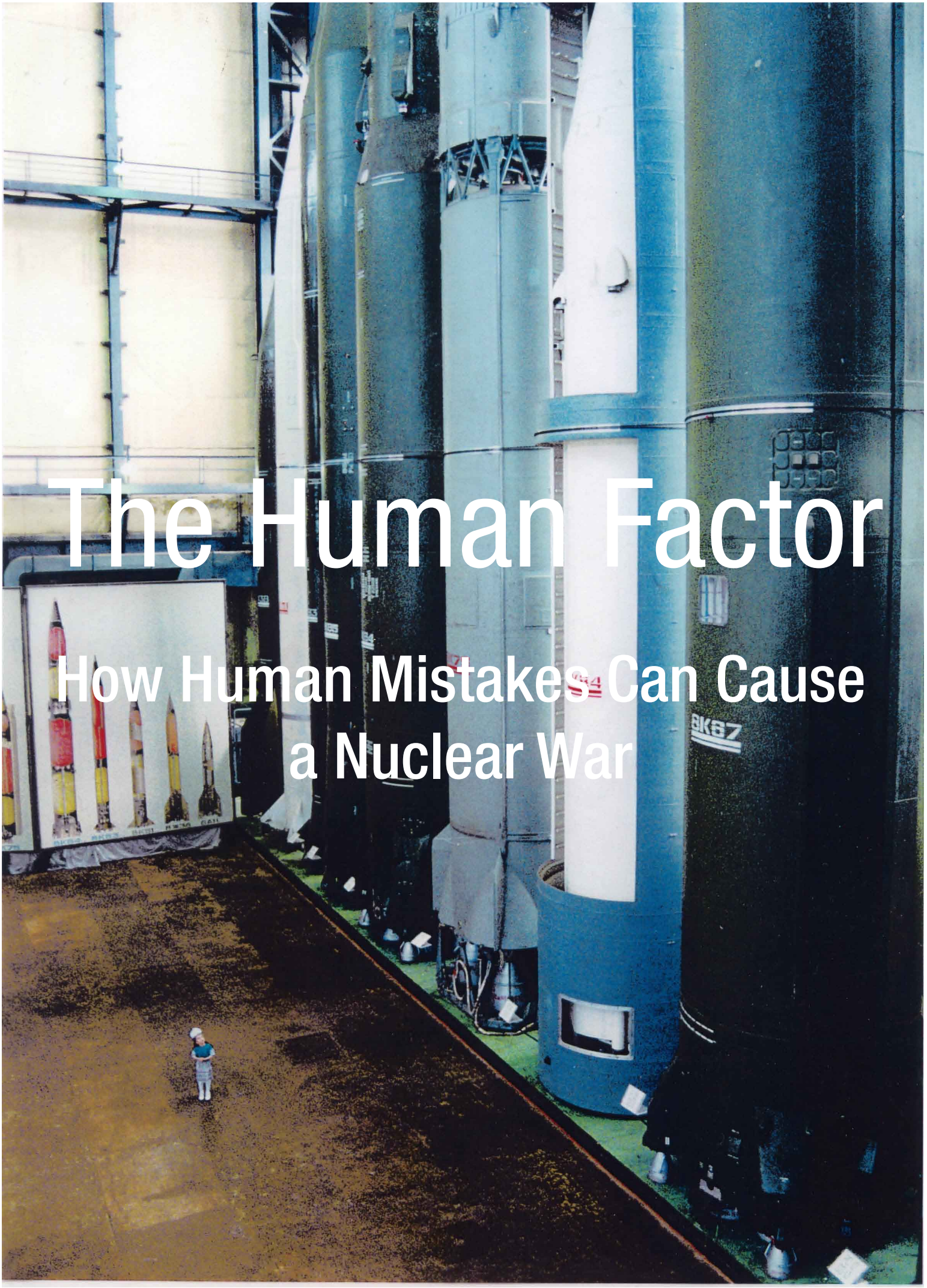

The Human Factor

How Human Mistakes Can Cause a Nuclear War

The Human Factor: How Human Mistakes Could Cause a Nuclear War

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Introduction

When the Cold War ended two decades ago, we all breathed a collective sigh of relief. We knew the world had not suddenly become a peaceful place, but it seemed at least we had managed to bring the nuclear arms race to a close without the nightmare of nuclear war. By a combination of good sense and good luck, we had somehow exorcised the terrifying specter that had haunted all of us since that mushroom cloud first rose into the morning sky over Hiroshima.

Of course we knew the arsenals of nuclear weapons had not disappeared. But that was just a matter of time, a final detail, a footnote to the history of history's most dangerous arms race. Surely now we would find a way to negotiate a process that would slowly but surely shrink the accumulated nuclear stockpiles of the existing nuclear states, while insuring against their proliferation to other countries.


The Nuclear Umbrella Photo: Josefin Lind

Twenty years later, we live in a world in which there are more nuclear weapons states, not fewer, and in which the major nuclear powers still stand ready to launch thousands of nuclear weapons at a moments notice. In the U.S., under the leadership of a President who publicly supports the goal of zero nuclear weapons, we have seen record amounts of money budgeted to nurturing American nuclear arsenals. The Cold War may be over, but the Cold War mentality lives on.

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The idea nuclear weapons can indefinitely keep us safe through deterrence is an illusion, built on yet another illusion we have yet to relinquish – the illusion that a species as prone to error and malevolence as ours can indefinitely control all the technologies we create, no matter how powerful, no matter how dangerous, and permanently avoid disaster.

No form of this illusion is more threatening to human survival than the belief that we can indefinitely maintain arsenals of devastating nuclear weapons without eventually triggering nuclear war, by intention or by mistake. The focus today is on the role of human fallibility in realizing the latter possibility, nuclear war by accident.

We will begin by briefly exploring the pervasiveness of human error, and then consider the nature and genesis of accidental war. Finally, we will take a brief look at a form of malevolence that links the possibility of accidental nuclear war with what has become a daily reality of present day life – the threat of

terrorism. This link is malevolence in one of its most virulent forms, the terrorism of mass destruction.

Human Error

Human error is a serious and pervasive problem. Between 1950-2008, almost 30% of 1300 fatal commercial airplane accidents worldwide were caused by pilot error unrelated to weather or mechanical problems. A 1998 study by the Union of Concerned Scientists of ten nuclear power plants (representing a cross section of American civilian nuclear industry) concluded that nearly 80% of reported problems resulted from worker mistakes or the use of poorly designed procedures. On July 20, 2006, the U.S. National Institute of Medicine released a report indicating that 1.5 million people are hurt and several thousand are killed every year in the U.S. as a result of errors in medication. The New York Times reported, "Drug errors are so widespread that hospital patients should expect to suffer one every day they remain hospitalized."

Lloyd J. Dumas at the IPPNW World Congress 28 August 2010
Photo: Josefin Lind

As we briefly survey some of the most important aspects of human error in dangerous technological systems, keep two key points in mind. The first is that failures do not have to be continuous in order to be dangerous. A drug or alcohol impaired nuclear weapons guard is not a problem most of the time, because most of the time nothing happens. But if that guard is not alert and ready to act the moment terrorist commandos try to break into the storage area, there could be a major disaster. Because there is no way to know when those critical moments will occur, every failure of reliability must be taken seriously.

The second point is that the difference between a trivial error and a catastrophic error lies not in the error itself, but in the surrounding situation. Many of the most trivial kinds of mistakes that all of us make on a daily basis would be disastrous if made in a very different context. For example, making a telephone call begins by entering a sequence of numbers on a keypad that is fed into computers that switch the call. If we enter the wrong number, we get the wrong person. The error is trivial. But on a clear night in December 1995, the pilots of American Airlines Flight 965 made essentially the same mistake as they were flying toward Cali, Colombia. They entered the wrong sequence of numbers into a computer, the plane's navigational computer. The plane steered into the side of mountain, and 160 people died.

Boredom

For all the potential risk involved, much of the day-to-day work of many of those who deal with dangerous technologies is really quite boring. Guarding nuclear weapons storage areas, going through checklists in missile silos, monitoring control panels at nuclear power plants is not all that stimulating. Boring work dulls the mind, leading to a lack of vigilance. Laboratory studies have shown that, after a few weeks, people exposed to extremely monotonous living and working environments sometimes experience serious mood swings, diminished judgment, and even hallucinations.

The things people sometimes feel driven to do to cope with grinding boredom can also cause serious reliability problems. They may try to distract themselves by focusing their attention on more interesting or amusing thoughts, which means they are not paying close attention to the task at hand. They may play games. For example, in the late 1970s, Tooele Army Depot in Utah con-

tained enough GB and VX nerve gas to kill the population of the earth 100 times over. According to newspaper reports, the guards at Tooele sometimes distracted themselves from the boring routine by drag racing their vehicles. They played marathon card games. Arsonists burned down an old building inside the Army Depot while guards on the night shift played poker.

Sometimes people try to make the boredom more palatable by drinking or taking drugs. In 1987 it was reported "Congressional committees, watchdog groups and the [Nuclear Regulatory] commission have repeatedly found operators of nuclear plants asleep or impaired by alcohol and drugs." Attempting to explain such behavior, a representative of the Atomic Industrial Forum (the industry lobbying group) said, "The problem is that it's an extremely boring job. It takes a great deal of training. Then you sit there for hours and hours and take an occasional meter reading". An American sailor who served as helmsman on the nuclear aircraft carrier Independence during the late 1970s/early 1980s claimed that he used LSD almost every day on duty. He said it was the only way to get through eight hours of extremely boring work.

"Congressional committees, watchdog groups and the [Nuclear Regulatory] commission have repeatedly found operators of nuclear plants asleep or impaired by alcohol and drugs."

Stress

Working with dangerous technologies can also be very stressful. We know that sustained high levels of stress can lead to serious physical problems, such as a compromised immune system, and serious emotional problems, such as severe depression and even post-traumatic stress disorder (PTSD). PTSD includes difficulty concentrating, extreme suspicion of others, recurrent nightmares and emotional detachment, all of which tend to reduce reliability. At least 500,000 of the 3.5 million American soldiers who served in Vietnam have been diagnosed as suffering from PTSD, as many as 30% of them may never lead a normal life without medication and/or therapy. As of 2008, there were at least 121 cases of troubled Iraq/Afghanistan veterans charged with committing homicide after they returned to the U.S. . In August 2009, the New York Times reported "the number of suicides reported by the Army has risen to the highest level since record-keeping began three decades ago."

Stress also appears to increase so-called "ironic errors". Writing in Science magazine in 2009, Harvard psychologist Daniel Wegner defined an ironic error as "when we manage to do the worse possible thing, the blunder so outrageous that we think about it in advance and resolve not to let that happen…. [M]ental…monitoring processes increase the likelihood of such errors when we attempt to exert control under mental load", such as when we are under severe stress.

Drug and Alcohol Abuse

Boredom and stress can lead to drug and alcohol abuse. Data released by the Pentagon for the years 1975-1990 show that almost 20,000 American military personnel were permanently removed from nuclear duty over that period as a result of drug abuse. Alcohol abuse added about another 7000 to the total.

Disrupting the Biological Clock

Many of those who deal with nuclear weapons must staff all critical duty stations throughout the 24-hour day, every day. That kind of round the clock shift work inevitably plays havoc with the biological clock. There appears to be an underlying body time rhythm that reaches its lowest levels at night, regardless of sleep/wake schedules. Thus, night shift workers inherently tend to perform less well than day shift workers. Swedish studies showed that the normal performance of night shift workers was similar to that of day shift workers who had lost an entire night's sleep. Rotating the work schedules of shift workers both aggravates the problem and spreads it to the day shift.

The Fallibility of Groups

One common strategy for assuring that an unreliable individual cannot cause a disaster in the nuclear military is to require that a group act together to, say, launch a missile attack. But sometimes groups can be less reliable than individuals.

In bureaucracies, the flow of information from subordinates to superiors is often distorted. One classic example is the "good news" syndrome: subordinates edit problems out of the information

they send to higher management in order to pass along a more pleasant picture. The result of all this good news is that top-level decision makers have a very distorted picture of what is really going on. And this problem tends to get worse, not better, when there is more at stake, as in organizations dealing with dangerous technologies.

"Groupthink" occurs when the quality of decisions made by a group deteriorates as a result of the pressure to maintain consensus among its members. Increasingly isolating themselves from other points of view, group members can develop an illusion of invulnerability that sets the stage for very risky decision making. For example, during the Korean War, after the North Koreans had been successfully driven out of the South by US-led UN forces – the original goal of the war – groupthink was involved in the US decision to press on and invade North Korea. Even though the Chinese threatened to enter the war if North Korea were invaded, and every member of the key American decision group believed that Chinese entry would be a disaster, they somehow managed to convince themselves that the Chinese would never challenge the US. They decided to invade. That drew the Chinese into the war, as they had warned. They overwhelmed American forces and drove deep into South Korea. Years of fighting followed to regain the ground lost. That reckless, foolish decision cost of millions of lives.

It seems that the relatively easy U.S. victory over the Taliban in Afghanistan encouraged the same kind of arrogant over-optimism in the Bush administration, and led us into the same self-made trap in Iraq. Based on the misinformation that Iraq was actively developing nuclear weapons, that war has proved a terrible mistake, disastrous expensive in both blood and treasure.

Group psychosis is a situation in which a crazy but charismatic leader is able to draw the otherwise sane members of a group into his/her own delusional worldview by isolating them and controlling the conditions in which they live. Twentieth century examples include the Reverend Jim Jones and his followers at Jonestown, Guyana in the 1970s and David Koresh and the Branch Davidian at Waco, Texas in the early 1990s.

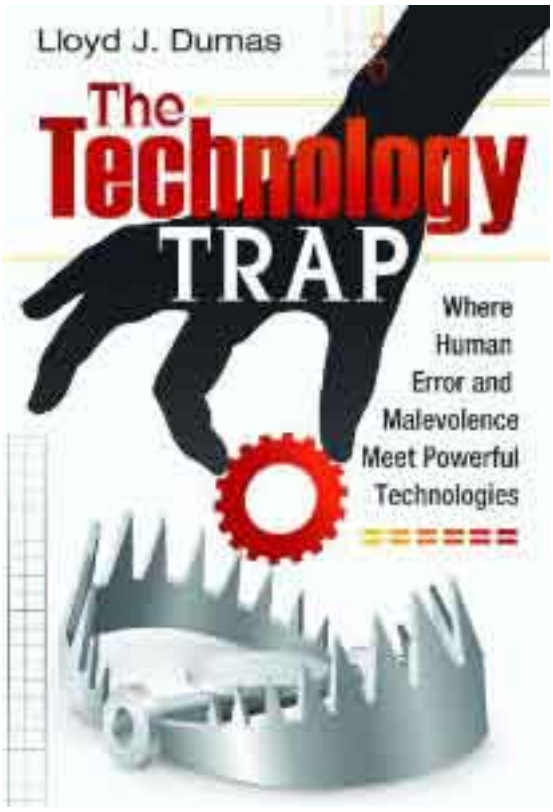
Suppose a charismatic military commander, who seemed fully functional, had become deeply disturbed. With great control over the lives of troops already primed for obedience by the very nature of military life, such a commander might be able to draw them into his/her delusional world. The crew of a nuclear missile submarine is isolated for months at a time. The captain has nearly complete control of the conditions in which they live and work. And every nuclear missile submarine carries enough firepower on board to devastate any nation on earth.

In short, relying on groups does not fix the human reliability problem.

Nuclear War by Accident

In January 1987, the Indian Army prepared for a major military exercise near the bordering Pakistani province of Sind. Because Sind was a stronghold of secessionist sentiment, Pakistan concluded that India might be getting ready to attack and moved its own forces to the border. The two nations had already fought three wars with each other since 1947. Both of them were now nuclear-capable: India had successfully tested a nuclear explosive device more than a

decade earlier; Pakistan was widely suspected of having clandestine nuclear weapons. The buildup of forces continued until nearly one million Indian and Pakistani troops tensely faced each other across the border. The threat of nuclear war hung in the air as they waited for the fighting to begin. Then, after intense diplomatic efforts, the confusion and miscommunication induced by human error began to clear and the crisis was finally defused. India and Pakistan had almost blundered into a catastrophic war by accident.



With both India and Pakistan armed with nuclear weapons, during the 1999 Kargil war over Kashmir, Pakistan reportedly got its intermediate-range missiles ready for nuclear attack and "High level officials in both countries issued at least a dozen nuclear threats". In the midst of an active military conflict between two long-term rivals with both sides actively threatening each other with nuclear attack, it would not take all that much miscommunication, misinterpretation, systems failure or simple human error for the conventional conflict to escalate out of control and unintentionally precipitate an accidental nuclear war. According to an American intelligence assessment completed in May 2002 – as tensions between India and Pakistan once again intensified – whatever its cause, "a full-scale nuclear exchange between the two rivals could kill up to 12 million people immediately and injure up to 7 million". By 2010, both nations have made great progress in developing their nuclear arsenals, and little or no progress in resolving the tensions that have repeatedly brought them so close to accidental disaster. Pakistan and India share a border with China (some of it, in the region of Kashmir). China has a much larger nuclear arsenal. Aside from the catastrophic loss of life that would result from a nuclear war between India and Pakistan, if one or more of their nuclear-armed missiles accidentally landed in China, the world could be drawn into a much larger conflagration. And the whole chain of events could easily be set in motion by human error.

Is this an exaggeration? Do we have any real evidence that a disastrous war can actually be started by mistake? Think back to 1914. Two alliances of nations were locked in an arms race, faced off against each other in Europe. Both sides were armed to the teeth and convinced that peace would be maintained by the balance of power they had achieved, despite the growing tensions.

Then on June 28, 1914, Archduke Ferdinand of Austria-Hungary and his wife were assassinated by a Serbian nationalist. The assassination set in motion a chain of events that rapidly ran out of the control of Europe's politicians and triggered a war that no one wanted. By the time it was over, 9 to 11 million people had lost their lives. Yet the whole thing might have been prevented, but for a simple failure of communications. The Kaiser had sent the order that would have stopped the opening attack of World War I (the German invasion of Luxembourg on August 3, 1914) before it was to begin. But the message arrived 30 minutes late. In a classic understatement, the messengers who finally delivered the belated order said, "a mistake has been made."

For an accidental nuclear war to occur there has to be a triggering event. During the nuclear age, there have been many serious false warnings of nuclear attack that could have played a key role in unleashing nuclear forces by mistake. For example, in 1995, Russian warning radars detected a rocket rising from the Norwegian Sea that appeared to be a U.S. submarine-launched Trident missile targeted at Moscow. The warning was relayed all the way up to President Yeltsin, who had only a few minutes to decide whether to launch a nuclear attack in response. Fortunately, the Russian military determined that

they had made an error in projecting the missile's trajectory. It was headed far out to sea, not targeted on Moscow. The rocket was American, but it was not Trident missile. It was a scientific probe designed to study the Northern Lights. The Russian government had been told of the launch, but apparently "a mistake had been made", and word never reached key military commanders.

It is widely assumed that with the end of the Cold War and the disappearance of the "Soviet threat", Russian and American missiles were taken off hair-trigger alert and no longer configured for launch-on-warning of attack. But that is simply not true. Testifying before Congress on July 18, 2007 – sixteen years after the demise of the Soviet Union – former Secretary of Defense William J. Perry said, "Both American and Russian missiles remain in a launch-on-warning mode". Perry then added, "And the inherent danger of this status is aggravated by the fact that the Russian warning system has deteriorated since the ending of the Cold War." In August 2007, "Russia declared… that it would begin regularly sending its strategic bombers within striking distance of the United States and allied nations for the first time since the end of the Cold War". Since that time, Russian bombers have been intercepted by British and Norwegian fighter jets in NATO airspace, by Danish fighters close to Danish airspace, and repeatedly by U.S. and Canadian fighters as they approached North America.

When the plane crashed it was headed toward, and only about 120 miles (about 15 minutes flying time) from the Three Mile Island nuclear power plant.

During a time of confrontation and crisis, a weapons accident that resulted in a nuclear explosion on the territory of a nuclear-armed country or its allies could trigger an accidental nuclear war. It is even possible that an accident involving the weapons of friendly forces might be surrounded in fog long enough to be misread as an enemy attack. But a weapons accident does not have to involve a nuclear explosion to trigger nuclear war.

In my new book, The Technology Trap, which will be published next month by Praeger/ABC-CLIO, I list 100 publicly reported major nuclear weapons-related accidents that occurred over the period from 1950-2009 – an average of one almost every 7 months for 60 years. They involve the nuclear forces of the U.S., Russia, France and Britain. In a number of these accidents, the powerful conventional explosive in one or more nuclear weapons was detonated. Suppose one of these bombs had fallen into a nuclear weapons or nuclear waste storage area, the huge explosion and high levels of radioactivity that would result could easily be misinterpreted as an act of enemy sabotage or a deliberate attack – especially under the pressure and confusion of a crisis. Such incidents appear in the public record: in the summer of 1956, a B-47 bomber crashed into a storage igloo containing three nuclear weapons in England; on June 24, 1994, a B-52 bomber crashed as the pilot pulled the plane into a fatal stalling turn in a successful last minute attempt to avoid crashing into a nuclear weapons storage area.

It is also possible that a sufficiently deadly terrorist attack could trigger an accidental nuclear war. A terrorist attack with nuclear weapons on the soil of a nuclear weapons state might lead to a military counterattack involving nuclear weapons against a country that that state supposed or assumed had aided or encouraged the terrorists –even if they had not. Could terrorists actually launch such an attack?

The Terrorism of Mass Destruction

There are two basic ways that terrorists might carry out an act of truly mass destruction. One is to use a weapon of mass destruction that they have built, bought or stolen; the other is to stage a conventional terrorist bombing of a toxic chemical plant, a nuclear power plant, or a toxic chemical or nuclear waste storage area.

All the information necessary to design nuclear bomb has been available in the public literature for decades. More than 30 years ago, two undergraduate students – one at Princeton, one at MIT – independently designed workable nuclear weapons using only publicly available sources. In 1996, Time magazine reported that 17 scientists at Los Alamos nuclear weapons labs had been given the assignment of designing AND building terrorist-type nuclear weapons using "technology found on the shelves of Radio Shack

[a typical consumer electronic store] and the type of nuclear fuel sold on the black market". They successfully assembled more than a dozen "homemade" nuclear bombs.

Terrorists might also be able to steal — or buy — a well-designed, ready-made weapon. In 1997, on American television, Russian General Alexander Lebed claimed that Russia had lost track of some 100 "suitcase" nuclear bombs.

If the terrorists who bombed New York's World Trade Center with airliners had used even a crude, inefficient nuclear weapon instead, the death toll would not have been in the thousands, it would have been in the tens or hundreds of thousands.

What about conventional attacks against nuclear facilities? In early 2002, the U.S. reported that it had found diagrams of nuclear power plants in suspected terrorist hideouts in Afghanistan.

We may have already had a very close call. The fourth jetliner, the Boeing 767 that crashed near Somerset, Pennsylvania during the barrage of hijackings on September 11, flew out of the East Coast headed west and slightly south. After it was hijacked, it looped around and headed east again, and apparently went down when the passengers and crew fought the hijackers. When the plane crashed it was headed toward, and only about 120 miles (about 15 minutes flying time) from the Three Mile Island nuclear power plant.

The Nuclear Regulatory Commission has admitted that the containments of American nuclear power plants were not designed to withstand the impact of a 767 flying at 500 mph. If the plane had reached and crashed into the nuclear reactor building at Three Mile Island, we likely would have had an American Chernobyl on our hands.

Conclusions

We humans are a very powerful and capable species, but we are not perfect, and we never will be. Our fallibility is part of what makes us human, and like it or not, we must recognize that it will always be with us. It sets inherent limits on our ability to avoid error, even disastrous error. There are also those among us who consider the human life that physicians are trained so carefully to preserve, to be just another commodity, expendable in the quest for whatever goals they seek. Perhaps someday we will find a way to stop creating such people. But until that day comes we must remove even the possibility that they can acquire the means by which to do catastrophic damage to our species.

For both these reasons, we will never find peace and security until we have rid the earth of nuclear weapons. There is nothing they can do for us that is anything as important as the damage they will eventually do to us, by intention or by accident. We must get rid of them, the sooner the better.

There are better ways to fight terrorism than with massive military force; there are better ways to find security than through the threat or use of nuclear weapons. (I will be talking about one of them in the plenary tomorrow morning). We are such an adaptable species; there is little doubt that we can learn to use them.
We can no more avoid the boundaries imposed by our fallibility than we can revoke the laws of nature. If we want to survive, let alone prosper, we must learn to live within those boundaries.

There is no other choice.

The Human Factor

Safety and Nuclear Weapons

IPPNW Congress - Basel 28th August 2010

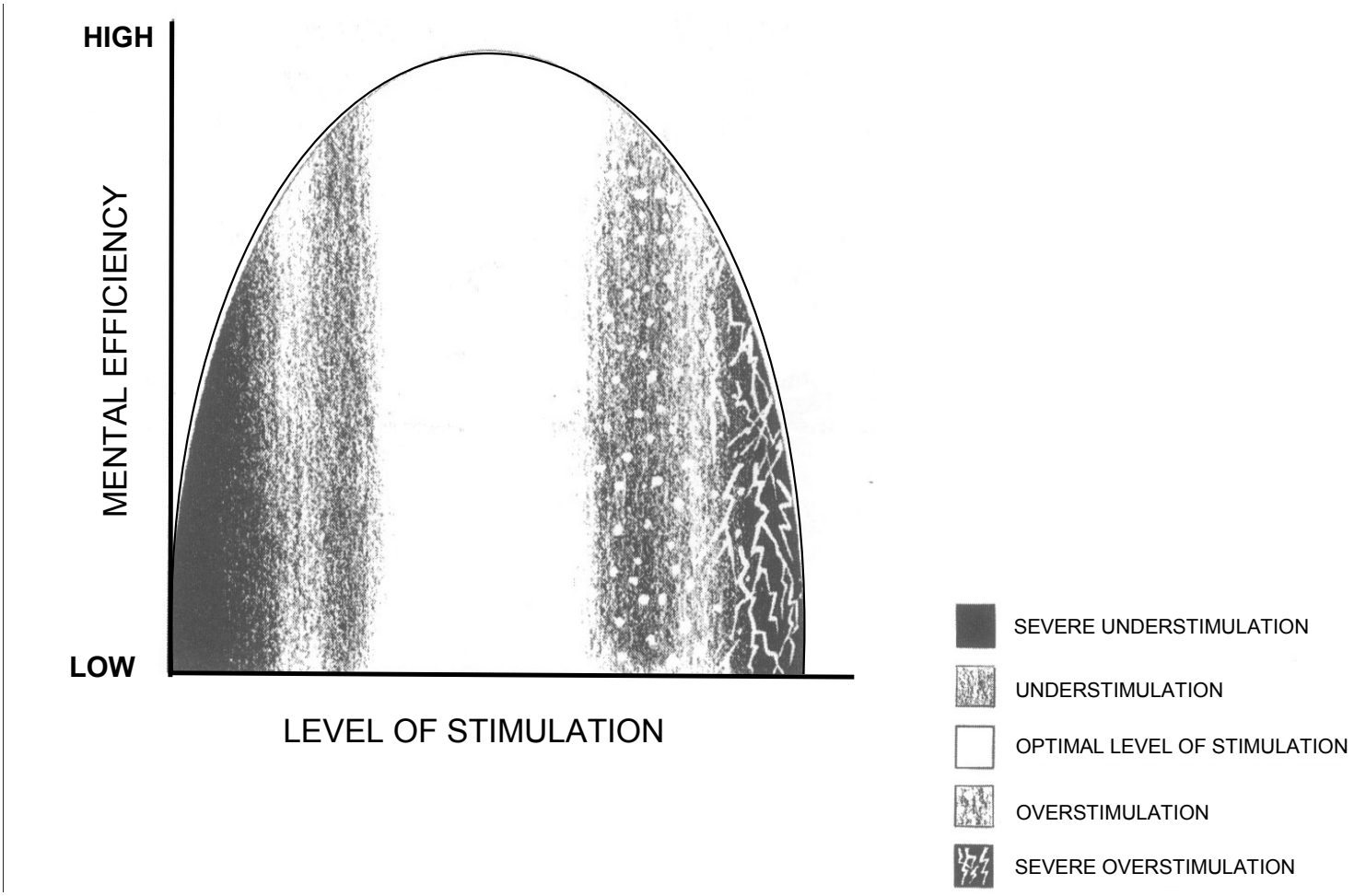
Christina Vigre Lundius MD
SLMK Sweden

At this very moment several thousand warheads mounted on intercontinental nuclear missiles are on alert for delivery.

The safety of mankind is ultimately dependent on the vigilance and alertness of a limited group of observers monitoring perimeter radar systems.

Human errors

- Airplane — 60-85% of incidents and accidents
- Chemical industry — 80-90% of accidents
- Off-shore — 79-90% of accidents
- Nuclear power — 40-60% of incidents and accidents



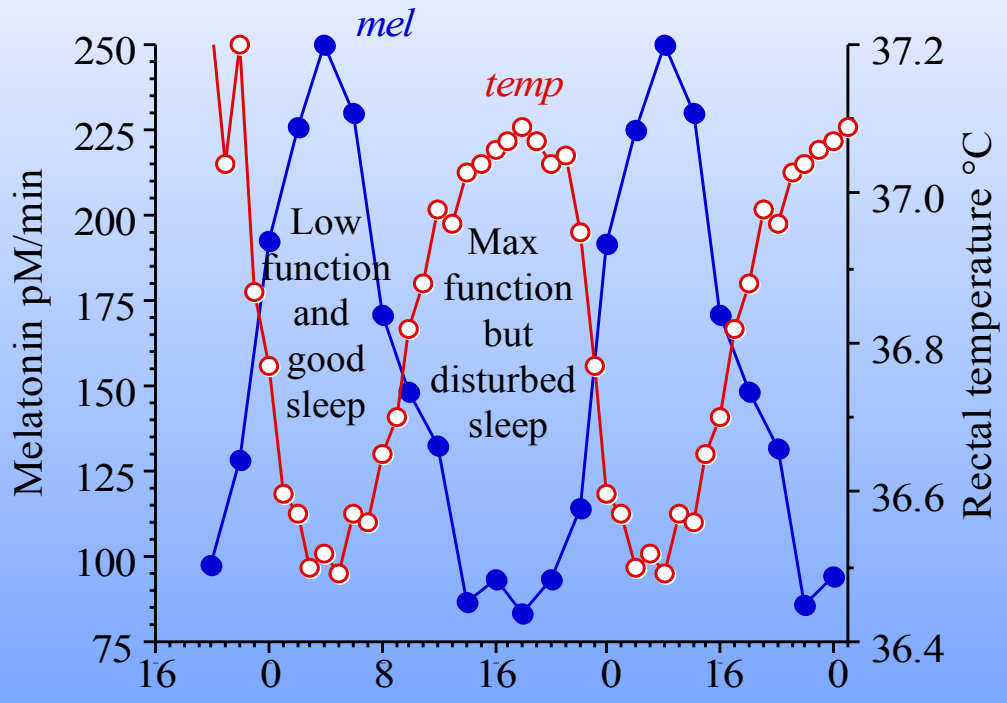
Under stimulation - Fatigue effects

- Difficulty to concentrate
- Hard to find a memory trace
- More difficult to find a new strategy
- More incoherent thought and speech
- Lack of communication

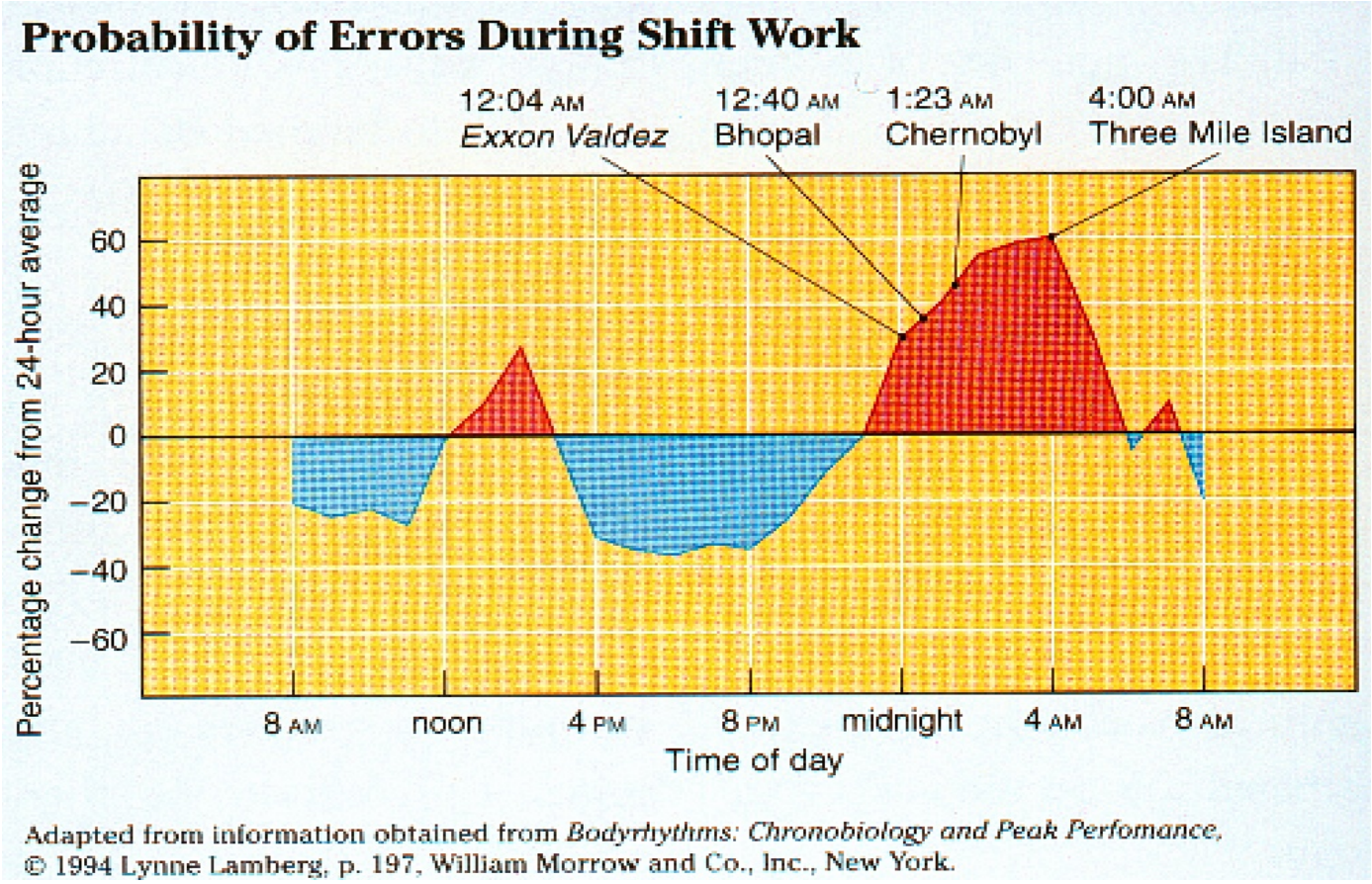
Over stimulation - Mental stress common in a crisis

- Decreased flexibility and capability to solve problems
- Hasty decisions
- Inability to make decisions
- Impaired judgement, risk taking

Biological clock



Accidents and time of day



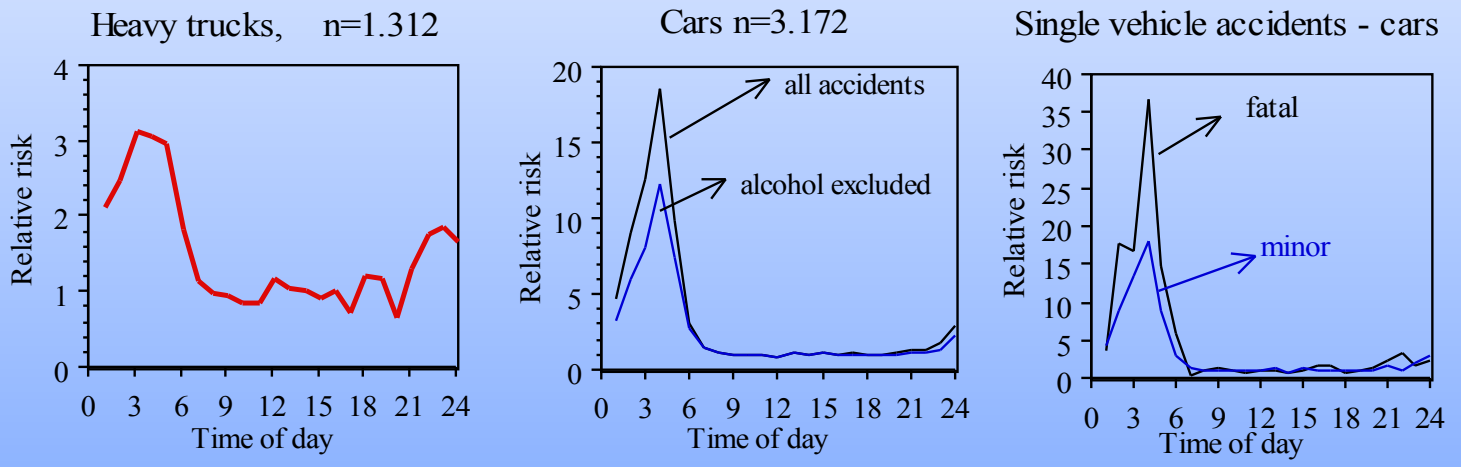
The causes of fatigue

- Extended time awake
- Monotony (incl. social isolation)
- Low level lighting, infrasound, poor oxygenation
- Sleep disturbances

Sleepiness/fatigue and accidents

- Increase with increasing length of the work shift
- Accident rate increase threefold after 16h work.
- Accidents have a probability of occurring in the late night hours.

Night working and road accident risk



Other factors that may increase risk

- Alcohol and drugs
- Physical/Psychiatric disease
- Group thinking
- Fear, paranoia e.g. of terrorism

Submarine admiral

“We often went submerged for a month or more.
Sometimes I could not leave the bridge
for more than a few hours in a week.

We were often provoked by American fighter submarines.I kept awake on coffee and vodka.
I was often so tired so I could not discriminate between red and green lights on the instrument panel.”

Prof. Lloyd Dumas:

”The difference between a trivial error and a catastrophic error lies not in the error itself, but in the surrounding situation.”

TABLE 4-2

MAJOR NUCLEAR WEAPONS–RELATED ACCIDENTS, OTHER THAN U.S.

DATE	WEAPON SYSTEM	LOCATION	DESCRIPTION
957-58	**Soviet** Nuclear Waste (from nuclear warhead production)	Kyshtym, Southern Ural Mountains, USSR	Underground nuclear waste storage area explodes “like a volcano.” 375 square mile area contaminated: hundreds of people die, thousands are affected
an 30, 1968	**British** Vulcan Bomber	Cottesmore, Rutland, United Kingdom	Strategic bomber crashes, burns; RAF claims no nuclear warheads aboard, but RAF firemen sent are equipped with radiation monitors (*Times,* Jan. 31, 1968)
Apr 11, 1968	**Soviet** *Golf* Class Nuclear Missile Submarine	Pacific Ocean, 750 miles west of Oahu	Submarine, carrying three ballistic missiles and probably two nuclear torpedoes, sinks after a series of explosions on board
Before 1970	**Soviet** Military Aircraft (unspecified)	Sea of Japan	American military reportedly recovers nuclear weapon from Soviet aircraft that crashed (*NBC Nightly News,* Mar. 19, 1975)
Early Feb 1970	**Soviet** Nuclear Submarine Construction Facility	Gorki, USSR	Large explosion rocks main Soviet nuclear submarine shipyard; several killed, radioactive wastes contaminate Volga River (*Daily Telegraph,* Feb. 21,1970 *Japan Times,* Feb.22, 1970)
Apr 12, 1970	**Soviet** *November* Class Nuclear Attack Submarine	300 Nautical Miles Northwest of Spain	While in heavy seas, submarine develops serious nuclear propulsion problem. Fails to rig towline to nearby merchant ship and apparently sinks. Submarine probably carrying 2 nuclear torpedoes
Feb 25, 1972	**Soviet** Nuclear Missile Submarine	North Atlantic Ocean, off Newfoundland	Submarine crippled by unknown causes, wallows in high seas (*Times,* Mar. 1, 1972; *International Herald Tribune,* Mar. 10,1972)
Dec 1972	**Soviet** Submarine	Off North America (East Coast)	Nuclear torpedo ruptures, leaking radiation (*SF Chronicle,* May1,1986)
Mar 30, 1973	**French** Mirage IV Strategic Bomber	Atlantic Ocean, near France	Bomber with landing gear problem told to ditch at sea; claim not nuclear-armed. Nuclear-armed Mirage carries bombs under wing, which could explain reluctance to land with landing gear problem (*LeMonde,* Apr. 1, 1973)
May 15, 1973	**French** Mirage IV Strategic Bomber	Luxueil, France	Strategic bomber crashes on takeoff (*Le Monde* , Sep. 28, 1973)
June 18, 1973	**French** Mirage IV Strategic Bomber	Near Bellegard, France	Bomber crashes, allegedly on training mission (*Times,* Jun. 19, 1973)
Aug 31, 1973	**Soviet** Nuclear Missile Submarine	Atlantic Ocean	Sub, carrying 12 nuclear-armed SLBMs, has accident in missile tube
Sep 1973	**Soviet** Nuclear Missile Submarine	Carribean Sea	U.S. aircraft spot surfaced Soviet submarine with 8- foot gash on deck (*Daily Telegraph,* Sep. 6, 1973)

DATE	WEAPON SYSTEM	LOCATION	DESCRIPTION
Sep 8, 1977	**Soviet** *Delta* Class Nuclear Missile Submarine	Off Coast of USSR, near Kamchatka	250-kiloton nuclear warhead accidentally thrown high into air when malfunction forces crew to open missile tube to correct dangerous pressure buildup and clear smoke filling missile compartment. Warhead falls into sea (later recovered)
1979–1980	**Soviet** “Echo” Class Submarine	Pacific Ocean	Sub, armed with nuclear torpedoes, is badly damaged in collision with another sub (rumored to be Chinese and to have sunk).
Sep 1981	**Soviet** Submarine	Baltic Sea	Series of powerful jolts rock sub; rupture in nuclear reactor; radiation leaks; some crew contaminated (*SF Chronicle,* May1,1986)
Oct 27, 1981	**Soviet** Submarine	Near Karlskrona Naval Base, Sweden	Diesel-powered sub believed to be nuclear armed runs aground in Swedish waters, unable to move for 10 days (*NY Times,* Nov. 6, 1987)
Jun 1983	**Soviet** Nuclear Powered Sub	North Pacific Ocean	Soviet submarine sinks, with about 90 people aboard (*NY Times,* Aug.11, 1983)
May 13, 1984	**Soviet** Northern Fleet Ammunition Depot	Severomorsk, Russia (on Barents Sea)	Huge explosion, then series of explosions and fires destroys major ammunition stocks, killing 200-300 people; over 100 nuclear-capable missiles destroyed; no evidence of nuclear explosion or radiation (*NY Times,* Jun. 23, 26 & Jul. 11, 1984)
Sep 20, 1984	**Soviet** *Golf 2*-Class Nuclear Submarine	Sea of Japan	Missile fuel catches fire, disabling nuclear-armed sub, setting it adrift (*Dallas Times-Herald,* Sep 21,1984)
Aug 10, 1985	**Soviet** *Echo*-Class Submarine	Chazma Bay (near Vladivostok)	One reactor explodes during refueling
Dec 1985	**Soviet** *Charlie/ Victor*-Class Submarine	Pacific Ocean	Human error causes reactor meltdown
1986	**Soviet** *Echo*-Class Submarine	Cam Ranh Bay, Vietnam	While on combat duty (with nuclear-armed torpedoes and cruise missiles) radiation detectors jump when crew adds wrong chemicals to reactor cooling system (possible meltdown)
Oct 6, 1986	**Soviet** *Yankee*-Class Nuclear Missile Submarine	600 miles Northeast of Bermuda	Liquid missile fuel catches fire, causes explosion. Submarine sinks, carrying 16 ballistic missiles and two nuclear torpedoes; 34 nuclear warheads aboard, (*NY Times,* Oct. 7, 1986)
Jun 26, 1987	**Soviet** *Echo 2*-Class Nuclear Submarine	Norwegian Sea	Pipes burst, crippling sub’s nuclear reactor; sub carries nuclear warheads
Apr 17, 1989	**Soviet** *Mike*-Class Nuclear Attack Submarine	Norwegian Sea	Fire, reportedly caused by short circuit, causes submarine to sink with two nuclear torpedoes aboard
Dec 5, 1989	**Soviet** *Delta IV*-Class Submarine	White Sea	Control of missile lost during missile test launch accident

References

Sweden:

- Prof. T Åkerstedt, IPM, Karolinska Institute
- Prof. T Theorell, IPM, Karolinska Institute
- Prof. M Frankenheuser, Karolinska Institute

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