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To: John Graham/OMB/EOP@EOP
cc:
Subject: Event Tree analysis for Terrorism

Dear John,

Now I am getting older, (77 next month) and note that the risk of dying
from a fall is 10 times greater when you are over 70, I escaped from the
New England winter and have been spending the winter in New Mexico (Los
Alamos). I have been continuing to think about proper risk analysis
procedures for terrorism.

I gave a talk at the University of New Mexico and was immediately asked to
give an invited talk at a conference on bioterrorism (BTR 2003) in
Alberquerque arranged by Brigadier General Annette Sobel of Sandia LAbs. I
will do so tomorrow afternoon.

You may be interested in my talk. My general proposition is that most of
society, excepting the nuclear industry, has not done a proper safety
analysis and in particular ignores accidents which are a rare combination
of circumstances but can have high consequences.   (The Low Probability -
High Consequence Accident).

Yet a terrorist will look for these, and increase the probability.

Thus the best defense against terrorism is NOT duct tape, but to think
through rare accident situations and fix them.

The night club fire in Rhode Island was utter stupidity on everyone's
part; each and every band member, the building owners and janitors, the
regulator and even the patrons for not practicing going out of the
emergency exits. This was an accident. But how many night clubs in the
USA are just waiting for a terrorrist?

Is there any where else I can get this message across?

I attach the text

Dick
 - terrorism_Alburquerue_2003.doc

Combating Terrorism: an Event Tree Approach
Richard Wilson
Harvard University
Visitor at Los Alamos National Laboratory

Introduction

Physicists are used to thinking quantitatively. They are used to defining quantities and units carefully. This turns out to be important in discussing terrorism. Often, in a dispute, both sides use terror tactics. Although terror tactics in either side are abhorrent to most of us, they are often justified by their proponents as legitimate responses to the constraints imposed upon them. In addition, physicists have had to think through problems in nuclear reactor safety and other problems in an event tree analysis. In such an analysis one tries to imagine all *initiating* events and tries to follow through the possible consequences thereof to an ultimate end point. This procedure, called *Probabilistic Risk Assessment,* was developed for understanding nuclear power accidents, a technology where the application is probably the simplest (Rasmussen et al. 1975). It is an extension of what the old Atomic Energy Commission called "Defense in Depth". But it has also been used to understand accidents in chemical refineries and more recently is being adopted by NASA and other US Agencies. The application to terrorist activities is much more difficult. One of the advantages of the "defense in depth" policy, is that if the means for preventing an accident are independent of each other, the probabilities of failure multiply. However, human intervention, sabotage or terrorism, can couple these independent events and make the improbable event much more probable. Nonetheless the understanding of a system that the event tree approach provides should prove useful in discussion of sabotage and terrorism. It automatically leads to a multifaceted approach to combating terrorism of which I discuss three facets; the avoidance of world situations that breed terrorism; the containment of the terrorist; and the difficult task of limiting the damage that a terrorist might cause. This in turn maybe broken up into parts subsidiary event trees. It will be seen that I build primarily on my own experience and studies over a period of years.

Definitions- What is a terrorist?

Most people think they know very clear what a terrorist is. It is a person who terrorizes him. But we need a more objective definition to ensure that in coping with terrorism everyone is talking about the same subject. In this attempt I go to the uses of the word in the Oxford English Dictionary .

The first use of the word discussed was applied to the Jacobins in the reign of Terror in the France of 1795. "The terrorists, as they were justly denominated, from the cruel and impolitic maxim of keeping the people in implicit subjugation by a merciless severity".

Another use was to the extreme revolutionary society in Russia, and the implication of important people. Thus in 1905 "Several notables are believed to be more or less implicated in the acts of the Terrorists".

It was also applied (in 1866) to those in Ireland objecting to British rule: "Miss G...., daughter of a Wexford terrorist, directed many of the tortures which were so extensively practiced".

And in 1805 there were the religious terrorists: "some book of the religious terrorists which tended to infuse the alarm of foul perdition".

These uses of the word terrorist all in some way apply to a person or people, individual or governmental, which terrifies people. I ask each and every reader: how do *you* use the word? President Bush used the word terrorist in his speech of September 2001 in a way which achieved wide, almost universal, support. He used it as an act against a people with no apparent purpose but to disrupt. But now he seems to use it in a different way – to apply to those who oppose the policies of governments or entities whom America (Mr. Bush) likes and by extension the word is now widely used against any people, or a government that America (Mr Bush) did not like. The President of Pakistan took care to explain that he opposes terror in all its forms- by which I assume he includes oppression of a people by its government or an occupying government. I suggest that we all heard it in the way we wanted.

It is important that each one of us, when discussing government actions, to consider how we would use the word. I list a number of conundrums .How many of your friends will agree with your assessment on *all* of these?
(1) Was Hitler and his Nazis a gang of terrorists even though they were the legitimate government of Germany, originally elected by the people? Were opponents of Hitler terrorists? Especially Colonel Von Stauffenburg who tried to assassinate Hitler with a bomb in a brief case?
(2) Were the Hutus in Ruanda terrorists even though they were (as we know) supported by the legitimate government in

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their slaughter of the Tutsis?

(3) Were the Young Turks terrorists when they victimized the Armenians in 1916? Or were the Armenians terrorists because they were not model citizens of the Ottoman Empire and would not be slaughtered quietly?

(4) Again, were (and are) the opponents of British rule (or Protestant rule) in Ireland (or part of it) terrorists? Has the situation changed since partition was generally agreed in 1922?

(5) Is the government of Russia guilty of terrorism against the people of Chechnya (who have as much voting power as other residents of Russia) or are the radical Chechens guilty of terrorism against Russia? Or both? Has that changed in the second war against Chechnya?

(6) Is the government of Sri Lanka acting like the Jacobins against the Tamils of the north, or are the Tamils a bunch of terrorists to be tamed?

(7) Were the French fighting a terrorist group, Greenpeace, when they sank the ship in a New Zealand harbor? Or were they terrorists themselves?

(8) Was Oliver North a terrorist? He was arranging the financing of the Contras, a group opposing the legitimate Government of Nicaragua, for his own ideological reasons, and contrary to the explicit instructions of the elected US Congress.

(9) When does a government using excessive force against a dissident group become terrorist themselves? Were the actions against the dissidents in WACO Texas, terrorist activities in the Jacobin sense or were they fighting terrorists? At least one American (Timothy McVeigh) thought the former and became a terrorist himself in response.

(10) Was General Custer fighting a band of Indian terrorists as he made his last stand, or were the Indians fighting an oppression worse than the French had experienced in 1795? I note that at the time most Americans believed the former. Nowadays it is politically correct in some circles to believe the latter. It is safe to do so, since the Indians are dead or cowed, and it costs the rest of us nothing to do so.

(11) Was Castro a terrorist or a freedom fighter when he opposed the government of Batista? Are the people who oppose him terrorists, whether they live in Cuba or Florida? What about those branded by Castro as terrorists to whom the USA has given citizenship? Does the US oppose just Castro or anyone who disagrees?

(12) A professional must not duck difficult issues even when emotion is involved. . It is here that his professionalism can be most useful. Is the government of Israel a terrorist government because with respect to the Palestinians they follow (like the Jacobins) "the cruel and impolitic maxim of keeping the people in implicit subjugation by a merciless severity"? Or are the Palestinians all terrorists because they belong to an organization opposing the present government of Israel and its policies and particularly in its early days, to drive them into the sea? Are the Israeli actions of 2001-2003 justified because of Palestinian terrorism (or resistance) or unjustified because (according to many people) even the Israeli presence in the west bank and Gaza is contrary to UN Security Council resolutions?

Everyone has a tendency to "take sides" in a conflict. But usually both sides are wrong and for an outsider to take sides is dangerous. Let us examine this.

One man's terrorist is another man's freedom fighter.

The expression "freedom fighter" has been used by those who argue that a particular group is fighting for the freedom of his country against foreign domination and oppression and that this somehow justifies any otherwise unpleasant act that he or she performs. This phrase needs definition more than most others but the definition is inevitably subjective.

The late theoretical physicist Professor Victor Weisskopf once (in my presence) corrected a Russian interpreter for referring to the October revolution of November 1917 as a rebellion. Rebellion according to OED is organized armed resistance to the ruler of Government of one's country. But when the rebellion succeeds, it becomes a revolution: "the complete overthrow of one's government." Likewise when a terrorist succeeds in his objective of overthrowing the established order, he is regarded as a freedom fighter.

Clearly Thomas Jefferson, once a rebel, became a freedom fighter. (Most people would not call him a terrorist because he did not engage in violence, although he indirectly urged it. However Jefferson did not, in his writings condemn terrorism.)

Monachem Begin was definitely a terrorist organizer in 1945 when he organized various activities such as the blowing up of the King David Hotel in Jerusalem. But he later became leader of his country (Israel) which had become free and independent.

Bourgiba was jailed as a terrorist by the British in Cairo, but later went on to become the first President of his country (Tunisia).

Nelson Mandela clearly engaged in terrorist activities in South Africa. But now he is widely honored as the founder of the new state.

Syria was on a short list of States that the US State Department accuses of encouraging terrorism. Yet Syria supported the USA in the Gulf war and now has a seat on the UN Security Council. Has Syria thereby stopped being a terrorist country? Or were we wrong in thinking it was one before?

Americans have to look back at their own history to grasp the complications of such a simplistic distinction.

"Single acts of tyranny maybe ascribed to the accidental opinion of the day; but a series of oppressions, begun in a distinguished period and pursued unilaterally thro' every change of ministers, too plainly prove a deliberate, systematical plan of reducing us to slavery".

As I read these worlds aloud a listener thought that these might be the words of Gerry Adams - the leader of the IRA. But they might also be the (translated) words of a Kashmiri leader, or of Yasser Arafat. But no. These words were written by Thomas Jefferson in 1774. They propelled him to the Congress in Philadelphia as a representative from Virginia. Jefferson was clearly accusing George III of the form of terrorism according to the usage I listed first in this memo. This was before the Jacobins came to power and the word "terrorist" became popular. Indeed on July 4th every year Americans celebrate the day when terrorists became patriots and rebels became statesmen.

I then go on with my difficult questions.

(13) Were the perpetrators of the Boston Tea party "terrorists" as George III might have said, or freedom fighters? They wantonly destroyed private property but they killed no one.

(14) Almost everyone in the USA and many others seem to agree that the people who deliberately flew airplanes into the world trade center were terrorists. But the further one gets into the complicated disagreements, the more difficult it is to agree upon a consistent definition.

(15) In May 1940, after Dunquerque, most Englishmen feared a Nazi occupation of England within a few weeks. Teenagers, including myself, learned rules of unarmed combat. While before 1939 we had been taught the "Queensbury Rules" of boxing, we were now told: "always hit below the belt" and "stamp on the instep". I was shown how to creep up on a German sentry and cut off his head with a sharp wire such as used for cutting cheese. Was this education in resisting unwanted occupation a training in terrorism or training in fighting for freedom?

(16) The birth of Bangladesh 31 years ago illustrate show how a metamorphosis can come about. Some people in East Pakistan picked up guns to oppose the government of West Pakistan. How would you describe them? I think they were terrorists. As the weeks passed they became freedom fighters. When they succeeded they became the first statesmen of their new country. But the Pakistani Army objected even as they were losing. On December14th, "Martyred intellectuals day", the Pakistani army systematically slaughtered hundreds of intellectuals: judges, lawyers, physicians and professors Such behavior, disguised to appear as a legitimate and proper response to those trying to destroy law and order can also be assumed to be a deliberate attempt to deprive a new nation of its leadership, is all too common and can be seen today.

Opinions of people will differ on each of these cases, and few will come out on the same side on all of them. But we can probably all decline the irregular verb and say literally:

"I am a statesman
You are a freedom fighter
He is a terrorist"

(17) Dr Elena Bonner said about the fighting between the Armenians and the Azeris in the early 1990s, "both sides did bad things but (in her view) the Azeris were bad first" because they massacred ethnic Armenians in Sumgait just north of Baku. But is that enough reason in itself for choosing sides? If not what are the criteria?

(18) Is it only individual terror that we object to or is state sponsored terrorism equally bad? If the first why are we worried about Saddaam Hussein?

(19) The late Edwin H. Purcell, Nobel Laureate in Physics and for six years a member of the President's Science Advisory Committee, used to describe his view of the US administration's position (which he opposed, particularly as it applied to Vietnam): "A terrorist is a man with a bomb and no airplane to drop it from".

(20) I recently talked about terrorism in Chatham House where William Pitt (the elder), Earl of Chatham, once lived. After a distinguished period in office, George III replaced him as prime minister. Chatham said in his last speech: "My Lords, if I were an American, as I am an Englishman, while a foreign troop was landed in my country I never would lay down my arms- never, never, never. I would not rest until the last foreign soldier had left my soil". I commend these words to statesmen in any country whose troops are on the soil of another.

This was a long time in preliminaries. But the preliminaries are essential to be sure that we are talking about the same subject. I now come, at last, to the three independent steps that I believe to be essential if we wish to combat

terrorism. As is usual in discussions of series of events, it is easier and more important to address the first step in the chain and discuss the probability of its occurrence and whether that probability can be reduced..

Step 1: The root causes of Terrorism

Why is a terrorist? Can we alter the probability that a person becomes a terrorist? I think we can.   In doing so there is no need to approve of the terrorist or agree with the motivation that led him to become a terrorist. Indeed in most cases we might consider the terrorist, government or individual despicable. We *do* need to recognize, perhaps by considering the examples above, that pragmatically addressing the root causes works, and maybe the only procedure that does work. Far too little attention is being paid to this internationally. Terrorism has been with us for centuries and seems to be a permanent facet of our existence.   I therefore think it is very important to attempt to find, and eliminate or reduce, the root causes of terrorism. Among these root causes are clearly frustration and despair caused by poverty, hunger, ignorance, injustice and intolerance. In the various long run disputes that plague the world, most people are not armed; and believe in peaceful solution to problems.   But when oppression becomes, or is perceived to become, intolerable, these peaceful people will refrain from denouncing those that take up arms in their cause. These that are killed while fighting become martyrs and are honored.   It is not hard to see that these "freedom fighters" can go over the edge. Terrorism then becomes an end in itself independent of the cause.

Terrorism has been described as a cancer on our society.   If we develop the analogy further, I note that cancers can be controlled and even cured until they metastasize to another location. When IRA terrorists, now seemingly, and most of us hope permanently, found themselves unemployed as terrorists at home, they started training terrorists in Columbia, such metastasis occurred. Many of us fear a metastasis of the Palestinian/Israeli conflict. Indeed one Israeli foreign Ministry representative, talking in February 2002 on National Public Radio, implied that metastasis had already occurred by blaming the Palestinians for setting a bad example to other arabs who had perpetrated 9/11. . Most of us agree that these long running disagreements can be a breeding ground for terrorism. When disagreements between people are also seen, or perceived, to exist side by side with wealth, extravagance and aggression of another group, particularly an oppressing group, there is likely to be trouble. In my view the solutions must lie in charity, tolerance, and humility in understanding and helping other peoples.

I therefore insist that the first step in dealing with the threat of terrorism is try to divine the *cause* for which they are fighting. Then to address the cause by peaceful means.   It is, however, difficult to put the aims of the perpetrators of 9/11in the categories above. The perpetrators were Egyptians and Saudis. Surely not countries being (directly) oppressed by another country.   But even here one can find a cause.   But many analysts have noted that these two countries have governments that are responsive to the needs of the rich but not of the poor. They also leave little room for the poor to express themselves politically. There is no opposition party in the western sense. The poor, and the middle class people who support the poor seem to have no option but to turn to organizations such as the Moslem Brotherhood (in Egypt) who seem to have people dedicated to help the poor. Both the people of the USA and their governments prefer to deal with a stable, even though undemocratic, government than one in political turmoil. The US government supports the governments both of Egypt and Saudi Arabia; providing aid in the former case and protection in the latter. This automatically makes the US complicit in the government's actions and a target for those (the suicide hijackers and Bin Laden) who object.. The recent attacks were clearly against symbols of America's domination: the pentagon with its military domination and the World Trade Center with its financial domination. This suggests an important step in reducing the chance of people joining Al Quaeda. The US should comport itself so that it does not appear to be arrogant and dominating. There is no easy way out. The USA gave strong support for President Syngman Rhee of South Korea, and we were fortunate that the Koreans eventually made their own internal reforms.

There is an interesting cheerful corollary to the above thought. The population of Iran has more than doubled since the Shah was overthrown and the clerical government took over. A majority of the population is under 30 and never knew the Shah. These are the young people who might engage in violence. Yet their frustration with lack of progress of the country seems to be aimed at their government not at us. For the USA can hardly be blamed for supporting the existing, clerical, government. To the very limited extent that President Bush is correct in calling the government of Iran as evil, this does not seem to apply to the young people of Iran and in my view these comments like many recent comments of the President are counterproductive.

Step 2: Keeping Terrorists at Arm's length

I assume that in spite of mankind's attempts to reduce the creation of there will be terrorists who must be contained, isolated or eliminated (killed). In the immediate aftermath of the World Trade Center destruction, President Bush assembled a truly remarkable coalition of world leaders to denounce terrorism. One must not belittle the importance of this achievement by comments that many of them are not leaders of democracies, or are in some way oppressing other people. Some of the most emotional support for America has come from people from other countries who are trying to build American values in their 3rd world countries. Yet there is a perception that American actions do not always follow the stated ideals. Palestinians and nearby Arab states, for example, complain that the US government continues to subsidize, and provide arms to, Israel regardless of what Israel does. Indians complain that we fail to denounce the failure of Pakistan to halt terrorism in the Kashmir.

There is general agreement with Jefferson's concept that "no society can survive without a decent respect for the opinion of mankind."(quotation from memory). This unanimity in the world in 2001 was probably greater than at any time since 1945 when several unlikely major countries were allies against the scourge of Hitler. We must capitalize on it. In this context I commend and support a fine op-ed piece in the NY Times by Mikhail Gorbachev who argued that we had setup an organization in 1945 to cope with matters such as this and we should use the UN. But of course we should not hesitate to modify it if necessary. Indeed I believe that modification is appropriate. In the General Assembly the voting power of populous countries like USA, Russia, China and India is no greater than the voting power of the many small countries, and this has led both USA and USSR to avoid taking to the UN issues of importance to Russia or the USA. Something must be done to avoid this international impotence. I am deeply concerned about the posture of the present US president in this.

In 2003 we learn, in the UN and elsewhere, that the world is not unanimous and that support for the US may not be as firm and strong as USA presently desires. In my view that is partially because the US has not faced up to the difficulty of defining terrorism, and modifying its own thoughts on the contentious issues mentioned earlier to more nearly accord with international views. It is urgent for all people of good will to discuss these issues. Finally I believe that although the UN has been wise in restricting its actions to external rather than domestic problems, (because otherwise it would be overwhelmed), I believe it must intervene and act and act firmly, with justice and generosity, in any conflict that has existed for more than 50 years. These include Ireland, Sri Lanka, Kashmir, and of course the Holy Land. If the world waits, the wound to society will fester.

It is at keeping terrorists at arms length here that President Bush has paid most attention, and created the Office of Homeland Security. But keeping terrorists at arms length often involves keeping all suspicious people at arms length and violating their human rights. Brzezinski (2002) discusses various steps that are taken in Israel to achieve this and also discusses the dangers that this imposes.. Some of the steps are obvious and should not be troublesome. But he also raises the scepter of others that he would not wish to see employed.

While almost all of us believe that religions have played a major part in making the world a better place for its citizens, there is no doubt that wars fought in the name of religion, particularly in the crusades and the wars of the 17th century, have created major havoc. Thus has been built the concept of religious freedom and the vital importance of toleration for the religion and opinion of another. But there are limits to toleration. Society cannot survive if it allows the extremists of any religion to attack others. Most Moslems might insist that "jihad" means an inner struggle. The capturing or restriction of the word to mean armed struggle against another person is already a sign of trouble and western society has become wary of groups such as "Islamic Jihad". The defining and enforcement of these limits is one of the most important problems of this second step in combating terrorism. It has received little attention so far.

Step 3: Making Society Safer

Americans are fortunate that the attack on September 11th was against symbols of power and not against other targets in America which, as I will discuss later, could do much more damage to US civilian life. I suspect that terrorists will again attack symbols of power. But we can't be sure. Nonetheless, this thought then might well help us in assigning priorities.

America is an extraordinarily safe place - although there is a higher murder rate in America than in England.. My father's house in London was robbed 3 times in 25 years. My house in America has never been robbed in 46 years, although we accidentally left the doors unlocked for a month during one vacation. That is, in fact, one reason why the 2,800 people killed in the World Trade Center attack was so troubling. It is here that Risk Analysts can and should provide the most help. I argue here that making society less vulnerable to terrorist attacks is similar to making it less vulnerable to accidents. Especially making it less liable to accidents of high consequence – even though they may be of low probability. A terrorist will act to increase the probability. We address safety in all aspects of society. But all to often we neglect the low probability high consequence accident A serial killer is a terrorist who goes after one target at a time. But the terrorist who causes us the most concern is one who tries to disrupt society by killing many people at once.. In what follows I discuss some examples of this. The reader will note that I am not completely inclusive in this discussion: I merely take some examples from my own personal experience.

Examples of high consequence low probability situations.

An aircraft hitting the World Trade Center is a clear example of an accident of high consequence but which was believed to be of low probability. The FEMA report (FEMA 2002) missed the major conclusion. Although the building was a strong building, and built according to code, no one in the building industry, had considered the low probability high consequence accident.. We must consider such accidents in advance of the terrorist and make our society as secure as we can. In that we have available the tool of the event tree. My major conclusion is that the building industry, as all other industries, MUST do a full event tree analysis and pay particular attention to high consequence events. Nolan et al. (2003) discuss the event and point out that little asbestos was found.

There are detailed problems with the FEMA report. Steel buildings, and in particular steel supports are more vulnerable to fire that concrete or even wood. US builders may not have understood this, but the captured tape that was released on December 14th 2001 showed that Osama bin Laden understood it well. Steel conducts heat more readily, and can bend and melt at fire temperatures. At the World Trade Center the steel uprights and horizontal floor supports were originally planned to be insulated with asbestos to retard fire. Langer and Morse (2002) suggest that the inferior properties of the fiberglass insulation as compared to asbestos was an important issue, in the collapse. Certainly the insulation did not stick to the beams at the time of collapse. These authors suggest that the material was sprayed on steel beams that were rusty and the material may well have peeled off again. Electricians and members of other crafts often scrape off insulation to install their own devices. Some photographs of the fallen beams suggest that, indeed, many of the beams were denuded of insulation. It appears that no one checked that the insulation was secure after the other construction trades had done their worst. There were no enforced regulations at the time. It is possible that if asbestos had been used as originally planned, or the building redesigned, it would be standing today. It is irrelevant whether Langer and Morse are right. What IS relevant is that no one seems to be able to disprove their suggestions. This suggests that any and all tall buildings built at that time be checked in detail to see whether the insulation is still present.

My colleague Dr Pompei suggested a simple method. Test the insulation by a reverse process. Apply heat to a steel beam at one location, measure the temperature at all nearby locations and compare with a calculation assuming that all insulation is in place. This might cost $50 million per building. But that is cheap compared with bombing Afghanistan or 9nvading Iraq. It is also not correct that no one raised a warning. The man who was most responsible for the use of sprayed on asbestos, the late Mr Herbert Levine, founder of Asbestospray, was concerned. He told anyone who would listen (including me in 1991) that "if a fire breaks out above the51st floor (where asbestos stopped) the building will fall down. This raises another question. Should one pay attention to every warning? I suggest that this warning was a warning of a vulnerability that should have been examined.

Again nothing is perfect, and we should have had defense in depth. Evacuation of people in the anticipated 4 hours time available in which the fire resistant material would last was foreseen and indeed evacuation occurred to a remarkable extent, but not everyone would get out, and there was major property damage as the buildings fell. Many disaster movies have shown helicopters picking people off the roof of a burning skyscraper, and spraying foam into the fire below. Where were the helicopters on September 11th? Were there any disaster plans? Clearly any new tall building should have had, and must now have, plans to cope with such disasters and must take account of events of low probability and high consequence.

Buildings can be protected from airplane attacks. In world war II cables were hung from barrage balloons to cut off the wings of any aircraft willing to fly into them. Sensitive facilities at Los Alamos are protected by cables hanging from tower - no more conspicuous than cell phone towers. These would not completely protect against air attack, but the probability of serious consequences would be diminished.

In the first few months after 9/11the public discussion was about preventing an accident of the same type. I believe that it is unlikely that it will be attempted again soon. For the last 10 years airplane hijackings have been handled peacefully by the pilot following instructions of the hijacker and arguing (negotiating) when the plane has landed. Pilots basically "gave in", thereby reducing the chance of a lower consequence event but increasing the chance of a high consequence event. After September 11th 2001 that has clearly changed. Pilots will obviously resist even though the probability of a terrorist being a suicide bomber is probably small.. But there are a number of technical steps that can betaken. They have even been suggested and put aside. Barring the cockpit door is obvious. The pilot could have a special button that a pilot can press to alert FAA of a hijacking just as bank tellers alert police by a button when a bank robbery is in progress. It is also possible to set by such a button, or by command from the ground, a preset flight and landing pattern. These have their own possibilities for sabotage, but there seems to have been no study and discussion. But all of these are addressing, at last, the low probability High Consequence Accident.

General vulnerability of Society

It takes very little thought to realize that society is very vulnerable to sabotage and terrorism. But it can be made more secure without excessive expense . We could start by taking basic safety precautions. In this it is important to emphasize the role of the individual. In public health it is well known that a healthy workplace is one where management and workers collaborate in thinking about safety.

The night club fires in Chicago and Rhode Island in February 2003 underline how ill prepared America is for terrorist attacks. Most terrorist attacks involve deliberately creating a situation that sometimes can occur by accident. A terrorist can easily set a fire in a crowded night club. just as an airplane can accidentally hit a tall building. The best defense against terrorism is similar to the best defense against accidents. It is tempting to put the blame for such accidents on inadequate regulation. That is one defense against such incidents. But regardless of whether they had formal permission or not, each and every member of the band should have realized that setting off pyrotechnics in that Rhode Island night club was sheer madness. The owners should have had a representative in the building to recognize the danger. Understanding these matters should be mandatory for every performer and every club owner. Each patron should, on entering, have noted the emergency exits, and figured out how to get there in the dark. Anyone visiting the club more than once should have practiced leaving the club by the emergency exit - so that the way was firmly in mind in an emergency. This would reduce the chance of panic. Building designers should recognize that fire can disable all emergency systems simultaneously and install fire protection. Maybe we should even return to asbestos fire curtains..

When I visit a hotel with more than 3 floors, I walk down the emergency stairs soon after check in so that I can do so automatically when bleary eyed and in the dark. But often the way is cluttered with such items as garbage bags. I have, after a performance, left a theater by the emergency exit, , and found the passageway strewn with broken glass. The theater owner laughed at my complaint. In the London of my youth every theatre emphasized the Lord Chamberlains' regulation "The public may leave at the end of each performance by all exit doors and at that time the doors must be open".

There is clearly potential for a terrorist to cause great harm by making sure that we do not store a lot of fuel in one place nearby a lot of people in one place. Oil tanks and Liquefied Natural Gas (LNG) facilities should be in remote areas. (Wigner 1974). In my opinion it is more important to locate such sensitive facilities in remote areas than it is to locate nuclear power plants in remote areas. I commend the citizens of London who, a century and a half ago in 1848, decreed that petroleum products not come up the river Thames closer than 30 miles east of London bridge. The accumulation of over one hundred 17 million gallon tanks (LNG, oil, ammonia) in Canvey island (30 miles east of Tower Bridge) was not good. That planners allowed seaside vacation bungalows to be built at the east end of the same island, with two bridges to the mainland converging on one traffic circle (roundabout) was NOT good. It prevented evacuation if trouble occurred whether caused by the IRA, Okaeda or the Tamil Tigers. But the decision of the UK government to ask the Atomic Energy Authority experts in Risley to carry out a safety analysis was excellent. Their report, CANVEY

(1975) to the UK Health and Safety Executive is an excellent example of clarity of thinking and exposition. One can doubt their numerical assessment of safety, particularly because they did not address international terrorism although they addressed sabotage; but it is hard to doubt the improvement that addressing their simple improvements achieved. But few localities have been as cautious as the good citizens of London 150 years ago.

Co-location of long unprotected rail, gas pipe and water pipe lines is a recipe for disaster. I am well aware of the financial and social advantages that using a common, already paid for both politically and financially, right of way can afford, whether in a capitalist country or one with a "centrally planned economy". But we only have to look at the Soviet LPG accident in the late 1980s,when a gas pipe line leaked and was set alight by a couple of electric trains on the co-located railroad to see the problem. In this little publicized accident 800 people were burned to death - far more than Chernobyl yet with less international publicity and consequent domestic concern. In the USA, an overloaded freight train derailed in Cajun Pass and broke the accompanying gas pipe line which later exploded- killing 2 people. This has always seemed to me fruitful ground for a terrorist - and terrorists like Osama Bin Laden are now more intelligent than many politicians.

In 1972 or 1973 I had a phone call from a distraught resident of a suburb of Providence, Rhode Island. The local gas company was planning to put a big multimillion gallon LNG storage tank 500 feet from a local school. There were other sites. One obvious one was ruled out because it was 500 feet from a power line (surely less important than a school). I gave testimony suggesting that there was inadequate caution and was on the witness stand for 6 hours. But the local residents won. In 1975 I reviewed a risk assessment for an LNG tanker terminal on the west coast near a major city. The calculated risk was small (10^{-35}). But the study had had left out sabotage or terrorism where the risk is unfortunately *much* bigger. I pointed this out to a director of the gas company who had paid $1,500,000 for the study. I suggested that he rethink the conclusions. If he used the study to justify building the terminal I could (and might well) destroy him.

The methane in an LNG tank only has to be mixed with easily available oxygen to be highly inflammable and in some circumstances explosive. In contrast neither the fuel itself nor the stored fuel in a nuclear power plant is easy to sabotage in the same way. In Boston there are two 17 million gallon tanks within 2 miles of the center. If mixed stochiometrically with air each would have the energy content of 3 Hiroshima bombs. 25 years ago I participated in a study for the General Accounting Office (GAO) and in a session deliberately unrecorded, we found many ways to wreak a lot of havoc. These scenarios were deliberately not written down and will not be here. Suffice to say that a week or so later, I stopped for coffee along the Massachussets turnpike and found three trucks side by side at the rest stop. One was a gasoline truck. Another a liquid oxygen truck. A third was an LNG truck. I went on to the next rest stop. We must now pay close attention to these events of low calculated probability but high consequence. The terrorists will.

Hydroelectric dams are necessarily upstream of an estuary. For reasons of easy communication, by sea, society has usually built a town at the estuary. Hydroelectric dams have sometimes given way naturally, and at one time the "natural" failures made hydropower one of the more dangerous energy sources. Natural failures have been reduced, but few analysts have considered sabotage. In 1944 an Englishman (wing Commander Gibson) destroyed a hydroelectric dam in Germany under very unfavorable circumstances. He had to do so from the air (with a 7,000 pound bomb) while being shot at from the ground by merciless antiaircraft fire. This was documented in the film: "The Dam Bsters". With more modern explosives, this could be done with a 1000 pound bomb from the ground. To test the possibility of this route of sabotage I deliberately drove out onto an unguarded dam in the upper Connecticut river, stopped long enough to take such a heavy object from my car and drove away. No one said anything. The late Professor Arthur Casagrande, one of North America's major dam designers, told me 30 years ago that if a dam in the upper Missouri were to fail naturally or be destroyed deliberately in time of flood, then all the dams downstream would fail! But he pointed out that he had anticipated to some extent this low probability high consequence accident. Someone (I believe he) had deliberately designed a dam half way down the Missouri/Missisipi to cope with such a contingency. At the Connecticut River we both had little doubt that if I had blown up this dam on the upper Connecticut in time of flood, all dams would fail in turn down to the sea. After I related this story at the PSAM6 meeting in Puerto Rico in 2002, a risk analyst in the audience told me that he had studied the risks of all of these dams for an insurance company but had failed to consider that these failures might be correlated (common mode failure).

Anthrax , Small Pox and other biological agents

The anthrax scare was technically easily avoidable. Surgical equipment in hospitals is sterilized at modest expense, by gamma irradiation. It would not be unduly expensive to pass ALL mail in a sorting office past a cobalt 60 (or cesium 137) unit, that sterilizes everything within. Society might decide that this would be undesirable as a general rule. It would stop my wife sending flower seeds to our children through the mail. But the equipment could be ready to be used immediately on the first outbreak.. A smallpox scare could be worse since it is airborne. Vaccinating everyone has been suggested as a solution, but this would subject everyone to a risk, about one in a million lifetime risk of death.

This is easily subjected to a risk-risk analysis. The swine flu scare in the early 1970s was an example of government panic. This was discussed by Schoenbaum, McNeil and Kavet (1976). Crouch and Wilson (1992) praised Shoenbaum's retrospective "The analysis was complete and informative, and convincingly demonstrated the benefits of using such a formal tool in the policy formulation processor. In particular, it clearly showed how greatest economic benefit to the nation could be obtained and how the program to obtain this might conflict with the desire of the individual to avoid a non-economic cost "A comparison of the risks of small pox vaccination and the risks of no vaccination was made by Catlin, Joyce and Reckhow (2003) and is presented to this meeting. . The optimum depends on the estimate of probability of a terrorist attack but for a wide range of such probabilities, it was found that the optimum policy is to vaccinate health care workers and *not* the general population. Many experts now agree and recommend that vaccine be made and stored but used only after an initial outbreak is detected.

These calculations are not difficult. What is difficult is to understand why they are not done routinely. They would do much to alleviate panic. A typical official panic arose recently when a Japanese working for a UK organization helping to fight Lassa Fever was suspected of having contracted it. Neither UK nor Japan would let him back to be properly diagnosed and treated – even under quarantine. Fortunately, Germany was wiser. He turned out *not* to have Lassa fever (Mellor 2003).

Agricultural Chemicals

Society did not learn as much as we should have from the Bhopal accident in India where a lot of isocyanate, used as an intermediate in fertilizer manufacture, was stored in one place and housing was allowed to be built nearby. I tend to believe the claim by analysts at Arthur D. Little that the release was deliberate sabotage by a disgruntled employee. It was a clear terrorist target. But the designers and operators of the plant were delinquent in many ways. They designed a plant which was easy to sabotage; the stored more isocyanate in one place than they needed; they allowed people to live nearby, and they failed to train the employees and community in the simple precautions (put a wet handkerchief over your face). The remedies are obvious.

Ammonia is used as an agricultural chemical intermediate and used to be stored in large tanks - 17 million gallons - often close to a community. If released over a residential area there would be a large loss of life. The day after Iraq invaded Kuwait in 1990, both my friend Dr Adnan Shihab Eldin, former director of the Kuwait Institute of Scientific Research, and myself remembered that there was a large ammonia tank in the port of Shuwaikh only 1/4 mile up wind from a population area. I don't doubt that this would have been released, when the wind blew in the right direction, to add to the mess created by the oil fires. Adnan and I discussed how to get someone to empty the tank. We later found out that a Kuwaiti who was in the country at the time had had the same thought and emptied the tank into the sea while telling no one. But the large tank need not have been so close to people in the first place.

Timothy McVeigh took advantage of easily available fertilizer, ammonium nitrate, to fashion an explosive that destroyed a building in Oklahoma city. This fertilizer is still easily available. After the Oklahoma bombing, Russell Seitz suggested at a Congressional hearing that all agricultural fertilizer be mixed with urea - to make it impossible to detonate. But farmers object because it makes the fertilizer stink. Maybe this should be reconsidered.

Chemical weapons and Nerve Gases

A great fear is that chemical weapons or nerve gases will be used by a terrorist Release in the open will normally only have an effect when used in large quantities against a large crowd – such as the advancing British army at Ypres. Where would the terrorist get his nerve gases? Small quantities are unfortunately not hard to synthesize. Public attention has been focused on a terrorist obtaining them from Iraq. But in the USA we still have 15,000 tons of Sarin,

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VX and Mustard in above ground storage.   An attack from the air would have a major impact on the local communities but the population there is low. But the terrorists of 9/11 turned our own society against us. Would it not be possible for a terrorist to obtain a small fraction of the stockpile? This puts emphasis in destroying these stocks as rapidly as we can.

Release in a closed space could have severe consequences. . Indeed they have been used in a Tokyo subway, I have seen no good idea on how to be prepared for a massive release in a subway train. We might have to contemplate the awful choice of getting all people out of the contaminated train at the next station or deliberately keeping them away from the station and other trains until emergency workers have arrived.   This is similar to a recommendation of a an ad hoc safety study on LNG (at Lawrence Livermore Laboratory) in 1978 where we recommended that if LNG were released from a tanker in a harbor, that someone light a match at once before the neutrally buoyant cloud had drifted ashore.

Drinking Water

Drinking water supplies can be easily contaminated and even the threat of contamination can upset a community. As a beginning graduate student I had to do some silver plating with silver cyanide solution. When I got a headache I looked up the poisonous properties and realized that I had enough cyanide in the cupboard to poison the whole city of Oxford. Of course this last remark is about as useful as the oft repeated remark that a kilogram of plutonium could poison the world. The poison would have to be spread uniformly. But I went on and found out exactly where to drop the material (from a small footbridge) to do the most harm The Oxford water supply system has since been upgraded but similar problems remain. Most water systems can be easily sabotaged. But the solution is simple. A state can make available a portable system that could be rushed to any threatened system to provide emergency water. Such systems exist (Waterchef 2003): they could provide 10,000 gallons a day at a cost (including paying off the loan) of 1.5 cents a gallon - somewhat cheaper than the bottled water many people store for such emergencies.

Nuclear Power Plants

There has been recently a lot of public attention paid to possible accidents in nuclear power plants. plant safety, including accidental aircraft hits.   Now similar attention is applied to possible terrorist attacks. Yet few other facilities are studied with the same thoroughness. In this, we can thank one again those who made the decision 40 years ago to build strong containments. The record shows that these are among the few facilities where sabotage has been considered, and even direct hits from large aircraft. Those close to airfields (such as Seabrook NH) are designed to withstand a crash of a Boeing 747at 500 mph. Others will withstand a large aircraft at landing speed (200mph) but even if parts of a faster plane penetrates the containment, there is no reason to believe that such a release could be large. A direct hit from a large aircraft could put such a power plant out of action - maybe for ever, the most important issue for public confidence is the possibility of radiation release. The probability of release is hard to calculate, and the Nuclear Regulatory Commission is rightly reexamining the issue as a matter of urgency. One matter is clear: hitting the containment vessel will not cause the worst accident. 20 years ago I discussed sabotage with Norman Rasmussen. "It is hard for a saboteur to do more than the clowns at Three Mile Island did on their own." But the probability can be increased. There are some places an airplane could hit that might cause real trouble. But do not tell me - except in general terms. I might tell a terrorist by mistake. There are reports , that must be confirmed, that discuss hitting the spent fuel pit will cause much damage. (Alvarez et al. 2003) Dry storage casks are better. The casks are hard to break open; almost impossible to burn. There is no radioactive iodine left, and it is hard to vaporize the fuel.

The above examples focused on actions that can cause death. But even actions that cause no casualties can be As I reminded NAE, a simple relay failure started the sequence of events that led to the blackout of the northeastern United States in 1966 (or maybe in was1965). A saboteur could do this - but he would have to know what relay! But a terrorist group may well be diligent enough to find the weak link. A single substation failure at Naperville, Illinois shut down the landing control system for O'Hare airport (AND, more important to me personally, shut down the E mails from my son at FERMILAB).

What should we do?

In all the above examples most elements of society have not even begun to think about the societal vulnerabilities that exist. Firstly society needs to consider the most elementary precautions using the "defense in depth"

philosophy. Then we can use the full panoply of techniques to assess the relative vulnerabilities of different parts of society. We can, and should, study sabotage and terrorism with the imagination (perhaps the imagination of a physicist) which we apply to other potential accidents. We should imagine what a terrorist might do and then devise a system to make it hard for him to do it This is the "defense in depth" and the "Event Tree Analysis" that are already successfully applied to nuclear power as nuclear power plants. We must imagine what a terrorist might do, make it unattractive, and also make the consequences low. This should be done in a comparative way so that excessive resources are not spent on one vulnerable point in society to the exclusion of all others. The actual risk that a terrorist poses is hard to calculate. We may therefore need an intermediate goal ,in the same way that NRC has an intermediate safety goal for US light water reactors; the reduction of core melt frequency to less than 1 in 10,000 per year. I suggest that assessed vulnerability could be the basis for such a goal.

Until recently America only experienced random, uneducated, terrorists. Until 1970 few experts thought further. But in 1970 it became clear that there could be educated terrorists with a "cause". These educated terrorists might take a reactor safety course at MIT to learn the weak points of a reactor, or my "Risk Analysis" course to learn all sorts of risky technologies that could be disturbed. But I thought that 19 terrorists acting in concert was very unlikely. I was wrong, and all of society must now recognize that the probability is, alas, quite large.

Weapons of Mass Destruction

Those who have been unable to get public attention properly latch on to any seemingly related event or idea to raise their unheeded concerns.   I am among them. I am, therefore, in delighted agreement with the general idea that there is now MORE emphasis among the US public on considering the dangerous proliferation of nuclear weapons. In that sense 9/11 may have been a blessing in disguise. 9/11 was a "wake up call" to America, just as Chernobyl may have been a "wake up call" to the USSR and a blessing in disguise. Marshal Yazov, defense minister of the Soviet Union, at a small meeting in his office in May 1991 stated to a small group of us that the Chernobyl accident persuaded hard line Soviet generals that a nuclear war could not be won. "If a reactor that was not supposed to explode made this much mess, a nuclear war would destroy the planet". I have worried about nuclear weapons proliferation for 50 years. I have worried about biological weapons for 40 years. I have worried about chemical weapons for 60 years since I was trained to cope with them in world war II. However, although are very nasty, chemical weapons are not really weapons of mass destruction in the same sense. But on issues of weapons of mass destruction it is not enough to raise concern in the State Department. Concern about proliferation of weapons of mass destruction must be raised in every citizen by instruction in every school, not only in the USA but all over the world. Mankind has a capability, which since 1945 has become very clear, of destroying itself completely. Indeed, from a technical point of view, destruction of the human race by these weapons of mass destruction seems far easier than planning for the continuation of the human race. A terrorist may prefer to destroy the human race. Most of us prefer to plan for its continuation.. But it is not enough to prefer it. We must think and act. As scientists (Einstein and Szilard come to mind) said loudly in 1945 - everything (technically) has changed but our ideas have not.

Risk Comparisons

We should be a little careful about doing too much. I understand that New York State has taken a lot of map directions off its web sites to avoid giving easy instructions to a terrorist. This is reminiscent of May 1940 when all the (road) signposts in England were cut down in anticipation of an imminent German invasion and the state controlled terror that we all anticipated. Such actions will make a terrorist's life more difficult, but may not reduce the probability of his success by much. In performing them we should be aware of Edward Teller's most frequent recent utterance; unnecessary secrecy harms society more than it harms the would be enemy, whether state, saboteur or terrorist.

I have insisted for 30 years on making Risk Comparisons in order to keep perspective (Wilson and Crouch 2001) It is hard to quantify the importance of living in a free society with our human rights that are so important to us. We must beware of giving up these rights for too small a benefit. I do not believe I am alone in thinking that it is these rights as a free man that makes life worth living.   2,800 people were killed at the World Trade Center. This was indeed terrible. But over 40,000 people are killed every year on US highways by automobile and truck accidents. Is this not more terrible? Yet somehow it does not seem so. I can identify two aspects which account for the difference. Firstly, a large number of people killed at the same time is psychologically more disturbing than the same number of people killed

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over a period of time. This seems to be true of other accident situations. Secondly, terrorism and the fear of more, even worse, terrorism seems to be even more disturbing than an accident of equivalent magnitude. Analytically, in a decision theoretic framework, one can take account of this by assigning a higher amount of money to avert a terrorist risk than other risks - perhaps $50,000,000 per life rather than the $6,100,000 per life now being used by US EPA in its arsenic risk assessment (EPA 2000) and its equivalent in NRC (NRC 1975).

Much more important is a comparison with the narcotics industry. Although the deliberate destruction of life and property on 9/11was an evil act, its consequences were far less than the yearly evil of drug traffic. Drugs kill or destroy many more people and are far more destructive of US society. Drug addiction can create despair. Desperation is, I believe, one of the motives that drives people to terrorism. We also must not forget the drug which society has accepted and society is intermittently trying to eradicate - nicotine. The New Yorker caught this idea well with Gregory's (Gregory 2002) cartoon One Afghan was talking to another ."If you still want to join an organization dedicated to killing Americans there is always the tobacco lobby".

Conclusion

Sabotage and terrorism are unfortunate facts of life. They will be with us until the end of the human race. Indeed, if we do not pay attention to them, there may well be a premature end to the human race. The countries of the world must get together and pay attention to the three facets above. We must resolve conflicts and situations that breed terrorism, isolate the terrorists, and make modern large scale technologies ever more difficult to attack

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