Optional Reading on Risk Analysis and The Cuban Missile Crisis

What is an acceptable level of risk?

As noted in Handout #1, there are significant advantages to describing the ultimate goal implicitly as a state of acceptable risk, instead of explicitly, as some groups do (e.g., nuclear abolition, world peace, or the rule of law being extended to an international level). This leads to the question, what is an acceptable level of risk?

When I talk about nuclear risk, people often ask, "What is the probability of a nuclear war?" But, the correct question is, "What is the probability of a nuclear war each year?" If there is a 0.1% chance of a nuclear war occurring each year, then in 100 years the risk is roughly 10%, while over 10 years the risk is roughly 1%. Similar remarks apply to the risk of nuclear terrorism.

Most people find it easier to think in terms of what I call the *time horizon* for an event. If nuclear war has one chance in a thousand of occurring each year, then it has a 1,000 year time horizon. Because the risk of a nuclear war varies with time, this is not the same as saying we expect to survive 1,000 years, even though, to simplify, I sometimes may say something like that.

Before studying ways that risk analysis can help us estimate the time horizon for a nuclear war, it helps to consider what various values for that parameter would imply. A 1,000 year time horizon at first sounds safe because none of us will be around that long. But, a child born today would have almost a 10% chance of not living out his or her expected life of 78 years. That risk is closer to 78/1000 or 7.8%, but when roughly estimating a number, scientists and engineers often use an *order of magnitude estimate*, in which the estimate is rounded to the nearest power of 10 (1, 10, 100, etc.) to avoid giving an impression of greater accuracy than is warranted. In that approach, a 7.8% estimate becomes 10%. The table on the next page puts the risk for various time horizons for a full-scale nuclear war into perspective, assuming that it would kill most people.

The second column is the probability that a child born today would die in a nuclear war; the third column is the number of nuclear power plants that would have to surround your home town to produce an equivalent level of risk; and the last column is how often you would have to skydive from an airplane to bear the same risk. Of course, it is not just one person's life that is at stake. For example, in the skydiving analogy, the whole world is in the harness with you.

The second column is found using probability theory, with the smaller numbers being equal to the annual probability of the event times the number of years life expectancy, and using 100

years as the order of magnitude value. For example, a time horizon of 10,000 years corresponds to one chance in 10,000 each year, so over 100 years the risk is roughly 100/10,000 or 1%.[1]

Time Horizon (years)	Pr(child dies)	# of nuclear plants	Skydiving
10	Almost 100%	100,000	30 times per day
100	50%	10,000	3 times per day
1,000	10%	1,000	Twice a week
10,000	1%	100	Once a month
100,000	0.1%	10	Once a year

Equivalent levels of risk for different time horizons for a full-scale nuclear war

The third column uses the fact that a modern nuclear power plant is designed so that the probability of its suffering a catastrophic failure in any year is at most one chance in a million. Ten thousand such plants surrounding a town would add up to one chance in 100 per year, which corresponds to a 100 year time horizon. Hence the 10,000 entry in the 100 year time horizon row.

While Chernobyl might seem inconsistent with that million year design goal, it is not considered a modern design because it did not have a containment vessel. The accident at Three Mile Island was not catastrophic because its containment vessel did what it was supposed to – contain the radioactivity that was released by the accident. As a result, Three Mile Island produced no immediate fatalities. (There is disagreement as to whether there are any long-term fatalities.) In contrast, Chernobyl killed over 50 people immediately, and the total death toll is estimated to be at least in the thousands, with some arguing that the number is nearly a million.

The last column is based on skydiving having a fatality rate of one in 100,000 per jump. Skydiving 3 times a day, or roughly 1,000 times a year, therefore would have a 1-in-100 or 1% annualized fatality rate, the same as for nuclear war having a 100 year time horizon.

Different people are willing to tolerate different levels of risk, but I suspect that the vast majority of people would not accept anything less than a 10,000 year time horizon for a nuclear war, corresponding to living next to 100 nuclear power plants. I suspect a majority would demand an even longer time horizon.

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[1] Optional: The smaller time horizons (higher risk assumptions) clearly cannot use such an approximation. For example, the "small probability" approximation when the time horizon is 100 years is 100% (100/100), whereas the more exact value is $(1 - 0.99^{100})$ or about 63%.

A table similar to the one shown above can be constructed for a nuclear terrorist event, but the entries would depend on where you lived and the assumed severity of the event. Someone living on a remote ranch in Arizona would bear almost no risk, while someone living in New York City would bear a significant fraction of the overall risk. For a New Yorker, assuming New York has a 10% chance of being the target, and assuming 10% of the city's population is killed in such an attack, the numbers in the table would be reduced by a factor of 100. This helps explain why, even though most research about the danger of a nuclear disaster focuses on nuclear terrorism to the exclusion of nuclear war, I believe it is necessary to consider both possibilities. Nuclear war has a lower probability each year, but a much higher cost – potentially infinite.

A preliminary risk analysis of nuclear deterrence

In March 2008 I published what appears to be the first quantitative risk analysis of nuclear deterrence. That paper was intended for an engineering audience and therefore used some mathematics that is beyond the reach of the layperson. However, I believe the basic ideas can be expressed in plain English, as I will attempt in the next few sections. If the math is more complex than you can handle, just skip over that part and don't worry since it is not be crucial to what follows. Even if you cannot follow the math, the descriptive material should help explain why the risk is so much greater than most people realize.

An in-depth risk analysis would have required expertise in a number of areas, and involved a large team effort. Working by myself, I therefore simplified the analysis by considering only one possible trigger mechanism for a nuclear war, a crisis involving Cuba. Because that approach ignores other potential causes, it underestimates the risk and is called a *lower bound*. Following risk analysis' approach of breaking down a catastrophic failure into a sequence of smaller failures, I broke the process into four steps:

1. the occurrence of an event that had the potential to initiate a major crisis involving Cuba;
2. whether or not the potential initiating event actually produced a crisis;
3. whether or not the crisis crossed the nuclear threshold; and
4. whether or not crossing the nuclear threshold resulted in full-scale war.

Step 1: Potential Initiating Events

A study of the first 50 years of the nuclear deterrence era (1960-2010)[2] showed that there were three potential initiating events (step 1 above).Three events divided by 50 years produces an occurrence of 6% per year. Equivalently, I estimated that such events will occur approximately every 17 years since 1/0.06 = 17. The three events I identified were:

- The United States placing missiles in Turkey, starting in 1961. This has been discussed in detail earlier and produced the 1962 Cuban Missile Crisis crisis.
- In the 1980s, President Reagan threatened to reimpose a naval blockade of Cuba to staunch a perceived flow of arms to a leftist insurgency in El Salvador. Such an action would have violated one of our key concessions (lifting the blockade) in return for which the Russians removed their Cuban missiles. Had Reagan reimposed the blockade, the Russians would likely have taken some action, possibly even threatening to redeploy missiles unless the blockade was lifted. Such a reaction was made more likely by the fact that, at that same time, Reagan was in the process of deploying Pershing IRBMs (so-called "Euromissiles") in Western Europe, over strenuous Soviet objections. While not as close to the Soviet border as the Turkish Jupiters had been, the only way the Soviets could match such weapons was with missiles in Cuba.
- The United States' Eastern European missile defense system, discussed in detail earlier in this handout, came close to precipitating a crisis, and still might.

Step 2: Potential Initiating Events Becoming a Crisis

The next step in my analysis was to estimate the probability that, once an event had occurred with the potential to initiate a major crisis involving Cuba, such a crisis actually followed. Only one of the three possible initiating events listed resulted in a major Cuban crisis, so the empirical probability (i.e., based on the observed data) is ⅓. Because only the first initiating event led to a full-blown crisis, it might be argued that we learned from that mistake and ⅓ is too large an estimate today. Conversely, the fact that the latter two potential initiating events occurred at all is evidence that we did not adequately learn from the first mistake, or that we learned the wrong lesson. Because these two factors tend to cancel each other, I used ⅓ as a reasonable estimate. Multiplying this by the 6% chance each year of a potential initiating event, results in a 2% probability of having a Cuban crisis each year. Equivalently, I estimated that we can expect to see a Cuban crisis about once every 50 years. This is not a precise estimate and 1% per year (100

[2] Although nuclear weapons were first developed in 1945 and a second nation obtained them in 1949, until approximately 1960 there were too few weapons for the strategy to be called deterrence in the sense that we think of it today.

years between crises) or 4% per year (25 years between crises) could also be argued, but would not change the conclusion appreciably.

Step 3: Crossing the Nuclear Threshold

Up to this point, I was able to make use of historical data in estimating probabilities, but that is not possible in estimating the probability that a crisis comparable to 1962's actually crosses the nuclear threshold. Because nuclear weapons have not yet been used during the deterrence era (i.e., when the other side could retaliate), this estimate, of necessity, involves some subjectivity. In such cases, risk analysis uses a technique known as *expert elicitation*. In that process, opinions of experts with different views of the risk are combined. Since my expertise in this area is limited, my analysis used a crude form of expert elicitation to estimate the probability of crossing the nuclear threshold once a full-blown crisis existed by citing, and then analyzing, the following data points:

- During the crisis, Kennedy ordered families of White House staff to either leave Washington or be near a telephone[3] providing evidence for his estimate that the chances of war were "somewhere between one out of three and even." [4]

- Kennedy's Secretary of Defense Robert McNamara described his feelings at the height of the crisis in the following terms: "As I left the White House and walked through the garden to my car to return to the Pentagon on that beautiful fall evening, I feared I might never live to see another Saturday night." [5]

- Kennedy's National Security Advisor McGeorge Bundy thought the odds of war were much lower, on the order of 1%.

- Douglas Dillon, another of Kennedy's advisors, also had little fear of the crisis blowing up and, at a 1987 conference commemorating the crisis' 25th anniversary, stated: "My impression was that military operations looked like they were becoming increasingly necessary. … The pressure was getting too great. … Personally, I disliked the idea of an invasion [of Cuba] … Nevertheless, the stakes were so high that we thought we might just

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[3] Fedor Burlatsky, *Khrushchev and the first Russian Spring*, Scribners, New York, 1988, page 168.

[4] Theodore C. Sorensen, *Kennedy*, Harper & Row, New York, 1965, page 705.

[5] Robert McNamara, *Blundering Into Disaster: Surviving the First Century of the Nuclear Age*, Pantheon Books, New York, 1986, page 11.

have to go ahead. Not all of us had detailed information about what would have followed, *but we didn't think there was any real risk of a nuclear exchange*."[6] [emphasis added]

These statements from participants support a range from 1% to 50% for the odds of the crisis crossing the nuclear threshold.[7] In my analysis, I used a range of 10% to 50% for this probability, discounting Bundy's and Dillon's optimism for the reasons explained in the following two subsections.

The unknown nuclear torpedo A major danger of crossing the nuclear threshold was totally unknown to Kennedy and his advisors. Only on the 40th anniversary of the crisis in 2002, did we learn that two Soviet submarines that had been forced to surface by American destroyers each possessed 15-kiloton nuclear torpedoes (comparable to the weapons that destroyed Hiroshima and Nagasaki) and that the subs' captains considered using them. The destroyers were under orders to enforce the American naval blockade of Cuba and used what they regarded as signaling depth charges to command the subs to surface. Though smaller than normal depth charges, they still caused damage to the sub, leading the crews to believe they were under attack.[8] Because submarines maintain radio silence when being hunted, at least one captain also feared that World War III had started up on the surface. Due to being submerged for a long period of time, the temperature on that same sub had skyrocketed past 120 degrees, adding to the already heavy pressure on the crew. A book on the incident, quotes the captain of the sub as saying, "There may be a war raging up there and we are trapped here turning somersaults! We are going to hit them hard. We shall die ourselves, sink them all but not stain the navy's honor!" Fortunately, others on board the sub succeeded in calming the captain and he eventually surfaced, even though such a "surrender" was a blot on both the officer's and the Soviet navy's honor.

Soviet battlefield weapons for repelling an American invasion During the crisis, there was repeated, strong pressure for an American invasion of Cuba. Those advocating this strategy either were unaware of or did not adequately consider the risk that the Soviets might have battlefield (tactical) nuclear weapons on the island to repel such an invasion – which we later learned they did. Given the logistical advantage the US had (a supply line only ninety mile long versus thousands of miles for the Soviets) and repeated American threats to invade Cuba, Kennedy and

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[6] James G. Blight and David A.Welch, *On the Brink: Americans and Soviets Reexamine the Cuban Missile Crisis*, Hill and Wang, New York, 1989, page 72

[7] It should be noted that the three statements do not specifically mention the first use of a nuclear weapon. They could be interpreted as being about conventional war between the US and the USSR, or they could be interpreted – especially McNamara's statement – as relating to full-scale nuclear war. These two factor tend to balance one another.

[8] Adding to the danger, Washington had only communicated to Moscow its "Submarine Surfacing and Identification Procedure" *after* the crisis had started. Given that submarines routinely practice radio silence in a war zone, I suspect that these details on the signaling procedure never reached the sub.

his advisors should have considered that the Soviets would take such a step and were delaying the announcement until (and if) it was needed. Yet declassified records show that, at a minimum, that possibility was given inadequate attention and often seems to have been totally overlooked.

The unsuccessful 1961 Bay of Pigs invasion had humiliated Kennedy and the United States and, when the Soviet missiles were discovered on Cuba, intensified pressure to invade the island, topple Castro, and "excise" what many saw as a communist cancer in the Western hemisphere. Evidence for this perspective comes from tapes Kennedy secretly made of his ExComm meetings. (ExComm was the name given to the group of advisors Kennedy assembled to deal with the crisis.) Sheldon Stern, the longtime historian at the John F. Kennedy Library is the acknowledged expert on decoding these often-barely-audible recordings. Stern describes a meeting on Friday, October 19, 1962, when the existence of the missiles was still being kept secret from the American public and even Congress:

> General Earle Wheeler, Army Chief of Staff, increased the pressure by insisting that only bombing [the missiles], a blockade, *plus* an invasion could protect the United States against a nuclear strike from Cuba. … 'You'll have to invade the place,' [Marine Corps Commandant David] Shoup … declared, banging the table for emphasis.[9] (emphasis in original)

While Kennedy never convinced his military advisors of the wisdom of delaying an attack on the missiles and Cuba, he did manage to restrain that sentiment within the ExComm. Even so, three days after the above described meeting, Kennedy was confronted with forceful, new pressure to invade when, two hours before he told a stunned nation about the missiles in a television broadcast, he briefed key Congressmen and Senators for the first time:

> [Georgia's] Senator Russell suddenly lashed out: "Mr. President, I could not stay silent under these circumstances and live with myself. … We're either a first-class power or we're not. … And I think that you should assemble as speedily as possible an adequate force and clean out that situation. … The time's gonna come, Mr. President, when we're gonna have to take this gamble … for the nuclear war." … Russell insisted that an invasion would present the Soviets with a *fait accompli* and make war *less* likely – the same arguments made three days before by General LeMay. … Another influential Southern Democrat, Senator William J. Fulbright, abruptly weighed in against the blockade. An invasion, he insisted, was *less* risky [because] … "it's just between us and Cuba … [but] if you're confronted with a Russian ship, you *are* actually confronting Russia."[10]

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[9] Sheldon M. Stern, *The Week the World Stood Still: Inside the Secret Cuban Missile Crisis*, Stanford University Press,Stanford, CA, pages 68-69.

[10] Sheldon M. Stern, *The Week the World Stood Still: Inside the Secret Cuban Missile Crisis*, Stanford University Press,Stanford, CA, pages 87-90.

Definitive evidence that the Soviets had battlefield nuclear weapons on Cuba only came to light twenty-five years later, after the breakup of the Soviet Union lifted the veil of secrecy from many of their records. In their 1997 book *One Hell of a Gamble,* (W. W. Norton & Co., New York) Aleksandr Fursenko and Timothy Naftali used access to formerly secret Soviet-era documents to conclude:

> Page 212: Khrushchev understood the importance of the decision he had just made [to send tactical nuclear weapons to Cuba] and took pains to maintain direct control of these special weapons. A day after he authorized the new shipment, the Minister of Defense [Malinovsky] drafted an order permitting the Soviet commander in Cuba, General Issa Pliyev, to employ these battlefield nuclear weapons in the event that communications to Moscow were cut and a U.S.-led invasion had begun. The order required two signatures. Malinovsky's deputy, Marshal Zakharov, signed in his capacity as army chief of staff, but Malinovsky did not. … The document was to sit [half] unsigned in the files until events in Cuba warranted a change. [It should be noted that there is a major difference between authorization to use nuclear weapons and the ability to use them. With or without authorization, Pliyev almost surely had the *ability* to use the nuclear weapons under his command, as did a number of lower level Soviet officers. The use of Permissive Action Links or PALs (similar to a combination lock) to prevent unauthorized use of nuclear weapons did not become widespread until later. Even today, such safeguards are likely to be removed if armed conflict seems imminent. Otherwise the weapons are useless both as a deterrent and as weapons. Under the intense pressure of an American invasion, Pliyev might well have used the weapons even if not authorized to do so. Later discussion of the unauthorized use of a Soviet surface-to-air missile to shoot down an American U-2 is germane since that decision was made under similar time pressure.]
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> Page 241 bottom: [Khrushchev's] mind kept returning to what the Soviet Union would have to do if the United States attacked Cuba. As "another possibility… In case of attack," said Khrushchev, the Kremlin could declare that "all of the equipment belonged to the Cubans and the Cubans would announce that they will respond." He assured his colleagues that he did not envision letting Castro threaten the use of the medium-range ballistic missiles against a U.S. invasion, but as a way of deterring the United States the Cubans could declare that they would "use the tactical ones."
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> Page 242: On the assumption that a U.S. invasion was more likely than a blockade, the Presidium worked out a set of instructions for the Soviet commander in Cuba, General Pliyev. The group's first reaction was to take steps to avoid an accidental nuclear exchange. A cable was drafted that ordered Pliyev to "put all of his forces on alert" but not to contemplate using any of the nuclear weapons deployed at his command. The more the Soviet leaders thought about the restrictive language of this cable, however, the less they liked it. If the Americans attacked Pliyev and the 41,000-man Soviet contingent in Cuba

would be outnumbered. The nuclear tipped Luna and cruise missiles were his only potential salvation. Unwilling to sacrifice the Soviet group, the Presidium tentatively came up with a different set of instructions. Pliyev would be authorized to use the tactical nuclear weapons in the event of a U.S. landing; but without a direct order from Moscow, he was not to fire the 1,100-nautical-mile R-12.'s. …

Pages 242-243: And what would be the US reaction to the first use of nuclear weapons by the Soviet Union? A look at the blast effects of these weapons left little doubt that if Pliyev used his battlefield nuclear weapons there would be enormous pressure on President Kennedy to destroy Cuba, at the very least. Each Luna had a range of 31 miles and a two-kiloton nuclear payload.… Each one would have a devastating effect on the battlefield. … with the 12 at his disposal the Soviet commander in Cuba could easily destroy any beachhead established by U.S. Marines in an invasion of Cuba and obliterate the U.S. base at Guantánamo, at the southeastern tip of the island.

Page 243: The cruise missiles, the FKR, if used, would not have as dramatic an effect on the battlefield but, as predicted by Soviet military journals, could inflict heavy costs on the U.S. Navy task force participating in an attack. One FKR cruise missile carried enough power, roughly twelve kilotons of TNT, to blow a U.S. aircraft carrier group apart. Of the eighty missiles with nuclear warheads originally ordered to be shipped, the Kremlin had already sent thirty-six to the island.

Despite such dangerous thinking, some rationality eventually prevailed:

Page 243: Concerned that Khrushchev and the Presidium were rushing to the brink of nuclear war prematurely, Malinovsky recommended to the group that it wait until 1 AM, or 6 PM Washington time, to authorize Pliyev to fire the Lunas. Fearful that Washington would somehow learn about this delegation of authority, Malinovsky cautioned that they should not give the Americans "a pretext to use their own nuclear weapons" before this was absolutely necessary. Persuaded by Malinovsky, the Kremlin decided to send the first set of conservative instructions immediately, barring the use of any nuclear weapons. The second set of instructions – the order prepared in September 1962 but not signed by Malinovsky – would be held pending developments in the Caribbean.

Summary The two previous subsections are intended to support my discounting McGeorge Bundy's 1% estimate for the crisis leading to war, and Douglas Dillon's statement that "Not all of us had detailed information about what would have followed [an invasion of Cuba], but we didn't think there was any real risk of a nuclear exchange." As you can see, not only did Dillon not have detailed information on "what would have followed," but that was also true for Kennedy and all of his advisors. At a minimum, they were unaware of the nuclear torpedoes on

the Soviet submarines, and the record shows little to no concern for the possibility (which turned out to be an actuality) of Soviet tactical nuclear weapons being used to deter – and if need be repel – an American invasion.

Multiplying the 10% to 50% range that I estimate for the probability of such a crisis going nuclear by the 2% per year probability of a Cuban crisis occurring in the first place, results in a range of 0.2% to 1% per year for the probability of crossing the nuclear threshold.[11] Over one human lifetime (78 years in the United States), the corresponding risk ranges from 15% to 50%. As usual, I rounded those numbers to avoid implying greater accuracy than is warranted.

When other potential initiating events that could cause us to cross the nuclear threshold (e.g., a nuclear terrorist attack, or a crisis involving Georgia) are included, the risk becomes even larger. Given the statement by Kissinger and Senator Lugar's survey, mentioned earlier in this handout, nuclear terrorism, all by itself, has a much higher probability of causing a nuclear disaster. Considering a sequence of events such as above is important however, since a first use of nuclear weapons in a Russian-American confrontation carries a higher risk of producing a full-scale war than if the first use is by terrorists or India or Pakistan.

Two issues that will be considered in later sections of this handout deserve to be mentioned now: How relevant is data from 1962 to today's world? And what do we do if you disagree with my estimate? Stay tuned for the answers in later sections of these notes.

Step 4: Full-Scale War

The previous section's conclusion – that a crisis involving Cuba has somewhere between a 15% and 50% chance of causing a nuclear disaster over the lifetime of a child born today – is so serious that, in a way, this section is not needed to make the case for changing our approach to nuclear weapons. That somewhat alleviates the difficulty of again estimating the probability of an event that has never happened, and one that is even more difficult to envision than crossing the nuclear threshold.

This last step is to estimate the odds of a full-scale nuclear war resulting from a Cuban crisis, given that the nuclear threshold already has been crossed earlier in the crisis. While Kennedy did not specify what he meant by the 1962 crisis ending in war, his evacuation order to the families of White House staff lends support to the hypothesis that he meant full-scale nuclear war. McNamara's stated fear that he would not live out the week is also consistent with that

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[11] While it is sometimes wrong to multiply probabilities, it is can be done here because the probabilities are *conditional probabilities*. Explaining that would be far beyond the scope of this handout, but I wanted you to know that I took that issue into account. A similar comment applies in the next section (Step 4). It should also be remembered that these estimates are lower bounds, so the true risk is higher.

interpretation. If that is the case, then the probability range calculated in the last section is for a full-scale war, not just crossing the nuclear threshold. However, to avoid being seen as alarmist, my estimate used a range of 10% to 50% for this new probability as well. Multiplying that range by the previous range (0.2% to 1% per year) for crossing the nuclear threshold results in a range that runs from 0.02% per year to 0.5% per year for the risk of a full-scale nuclear war. The corresponding risk of such a war over the lifetime of a newly born child ranges from 1.5% to one-in-three, *considering only crises involving Cuba as the cause of the war.* When all possible trigger mechanisms are considered, the risk becomes even higher.

Other Risks During the Crisis

The following list of additional dangerous incidents that occurred during the crisis might support an even higher estimate of the probabilities involved in steps 3 or 4:

1. Operation Northwoods demonstrates how intent the Joint Chiefs of Staff were on toppling Castro. (That link is to scanned, declassified documents. Wikipedia has the main text in computer readable form.) In March of 1962, the Joint Chiefs recommended this plan that proposed a number of possible ruses "to place the United States in the apparent position of suffering defensible grievances from a rash and irresponsible government of Cuba and to develop an international image of a Cuban threat to peace in the Western Hemisphere" with the "ultimate objective … [being to] provide adequate justification for US military intervention." If the goal were not so serious, the proposed ruses would read like a slapstick comedy routine. There are too many to list here, so I will just mention the *piece de resistance:* "A 'Remember the Maine' incident could be arranged … [For example,] We could blow up a US ship in Guantánamo Bay and blame Cuba." Fortunately Kennedy rejected the plan.

2. When the crisis first started to unfold, Kennedy was unaware that we had similar missiles in Turkey.[12] In a meeting, Kennedy explained why the Soviet missiles in Cuba were so unacceptable: "It's just as if we suddenly began to put a major number of MRBMs in Turkey. Now that'd be goddam dangerous, I would think." His National Security Advisor McGeorge Bundy then reminded him, "Well we did, Mr. President." Somewhat flustered, Kennedy tried to find an excuse, "Yeah, but that was five years ago. … That was during a different period then." In actuality, our Turkish missiles became fully operational in April 1962.

Even after Kennedy had equated our Turkish missiles to the Soviet missiles in Cuba and been reminded that they existed, a dangerous attempt was made to hide that equivalence throughout the decision process:

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[12] Richard K. Betts, *Nuclear Blackmail and Nuclear Balance*, The Brookings Institution, Washington, DC, 1987, pages 112-113.

> The decision-makers in 1962 were well aware of the analogy between U.S. Jupiter missiles in Turkey and Soviet missiles in Cuba but preoccupied with finding ways to deny it. At an October 18 meeting the conferees' tortured reasoning led them to agree that the difference lay in the universal understanding "that sensitive areas, such as Berlin, Iran, or Laos, should not be turned into missile bases, and that missile installations only be established pursuant to open military alliances, such as NATO."[13]

3. The United States repeatedly violated Cuban airspace. Initially this was done with high level U-2 photo reconnaissance missions, but later, when more detail was needed to convince the general public (and UN ambassadors), American jets screamed over Cuba at 500 knots, just above treetop level. In spite of the fact that Cuba and the Soviets would have been within their rights to fire on these American planes, the Soviet government and top brass recognized the danger of escalation and issued strict orders to prevent an unnecessary incident. In spite of this attempt to keep the crisis under control, on October 27, Major Rudolf Anderson was killed when a Soviet surface-to-air missile shot down his U-2 spy plane.

The downing of Major Anderson's U-2 led a number of Kennedy's advisors to urge military action. Assistant Secretary of Defense Paul Nitze saw it as, "They've fired the first shot." Chairman of the JCS, General Maxwell Taylor argued, "We certainly shouldn't [conduct any more U-2 flights] until we retaliate, and say that if they fire again on one of our planes that we will come back with great force." Secretary of Defense McNamara felt that, "We ought to go in at dawn and take out that SAM site [that had downed Anderson]."[14]

4. The surface-to-air missile that hit Major Anderson's U-2 was fired without the required permission and in violation of a standing order. Trying to contain the crisis, General Pliyev had given orders that such action should only be taken on his command, but his deputies were unable to reach him during the short time when they had any chance of hitting Anderson's U-2. Fursenko and Naftali explain the irony:

> For all of Khrushchev's efforts to control the use of force in Cuba, he had not been able to prevent the first American casualty. His commanders in Cuba had given a liberal interpretation to his earlier order to defend their positions from a U.S. air attack. [Pliyev's deputies who authorized firing the missile "mistakenly believed that whatever photographs Anderson's plane was taking would facilitate a U.S. air attack later that day or the next."] The

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[13] Richard K. Betts, *Nuclear Blackmail and Nuclear Balance*, The Brookings Institution, Washington, DC, 1987, page 113.

[14] Michael Dobbs, *One Minute to Midnight*, Alfred A. Knopf, New York, 2008, page 293.

crisis now moved into its most dangerous phase since October 22 [when Kennedy announced the naval blockade].[15]

5. On the same day that Major Anderson's U-2 was shot down, Captain Charles Maultsby flew a U-2 out of Alaska, became lost, entered Soviet airspace, and was detected by their air defense. Soviet fighters scrambled in an effort to shoot him down, and Roger Hilsman, the State Department's chief of intelligence saw that, "The implications were as obvious as they were horrendous: the Soviets might well regard this U-2 flight as a last-minute intelligence reconnaissance in preparation for nuclear war."[16]

6. While Soviet or Cuban attacks on American aircraft within their airspace were seen as "firing the first shot," potential Soviet penetration of American airspace was seen in a very different light. General John Gerhart, commander in chief of the North American Defense Command asked the Pentagon for advance permission "to use nuclear weapons … in the event of an IL-28 [Soviet bomber] raid from Cuba which penetrates U.S. air space." The Joint Chiefs agreed to his request, in the event that his air defense system indicated a general "Cuban and Sino-Soviet attack."[17] While such a plan made military sense if Soviet bombers were en route to destroy an American city, it also opened up the possibility for errors similar to Maultsby's unintentional violation of Soviet airspace and the unauthorized firing of the missile that took out Major Anderson's U-2.

7. The day before Major Anderson was shot down, on October 26, a Soviet convoy was ordered to move a cruise missile with a 14-kiloton nuclear warhead into position to attack the American naval base at Guantánamo Bay should war break out. Traveling at night, with lights blacked out, on treacherous roads, one of the vehicles fell into a ravine, killing three people and injuring a number of others. The sudden sound of the crash, accompanied by screams, at first led some in the convoy to believe they were under attack by rebel forces or even American troops. Fortunately, the vehicle carrying the warhead was not involved. If the Soviet warhead had accidentally detonated, in the confusion and chaos, it could have been mistaken for an American nuclear attack on Cuba.

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[15] Aleksandr Fursenko and Timothy Naftali, *One Hell of a Gamble*, W. W. Norton & Company, New York, 1997, page 278.

[16] Michael Dobbs, *One Minute to Midnight*, Alfred A. Knopf, New York, 2008, page 269.

[17] Michael Dobbs, *One Minute to Midnight*, Alfred A. Knopf, New York, 2008, page 248.

Resolution of the Cuban Missile Crisis

Early in the crisis, Kennedy felt that, at a minimum, he would have to bomb the Soviet missiles.[18] Fortunately, with cooperation from the press which had been ready to break the story but held back in the interests of national security, he was able to keep the situation secret from the public for six days, during which time he was better able to recognize the implications of such actions. He realized an attack on the Cuban missiles would require an equally forceful Soviet response, most likely a tit-for-tat bombing of the American missile sites in Turkey or blockading West Berlin, where a crisis the year before had brought the two nuclear superpowers close to war. Adding to the danger, an attack on Turkey, under NATO's Article 5, was to be considered the same as a Soviet attack on American soil. Kennedy also came to realize that an air strike could not guarantee taking out all the missiles, jeopardizing Miami, Washington, and other American cities that were within range of the surviving missiles. Even if the Soviet hierarchy did not authorize such an attack, it was recognized that a low level officer in charge of a missile battery might take matters into his own hands if under attack.

Thus, in spite of his own initial reaction and repeated external pressure for both an air strike and an invasion of Cuba, Kennedy decided to start with a naval blockade of the island, and announced that in his Monday, October 22, television broadcast to the nation. While that would not prevent more of the missiles that were already on Cuba from becoming operational (reconnaissance had shown feverish work to complete the missile sites), it would prevent new ones from arriving, and send a strong message to the Soviets with less risk of escalation than an outright attack.

Kennedy was aided in his effort to portray Khrushchev's actions as fundamentally different from America's placement of missiles in Turkey because the the American deployment had been done openly, while Khrushchev had repeatedly denied any intention to place missiles on Cuba, thereby making the Soviet actions appear more sinister. Khrushchev had acted surreptitiously because he correctly assumed that American public opinion would react violently to his action. He reasoned that announcing the missiles only after they were fully operational, would leave America little choice but to accept what the Soviet Union had lived with for years – hostile forces close to its borders.

A naval blockade is technically an act of war, and when first appraised of Kennedy's intention to force Soviet ships to undergo inspection before docking in Cuba, Soviet Ambassador Anatoly Dobrynin did, in fact, declare: "That would be an act of war."[19] In an attempt to parry that accusation, Kennedy decided to use the less onerous term *quarantine*, and sought (and obtained)

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[18] Aleksandr Fursenko and Timothy Naftali, *One Hell of a Gamble*, W. W. Norton & Company, New York, 1997, page 238.

[19] Michael Dobbs, *One Minute to Midnight*, Alfred A. Knopf, New York, 2008, page 73.

approval from the OAS (Organization of American States) for that action. In spite of these fig leafs – which Kennedy's tapes show were portrayed as a complete suit of clothes by his advisors – the president and his ExComm held their breath as Soviet ships approached the line Kennedy had drawn in the water. On Wednesday, October 24, the ships stopped moving toward the line, leading Secretary of State Dean Rusk allegedly to observe, "We were eyeball to eyeball, and the other fellow just blinked."[20]

While those Soviet ships reversing course relieved some of the tension, the crisis was far from over. Other ships approached the quarantine line days afterward, producing new concerns about what would happen and how to respond. The previously described, dangerous confrontation between the American destroyers and the nuclear-torpedo-armed Soviet submarines occurred three days later, on Saturday, October 27. That is also the day that Anderson's U-2 was shot down, Maultsby's U-2 violated Soviet airspace, and McNamara reflected that he feared he might not live to see another Saturday night.

The danger continued for months after the public thought the crisis ended. A 2007 article cites evidence in the John F. Kennedy Library to claim that, "The U.S. Joint Chiefs of Staff (JCS) continued to prepare to invade Cuba if the diplomatic settlement fell apart. Military readiness for such an operation peaked on 15 November." The danger of that occurring was exacerbated by Castro prohibiting American inspections on Cuban soil, leading Kennedy's advisors to fear that perhaps the Soviet missiles had not all been removed. If Khrushchev could lie before and during the crisis, falsely maintaining that no Soviet missiles were on Cuba, why should we now trust that the weapons had been removed? Those fears persisted even though, as shown in the photograph on the next page,[21] the Soviets took steps – leaving the missiles in plain view as they left Cuba – to help American reconnaissance aircraft verify their removal.

Both sides operated under tremendous time pressure during the crisis. The Soviets felt the need to have all missiles operational as soon as possible, in order to fulfill Khrushchev's original plan of having a local nuclear deterrent to prevent American attacks on either the missiles or Cuba. For exactly the same reason, Kennedy and his advisors felt pressure to take out the missiles or invade Cuba *before* more missiles were operational. Confusion resulted from that pressure. For example, Kennedy received two conflicting messages from Khrushchev. The first, sent privately on Friday evening, October 26, was a highly personal, even rambling letter that talked of the

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[20] Michael Dobbs, *One Minute to Midnight*, Alfred A. Knopf, New York, 2008, page 88. Dobbs notes that Rusk and the others mistakenly believed that it was the missile-carrying ships that turned around at that point in time, even though they had done so the day before. But, even a Soviet ship carrying innocuous cargo could have tested the blockade, with possibly deadly consequences. What the ships carried was less important in some ways than what the Americans feared they might carry.

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horror of war and offered to remove the Soviet missiles in return for an American pledge not to invade Cuba. The entire letter is on line as part of a large collection, and you can locate it within the collection by searching on *Moscow, October 26, 1962*. A second, public, more formal, and more demanding letter arrived the next morning. It took a stance of equality with the U.S. by proposing that the Soviets remove their Cuba, the United States remove its missiles from Turkey, the U.S. agree to respect Cuba's borders (including a no invasion pledge), and the U.S.S.R. agree respect Turkey's borders (including a no invasion pledge). Concerning the dilemma Kennedy faced in dealing with these two very different proposals, JFK Library historian Sheldon Stern wrote:

> President Kennedy had actually been probing the Turkish option for more than a week and asked, "where are we with our conversations with the Turks?" Assistant Defense Secretary Paul Nitze responded firmly, "The Turks say that this is absolutely anathema" and view it "as a matter of prestige and politics." … Under Secretary of State George Ball declared that approaching the Turks on withdrawing the Jupiters "would be an extremely unsettling business." "Well," JFK barked, "this is unsettling now George, because he's got us in a pretty good spot here. Because most people will regard this as not an unreasonable proposal. I'll just tell you that." "But, what 'most people,' Mr. President?" Bundy asked skeptically. The president shot back: "I think you're gonna have it very difficult to explain why we are going to take hostile military action in Cuba … when he's saying, 'If you get yours out of Turkey, we'll get ours out of Cuba.' I think you've got a very tough one here." …

In the end, Kennedy largely ignored the second letter and respond to the first, with private assurances – that he insisted be kept strictly secret or the deal would be off – that our Turkish missiles would also be removed within months. This saved Kennedy from having to deal, at least immediately, with objections from Turkey, and gave the appearance that he had won the contest of wills. Being the apparent winner had important domestic political overtones since midterm elections loomed early in November. Had the missile trade been publicly known, Kennedy would have been skewered by the Republicans who were still smarting from his use of a fictitious missile gap to defeat Richard Nixon in the 1960 presidential election.[22] Instead, basking in the glow of seeming victory in the Cuban crisis, the Democrats performed much better in those elections than originally forecast. Of course, Kennedy's advantages from this secret deal were Khrushchev's problems. Although Kennedy did not have to deal with Turkey feeling publicly betrayed, Khrushchev had precisely that problem with Cuba. And, even though in reality Khrushchev had struck a good bargain, getting the two key concessions he wanted (a no invasion pledge from the U.S. and removal of the Turkish missiles), on the surface he appeared to lose. While other factors were also involved in his ouster as leader of the Soviet Union two years later,

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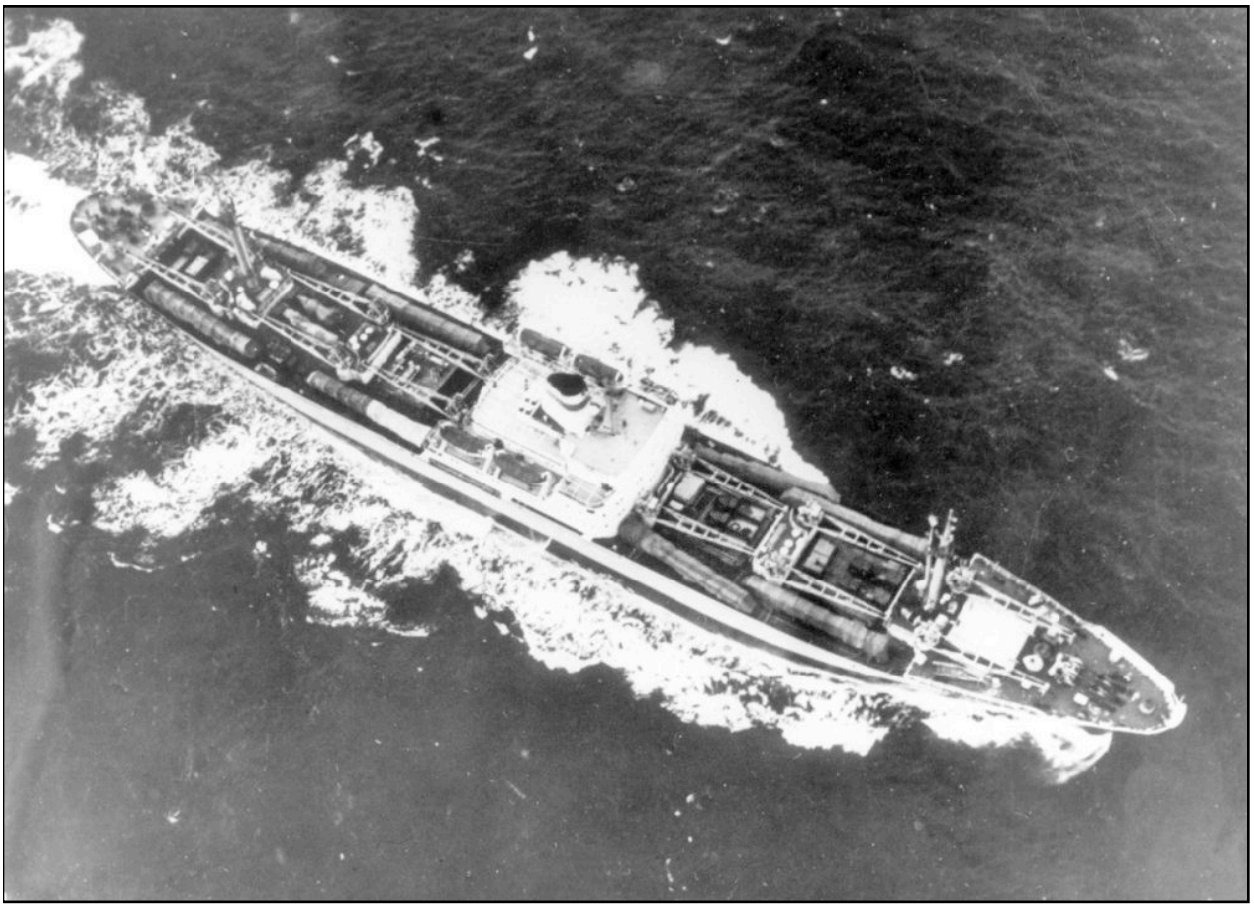
[22] While these days, it is usually Republicans who paint (and taint) Democrats as "soft on defense," they learned the value of doing this from Kennedy.

in October 1964, one of the accusations was "juggling the fate of the world [in Cuba]."[23] Khrushchev's problems eventually came to haunt America, as later Soviet leaders built a much larger nuclear arsenal and expanded their navy to avoid again being in a seemingly inferior position. (Even though, in reality, the Soviets had an adequate nuclear arsenal to deter Kennedy from taking the most provocative actions, our relying on the appearance of strategic superiority due to our numerical advantage had predictable, but unforeseen, negative consequences for the arms race.)



On 12 November 1962, US reconnaissance planes photographed the Soviet freighter 'Kurchatov' on her return to the Soviet Union. Missiles can be seen on the ship's deck because the Soviets purposely uncovered them to allow the US to monitor their withdrawal.

Does Historical Data Have Relevance Today?

Returning to my preliminary risk analysis of nuclear deterrence, a key question is the extent to which historical data is relevant to estimating today's failure rate for nuclear deterrence (i.e., the

[23] William Taubman, *Khrushchev: The Man and his Era,* W. W. Norton & Company, New York, 2003, page 12.

risk that deterrence will fail within the next year, or the year after, etc.). The four steps that I used in that analysis allow us to break down that question into four sub-questions:

- How relevant is the historical data to the rate of occurrence of potential initiating events?
- How relevant is the historical data to the chance that a potential initiating event results in a crisis?
- How relevant is the historical data from the Cuban Missile Crisis to the chance of a new crisis crossing the nuclear threshold?
- How relevant is the historical data from the Cuban Missile Crisis to the chance of a new crisis that has crossed the nuclear threshold escalating to full-scale war?

How relevant is the historical data to the rate of occurrence of potential initiating events? This first sub-question can be at least partially answered by noting that the three potential initiating events I identified with respect to Cuba (the Turkish missiles, Reagan's threats to reimpose a naval blockade of Cuba, and our Eastern European missile defense system) occurred from 1959-62 (from signing an agreement with Turkey to full operation of the missiles), 1981-87 (from the start of President Reagan's term in office until he and Gorbachev became friendly) and from 2002-2009 (from President Bush's withdrawing from the ABM Treaty through President Obama modifying the original plan in ways that were not as threatening to the Russians – though it could be argued that potential initiating event is either still active, at a reduced level, or in hibernation, awaiting a new president who might reactivate the original plan). The starting points for these potential initiating events occur approximately every 20 years, including after the end of the Cold War. Further, events such as the 2008 Georgian war (which we will study in greater detail) show that potential initiating events for non-Cuban crises are continuing to occur. An in-depth study would catalog many more such events, rate their severity, and result in a plot of these events versus time. That effort would likely show variation with time, and that variation could then be brought into the analysis to produce a better estimate of the risk we face. However, based on the evidence I have seen thus far, I doubt that it will affect the overall conclusion of my preliminary study that the risk of nuclear deterrence failing is orders of magnitude greater (i.e., at least ten times greater, and probably hundreds or thousands of times greater) than society will accept with respect to other technologies capable of causing widespread destruction (e.g., nuclear power plants).

How relevant is the historical data to the chance that a potential initiating event results in a crisis? In July 2008, the last potential initiating event I identified (our Eastern European missile defense system) came close to producing a full-blown crisis over Cuba. As discussed earlier in this handout, after the Russians indicated they would respond to that perceived threat to the credibility of their deterrent by basing bombers on Cuba, Air Force Chief of Staff, General

Norton Schwartz responded that "we should stand strong and indicate that is something that crosses a threshold, crosses a red line." As can be seen from the 1962 Cuban crisis, drawing red lines boxes one into a corner. As Michael Dobbs observed in his book *One Minute to Midnight* (page 16), Kennedy had done that in 1962:

> Under attack by the Republicans for his passivity over Cuba, the president had issued a public statement on September 4 warning the Soviets that "the gravest issues would arise" if they developed "a significant offensive capability" in Cuba. He had planted a marker in the sand, and was now committed to defending it. "Last month I should have said we don't care," Kennedy said wistfully, as if to himself. [It is now October, and he is facing Soviet missiles on Cuba.] "But when we said we're not going to, and then they go ahead and do it, and then we do nothing …" His voice trailed off. Doing nothing was no longer an option.

The Russian response to General Schwarz' "red line" could just as well have been to draw one of their own, or point out that they had effectively already done so when they strenuously objected to the placement of American missiles in Poland.[24] Such a response would have brought us much closer to, if not into, a full-blown crisis. Fortunately, the Russians took a much more cautious approach, issuing a formal denial of the first press report, while still having military planes quietly visit both Cuba and Venezuela. (See the subsection *Step #6: Khrushchev's deployment of ballistic missiles in Cuba* earlier in these notes for details.) Even that response could have blown up if American media, or the president's political opposition, had picked up on it and brought it into the public spotlight. And, as noted earlier, the chances of that happening depend on who is president and the nature of his or her political opposition. If something like that were to happen now, with Obama in office, I suspect that the risk would be higher.

An in-depth risk analysis would look at this question in more detail, but again, the preliminary evidence seems to indicate that any changes in the estimate for a potential initiating event producing a crisis will not be so large as to invalidate the need for reducing the risk. In fact, some changes will increase the risk. For example, in the past, we have benefited somewhat from Russian leaders knowing the horror of war on their own soil and tending to act more prudently as a result. As a new Russian generation takes power, that tendency may be reduced, increasing the risk.

How relevant is the historical data from the Cuban Missile Crisis to the chance of a new crisis crossing the nuclear threshold? Once a major crisis has erupted, the primary question becomes the maturity level of the actors involved. The more mature they are, the more likely they can defuse the crisis before any nuclear weapons are used. What is required is an ability to

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[24] Some of the missile interceptors in Bush's plan were to be based in Poland. In September 2009, President Obama modified the plan, at least initially moving to what many saw as a more flexible (and less threatening to Russia) sea-based system.

put aside hurt pride and understand the opposing point of view – not necessarily to agree with it, but in order to respond more effectively. There has been some growth in human maturity over the last 50 years, with women's rights and minority rights being indicators. But that growth is limited geographically and tends to be one of the first victims of war fever. For example, even though there is little to no credible evidence that Saddam Hussein was associated with the terrorist attacks of 9/11[25] as a result of war fever building in America, from 2001 to 2003, the fraction of Americans who associated Iraq with the attacks went from 3% to 45%. In the later poll, 45% believed Saddam Hussein was "personally involved" in the attack. In a related poll also done in 2003, 44% of Americans believed that "most" or "some" of the hijackers were Iraqi citizens. In fact, none were.

Today's nuclear weapons have more safeguards than those of 1962, making it harder to bypass the chain of command. But, once a crisis has reached major proportions, there will be strong pressure to remove those safeguards. If a commander in the field is facing a possibly nuclear-armed adversary, he is at a major disadvantage if he must receive approval before being able to fire. As an example of the military's greater concern that nuclear weapons be available for use compared to their concern that they might be used without authority, consider the following story related by Bruce Blair in 2004. Blair is president of the World Security Institute, a former Minuteman Launch Control Officer, and an expert on nuclear command and control:

> Last month I asked Robert McNamara, the secretary of defense during the Kennedy and Johnson administrations, what he believed back in the 1960s was the status of technical locks on the Minuteman intercontinental missiles. … McNamara replied, in his trade-mark, assertively confident manner that he personally saw to it that these special locks (known to wonks as "Permissive Action Links") were installed on the Minuteman force, and that he regarded them as essential to strict central control and preventing unauthorized launch. …
>
> What I then told McNamara about his vitally important locks elicited this response: "I am shocked, absolutely shocked and outraged. Who the hell authorized that?" What he had just learned from me was that the locks had been installed, but everyone knew the combination.
>
> The Strategic Air Command (SAC) in Omaha quietly decided to set the "locks" to all zeros in order to circumvent this safeguard. During the early to mid-1970s, during my stint as a Minuteman launch officer, they still had not been changed. Our launch checklist in fact instructed us, the firing crew, to double-check the locking panel in our underground launch bunker to ensure that no digits other than zero had been inadvertently dialed into the panel. SAC remained far less concerned about unauthorized launches than about the potential of

[25] Saddam Hussein was a secular dictator, who did not share power with religious elements – or any others. Al-Qaeda is a fundamentalist Islamic organization which wants to replace such secular governments with Islamic-based ones.

> these safeguards to interfere with the implementation of wartime launch orders. And so the "secret unlock code" during the height of the nuclear crises of the Cold War remained constant at 00000000. … The locks were [finally] activated in 1977.

A more recent example of this unsafe approach is described in one of my blog posts from October 2010. When a system failure at Warren AFB in Wyoming affected fifty ICBM's, various security protocols built into the missile delivery system, like intrusion alarms and warhead separation alarms, were offline. Assuaging fears that America's nuclear deterrent might have been compromised during this failure, it was noted that the missiles still could be launched from airborne command centers. An administration official offered assurances that "at no time did the president's ability [to launch] decrease." That sounds risky because there is an unavoidable tradeoff between the danger of not being able to launch our missiles when wanted versus accidentally launching them. The system design can reduce the risk of either of those errors, at the expense of increasing the other. A design that allows the missiles to be launched during a system failure would seem to increase the risk of an accidental launch.

For these reasons, I suspect that an in-depth risk analysis will find little change in the odds of a new crisis crossing the nuclear threshold, even when just a Russian-American crisis is considered. When the new risks of nuclear terrorism and a war between India and Pakistan are factored in, it is conceivable that the odds today are even worse than they were in 1962. There is another factor that reduced the risk of crossing the nuclear threshold in 1962 that is unlikely to be repeated in a modern-day crisis, and therefore would tend to increase today's risk:

Kennedy had almost a week from the discovery of the missiles until he was forced to go public with that information and present a plan of action. During that time, as he thought through the implications of his initial plan to bomb the missiles, his opinion changed, and he fought off repeated calls for such action from others, notably the entire Joint Chiefs of Staff. One of Kennedy's advisors during the crisis, George Ball, talking about a group meeting some years after the crisis: "Much to our own surprise, we reached the unanimous conclusion that, had we determined our course of action within the first 48 hours after the missiles were discovered, we would almost certainly have made the wrong decision, responding to the missiles in such a way as to require a forceful Soviet response and thus setting in train a series of reactions and counter-reactions with horrendous consequences."[26] Unless a modern day crisis of similar proportions also offered the president time to think through options before acting, the risk of crossing the nuclear threshold would be increased. Kennedy had the luxury of so much time partly because the press cooperated when he asked them to hold their stories until after his television address. Such media cooperation is less likely in today's world.

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[26] William L. Ury, *Beyond the Hotline: How We Can Prevent the Crisis that Might Bring on a Nuclear War*, Houghton Miflin Company, Boston, 1985, page 37.

How relevant is the historical data from the Cuban Missile Crisis to the chance of a new crisis that has crossed the nuclear threshold escalating to full-scale war? My estimate of 10% to 50% for this probability depended more on human behavior during times of crisis than any specifics of the Cuban Missile Crisis. Hence it would seem to be just as applicable today as with respect to 1962.

Integrating Criticism of my Preliminary Risk Analysis

Earlier in this handout, I raised the question: "What do we do if you disagree with my estimate?" This section answers that question.

The first question to ask in that event is "Do our estimates differ enough to affect our conclusions?" For example, my preliminary risk analysis indicates that our current nuclear strategy is at least 1,000 times riskier than living next to a nuclear power plant. If we agree that an acceptable level of risk would be no greater than living next to one such plant, then my analysis indicates that the risk needs to be reduced by at least a factor of 1,000. Even if your estimate of the risk is 100 times smaller than mine, that still would leave at least a factor of 10 that needs to be dealt with.

Moving beyond that first question, a very insightful paper on risk analysis (use this link if you cannot access the first one) by MIT's Prof. George Apostolakis argues that risk analysis needs to be seen as a process, not a one-time effort, and that decisions should be risk-informed as opposed to risk-based. That is, risk analysis should be one of the tools brought into the decision process, but should not be thought of as a dictator, telling us exactly what needs to be done.

Apostolakis also explains that risk analyses need to be peer reviewed and improved based on that process. If the best risk analysis in an area has problems, that calls for correcting those problems to the greatest extent possible, not throwing out the baby with the bath water. Decisions made in the absence of a quantitative risk analysis still depend on subjective estimates of the risk, but those making the decisions no longer have to justify the assumptions that support their conclusions. In contrast, my risk analysis of nuclear deterrence forced me to explain why I chose the numbers I did, allowing objective criticism to correct errors. If you disagree with my estimate of 6% per year for the rate of occurrence of potential initiating events, you can explain why you believe the evidence I presented is incomplete or inapplicable, and offer new evidence of your own. If you disagree with my estimate of 10% to 50% for the probability of a full-blown Cuban crisis crossing the nuclear threshold, again we can argue our positions more objectively. Contrast the benefit of knowing where and why we disagree in our estimates with the situation when no risk analysis is available. Then, our argument would be similar to two children arguing "Is too!" versus "Is not!" except here those positions would become "Our current nuclear strategy is too

risky!" versus "Our current nuclear strategy has worked fine for 65 years, so don't mess with success. It's too dangerous!"

My own experience dealing with nuclear deterrence from a risk analysis perspective over the last several years has convinced me of the value of that approach, and I hope this introduction has conveyed some of the lessons I have learned.

Risk Analysis Provides Early Warning Signs

Risk analysis provides early warning signs for faulty system designs that are headed for catastrophic failure – but only if we pay attention to those signs. Unfortunately, history shows that society usually makes the mistake of distorting early warning signs into evidence that all is well. "After all," the reasoning goes, "we had a scare [the near miss], but our backup systems worked and nothing bad happened. Clearly all is well." Examples of that dangerous thinking follow:

The Gulf Oil Spill: As noted earlier, just five months before British Petroleum's Deepwater Horizon rig created an environmental disaster, its vice president for exploration in the Gulf of Mexico told Congressional Hearings that Outer Continental Shelf drilling "has been going on for the last 50 years, and it has been going on in a way that is both safe and protective of the environment." The reality was very different, as shown by a December 2010 *The Wall Street Journal* article:

> The oil industry has said the Deepwater Horizon rig catastrophe was a unique event, the result of an unprecedented series of missteps that are unlikely to be repeated. The recent history of offshore drilling suggests otherwise. In the months before and after the rig exploded and sank, killing 11 and spilling millions of barrels of oil into the Gulf of Mexico, the industry was hit with several serious spills and alarming near-misses, some of them strikingly similar to what happened aboard the Deepwater Horizon. … The industry's faith in its ability to safely develop oil and gas from facilities at sea is largely unshaken. The Deepwater Horizon "was an isolated incident," says Erik Milito, a senior official at the American Petroleum Institute. "We do not believe there is a systemic failure across the industry."

In contrast to the industry's complacent attitude, an interim National Academies report on the Gulf oil spill found a glaring systemic failure:

> The failures and missed indications of hazard were not isolated events during the preparation of the [British Petroleum] Macondo well for temporary abandonment. Numerous decisions to proceed toward abandonment despite indications of hazard … suggest an insufficient consideration of risk and a lack of operating discipline. … The various failures mentioned in this report indicate … a failure to learn from previous near misses. … the testimony failed to discern any standard practice employed to guide the tradeoffs between cost and schedule and the safety implications of the many decisions (that is, a risk management approach). … in an effective risk management approach reflecting a safety culture, "near misses" provide opportunities to improve, and the reporting of errors, omissions, and questionable results is highly encouraged.

As we now know, all those early warning signs were ignored and the near misses mistakenly seen as proof that all was well. The result was a catastrophic failure.

The Challenger Space Shuttle Disaster: Ignoring early warning signs and mistakenly viewing near misses as proof that all was well also led to the loss of the Challenger space shuttle. The O-rings on the shuttle's booster rocket were designed to prevent hot gases from escaping from the combustion chamber. Partial O-ring failures on flights prior to the Challenger disaster showed that the system was not working as designed and should have been cause for alarm. Instead, these early warning signs were turned into evidence of a significant (and illusory) safety margin: It was decided that, because the O-rings had only burned ⅓ of the way through, there still was "a safety factor of three." In his personal observations on the Rogers Commission report, Physics Nobel Laureate and commission member Richard Feynman criticized that approach:

> This is a strange use of the engineer's term, *safety factor*. … The O-rings of the Solid Rocket Boosters were not designed to erode. Erosion was a clue that something was wrong. Erosion was not something from which safety can be inferred.

Ignoring the early warning signs and misinterpreting near misses as successes[27] because an accident had not yet occurred proved fatal to the Challenger's crew.

Hurricane Katrina: Prior to being destroyed by Katrina, New Orleans was known to be vulnerable to a slow moving category 3 hurricane. A year earlier, an emergency preparedness exercise had simulated the effects of such a fictional "Hurricane Pam" and predicted a

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[27] In testimony to the Rogers Commission, the manager of NASA's booster rocket program, Lawrence Mulloy, stated that his frame of mind in overriding the Thiokol engineers' objections to launching in such cold weather included, "What you are proposing to do is to generate a new Launch Commit Criteria on the eve of launch, after we have ***successfully*** flown with the existing Launch Commit Criteria 24 previous times." [emphasis added]

catastrophe. A Louisiana State University report notes that "experts involved in the Hurricane Pam exercise were struck by the similarity of the simulation to the actual destructive conditions wrought by Katrina." I do not know for sure why this early warning sign was overlooked, but suspect that successfully escaping a real near miss the year before played an important role. When Hurricane Ivan (a real one, not a simulation) had a 23% chance of hitting New Orleans with disastrous results, an evacuation was ordered. Given the catastrophic consequences of failing to evacuate when needed, even a 23% chance of a disaster warrants evacuating. As it happened, the 77% chance won out and Ivan did not hit New Orleans, leading many residents to believe that disaster management personnel had "cried wolf." Many people therefore ignored the evacuation order for Katrina which had a slightly smaller 21% chance of hitting the city.

Even after Katrina's devastation, this dangerous mentality persisted. In 2008, Hurricane Gustav triggered the largest evacuation in U.S. history. Gustav weakened before making landfall, leading one evacuee to complain, "Next time, it's going to be bad because people who evacuated like us aren't going to evacuate. They jumped the gun." It takes time to evacuate a city, so the decision must be made well before the hurricane hits, when its ultimate strength and path are only roughly known. An objective analysis is needed that balances the costs of the two types of error – needlessly evacuating versus not evacuating when we should – and then factors in the probability of a particular storm hitting the area in question. In the case of Ivan, Katrina and Gustav, I suspect such analyses would vindicate the evacuations that were ordered. The problem is getting society to recognize that we live in a world with imperfect information, so seemingly "needless evacuations" (errors of the first kind) are needed to reduce the risk of disaster (errors of the second kind) to an acceptable level.[28]

The Economic Crisis: The financial meltdown, from which we are still trying to extricate ourselves provides another good example of how hard it is to get society to start paying attention to early warning signs and to stop seeing near misses as proof that the systems in place are functioning properly. The meltdown first came to public consciousness in the summer and fall of 2008, when the nation was told that, if it didn't provide $700 billion to Secretary of the Treasury Henry Paulson to buy mortgage-related securities, we faced a crisis that could rival the Great Depression. The situation was so dire that Section 8 of Paulson's original proposal stated that all of his actions in using those funds "may not be reviewed by any court of law or any

[28] One of the first things I learned as a graduate student studying decision theory is that, without perfect information, the only way to have zero errors of one kind is to have 100% errors of the other kind. While a proof is clearly beyond the scope of this seminar, you may be able to see that: If you cannot be 100% certain of your decision (that's what imperfect information means), then the only way to never "needlessly" evacuate is to never evacuate. That guarantees that every time you should have evacuated, you won't, giving an error rate of 100% in that direction.

administrative agency." While Congress added some oversight provisions before appropriating the funds, that section of the original proposal gives some idea of how serious matters had become. The figure below charts the Dow Jones Industrial Average for a five year period from 28 JAN 2006 to 28 JAN 2011. It shows that, until the meldown started, its potential magnitude was not appreciated even by sophisticated investors. (While not all investors are sophisticated, mutual funds control a large portion of investments and are supposed to be run by financial experts.)

Yet there were numerous, overlooked early warning signs:

- In the *Washington Monthly's* October 1994 cover story, Senator Byron Dorgan wrote extensively about the danger of financial derivatives: "here's the real kicker: Because the key players are federally insured banks, every taxpayer in the country is on the line. … What is surprising is that the Office of the Comptroller of the Currency (OCC) and the Federal Reserve agree, too, that legislative reform is unnecessary. 'As far as the Federal Reserve Board is concerned,' Chairman Alan Greenspan testified in May, 'we believe that we are ahead of the curve on this issue as best one can get.'" Dorgan further noted that "derivatives were now a $35 trillion – that's right, trillion – worldwide market." By 2008, they had mushroomed to a $600 trillion market. While derivatives were not the sole cause of the meltdown, their use of leverage greatly amplified the damage.

The Dow Jones Industrial Average from 2006 to 2010

- Several years later, the head of the Commodity Futures Trading Commission (CFTC), Brooksley Born, recognized the danger posed by derivatives, but was blocked from regulating them by Congress. As reported in the March/April 2009 issue of Stanford's alumni magazine. "Ultimately, Greenspan and the other regulators foiled Born's efforts, and Congress took the extraordinary step of enacting legislation that prohibited her agency from taking any action."

- In March 1998, *DowJones Financial News* had an article, "Buffett turns Cassandra over catastrophe bonds." He had warned in his annual letter to Berkshire Hathaway shareholders that disaster awaited those who invested in those related financial instruments. Even "the Oracle of Omaha," as Buffet is often called, can be seen as a Cassandra when his warnings contradict a widespread belief that all is well.

- Four years later, in his 2002 annual letter, Buffet zeroed in on financial derivatives and warned, "Charlie [Munger, Buffett's partner in managing Berkshire Hathaway] and I are of one mind in how we feel about derivatives and the trading activities that go with them: We view them as time bombs, both for the parties that deal in them and the economic system. … In our view, however, derivatives are financial weapons of mass destruction, carrying dangers that, while now latent, are potentially lethal."

- In January 2008, just months before the financial meltdown began in earnest, *Business Week Chicago's* headline called Janet Tavakoli "The Cassandra of Credit Derivatives." Buffett has a different take and said, "Janet Tavakoli should have been listened to much more carefully in the past … and will be in the future."

In spite of these repeated, specific warnings ("financial weapons of mass destruction" is about as graphic as you can get) and in spite of the credibility of their sources (Buffet is widely regarded as a financial genius) society overlooked the danger, an error for which we all now are paying a heavy price. Two other early warning signs that were mistakenly seen as proof that all was well deserve mention:

- In 1998 the Federal Reserve Bank of New York, fearing that the collapse of the Long Term Capital Management hedge fund could cause systemic failure, engineered a bailout. While no public funds were used, this should have been seen as an early warning sign that high leverage could produce systemic effects. Instead, the successful wind-down appears to have added to complacency that the financial system was working as planned. At the start of 1998, LTCM had leverage greater than 25:1 on $129 billion of debt, and derivatives tied to $1.25 trillion of financial instruments. To put that in perspective, stock

investors can only leverage 2:1. Prior to the Great Depression, stocks could be leveraged 10:1, but that ratio was lowered when it exacerbated the crash of 1929.

- In the 1980's, many regulations designed to protect US government insurers (e.g., the FDIC) from risky bank and S&L investments were repealed. People continued to trust their money to risky financial institutions because they were protected by government backed insurance, and the risky institutions paid higher interest rates. This deregulation without de-insurance led many institutions to take outsized risks and ultimately cost American taxpayers $124 billion. Because the cost was not catastrophic, this early warning sign was largely neglected.

Conclusion: The above evidence shows that society often overlooks catastrophic risks until it is too late. In the case of nuclear weapons, that approach clearly is unacceptable. Here are some of the early warning signs of a nuclear disaster (most treated in earlier handouts) that are being overlooked:

- South Africa stores the highly enriched uranium (HEU) fuel from about a dozen dismantled bombs in their Pelindaba facility. It was successfully attacked and entered by armed men in November 2007. Fortunately, they were scared off without any loss of HEU.

- Even the U.S. nuclear arsenal is less secure than it should be as demonstrated by the US Air Force losing six nuclear warheads in August 2007 for a day and a half. While they were lost, these six weapons were inadequately protected from theft.

- During the 9/11 terrorist attack, jet fighters were scrambled to protect Washington, but in the confusion, the lead pilot thought Russians had attacked us. That same day, Russia was flying strategic bombers toward the United States in an exercise. If the Russian military had not learned of the terrorist attack and grounded the bombers before an accident could occur, in the confusion, they might have been shot down even while outside U.S. airspace.

- Due to circumstances not understood in the West at the time, the 1983 Able Archer military exercise caused the Soviet leadership to fear an American nuclear first strike was in progress. Secretary of Defense Robert Gates has called Able Archer "one of the potentially most dangerous episodes of the Cold War." [29]

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[29] Gates Robert M (1996) *From the Shadows*. New York: Simon & Schuster, pages 270-273.

- Both the 1991 and 1993 Russian coup attempts created dangerous conditions that also were not generally understood in the West. During the latter, a number of American intelligence officers at the North American Aerospace Defense Command (NORAD) headquarters who did understand the danger called their families and told them to leave Washington out of fear that the Russians might launch a nuclear attack.[30]

- In 1995, Russian air defense mistook a meteorological rocket launched from Norway for an American submarine-launched ballistic missile, causing the Russian "nuclear football" – a device that contains the codes for authorizing a nuclear attack – to be opened in front of President Boris Yeltsin.

- The August 2008 Georgian war, coupled with dangerous misperceptions, created conditions that could have led to more general war. Ongoing tensions could produce a rematch, and Sarah Palin, reflecting the misunderstanding that plagues many Americans, has said that the United States should be ready to go to war with Russia should that occur.

- NATO's expansion has caused Russia to feel increasingly encircled. In the words of Admiral Ulrich Weisser, a former high ranking German defense official: "Moscow also feels provoked by the behavior of a number of newer NATO member states in central and Eastern Europe. Poland and the Baltic states use every opportunity to make provocative digs at Russia; they feel themselves protected by NATO and backed by the U.S."

Unlike with the Gulf oil spill, the space shuttle disaster, the destruction of New Orleans by Hurricane Katrina and the economic meltdown, the consequences of a failure of nuclear deterrence would be so catastrophic that overlooking these early warning signs is not an acceptable option. It is time for society to wake up. As explained on my related web site, your involvement, coupled with in-depth risk analyses of nuclear deterrence, has the potential to play a key role in bringing the danger into clear focus before disaster strikes. If we do that, we can reverse Einstein's "drift toward unparalleled catastrophe." To end this section on a positive note, in the process of combatting the ignorance and misperceptions that produce much of the nuclear risk, we will create a better world that we can be proud to pass on to future generations. That positive goal motivates my efforts even more than eliminating the danger, and I encourage you to think in those terms as well. It provides a better foundation both for one's own mental state and for reaching out to others.

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[30] Peter Vincent Pry, *War Scare*, Praeger, Westport, CT, 1999, pages x, 53-86 and 129-169.