrument at a level of detail necessary to convince my audience that the path toward closure is indeed possible and feasible.



One of the highlights of visiting Fairbanks was meeting with friends. Here is a photograph of me with Dr. Don Hampton (left), a colleague associated with the Geophysical Institute geospace group. We went to visit the exhibits of the Ice Sculpture Festival that is held every March to help celebrate the end of winter and the first day of spring.

I need to call attention to the many colleagues that worked with me in achieving first light of a Fabry-Perot observatory at so many locations that I made reference to in this essay. On this list are the engineers and technicians at SPRL, in Alaska (Geophysical Institute) and Greenland, my mentor Paul Hays who started me on this career path, and especially at the Physics Department machine shop at Clemson University, and especially, from our classmate, Peter Sherwood. I also had help from many students during the years that I was Professor at Clemson. I remember one undergraduate student who when he graduated, he spent a year working on a part time basis with me as a research assistant. I sent him along with another student to help install a FPI in Peru near Lima, at a location that became known as MeriHill. He left to go to graduate school in Canada and became a medical physicist operating a linear accelerator. In another case a woman that took my Optics class spent the following summer working with me. Her family lived in Nova Scotia, CA. Inspired by our conversations with her about her home, my wife and I took a vacation in Halifax and went north to explore the country coastline on the west coast of Cape Breton where her family lived. We were treated to a nice lobster luncheon prepared by her mother and sister.

Because I had done my best along with my colleagues to publish our findings combined with numerous presentations at conferences, I had become regarded as an expert in aeronomy. I never really thought of myself in such terms. It was more that a body of research resulted in new knowledge that I did my best to publish. I have always regarded publication as being a duty and obligation because my work was supported primarily by government funding from the National Science Foundation. It is hard to justify continued funding if you do not expend the time, energy, and resources to publish your findings and conclusions. So, the number of papers increased from year to year, and at last count, this number exceeded 200. A substantive sustained level of productivity, yes, but these contributions were also well regarded. Still, I did not take myself to be anything other than an active researcher.

One August evening in 2019 I was checking through my emails and was faced with an email from the American Geophysical Union. What is this, I asked myself. I read the message and found that I had been elected to be a member of the AGU 2019 Class of AGU Fellows. This is an honor that is received by a rather small fraction of AGU members to recognize research contributions that are thought to be particularly noteworthy. I had no clue that this activity was going on. In fact, I had retired from academic teaching in the summer of 2015, though I continued working at the National Science Foundation as the Geospace Facility Program Officer. It was a nice surprise, and it led to a ceremonial celebration at the AGU 100th Fall Meeting in December 2019. By a strange coincidence, one of my classmates in the chemical physics graduate program at the Univ. of Maryland also received this honor. It was quite an experience for us both to be called upon to march up to the podium in tuxedo with a bow tie to receive a plaque and a medal. My citation read: "*For fundamental contributions to understanding the thermal and dynamical structures in Earth's upper atmosphere*."

To come back to the theme of this essay, a question to ask is how much of my experience represents an experience that applies across the board to all of us. I did not anticipate the technological changes that came forward these past five decades, namely, the PC, the internet, expansion of hard disk data storage capacity, and the condensed matter technology that is represented by the CCD camera chip. These are major changes that affected all of us.

My own experience is more that as I became aware of these innovations and developments, I sought to introduce them into my research. I was able to time my efforts to learn and adapt the new technology to the needs that I had. Thus, learning to use the new technology proved to not be too much trouble. In doing so, though, I was rather unaware of how potentially valuable the enhanced sensitivity of the FPI would be to achieving new science. This leads into the question – can one always assume that new technology translates into new science that represents significant advances? That is the faith that we all have, and it is a philosophy that MIT advocates pretty much from day 1 of our education.

There is one last issue though to be raised in regard to discussions about the role of technology in attacking society problems. Changes in technology might not always constitute progress that rewards the investment made in the new technology. I am thinking here about tipping points involving paradigm shifts. The technology developed through incre-

mental change might in the end not be worthwhile because it has been rendered obsolete by some other technological solution.

One example that particularly comes to mind is one that I was wondering about when I was a senior at MIT. In early May 1964, I took it upon myself to go see Prof. Jerome Hunsaker who at the time was the chair of the MIT Aerospace Engineering Department. In my visit I spent a few minutes asking him about what he knew of Uncle Jack. His response was somewhat guarded, but he indicated that he had had dinner several times with him and my great aunt Cary. I then asked him to satisfy my curiosity as to whether Uncle Jack had ever thought of developing jet engines as an alternative means of propulsion for airplanes. Such a technology was demonstrated by the Germans in the closing days of WWII. Dr. Hunsaker's response was negative. I got the impression that he thought Uncle Jack's vision in the late 30s was too narrow to think on a broader front. Perhaps the reason was that Uncle Jack knew then that there was still a long way to go to have a jet engine that could successfully be flown. Perhaps the real reason was that Uncle Jack's own passion was focused upon the continued development of the aircraft engine. He could not bring himself to view aircraft propulsion development in any other way beyond the horizon of the combustion engine.

Thus, in regard to technology issues, to my mind one has to exercise judgement. To ensure that your chances of making the right call are good, one has to be continually engaged in studying how the two disciplines of engineering and science intertwine and reinforce each other. To me this was the real grasp of technology that informed Rogers' vision to focus upon technology as the *raison d'etre* for MIT educating and training the new generation of talented students.

A lifetime of notebooks and collection of memorabilia including my first Apple Macintosh computer obtained in 1987.

John Meriwether '64 Course V, Chemistry; PhD, chemical physics at University of Maryland in 1970. He held postdoctoral positions at the NASA Goddard Space Flight Center and at the High Altitude Research Laboratory, University of Michigan. He married Erika in August 1973, and then became a research associate at Arecibo Observatory for four years. After 8 years at the Space Physics Research Laboratory at the University of Michigan and four years at the Air Force Geophysics Laboratory in Bedford, MA, in 1992 he became Associate Professor of Physics and Astronomy at Clemson University, South Carolina. He was promoted to Professor and received tenure in 1998. He retired from teaching in 2015 and became a NSF program officer, Geospace Facilities, in the summer of 2015. He was appointed Distinguished Research Professor, Center of Solar Terrestrial Research, New Jersey Institute of Technology in the fall of 2019. He was elected to be an AGU Fellow in December 2019. He and Erika have one son, Alexander, who is now the office manager of the Harvard Book Store. John is a keen enthusiast of folk music sung by the singers from his generation, Joan Baez, Judy Collins, and Peter, Paul, and Mary. He also has a strong interest in classical music with particular reference to Beethoven, Mozart, Shubert, Bach, and Stravinsky.

Prolonged Exposure to Super Conductivity Can Lower Your Resistance

Bruce Strauss

Introduction

For Fathers' Day in 2002, my daughter, Lori, gave me a book edited by Marlo Thomas entitled "The Right Words at the Right Time." Looking over my professional life, I have found that the "Right Words" have made a difference and have been turning points.

Starting back in my young childhood, I was interested in planes and mentioned to my father that when I grew up, I was going to be a pilot. Dad thought about that for a few moments and said, "I don't think you will be a pilot; I think you will design planes." So much for top gun, but that statement certainly changed how I looked at the world and why things worked. As a teenager, I obtained a HAM license and enjoyed having short conversations with others worldwide. Dad was impressed when I got accepted to MIT, although I think he would have preferred something more Ivy League.

The first semester at MIT was a frontal attack on my ego. This was especially true as going from near the top of my high school class to wondering if I would flunk out. Things changed in the second semester when I took an introductory materials science class taught by Prof. John Wulff. Wulff was a professor of the old school who lectured in a dark suit and tie. In one of the first lectures, he walked in and stated, *"Gentlemen. Mark this down in your notebooks. Bell Labs just published a paper in Applied Physics Letters about Nb3Sn (Niobium Tin) wire wound into a small magnet. This news will have an impact on your careers."* He had been working on similar materials. Three years later, I found myself in his group doing my undergraduate thesis on the effects of strain on the superconducting magnetic properties of pure, electron beam zone melted Niobium. The experiment showed a transition from Type I superconductivity to Type II. [74] The group liked the work so much that I was invited to join them as a graduate student.

Besides John Wulff, the other Professor in the group was Bob Rose in his first years as an Assistant Professor. Both of them had an interesting philosophy that the following statement could summarize: *"Statistically you probably will not win the Nobel Prize. However, we will train you to be a professional."* Lesson one came a few weeks later. As I was walking down the hall in building 35, I felt a firm hand on my elbow. Prof. Wulff steered me into his office, and I wondered what I had screwed up. He sat me down in a chair and announced that I had a lesson on being a professional. I started to get out a notebook, and Wulff said I would not need it. The lesson was on writing recommendations. Simply, *"Write recommen-*

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[74] A **type I superconductor** keeps out the whole magnetic field until a critical applied field Hc reached. Above that field a **type I superconductor** is no longer in its superconducting state. A **type II superconductor** will only keep the whole magnetic field out until a first critical field Hc1 is reached.

dations in the superlative or don't write them at all. You will never damn someone by faint praise." I was then given the assignment to write a recommendation for promotion for Bob Rose. He got the promotion.

As many people in technology come to understand that you will learn more techniques from senior technicians than from the academic staff. To that, I owe thanks to Irvin Puffer for this training. Mr. Puffer's first lesson was in vacuum technology. I was trying to stem a leak in a vacuum joint by painting it over with Glyptal varnish. Mr. Puffer came up to me and said, *"If you ever want to get your degree, you will never do that again."* He then trained me in proper vacuum technology, a skill set that has helped me over the rest of my career.

Mr. Puffer was one of those great technicians that designed the experimental apparatus on the lathe and milling machine. For my thesis, I needed to clone a vibrating sample magnetometer designed by Si Foner of the MIT magnet lab. I went into Puff's office late one afternoon and showed him Foner's article in the *Review of Scientific Instruments* and asked if we could duplicate it. He said, "tomorrow morning." I wondered why we could not start immediately, and he noted that it was five minutes to quitting time. At 7:30 the following day, we were sharing cups of coffee. Puffer made a list of purchases, and we started touring local vendors and shops. The first stop was Radio Shack to purchase a 4-inch diameter speaker that would serve as a sample actuator. The next stop was a restaurant supply store buying a bain-marie pot as a vacuum chamber. A stop at a metals shop yielded a brass plate to be used as a vacuum flange. When we got back to the lab, Puffer chucked the brass plate into the lathe. A few moments later, he took out his O-ring tool, measured the groove's diameter, and sent me out to purchase an exact fit O-ring. The next stop was to fabricate a Teflon coil form to make the matched pickup coils. I was taking data that afternoon. The vibrating sample magnetometer took all of the data for my doctoral thesis.

My thesis measured the proximity effect in a niobium (Nb) and copper (Cu) composite. The niobium filaments were only several angstrom units in diameter. With such small filaments and inter-filament spacing, I could extend the superconducting wave function into the copper matrix. The experiment was published in the *Journal of Applied Physics* and the micrograph of the composite was the picture on the front page.

AVCO Everett Research Laboratory

My first job after getting my doctorate was at the Avco Everett Research Laboratory. The laboratory director was Dr. Arthur Kantrowitz, whose claim to fame was the invention of the ablative heat shield used during the reentry of vehicles returning from orbit or space. The other person of note at the laboratory was Dr. John Steckly, who had developed the method cryogenic stability for superconducting wires and magnets.

While high field superconductivity was announced in 1961, the first attempts at reliable superconducting solenoid magnets were unsuccessful. The magnets would spontaneously revert to the normal conducting state or quench. Steckly's approach was quite simple. He did not care about the cause of the quench. Instead, by cladding the superconductor with enough copper, the composite could be cooled by the liquid Helium without a thermal runaway. There was a balance of I^2R heating in the wire and cooling by the liquid Helium.

I was assigned to supervise the cooling and operation of the 10-foot-long superconducting dipole magnet that had been constructed at the lab. Using techniques that I was trained to do at MIT, I started to pre-cool the magnet with liquid nitrogen. When John Steckly saw that, he inquired as to what I was doing. After I explained, he told me to count the number of technicians standing around waiting for the cooldown and explained that their wages were much more expensive than the Helium that we might lose. This was my first lesson in commercial economics.

My other work was on advanced approaches to stability. The newer methods concentrated on preventing quenches using smaller filaments and twisting to decouple eddy currents. Our work generated a paper in the 1968 Brookhaven Summer Study.

My second daughter was born in March 1968. AVCO Everett lost all of their superconductor related grants shortly after and had a large layoff. Seven months after graduating I was without a job. A round of interviews resulted in an offer from the Argonne National Laboratory in Lemont, Illinois and a subsequent move to the Midwest.

Argonne National Laboratory

I started at Argonne the first week of July 1968 after driving from New Jersey. The first item of business after signing in was a physical exam. It was one of the shortest physicals that I ever had. The doctor put a stethoscope on my chest and said that I was fit for service except for one thing. He stated that I had a chronic case of Charles River Fever. He explained that he couldn't figure out why I was sitting on an exam table very far from the smelling distance of the Charles. He was one of the great diagnosticians.

The construction of the very large, 12-foot diameter, superconducting solenoid for the Argonne bubble chamber was just finished. As the new kid on the block, I was assigned as the chief operator for its first run. The data was strange until we realized that the top coil was operating in gaseous Helium.

Because superconducting magnets in ramped magnetic fields do show eddy current losses, Argonne proposed to build a fixed field alternating gradient (FFAG) accelerator. Being new to this technology I was told that the magnetic fields had to be perfect. A little bit of engineering design indicated that due to mechanical constraints this would be very hard. I went to speak with Bob Lari who was in charge of measuring the magnet fields of the accelerator dipole and quadrupole magnets. I asked if he had ever measured a perfect magnet. He laughed, pointed to my glasses, and stated that the good Lord didn't make perfect lenses either. This was a great lesson in engineering design. Make it close enough and learn how to correct it.

I stayed at Argonne National Laboratory for a year and moved to what was then the National Accelerator Laboratory (NAL) in Batavia, Illinois.

The National Accelerator Laboratory

NAL was about a year old and construction has begun on the four-mile circumference main ring along with projects for the injector string. This injector string consisted of a Cockroft

Walton pre-accelerator, a linear accelerator, a booster ring, and the main ring. My first assignment at NAL was with the experimental facilities group. The major superconducting project was for the 15-foot diameter hydrogen bubble chamber. Superconducting magnets were not considered for the main ring due to the immaturity of the technology, a wise decision.

At some point, everyone in the lab was assigned to the main ring group in a frontal effort to finish construction on schedule. I was able to solve a significant problem. The quadrupole or focusing magnets developed a vacuum leak in the stainless-steel beam tube about three months after they were installed. The cause of the leak is an interesting story. The main ring tunnel was sited 20-feet below the prairie surface. Construction was cut and fill, and pre-cast concrete tunnel sections were then lowered onto a concrete base and covered with earth so that the vertical loading was no different from pre-construction. The earth berm was an excellent thermal insulator, and the interior temperature of the tunnel was well below the dew point the following summer. In effect, a four-mile circular grotto was constructed with high humidity and water condensing and dripping on the magnets as they were installed. The quadrupoles' challenge was a brazed joint for the water cooling was located directly over the vacuum beam tube. Unfortunately, the technicians who brazed the joint used a stainless-steel flux that had a very high halide content. The dripping water dissolved the flux, and it dripped onto the beam tube. A quick look at one of my old corrosion textbooks yielded the fact that halide ions pit through stainless at the rate of 0.001 inches per day. The leaks on the .090 thick beam tubes were right on time.

The workable solution to the issue was to clean the surface mechanically and spray the area with clear Krylon lacquer. Crude, but the accelerator worked for over 30 years until the machine was dismantled.

Russian Internal H_2 Gas Jet Target

After the Main Ring was in operation, one of my assignments was to participate in the "Internal Target Experiment." The target was a Russian-designed hydrogen gas jet internal to the ring that featured a liquid helium cryogenically cooled pump. The Russians sent a team of about six physicists over to run the experiment. I was one of the liaison physicists on the American side. My colleague on the other side was Yuri Pilipenko, the Russian cryogenic expert.

My ex-wife and I picked them up at O'Hare airport. Yuri was primarily quiet until we reached a toll booth. After I paid the toll, he remarked that they heard about capitalism, but these tolls were beyond comprehension.

We, on the American side, would soon be participants in meshing two cultures. Back in our lab, everyone gathered to unpack the several crates of equipment that our Soviet friends had shipped. One of my technicians smelled a strong scent of fish during this exercise. It was found to be smoked fish. He asked one of the Russians how they got it through customs. The Russian pointed to some Cyrillic on the crate, and the tech asked what that meant. The Russian said that the word was electronics and then held up the fish and asked, "don't you recognize electronics when you see it?"

The laboratory furnished our Russian visitors with rather large apartments on site. A few weeks after their arrival, I was invited for lunch. Pilipenko asked me why the refrigerator had such a large ice cube compartment when I entered the flat. I said that it was for frozen food, and he responded that frozen food did not exist in Russia. He concluded that the American refrigerators were a capitalist waste. Within a few weeks, he changed his mind. On my next visit, he opened the freezer section and stated, *"24 half liters of vodka cold one time."* I note that they could get Stoli at 50 cents a bottle from the PX at the Russian embassy.

I also learned not to get in a toasting contest with vodka.

We had another culture incident when the project needed some machine shop work and the lab shop was overloaded. The lab had a number of small shops on a retainer and it was usually faster and less expensive to use these resources. Pilipenko reacted badly and said that it would cost more due to the management overhead. Once the work order was let, I took him to the shop. The machinist was working on a large horizontal milling machine. I shouted, *"Floyd, shut off the machine I want you to meet a colleague."* Floyd did stop the machine and I introduced him to Pilipenko as the Vice President of the firm. I then shouted, *"Gladys, please come out of the office."* She came out of the office and I turned to Yuri and introduced her as the firm's president. So much for small business capitalism.

The TEVATRON

The accelerator complex was finished ahead of schedule and under budget. Management was soon proposing an upgrade to double the particle energy to 100 GeV, making one foot long and three feet long prototype superconducting magnets ramped up. Dave Sutter and I were the first two physicists assigned to the project, and we tested three to five of these prototypes a week.

I was assigned the responsibility of obtaining production quantities of the copper stabilized multi-filament superconducting wire. At the start of the project, two companies were fabricating the niobium-titanium (NbTi) alloy rods, three small companies assembling the composite billets, and there was a mature copper industry. We decided on a standardized cross-section for the strands. Given the small size of the billet assemblers and to gain some time on the production schedule, the laboratory decided to order the NbTi rods and supply them to our vendors. We also ordered the copper extrusion cans and hex of round id copper tubes to clad the NbTi rods.

At this point in my career, I was fortunate enough to be mentored by several people. After completing the specification packages. Andy Mravca, then in the DOE Site Office at Fermilab, called me and asked me to come to his office for coffee. We went through the specifications line by line, where he asked the question: "Do you need it or do you want it?" I wondered what the difference between the two was, and Mravca answered, *"I will move heaven and earth to get you what you need and fight you to my dying breath to make sure you get nothing of what you want."* We would up with a much crisper specification.

Ed West, head of Fermilab contracts, and I had another meeting. He asked me, "How do you want to manage this procurement?" He went on to say that he used to be a buyer for Studebaker automotive, and in his desk, there was a preprinted and unsigned resignation letter. The letter was to be used if any part he ordered held up the production line by 30 seconds. This was an excellent calibration for parts in a production line. The production was held up once for 15 minutes because of late delivery of cable due to a traffic jam between O'Hare Airport and Fermilab.

Paul Reardon totally understood the difference between small procurements during early development and total production. I was in Boston performing short sample test on early superconductor wires at the Bitter National Magnet Laboratory at MIT. Late in the afternoon, I received a phone call from Reardon instructing me to meet him in Portland. Good, I said I would drive up. He responded that he meant Portland, Oregon and that a ticket was waiting for me at Logan Airport. We met at the Portland Airport and drove to Albany, Oregon, Wah Chang's site, which made refractory alloys.

The morning was spent with a plant tour covering the manufacturing processes for NbTi alloys. After lunch, we got down to business. Reardon asked the Wah Chang rep the size of their manufacturing billet or lot. The value was about 500 pounds. Reardon then looked at the Wah Chang sales manager and said, "We'll take four. Have the cost proposal on Strauss's desk in two days." Such was the negotiation for what was then the single largest purchase of NbTi alloy. The alloy composition was Nb46.5Ti that happened to be the average numerical composition of alloys used by the existing domestic composite wire producers. The laboratory wanted to save time in the production process by supplying the raw materials to the composite wire manufacturers.

On the way back to Portland airport, Reardon told me to call John Buckley of Phelps Dodge as soon as we returned to the laboratory. I asked who John Buckley was, and Reardon replied that he was the best damn copper salesman in the USA. Several days later, I had ordered a boxcar full of CDA-101 copper. This was to be the most significant and purest bulk copper load at that time.

To use the NbTi and copper, some intermediate fabrication needed to be processed into intermediate shapes for assembly and manufacturing. The NbTi rods were shaped into 0.125 rods by Wah Chang and the copper was shaped into hex od and round id tubes. The copper was also made into 12-inch od extrusion cylinders by Janney Cylinder Company in Philadelphia. The NbTi rods were inserted into the hex copper tubes, and 2400 of the composite tubes were placed in a honeycomb pattern in the extrusion cans.

Assembly and subsequent processing to 0.028-inch diameter strands were accomplished by Intermagnetics General and Magnetic Corporation of America. The strands were then formed into a Rutherford cable by New England Electric Wire (NEEW) in Lisbon, New Hampshire. NEEW also insulated the cable with a Kapton tape and a barber pole b-stage epoxy tape.

There is a cute story regarding NEEW. The b-stage epoxy tape needed to be kept under refrigeration to keep the b-stage tape from curing. I called the NEEW VP of production, Bob Meserve, and asked him to buy a walk-in refrigerator to store the epoxy tape. I, of course, was going to cover the bill. He replied he wasn't going to do it. I knew that hunting season was starting in New Hampshire the next week and asked him where he would store his kill. He immediately replied that the refrigerator would be installed within a week.
The resulting particle accelerator operated for more than thirty years. It won many history of technology awards. I was proud to be the master of ceremonies for the IEEE History of Technology award's dedication. A picture of me giving the introduction to the plaque dedication and the plaque is shown below.

I left Fermilab in 1978 after my divorce and worked for Magnetic Corporation of America (MCA), a small fabricator of magnets and superconductor strand until 1985. When I arrived at MCA, it was funded by venture capitalists on a project that was to extract energy from the exhaust of power plants to suck power with an MHD channel. After determining that it would take 10 to 12 years to get the permitting in California for the demo plant, the proposal died.

MCA was eventually acquired by Johnson & Johnson, which wanted to enter the medical capital equipment business. We made one of the first prototype superconducting MRI solenoid magnets. The demonstration was successful at the Cleveland Clinic except for one challenge. The patient was obese and unfortunately got an attack of claustrophobia during the FDA demonstration. It took a very long time to extract the patient from the magnet tube.

After my tenure at MCA, I spent several years in management consulting with Bob Powers. The majority of our work was independent cost estimates for large high energy physics construction projects. Our largest project was the technical components, such as superconducting magnets, for the Superconducting Super Collider (SSC) constructed in Waxahachie, Texas. Our cost estimate was much more nearly correct than the project estimate. Our assessment was more than 40% higher than the project. This difference was due to many factors discussed below.

The SSC's most extensive line cost item was the ensemble of superconducting dipoles and quadrupoles for the main ring accelerator and the booster. The project team made several erroneous assumptions in estimation. First, the project rules were to use current costs. The project used a projected cost for the NbTi alloy, which was lower than the current market and broke its own costing rules. The second error was in the project's use of the learning curve to fabricate the magnets. The project used a learning curve constant of 20%. Powers and I found that the production of magnets for the HERA project in Germany was 8% for each of the three magnet fabricators. (Note that Toyota, a noted manufacturing company, has an 8% learning curve.) Secondly, the project applied this learning curve to all of the materials when it should only have been applied to the touch labor.

SSC management tried to fit their budget to a minor total to get congressional approval. This action and other factors caused the SSC to be eventually canceled when the actual costs were realized! A significant other factor was the magnets' industrialization that failed for many reasons, including technology transfer failure from the High Energy Physics labs.

After the SSC, I ran a small consulting company doing tax planning as well as program planning.

In 1997 Dave Sutter said that there was an opening at the US Department of Energy (DOE) for a program manager with a background in superconductivity. I joined in May of 1997 on an Intergovernmental Personnel Assignment (IPA) for a two-year assignment in Germantown, Maryland. This assignment was later extended by two years, after which I was offered a permanent position. I stayed at DOE for 21 years total.

There are several achievements at DOE of which I am proud. Dave Sutter and I initiated a development project to obtain fine filament Nb_3Sn. This composite superconductor configuration was needed, especially for particle accelerator magnets to minimize electrical ramping losses. The advanced design was successful and is the basis for accelerator magnets and magnets for high field NMR spectrometers. The conductor is also the basis for the conductor used for the ITER tokamak fusion toroids.

CERN also asked me to chair the procurement review team for the superconducting quadrupole and dipole magnets for the Large Hadron Collider on the French/Swiss border near Geneva. As a result of my committee's work, CERN arranged for on-site inspectors at each of the four industrial fabricators of the magnets. This action resulted from my statement to Prof. Mianni that vendors lie. A situation that he was not aware of. Of the over 1000 magnets needed for the LHC ring only three were rejected for quality reasons.

I had an exciting experience at DOE working with Prof. Sam Ting of MIT. He has the only high energy physics experiment on the International Space Station. All physics experiments have a big magnet around the detector to enable the physicists to measure the particles' energy and mass passing through the detector. Ting's first magnet was a superconducting solenoid chosen to provide the highest sensitivity. Since I was the magnet expert at DOE, I was assigned to oversee this magnet's procurement. During one of my visits to CERN, my wife Suzanne was with me, and I was to meet Ting on a Saturday morning to witness his magnet's cryogenic testing. Ting picked me up at our hotel in the morning and insisted that Suzanne come with us to his lab. While I was crawling under the magnet, he took Suzanne aside and gave her a lecture on his experiment. While we were leaving, Suzanne looked at me and remarked that he explained physics much better than I did. Unfortunately, the magnet's cryogenic design was faulty, and it was replaced by a permanent magnet set up.

A fringe benefit of this activity is that both Suzanne and I got two personal tours of the Kennedy Space Flight Center. These activities included a guided tour of one of the shuttles on the launch pad. We started at the nose cone and spiraled down to the base. The Shuttle is an imposing device!

Suzanne and I were invited to the Shuttle launch that carried Ting's experiment to the ISS. It was an incredible experience! Flying back to Washington, we sat next to the NASA director of launches, who was happy with Ting and DOE, and we were invited to the next launch. Since this was the last Shuttle launch, I asked if I could bring my grandchildren. We wound up with five of the eight of them at the next launch

I had an exciting experience on the committee that wrote the specifications for the ITER tokamak specifications. This procurement was interesting as the project received contributions in kind from several countries. The project could not work with the fabricators directly but had a commercial relationship with several "domestic agencies." We insisted on an in-process quality control system that calibrated short sample performance measure-

ments over all of the suppliers. This project, in total, was the world's largest procurement of Nb_3Sn strand.

Epilogue

Superconductivity, with its near zero resistance to the flow of current, is induced by extremely cold temperatures. Progress in superconductivity has enabled the construction of ever larger accelerators. When I was an undergraduate at MIT, high field superconductivity was announced in 1961, and the first attempts at reliable superconducting solenoid magnets were unsuccessful. Opened in 2008, CERN's Large Hadron Collider on the French/Swiss border near Geneva is the world's largest and highest high-energy particle collider in the world, and uses many superconducting quadrupole and dipole magnets.

For nearly fifty years, I have been on the organizing committee for significant conferences in the field of superconductivity. This activity has resulted in considerable travel to meetings in the US, Europe, and Asia. I have also become an expert on the logistics of providing 1,500 attendees coffee in 20 minutes. Best of all, I have gathered friends and colleagues from around the globe.

So, Prof. Wulff was prophetic. Superconductivity has shaped my professional career and has lowered my resistance.

Bruce Strauss '64 Course 3, Metallurgy; '67 PhD., '72 MBA University of Chicago, has spent his career working with magnets as a scientist and project administrator.

The Changing Face of Atmospheric Sciences

Marvin A. Geller

My Entry to the Atmospheric Sciences in 1964

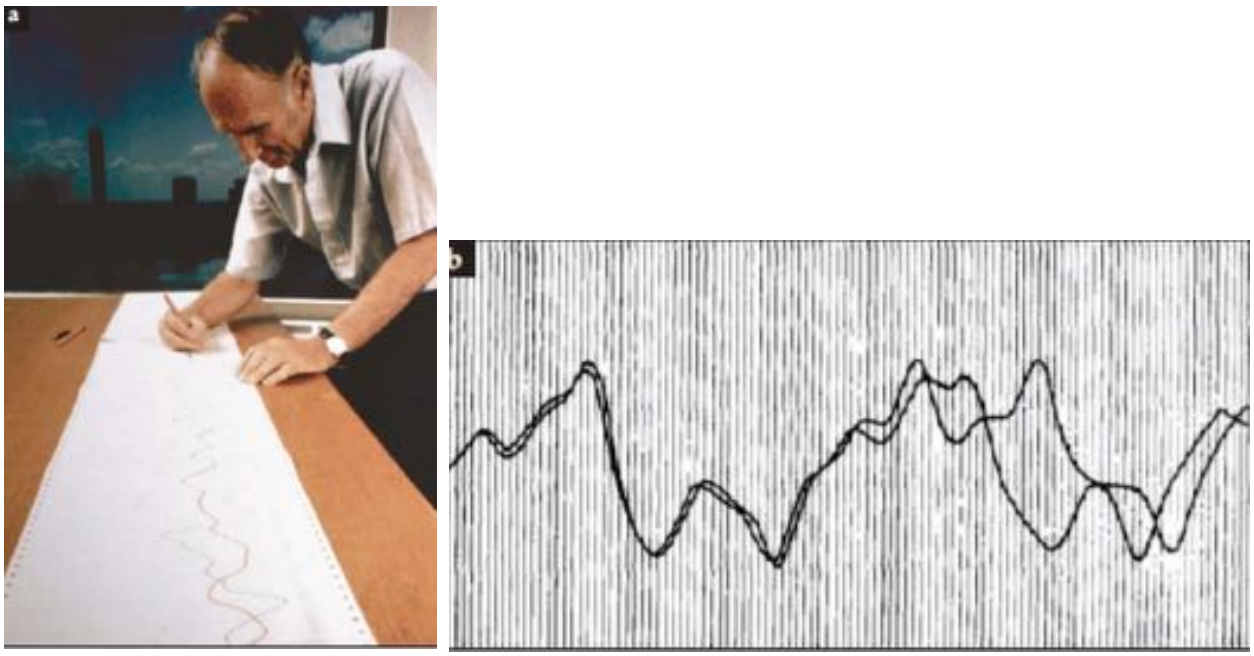
Personal circumstances led me to a career in the atmospheric sciences. As I prepared to graduate from MIT in the spring of 1964 with a BS in Applied Mathematics, my mother lay dying of cancer in a Boston hospital (my father had died the summer after my freshman year) disrupting my plans to study partial differential equations for my PhD in the Applied Mathematics Department at the University of Colorado. I had accepted a teaching assistantship, but not knowing how much time my mother had left, I wanted to remain in the Boston/Cambridge area (she did pass away that summer). I sought the advice of Professor C. C. Lin, an eminent MIT professor from whom I had taken courses. He recommended I see a colleague who "was a pretty good applied mathematician and seemed to have made quite a name for himself in the field of meteorology," Professor Jule Charney. Unknown to me, Professor Charney was regarded as the top meteorologist in the world at that time. He and John von Neumann led the group at Princeton University that produced the world's first numerical weather forecasts. Amazingly, Professor Charney arranged for me to be accepted as a graduate student in MIT's Department of Meteorology. Not knowing much at all about the field of meteorology, I was quite unaware what a remarkable department in which I was enrolling. That department included not only Jule Charney, but also Ed Lorenz, who originated chaos theory (more about that later), Henry Stommel, the first to explain the physics behind the Gulf Stream, Victor Starr, who became my PhD advisor, and several other eminent meteorologists.

The world was very different in 1964. I still remember my first classes in synoptic meteorology (weather analysis) with Professor Fred Sanders. Part of this course was learning how to read station meteorology reports on the teletype (remember them?). I was shocked to see reports on the winds and temperatures at flight levels over Moscow and Beijing, handy information for those considering an air attack on those cities. That experience introduced me to the global nature of the field where there was good international cooperation among countries that were not so cooperative in other ways. For those who are unaware, one of the earliest moves of the United Nations was the establishment of the World Meteorological Organization for free and open exchange of meteorological data (a fact that surprises some US politicians, even now). Little did I know at that time how much I would come to value the global nature of my field of study. During the decades that followed, I developed many precious friendships with atmospheric science colleagues all over the world, and I still have close relationships with many of them.

When I started graduate study in meteorology, the field consisted largely of large-scale fluid dynamics, radiative transfer, cloud physics, and some upper atmosphere physics. Also, the relatively new field of numerical weather prediction (the first numerical weather forecasts were made in 1950) was considered to be deterministic; that is to say, starting from an observed initial condition, the governing equations could be integrated forward in time to forecast the future state. This has all changed greatly during my career in that the probabilistic nature of numerical weather prediction is better appreciated.

Changes in the Field in the Following Decade

Lorenz (1963) illustrated that a relatively simple system of nonlinear, differential equations showed non-predictive behavior in that solutions from initial conditions that differed very slightly, when integrated forward in time, departed greatly from one another so that one could no longer tell they started from very similar initial states. Interestingly, in 1961 Lorenz had his first experience with a chaotic system when he was simulating weather patterns with a model with twelve variables. He was repeating a simulation, and to save time he started the simulation midway through a previous simulation. To his surprise, the simulation gave completely different results. He traced the cause for this to the fact that the computer simulation used 6-digit precision, but the simulation he started midway used the 3-digit precision from his printout.



Left - Professor Edward Lorenz examining his 1961 computer integration. Right - An image of his original 1961 integration showing the departure of the solution caused by using a 3-digit rounded initial condition rather than the 6-digit accuracy of the original computer simulation. Taken from Motter and Campbell (2013).

In 1975, the mathematician James A. Yorke named the theory for this type of behavior "chaos theory." Given the impact of chaos theory in many fields, it is interesting to note that the Lorenz (1963) paper that started it all was cited only three times outside of the meteorological community in the decade following its publication, but it has now been cited more than 23,000 times! Now, we greatly appreciate the probabilistic nature of numerical weather prediction. More plentiful meteorological observations have better quality than in the 1960s, but are not perfect. Furthermore, given the nature of numerical weather prediction, point observations characterize larger regions of the numerical model, thus imperfectly representing that model region. Also, the somewhat uncertain physical formulations in the model leave us with an initial condition that might be characterized as a region in probability space centered on our best guess, a somewhat

uncertain model, and chaos theory, which ultimately leads to uncertainty in the predicted outcome.[75] All of this is reasonably understood, and formalisms have been developed in which numerical weather prediction models not only predict the most likely outcome but also the level of uncertainty of the prediction. This has ramifications ranging for those planning the family picnic to those arranging industrial transportation schedules.

The increasing importance of meteorological satellites created another big change in the field of meteorology. One event that shaped the evolution of science was the launch of the Sputnik satellite in 1957. This, and the Cold War, led to increased US science funding from which I have benefitted in many ways, including graduate support from NASA, National Defense Education loans, and federal funding for my research over my career. The Sputnik launch was followed shortly thereafter by the launch of TIROS-1 (Television Infrared Observation Satellite) in 1960, the first meteorological satellite. Before that time, there were few meteorological observations over the ocean and in the Southern Hemisphere. Over the next several decades, the number and sophistication of meteorological satellites have evolved tremendously. I have been involved in three atmospheric science satellite missions. One was UARS (the Upper Atmosphere Research Satellite), launched in 1991. This satellite mission was motivated by concern about stratospheric ozone (more about that later). Another was TOMS (Total Ozone Mapping Spectrometer). While I was Chief of NASA Goddard Space Flight Center's Laboratory for Atmospheres during the period 1985-1989, that laboratory was the scientific home for the TOMS instrument. Finally, during my period of being Laboratory Chief, the TRMM (Tropical Rainfall Measurement Mission) was conceived as a joint US-Japan satellite mission, and I was very much involved in preliminary studies and concepts for that mission, which was launched in 1997, and operated for over seventeen years. Rainfall, perhaps the most obvious meteorological phenomenon, is also one of the most difficult to measure globally because of its sporadic nature in both time and space, and the fact that much of the global rainfall occurs over the oceans. Characterization of global rainfall is very important because the condensation of water in the atmosphere, leading to rainfall, releases great amounts of energy into the atmosphere and serves as an energy source for hurricanes. Atmospheric observations by satellite have both improved weather prediction and led to a much-improved understanding of atmospheric processes.

Atmospheric chemistry has been around for a long time, but it wasn't considered a mainstream subject when I was in graduate school. In fact, no atmospheric chemistry course was offered at MIT at that time. This fundamentally changed when air pollution became a major societal concern. Perhaps though, the biggest revolution in atmospheric chemistry came about as a result of the classic paper of Molina and Rowland (1974). This paper suggested that chlorofluorocarbons (widely used for many applications), while having an extremely long lifetime in the troposphere, were dissociated in the stratosphere, thereby catalytically destroying stratospheric ozone. Ultimately, this plus discovery of the Antarctic Ozone Hole by Farman et al. (1985) led to the adoption of the Montreal Protocol in 1987. One can easily see how the depth of the Antarctic

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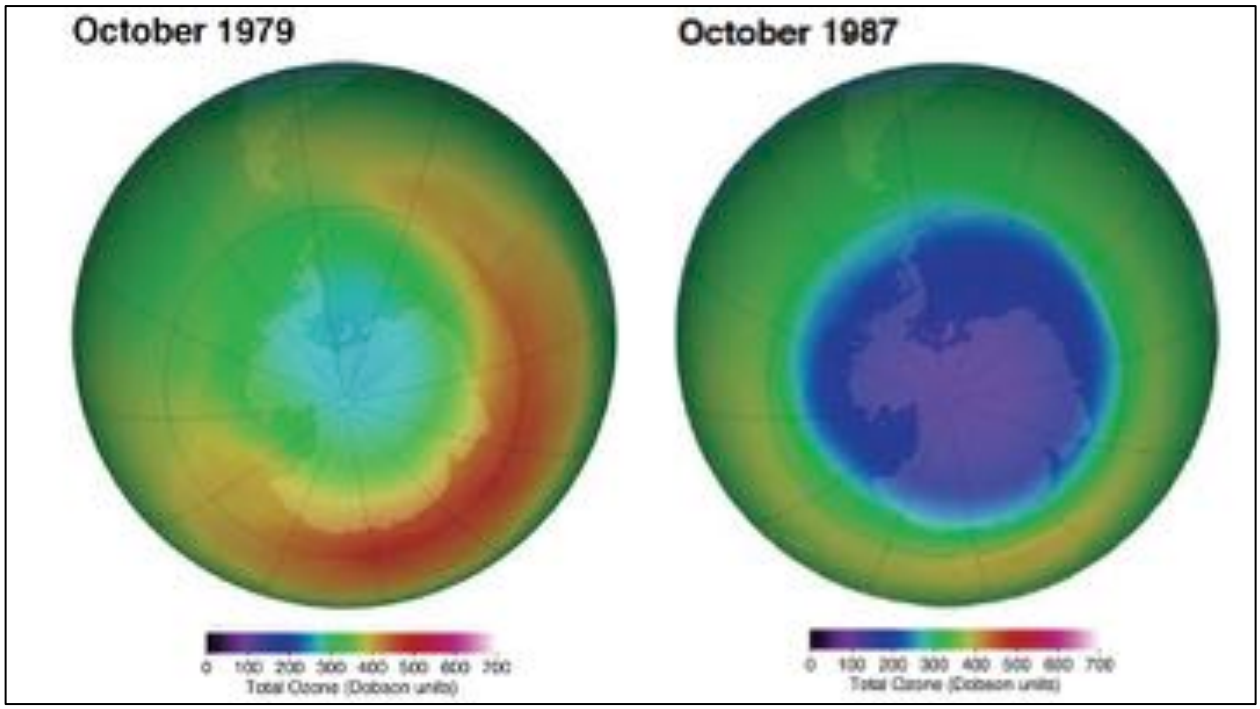
[75] Perhaps, the most familiar manifestation of this is the hurricane track forecasts we see on television. Clearly, a hurricane track forecast in which all the tracks are tightly clustered is more certain than one in which there is great dispersal in the tracks.

Ozone Hole increased by comparing it in 1979 to it in 1987, the year of the adoption of the Montreal Protocol.



Images of total ozone over the Southern Hemisphere for the months of October 1979 and October 1987. Maps show column ozone amounts in Dobson Units, which are units for the depth of the ozone layer in units of 10 mm if the ozone were brought to standard temperature and pressure. Images from NASA website.

This protocol, and subsequent amendments to it, led to discontinuation of production of chloro-fluorocarbons and other ozone-destroying chemicals. The 1995 Nobel Prize in Chemistry was awarded to Drs. Paul J. Crutzen, Mario J. Molina, and F. Sherwood Rowland for "for their work in atmospheric chemistry, particularly concerning the formation and decomposition of ozone." I would guess that almost every atmospheric science department in the world now offers courses in atmospheric chemistry. These developments had a great impact on my career. In the late 1970s, while on the faculty of the University of Illinois at Urbana-Champaign, I was invited to be a member of a NASA Goddard Space Flight Center committee to investigate the need for a satellite to study stratospheric ozone. Later, this was transformed into a NASA committee to formulate the science plans for such a satellite. While on the faculty of the University of Miami, I was selected to be a Principal Investigator on the UARS satellite mission. I left the University of Miami in 1980 to work at NASA's Goddard Space Flight Center heading a group to develop global models of atmospheric dynamics and chemistry. The launch of UARS was delayed until 1991 due to a halt in NASA shuttle operations resulting from the Challenger catastrophic launch disaster in 1986. I left NASA's Goddard Space Flight Center for Stony Brook University in 1989, so my research and that of my students using UARS data took place there. Planning for the UARS mission and research using UARS data were highlights of my career.

Some of My Contributions

While working at the Goddard Space Flight Center, I was privileged to take part in building the international consensus to adopt the Montreal Protocol. I, along with Bob Watson and others, visited the Soviet Union, Japan, and Kenya to explain the findings that resulted from the WMO/UNEP (World Meteorological Organization/United Nations Environmental Program) Assessment Report on Atmospheric Ozone to scientists from those and other nations. This helped set the stage for the Montreal Protocol, which was finalized in 1987. Velders et al. (2007) have indicated that the Montreal Protocol resulted in decreases in the radiative forcing of the climate system that was larger than would have been achieved by the reduction targets of the first commitment period of the Kyoto Protocol. Concerns about the greenhouse warming of the Earth's climate began with the early warnings of Arrhenious (1896). In 1979, Jule Charney chaired an ad hoc study group of the National Research Council, which wrote the report on "Carbon Dioxide and Climate: A Scientific Assessment." Their conclusions (NAS 1979) were that a doubling of the concentrations of carbon dioxide would result in "a global surface warming of about 3 °C, with greater increases at high latitudes," a result that is broadly consistent with today's estimates using more sophisticated climate models, as well as with observed changes. Since that time, there have been various international efforts to arrest this anticipated climate warming and its deleterious effects, and taking effective international actions to do so remains one of the world's greatest challenges.

Going back in time to my years in graduate school at MIT. In 1968, I was finishing my PhD dissertation, and was looking for an academic position. One of the offers I received was from the University of Illinois at Urbana-Champaign's (UIUC's) Electrical Engineering department. This was a bit odd, since the only courses I had ever taken in Electrical Engineering at MIT were on computer programming. The position involved research in the UIUC Aeronomy Laboratory, which studied the earth's ionosphere. At that time, it was well appreciated that understanding ionospheric structure involved ion chemistry, but the importance of atmospheric dynamics was just beginning, and I was to be the atmospheric dynamicist in that laboratory. I was uncertain whether I should undertake such a research path, so I consulted with Professor Norman Phillips in MIT's Meteorology Department on the wisdom of taking that position.

Marvin Geller lecturing at the blackboard in 1976 at the University of Illinois at Urbana-Champaign. Image taken from website on the history of the Atmospheric Sciences department at the University of Illinois at Urbana-Champaign.

I remember well him saying to me that there was a long history of ionospheric measurements, and there must be valuable information on atmospheric dynamics in those measurements. Those measurements started with the work of Sir Edward Appleton, who won the 1947 Nobel Prize in Physics "for his investigations of the physics of the upper atmosphere especially for the discovery of the so-called Appleton layer," Furthermore, I was aware that the UIUC was establishing a program in the atmospheric sciences. It was at the Aeronomy Laboratory where I became increasingly familiar with radar measurements of the ionosphere. A very interesting development occurred while I was at the UIUC. The Jicamarca Radar Observatory in Peru was built in the early 1960s for incoherent scatter measurements of the ionosphere, in which a powerful radar signal

scatters off of the free electrons in the ionospheric plasma, allowing measurement of such parameters as electron and ion temperatures and velocities as well as number densities of electrons and ions.

Image of Jicamarca Radar, located outside of Lima, Peru. Its antenna has approximate dimensions of 300m x 300 m, and is composed of 18,432 half wavelength dipoles. Its transmitter operates at a frequency of 49.9 MHz with 1.5 MW peak power. Image taken from Wikipedia.

Woodman and Guillen (1974) showed the first measurements of neutral winds in the stratosphere and mesosphere using Jicamarca data. Since that time, a number of powerful MST (Mesosphere-Stratosphere-Troposphere) radars have been built in the tropics, at midlatitudes, in the Arctic, and in the Antarctic. Less powerful radars allow wind measurements in the troposphere and stratosphere, and are known as ST (Stratosphere-Troposphere) radars, and such ST radars have been deployed around the world to give operational wind measurements. Interestingly and personally, while at the UIUC, I received a National Science Foundation grant to establish a meteor winds radar using the facility that Bowles (1958) used to obtain the first incoherent scatter radar measurements. Meteor radar measurements had been used since the 1950s to study winds at altitudes around 95 km by examining the Doppler shift of the radar returns from the ionized trail produced by meteoroids burning up as they enter the Earth's atmosphere.

I have done research on subjects ranging from ionospheric dynamics to subsurface soil moisture, but the bulk of my work has been related to atmospheric waves. These waves have many manifestations, ranging from the undulations in large-scale atmospheric pres-

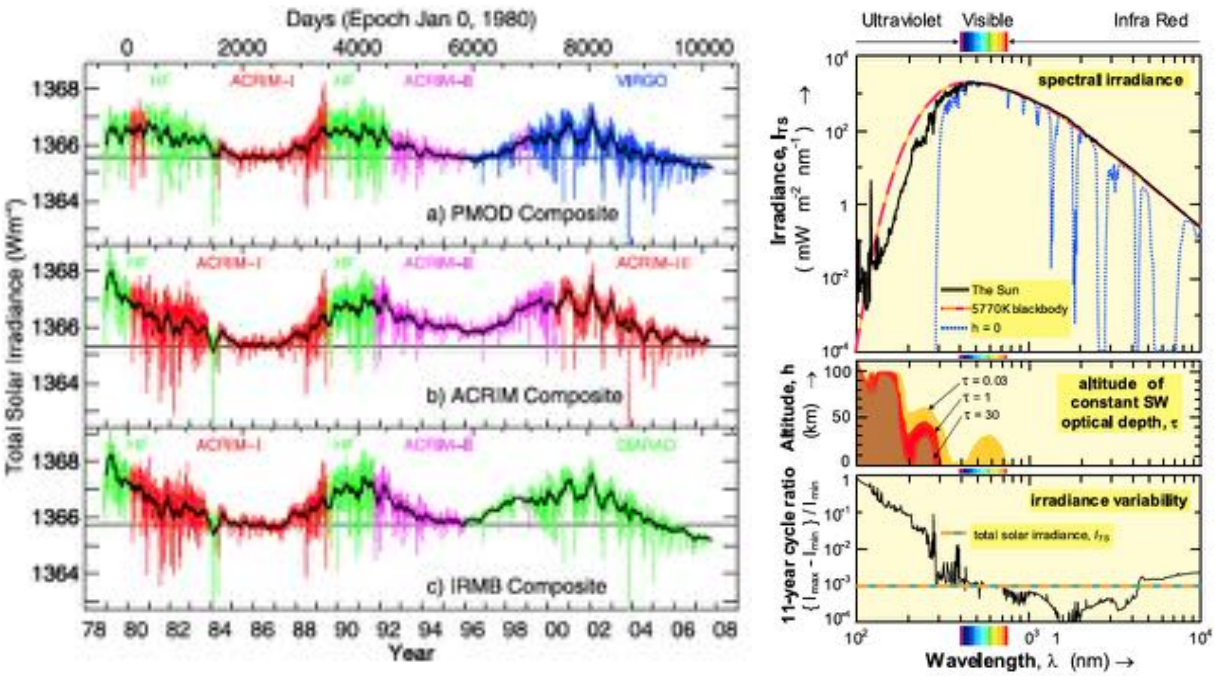
sure patterns to small-scale atmospheric oscillations that are forced by convective clouds and flow over mountains. Evidence of these small-scale waves can often be seen in cloud patterns.

Wave pattern in clouds as a manifestation of atmospheric gravity waves. Picture taken by my wife, Lynda Geller, near our Florida home.

The large-scale undulations in atmospheric pressure patterns are called planetary waves, and changes in their configuration are accompanied by changes in regional weather. Planetary wave propagation into the upper atmosphere has very important effects, and Jule Charney did fundamental research into this propagation. The gravitational attraction from the Sun and Moon and the Sun's heating of the atmosphere give rise to global-scale pressure and temperature oscillations, with periods associated with the Earth's rotation periods with respect to the Sun and Moon, that are called atmospheric tides. In fact, my PhD dissertation was on the lunar tide in the atmosphere. Smaller-scale atmospheric oscillations are called gravity waves, not to be confused with the gravitational waves that were predicted by Albert Einstein on the basis of his general theory of relativity. Atmospheric gravity waves exist by virtue of the atmosphere's stable stratification. If we consider an air parcel as analogous to a balloon, which is stably located at an altitude, and this air parcel is displaced vertically, it oscillates vertically about its equilibrium position in a stably stratified atmosphere. Atmospheric waves are important, not just because of their disturbances, but because waves can transport energy and momentum considerable distances without accompanying mass transports. Hines' (1960) classic paper showed that many atmospheric features were manifestations of atmospheric gravity waves and also illustrated many of the physical properties of these gravity waves. One fascinating atmospheric phenomenon that was discovered in the early 1960s was the discovery of the Quasi-Biennial Oscillation (QBO) by Ebdon (1960) and Reed et al. (1961). The QBO is a quasi-periodic fluctuation in tropical stratospheric zonal winds with a variable period that is about 28 months, on the average. The first theoretical explanation of its cause was given in the latter part of that decade, and relied upon tropical wave influences on the stratospheric zonal winds. I benefitted greatly from the great advances in the study of atmospheric waves. In fact, I have paid homage to my benefitting from those advances by giving occasional talks on "The 1960s, A Decade of Sex, Drugs, Rock and Roll, and … Advances in Middle Atmosphere Research."

Present day climate models used to assess such issues as what the climate consequences might be of various societal actions, or inactions, have evolved from atmospheric general circulation models. The first global, atmospheric model was constructed by Philips (1956). His idealized model used a simplified set of atmospheric equations and an idealized geometry. In the 1960s, more complex general circulation models were developed that used more complete atmospheric equations. Those models considered the different heat capacities of land and ocean, but few of the many complexities of the climate system were included in those early models. Present day climate models are much more sophisticated in that they include a dynamic ocean that has two-way interaction with the atmosphere. They also model the evolution of ice cover, and have idealized model treatments for soil moisture and the biosphere, so now we speak of Earth System Climate

Models. In considering the climate, various aspects of the Earth System have different degrees of "memory," in that they have different inherent time scales. For instance, the ocean, with its very large heat capacity, has a much longer "memory" than the atmosphere. Intermediate between the ocean and the atmosphere is soil moisture. After rainfall, moisture can be given up to the atmosphere for quite a long time, so climate models and medium-range weather forecasting models have treatments for evolving soil moisture. Another aspect of the climate system is solar variation. Satellite instruments have measured variations in solar radiation output reaching the Earth that follow the solar sunspot cycles, which have various periodicities, the most prominent of which is the 11-year sunspot cycle. The 11-year solar cycle has been shown to have an amplitude variation in solar light output of about 0.1 %. Solar light output at different wavelengths show different variation amplitudes, with variations in the short ultraviolet (UV) wavelengths showing considerably larger solar cycle variations than the variations of the longer wavelength visible radiation. Those UV wavelengths modulate stratospheric ozone amounts and heat the stratosphere. Current models for solar variations affecting climate consider the solar-cycle modulations in UV radiation, resulting variations in ozone and stratospheric temperatures, and the resulting variations in planetary waves that can have surface effects.[76]



Left - Various composites of satellite measurements of total solar irradiance; that is to say, the total energy reaching earth per unit area. Right-Top: Spectral irradiance; that is to say, the solar energy reaching Earth per unit area as a function of wavelength. Right-Middle: altitude to which irradiance penetrates into the Earth's atmo atmosphere. Right-Bottom: the fractional amplitude variation of the Sun's spectral irradiance at different wavelengths. From Gray et al. (2010).

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[76] I should emphasize here that while solar variations can produce measurable influence on the Earth's climate, those solar influences on climate are much smaller than the global warming attributed to increasing concentrations of greenhouse gases in the atmosphere.

While I have not spent the bulk of my career on soil moisture and solar-cycle influences on climate, I have contributed to those studies.

Closing Comments

In the preceding paragraphs, I have discussed various ways in which the atmospheric sciences have evolved since I finished my undergraduate studies at MIT in 1964, with emphasis on areas to which I contributed. In no way, should the advances I have discussed be taken as being exhaustive, however. Great advances have been made in forecasting severe storms, such as thunderstorms, tornadoes, and hurricanes. Tropical meteorology has advanced greatly, and long-range weather forecasting has advanced, particularly in understanding ocean-atmosphere interactions such as El Niño/Southern Oscillation in which changes in sea surface temperature patterns are related to changes in climate. While I have followed some of those advances, I have not myself participated in research in those areas in any great way.

It is now 56 years since I finished my undergraduate studies at MIT and 51 years since I completed my graduate studies, also at MIT. Although the personal circumstances that led me to study meteorology were not pleasant, what has followed in the five plus decades since has been very rewarding. I have supervised 20 PhD students at the University of Illinois at Urbana-Champaign, the University of Miami, and Stony Brook University, whose research have covered many topics, ranging from ionospheric dynamics to soil moisture, with most of the studies being concerned with the atmosphere in between. During my nine years at NASA's Goddard Space Flight Center, I was involved in exciting research on stratospheric ozone and was involved in three different satellite programs. I have atmospheric science colleagues all over the world, many of whom are good friends of mine. I have had a great career in the atmospheric sciences, and I'm not quite done yet. I still work on federal grants and publish papers. My professional life has worked out well for me, as has my personal life with a lovely wife, two wonderful children, and one delightful granddaughter.

Marv Geller, BS, '64 Course 18, Mathematics; PhD, '69 Meteorology (Course 19). Assistant Professor to Professor, University of Illinois at Urbana-Champaign, 1969-1977; Professor, University of Miami, 1977-1980; Space Scientist 1980-1985, Chief, Laboratory for Atmospheres, 1985-1989, NASA Goddard Space Flight; Professor, 1989-2015, Dean, 1998-2003, Stony Brook University. He retired from Stony Brook University in 2015, continues writing research papers and writing proposals for new research. Marv and Lynda Geller have been married 52 years. They have two children, Stephanie and Steven, and a granddaughter, Neala.

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Recreation

Left, A modern (Celestron) version of a 1960s vintage telescope on an equatorial mount with hand driven RA-DEC drive, which requires hand eye coordination of the mount to keep the object in view.

Below, The amateur astronomers of the 2020s have advanced mounts capable of carrying multiple telescopes with accurate guiding, high speed computing, exceptionally sensitive cameras, housed in remote observatories capturing images of celestial objects rivaling the best setups available in the 1960s.

Baghdad – Sleeping on Rooftops & Its Consequences

Viguen Ter-Minassian

I had the good fortune to be born on the shores of the Tigris in the heart of what is known as Mesopotamia, in the fairy tale capital of the One Thousand and One Nights, today's Baghdad the Capital of Iraq. During my childhood Baghdad was a cosmopolitan city, with a diverse ethnicity with people from many parts of the globe, small and large minorities, different trades, gold and silver smiths, tailors, engineers, and countless religious belief structures living in relative harmony. Population of Iraq at the time was no more than 4 million, Baghdad's population, anyone's best guess 500,000, perhaps less.

Naked Eye Observations – Just like the Ancients

One of the features of summer life was to sleep on the roof of the house. Baghdad's light pollution was practically zero. At night we had the luxury of seeing the stars and connecting the dots and creating our own constellations, the milky way was bright enough to cast a shadow. Seeing shooting starts was a common phenomenon, and on some occasion there were comets. Some lament the fact that modern technology has replaced the practice of sleeping on roofs with air conditioned bedrooms.

Eclipses are precise events. It is easy to pinpoint the exact time and date I saw my first partial eclipse of the sun. It was 1952 February 25 (Totality was in Basra, Iraq), I was in 6th grade elementary school, I recall vividly we were preparing viewing glasses by applying soot from candles on a piece of glass to be able to see this rare event. No one told us that you had to be an idiot to stare at the sun, even briefly with such contraptions, but we did. It had two lasting effects. The first was a fascination with celestial wonders. The second an impaired vision, many years later, at the MIT's clinic the ophthalmologist noticed a crescent like burn on my retina. Why should that stop a young mind from being fascinated by natural phenomena.

In the 50's there was a significant interest in Flying Saucers. People were reporting seeing such objects and went as far as making up stories about extra-terrestrials and Martians who surely were responsible for these sightings. Most were a hoax. Back on the roof one morning I did imagine seeing disk like objects, 5 of them near the horizon. It is easy to extrapolate what you read to what you might want to believe, after all you just had your own confirmation UFOs exist. Could there be a better explanation, there are atmospheric conditions that could generate disk like images, mirages are common where we lived, a natural phenomenon to explain my sightings made sense, that of aliens did not make sense.

Clouds and the imagination: vacationing in El Chalten Argentina in 1st of February 2012, I took the two photos of cloud formations, one close to sunset the other two days later 0n the 3rd.

Left: The blurry image of a saucer shaped cloud. Right: A daytime image of a similar cloud formation.

Effect of low frequency vibration on clouds.

The one on the 1st is somewhat obscure, allows the imagination to go in many directions, the one on the 3rd is clear as day, no imagination necessary it's a round cloud. There are many absolutely amazing clouds formations that become the subject of the imagination, like the one on the right, taken on the 2nd of February.

In 1957 October 4 came Sputnik. With that came an interest in Space and Rocketry. It was like catching the bug and building rockets was "***in***" for a few of us. After the Iraqi 1958 July 14 revolution, if you are caught with rockets, you were likely to end up in jail. As it turned out building rockets was a recipe to go to MIT. The Wests an American family were neighbors, Robert their son and I bonded, we had similar interest, we started designing solid fuel rockets, everything from scraps. The desert 40 miles out of Baghdad was our Cape Canaveral. Robert's brother, Burnell West (MIT '60) had come to visit his parents in Baghdad in '59, saw us with our well thought out contraptions and asked if I would consider going to an American University, MIT. I responded "What is MIT?". I did find the answer, and a year later I was walking across Harvard Bridge looking in complete amazement at the Dome as I crossed the Charles River.
I lived in Runkle first floor, where I met many wonderful friends, many of them became lifelong friends., inviting me to their homes, first, was Joseph Perkinson '64, with whom I traveled to his family's farm in Tennessee. Jason Fane '64 whose good advice I followed "Go for brains more than looks". I followed his advice. Peter Klock '65, I will never forget running

into him in front of Walker Memorial on that fateful day November 22, Pete telling me that Kennedy was assassinated. Ira Turner MIT '65, driving nonstop from Cambridge to Miami Florida, Christmas break '63. I will always remain grateful for his generosity.

A most memorable event was the Solar Eclipse 1963 July 20 Maine. Ira, three other MIT student and I decided to go to Maine to watch the Eclipse. Portland was in the path of the eclipse, the three passengers decided to get off in Portland, Ira and I kept going towards Greenville Maine, reaching it close to midnight, gas tank on empty, with no gas station open. We did find an airport and decided to take a chance. We drove to the airport, there was no attendant. This is Maine after all, they don't lock anything. Filled up with aviation fuel and voilà!

We stopped by the next day to pay for the gas we took the night before. At the time gasoline was about 30 cents/gallon.

The hotel we stayed at is still there. I remember the bill was about $3.50, I gave the cashier $20.00, and got back $17.50. I had to correct the cashier's counting skills. There were many other wonderful anecdotes, Maine is on a different planet. Ira and I wanted to canoe on Moosehead Lake, we stopped at a canoe rental shop but they had rented their last canoes, the owner of the outfit called several other outfitters found one and helped us reserve one for the morning, imaging getting that kind of treatment say in NYC in the 60s. Fortunately things are very different today in NYC.

It was getting cloudy, if we planned to see totality, all indications were that staying in Greenville was not a good idea, so we headed toward the Canadian border, on the way, meeting many astronomers with their telescopes properly aligned and anchored to the ground. In our case I had built a long pinhole telescope to safely view the projection of the sun's image at the bottom of the tube, it had a great advantage over the ones the astronomers we met would have, it was portable. The weather condition was looking questionable, we decided to drive closer to the Canadian border towards Sandy Bay and off on a dirt road. The conditions looked very favorable. First contact had started at 20:35 UT Totality where we had stopped would be at approximately 21:45 UT, (these times are not from memory, you can find these on the NASA sites, this is the beauty of how precisely you can tell when an eclipse will take place at particular spot on the planet). *Ira and I saw the totality of the eclipse of 1963 with all its glory*, the experience was better than that first youthful kiss. On our journey back, we saw the astronomers with their telescopes. They did not see Totality. Clouds had moved in just in time to ruin the show. It is my guess that in Maine or the entire USA, we were the only two that saw the totality of 1963. If the people in the customs house at Sandy Bay were looking, they probably saw it too.

Amateur Telescopes Grow More Sophisticated

There are those that are so hooked on seeing Total Eclipses, they go from one to the other. In 1970, March 7 the eclipse was conveniently passing through Martha's Vineyard. I lived in Belmont at the time. Several enthusiasts and I chartered a plane to go to Martha's Vineyard. The pilot arrived late, calculating that he can get there on time missed the fact that there were several hundred others with the same idea. The Airport at MV was full, they were ac-

cepting no more "in" flights. We missed the Martha's Vineyard Totality, had to enjoy a 99% version. Not bad, but nothing to charter a flight to, I shall place it on a scale comparable to a Night at the Pops, wonderful but no ecstasy. So far, my love is the one and only Totality I have seen in Maine.

For Newton's Principia we are indebted to a Comet! Today it is known as Halley's Comet named after Edmond Haley, its reappearance and unaided sighting was predicted during its apparition of 1985 through 1986. From the roof of our house in Baghdad, I had seen comets before, however the big comet deserved more attention, and although Halley is visible to the naked eye, I decided to track it and purchased a small 4" ($600) Schmitt-Cassegrain telescope. Tracking Halley as it marched through the sky and recording its position was an exciting experiment, seeing it in all its glory was a must. Predictions at the time were that the Southern Hemisphere would steal the show, wealthy enthusiasts flew to Australia to see it. In Virginia, on a freezing night my kids, Aram 11, Natasha 15, Monica 18, and Martha Goodway MIT '57, and I, hopped in to my car and headed to the Blue Ridge drive in Virginia. The comet was close to perihelion, it was a freezing cold moonless night, we arrived past midnight, Halley's tail was visible, long bright and stunning. Perhaps my kids will have a chance in their lifetime to see Halley's comet again. We have seen many magnificent comets since, but Halley will remain very memorable. *It's worth noting a roof sleeper in Babylon (in present day Iraq) recorded the passage of, what we call today, Halley's comet in 164 BC.* Regrettably the comet was a huge disappointment for the Australian crowd, what they saw was a comet whose tail had greatly diminished in size.

It was time to get serious, I decided to get a bigger telescope. In 1997 I purchased a 12" Go-To Schmitt Cassegrain telescope, a wonderful device that was computer controlled, setting up required proper alignment, it also required assembly and disassembly and carrying it to the observation site and back. The big attractions were the planets, especially Saturn and Jupiter with its moons. Messier object galaxies and Nebule were a delight. At star parties it was nice to show kids and adults alike the wonders of the universe some of us take for granted.

The remote observatory in West Virginia.

In 2015 I realized that setting-up and disassembly at a dark site was becoming increasingly difficult and dangerous. If I wanted to enjoy the hobby a more permanent setup was re-

quired. I started looking for areas with low light pollution, found and purchased a lot in West Virginia. On this lot today I have a permanent observatory with the finest laboratory grade telescope and remote imaging equipment. Instead of being at the site, the observatory is operated remotely. In mid-December a minor accident forced me to temporarily shut down the observatory, I call it an inconvenience, there will always be inconveniences, one has to endure even in the best of remote setups.

Imaged remotely M42 and Comet NEOWISE 2020.

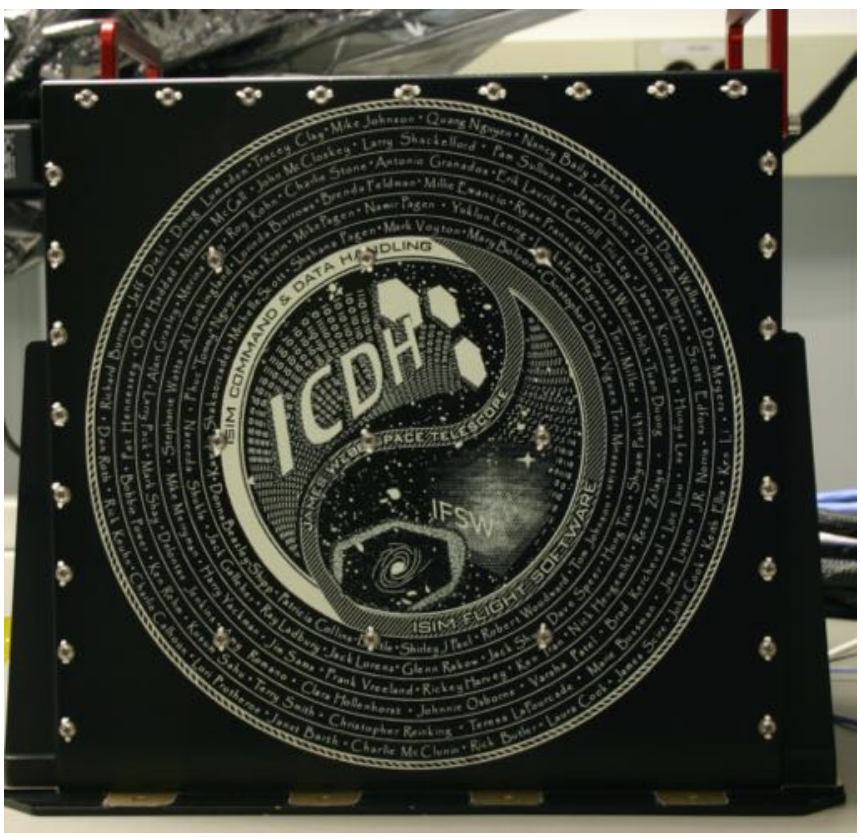
In the late 1950s or early 1960s you had to be wealthy to own a 3 ½" Questar telescope, beautifully crafted, affordable only by wearers of Rolex watches, or semi-professionals. Most enthusiast astronomers built their own telescopes; laboriously grinding mirrors and building optical tube assemblies. Thanks to automation, computer generated ray tracing and better glass for refractor telescopes, better mirrors for reflecting telescopes, high quality telescopes are within the reach of most amateurs. For less than the price of a Questar, amateurs can by a 12" Dobsonian. With the internet and the introduction of control software, the entire observing operation can be performed and recorded remotely. Today you can rent time on telescopes in Australia, Chile, Spain or Arizona, you don't need to own a telescope. In less than a half a century the field of astronomy has changed. It started as a purely visual study, then came plate film followed by CCD, CMOS imagining cameras, orbital observatories the likes of Hubble Space Telescope, and of course the Extremely Large Telescope (ELT) under construction in Chile. Some, including myself, want to experience seeing the photons that have traveled several billion years to excite our retina directly, just like the stars did on the rooftops. As we grow older, we learn to make compromises.

This essay would not be complete without mentioning the contribution of many astronomers that have devoted countless nights and days in the field of discovery and engineering. Amateur imagers contribute a vast amount of data with relatively sophisticate equipment, though not as skilled or trained in analysis, the data collected and submitted to skilled analysts has been invaluable. The impact on Jupiter was a discovery by an Australian astronomer A. Wesley, the discovery of comet Shoemaker-Levy that also impacted Jupiter. Robert Evans holds the record in discovering supernovae. Mentioned here are just a few that come to mind. Amateur astronomers young and old have made and continue to make discoveries

in the field. The Dobsonian telescope is nothing more than a Newtonian, named after John Dobson the inventor. Dobson designed an inexpensive, large, portable lightweight telescopes one that could bring deep-sky objects the amateur astronomer. Others contributed to making and improving the optics, the operation of the telescope, and in recent years the control software for data collection and control of the telescope and mount. Dr. Leonardo Orazi who teaches material science during the day, at night is an amateur astronomer; he developed Voyager, a software program that controls every aspect of the Observatory shown above, this level of automation was a subject of dreams, today it allows astronomers to dream as they sleep, while the observatory is collecting data.

Looking Back

Curiosity starts at a very early age, with some of us sleeping on the rooftop of houses in Baghdad, or on a grassy field in Oklahoma Tennessee, looking up, wondering and asking questions, connecting dots between stars, and even making imaginary characters; or doubting if we really saw flying saucers in the sky. Some of us wondered and looked in other directions, moving on different paths of curiosity. We tried to understand why certain thing behaved the way they did, and were not satisfied with many of the answers. Over time we understood the physics, the chemistry of what's out there. Many of us rejected the explanations that just didn't make any sense. Some of us are still exploring and asking questions. We influenced each other and hope we continue doing so. And keep looking up at the stars.



The Back of the James Web Space Telescope ICDH Plaque.

Viguen Ter-Minassian ’64 Course 2, Mechanical Engineering, has always been passionate about astronomy and rocketry. In the early 90s, he worked at Northrop Grumman developing, designing, analyzing, and testing instruments for the Goddard Space Flight Center (GSFC). Many of these instruments are today in earth orbit including ones on the Hubble Space Telescope and some orbiting the moon, like the Lunar Reconnaissance Orbiter (LRO). When the James Web Space Telescope (JWST) launches October 31, 2021 to Lagrangian 2 (L2), with the ISIM Command and Data Handling System (ICDH), Viguen’s name will be on the back of the JWST ICDH plaque, on its innermost circle. That is as close as he will come to realizing his rocketry passion.