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THE ETHICAL RELEVANCE OF RISK ASSESSMENT AND RISK HEEDING: THE SPACE SHUTTLE *CHALLENGER* LAUNCH DECISION AS AN OBJECT LESSON

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'We are in for a sequentiality of improbable possibles'

Finnegans Wake

Abstract: For the purpose of this analysis, risk assessment becomes the primary term and risk management the secondary term. The concept of risk management as a primary term is based upon a false ontology. Risk management implies that risk is already there, not created by the decision, but lies already inherent in the situation that the decision sets into motion. The risk that already exists in the objective situation simply needs to be "managed". By considering risk *assessment* as the primary term, the ethics of responsibility for risking the lives of others, the environment and future generations in the first place comes into the forefront. The issue of risk heeding is especially important as it highlights the need to pay attention to warnings of danger and to take action to redress problems before disasters occur. In this paper, the decision making that led to the choice of technology utilized and the implementation of such technology in the case of the space shuttle *Challenger* disaster will be used as a model to illustrate the need to take ethical factors into account when making decisions regarding the safety of technological systems and the

heeding of danger warnings. While twenty-five years separates the decision to launch the *Challenger* and the Fukushima Daiichi nuclear plant disaster, the lessons of the *Challenger* disaster are still to be learned.

Keywords: *Space Shuttle Challenger Disaster, Fukushima Daiichi Nuclear Reactor Disaster, Ethical Responsibility, Wide-risk Technology, Safety First Priority, Boisjoly, Ethics of Risk Assessment, Risky Technology, Preventing Disasters, Heeding Warnings*.

INTRODUCTION

THE CONSEQUENCES OF UNETHICAL RISK ASSESSMENT AND NOT HEEDING RISK WARNINGS

What is often not understood is the role that risk assessment and not heeding risk warnings play in decision making that sets technological disasters in motion, or creates conditions that make technological disaster more probable and most importantly, more consequential in terms of the populations that are affected when such disasters occur. This is all the more compelling when one considers that one-third to one-half of fatalities from disasters are children.[1]

The approach taken here is a universal, all-hazards approach to disasters.[2] With the potential of mega-disasters, such as another Fukushima Nuclear Disaster, which could have global implications, the need for preventing such disasters in the first place requires greater attention to disaster risk assessment and disaster risk heeding prior to the occurrence of the disaster.[3] Such attention to the prevention of disaster in the

[1] "Disaster Risk Management for Health: Child Health," World Health Organization, accessed September 15, 2015, http://www.who.int/hac/events/drm_fact_sheet_child_health.pdf

[2] An example of a multi-hazards approach is the one taken by the government of Pakistan in 2006 in 'Strengthening National Capacities for Multi Hazard Early Warning and Response System'. In that report, the importance of warnings is highlighted. *Cf.*, accessed September 15, 2015, http://www.pmd.gov.pk/Establishment%20of%20Early%20Warning%20System.pdf

[3] In a talk given at the East-West Center on August 18, 2013, Professor of Government and North Korean expert Victor Cha, stated that the nuclear reactor being built in North Korea had no sign of meeting international safety standards.

first place is a useful complement to the constructive research on the reduction of the risk of harmful consequences of disaster after disasters occur. The Asia Pacific region is the most disaster prone region in the world. The Hyogo report has placed special emphasis on disaster prevention.[4] Whose responsibility is disaster prevention? In a word, everyone's. Responsibility is not reduced by being shared. In the pithy dictum of the World Health Organization, 'Disaster risk management for health is everybody's business'.[5] When one considers that those most affected by disasters are children, elderly females, and those who suffer from economic poverty the ethics of disaster prevention comes strongly to the forefront. The issue of risk heeding is especially important as it highlights the need to pay attention to warnings of danger and to take action to redress problems before disasters occur. In this paper, the decision making that led to the choice of technology utilized and the implementation of such technology in the case of the space shuttle *Challenger* disaster will be used as a model to illustrate the need to take ethical factors into account when making decisions regarding the safety of technological systems and the heeding of danger warnings. While twenty-five years separates the decision to launch the *Challenger* and the Fukushima Daiichi nuclear plant disaster, the lessons of the *Challenger* disaster are still to be learned. The case of the space shuttle *Challenger* disaster, while itself not a case of wide-risk technological decision making, is a classic case of disaster so well documented that it can serve as a model of the kinds of mistakes that can be avoided so as to prevent disasters in the future, such as the Fukushima nuclear plant disaster. The space shuttle *Challenger* disaster well illustrates the contrast that exists between general, unknown risk and specifically foreknown risk, for example, the faulty and dangerous O-rings (known in advance to exist by managers and engineers though not by the principal risk takers) prior to the decision to launch the space shuttle *Challenger*. It is invaluable to examine this case in some detail so as to learn not to confuse general unknown risk with specifically fore-

[4] *Cf.*, The Hyogo Framework for Action in Asia and the Pacific regional synthesis report, 2010-2013, accessed September 15, 2015, http://www.unisdr.org/we/inform/publications/32851

[5] "Disaster Risk Management for Health: Overview," World Health Organization, accessed September 15, 2015, http://www.who.int/hac/events/drm_fact_sheet_overview.pdf. This phrase is a current version of the phrase I coined in my 1993 book on global disasters: 'The buck stops here and it stops everyplace else as well'. *Cf.*, Robert Elliott Allinson, *Global Disasters*, Prentice-Hall.

known risk in order to show how very important the concept of ethical responsibility is. It is the contention of this paper that the understanding of the ethics of risk is crucial to the prevention of technological disasters in the future.

PREVIOUS CONCEPTS AND CLARIFICATIONS

NATURAL AND MAN-MADE DISASTERS

The line between natural and man-made disasters is permeable since it can well be argued that decisions to locate hazardous technology near to areas in which the effects of disasters cannot be properly contained can turn a natural disaster into a (larger) man-made one. The International Federation of the Red Cross has estimated that between 1998 and 2007, there were nearly 3,200 technological disasters, including chemical disasters, with 100,000 people killed and 2 million people affected.[6] The Fukushima Daiichi nuclear reactor disaster which occurred on March 11, 2011 is an example of the harm that is done to human beings when corporations do not heed risk assessment notifications and as a result, preventable disasters occur. While the language of "weak signals" has not been utilized in accounts describing this disaster, either to describe the notification or the lack of heeding of the warning, the warning issued was not heeded. If the warning had been heeded, the Fukushima disaster could have been prevented (even though the earthquake and tsunami could not). It is important to take note that, by definition, a signal is not weak when human lives are at stake. In this case, an electrical company had control over the risky technology that affected the lives of hundreds of thousands of people in the Pacific Basin. Those who hold control over technology that can adversely affect large population centers need to be held to a higher standard of moral accountability. According to the Executive Summary of the Nuclear Accident Independent Investigation Commission appointed by the National Diet of Japan, chaired by Kiyoshi Kurokawa, former president of the Science Council of Japan, 'It was a pro-

[6] "Humanitarian Health Action: Disaster Risk Management for Health Facts Sheet," World Health Organization, accessed September 15, 2015, http://www.who.int/hac/techguidance/preparedness/factsheets/en/

foundly manmade disaster that could and should have been prevented.'[7] Naoto Kan, Japan's former Prime Minister stated that the Fukushima Daiichi nuclear plant should not have been built so close to the ocean.[8]

In financial terms alone, the cost of the Fukushima disaster will be enormous. The Japanese government has already allocated $15 billion for decontaminating the area and complete decommissioning of the plant is expected to take 40 years. According to the Japan Center for Economic Research, decontamination costs alone could be $600 billion.[9]

In humanitarian terms, human costs are immeasurable when one considers the forced evacuation of 150,000-300,000 people, forced to move multiple times, many never to return to their homes, resulting in increased stress and health risks and deaths among those who were seriously ill.[10] Of 328 senior evacuees, 75 died within one year due to changes in living environment, 2.7 times higher than the national average for senior deaths. According to the National Institute of Health's (NIH) National Cancer Institute, radiation emission levels are approaching those of Chernobyl where new cases of thyroid cancer are still appearing at an undiminished rate in the most heavily affected areas of the Ukraine, Belarus and Russia.[11] According to the National Institute of Radiological Sciences (NIRS), children in Fukushima prefecture received lifetime thyroid gland doses of internal radiation.[12] According to *Science*, 40% of the fish caught off Fukushima 12 months after the disaster have too much cesium to be safe to eat. Since cesium has a half-life of 30 years, this means that it will take 60 years to dissipate.[13] Cesium has even been

[7] Yoko Wakatsuki and Jethro Mullen, "Japanese parliament report: Fukushima nuclear crisis was 'man-made,'" *CNN*, July 5, 2012, accessed September 15, 2015, http://www.cnn.com/2012/07/05/world/asia/japan-fukushima-report

[8] "Japan woefully unprepared for nuclear disaster, ex-PM," *CTV News*, February 17, 2012, accessed September 15, 2015, http://www.ctvnews.ca/japan-woefully-unprepared-for-nuclear-disaster-ex-pm-1.769980

[9] Mari Saito, Kiyoshi Takenaka and James Topham, "Insight: Japan's "Long War" to shut down Fukushima," March 8, 2013, accessed September 15, 2015, www.reuters.com/article/2013/03/08/us-japan-fukushima-idUSBRE92417Y20130308

[10] James M. Acton and Mark Hibbs, "Fukushima Could Have Been Prevented," *NY Times*, March 9, 2012, accessed September 15, 2015, http://www.nytimes.com/2012/03/10/opinion/fukushima-could-have-been-prevented.html?_r=0

[11] *New Scientist*, March 24, 2011.

[12] Yuri Otawa, *Asahi Shimbun*, July 11, 2012, p. 27.

[13] Hiroko Tabuchi, "Fish Off Japan's Coast Said to Contain Elevated Levels of Cesium," *NY Times*, October 25, 2012, accessed September 15, 2015, http://www.

found in blue-fin tuna off America's West Coast, 6,000 miles from Japan.[14] While some might play down the risk of such levels of radioactive substance, one must remember that x-ray doses thought to be safe 78 years ago are now deemed intolerably risky.[15]

According to a previous study, preliminary computer simulations conducted in 2008 that suggested tsunami risk to the plant were not followed up and were only reported to the Nuclear Industrial Safety Agency (NISA) on March 7, 2011. NISA in turn failed to review simulation conducted by Tepco. What needs to be emphasized is that these failures to follow up risk assessments and report safety hazards were not due to bureaucratic stovepiping, that is, slowdowns and stoppages due to being held up by bureaucratic regulations and hierarchical structures, but were failures in moral responsibility. If one examines bureaucratic stovepiping on a case to case basis, one will discover that each case involves a failure in moral responsibility.

SAFETY FIRST

One takes life and death risks with others with their consent, as with surgery, only when it is necessary to promote or safeguard health. The issue of cosmetic surgery may be an exception, but in this case, consent is given in advance. In this discussion, which refers to exposing others to risk of life owing to decisions made to employ wide-risk technology, life takes precedence over risk. Ethical risk assessment recognizes the dignity of all human beings, their basic right to life and subsistence and their basic right to safety, that is, protection from known risks. The safety of human beings and the future environment of human beings is our utmost consideration. This is not to say that it is our *only* consideration, but that it is our *utmost* consideration. It could be argued, for example, that risks can be taken in the interest of public welfare, but this is a sticky wicket.

nytimes.com/2012/10/26/world/asia/fish-off-fukushima-japan-show-elevated-levels-of-cesium.html

[14] Alicia Chang, "Radioactive Bluefin Tuna: Japan Nuclear Plant Contaminated Fish Found Off California Coast," *Huffington Post*, May 28, 2012, accessed September 15, 2015, www.huffingtonpost.com/2012/05/28/radioactive-bluefin-tuna-japan-fukushima-california_n_1551431.html

[15] W. W. Lowrance, *Of acceptable risk: Science and the determination of safety*. Los Altos, Ca.: William Kaufmann, Inc., 1976, p. 9.

Who is to define public welfare? Safety may be defined as the protection of human life and limb and the environment against known risks that threaten human health, survival and the survival of a sustainable environment. This discussion is not meant to apply to cases in which careful and thoroughgoing advanced preparation has been taken to minimize the risks taken and to measure the benefits accruing versus the possible dangers posed. For example, this does not mean that no risks are ever taken. It means that there is a safety first priority to protect human life. For example, riding a bicycle poses risks to the rider. Requiring that bicyclists wear helmets protects riders from brain damage. In the case of automobile driving, one distinguishes between reckless driving and driving within safe limits. Automobile driving presents risks to drivers and to others. Requiring a safety belt is an example of taking a measure to protect life. Automobiles, in some states of the United States, must pass annual safety inspections. A safety first priority value may be defined as taking every feasible safeguard to protect human health, survival and the survival of a sustainable environment. A safety first priority also includes the obligation to inform risk takers of the known risks that they are taking and to receive their informed consent either directly or, when direct consent is impractical, through their elected representatives. In the case of the space shuttle *Challenger* disaster, the five astronauts and two civilians on board were not informed of the known risk (with the faulty O-rings) they were taking. At least three of the astronauts were breathing when the crew compartment had separated from the orbiter. There was no explosion. The spectacular smoke plume was due to the chemical reaction of the hydrogen colliding with the oxygen. Three personal egress packs were recovered activated after the blast. Thus, it was entirely possible that the astronauts and civilians could have been saved with an abort system. This is an example of not following a safety first priority. On all previous and subsequent flights, space shuttles were equipped with abort systems.

GENERAL UNKNOWN RISK VERSUS SPECIFIC AND FOREKNOWN RISK

There is a confusion that is frequently made between general and unknown risk that is operative in the universe and any specific risk that is known in advance to exist. For example, whenever one gets out of one's bed in the morning, one may trip, fall, crack one's skull and have a concussion. This is the general and unknown risk that is operative in the universe. We should not construe risk in these terms as this kind of risk exists, for the most part, outside of human control and intervention. Every human being exposes herself or himself to general, unknown risks on a daily basis. The risks which concern us are lethal risks that are known or should be known to decision-makers who employ wide-risk technology which places others under the lethal risks that the decision makers have created.

THE CASE

THE CASE OF THE SPACE SHUTTLE CHALLENGER AS AN OBJECT LESSON

One can argue that whenever an astronaut goes into space, that astronaut is subject to that general, unknown, universal-style risk of space travel. This, however, is not comparable to an astronaut going into space equipped with the full knowledge of the existence of a real, specific, pre-existing, and correctable mechanical fault that could be potentially fatal. NASA never told the congressional committees charged with overseeing the shuttle program about the escalating dangers of the O-ring problems. In the Presidential Commission report:

> Chairman Rogers raised the question of whether any astronaut office representative was aware [of the O-ring problem]'. Weitz, [an astronaut's representative] answered: "We were not aware of any concern with the O-rings, let alone the effect of weather on the O-rings.[16]

Two years after the horrific event, when the official, U. S. government committee on Shuttle Criticality, Review and Hazard Analysis examined the risk that had been taken in launching the *Challenger*, the Chairman of that committee wrote in the very first paragraph of chapter four of their report, entitled "Risk Assessment and Risk Management":

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[16] Robert Elliott Allinson, *Saving Human Lives, Lessons in Management Ethics*, Dordrecht: Springer, 2005, pp. 184-5, 187. These pages in the secondary source cited refer to a number of sources that corroborate the testimony of Weitz, the astronaut's representative, that was given before the Rogers' Commission, that the astronauts did not know of any problems with the O–rings.

> Almost lost in the strong public reaction to the Challenger failure was the inescapable fact that major advances in mankind's capability to explore and operate in space – indeed, even in routine, atmospheric flight – will only be accomplished in the face of risk.

And, later, in the body of that same report, the Committee wrote: "The risks of space flight must be accepted by those who are asked to participate in each flight"...[17]

It is rather easy to spot the fallacy that is being committed in this case. It is the fallacy of equating a general unknown risk (space flight in general) with a specifically foreknown fatal risk (the flawed design of the O-rings about which the senior engineer Roger Boisjoly had issued red flagged warnings).[18] *When one examines the Challenger case more closely, one discovers that there was no need to choose the technology that was chosen in the first place*. The risky technology in this case was the engineering design of the O-rings. Of four designs submitted, the one chosen was the least safe (and the cheapest). This *choice* was a case of *reckless epistemological assessment* on the part of the managers who chose this design that was an initiating cause of the *Challenger* disaster, and not the fact that they were obliged to employ a risky design in order to venture into space. It was an example of ethically insensitive decision making and reckless assessment. The design itself was risky. Why? This decision to place cost ahead of safety is an example of ethical misjudgment. There was no necessity to choose this particular design. Alternative designs were available. The O-ring design of giant rubber gaskets keeping combustible hot gases from leaking out, in actual fact, ranked fourth out of four submitted engineering designs and, according to an important article co-written by Trudy Bell, Senior Editor of the engineering journal, *IEEE Spectrum* and Karl Esch: the selection of this design was the chief cause of the

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[17] Preface by Alton Slay, Chairman, Committee on Shuttle Criticality, Review and Hazard Analysis, *Post-Challenger Evaluation of Space Shuttle Risk Assessment and Management*, Washington, D.C.: National Academy Press, 1988, p. v; p. 33.

[18] Robert Elliott Allinson, *Saving Human Lives, Lessons in Management Ethics*, Dordrecht: Springer, 2005, p. 138. Boisjoly's awe striking memorandum can be found in *The Report of the PRESIDENTIAL COMMISSION on the Space Shuttle Challenger Accident* (popularly known as the Rogers Report), Internal correspondence and memoranda, Appendix D, Washington, D. C., GPO, 1986, p. 249.

Challenger disaster.[19] For the next space flight, this design was replaced with a safer design. One of the original proposed designs, the McDonnell-Douglass proposal, actually anticipated the technical cause of the Challenger disaster in that it provided for a burn through wire that would have sensed O-ring leakage, then triggered booster thrust termination and the orbiter's abort rocket escape system. The McDonnell-Douglas proposed design included an abort rocket escape system. Their proposal of an orbiter incorporated a practical abort capability that would have protected the shuttle crew and passengers during all phases of the mission.

PROPOSAL

RISK ASSESSMENT AND RISK MANAGEMENT IN CONTEXTS IN WHICH DECISION-MAKERS PLACE OTHERS, THE ENVIRONMENT AND FUTURE GENERATIONS (OEF) IN HARM'S WAY

While the phrase "risk management" is employed with ethical responsibility when applied to reducing the consequences of disasters, the present context for the analysis of the terms "risk assessment" and "risk management" is one in which decisions are taken which place the environment, future generations, and human beings other than the decision-makers, in harm's way. For the purpose of this analysis, risk assessment becomes the primary term and risk management the secondary term. The concept of risk management as a primary term is based upon a false ontology. Risk management implies that risk is already there, not created by the decision, but lies already inherent in the situation that the decision sets into motion. The risk that already exists in the objective situation simply needs to be "managed". By considering risk assessment as the primary term, the ethics of responsibility for risking the lives of others, the environment and future generations in the first place comes into the forefront. While the ethics of responsibility will also be involved in managing the risk to OEF (others, environment and future generations) created by the initial decision, the initial decision that places others and the planet in harm's way is not given the same amount of attention that is given to the

[19] Robert Elliott Allinson, 'Risk Management: demythologizing its belief foundations,' *International Journal of Risk Assessment and Management*, Volume 7, No. 3, 2007, p. 302.

management of risk, once that risk has been created.[20] In the case of the *Challenger*, risk management was also unethical. Previous launches had included pressurized space suits, escape bolt hatches, and parachute descent systems. All of these may well have saved the lives of the astronauts and civilians who were alive and breathing at the moment of impact with the ocean floor. Whether one categorizes this failure to provide life support systems as an ethical failure of risk assessment or an ethical failure of risk management is a matter of semantics. Strictly speaking, as will be discussed below, it falls under ethically faulty risk assessment since the risk was taken at the time of the design of the space shuttle and was part of the initial design. Once the space shuttle was operational, there was no possibility of managing the risk that had been created.

WHAT CONSTITUTES ACCEPTABLE RISK?

In the case of the *Challenger*, Professor Feynman, the renowned physicist who was a member of the Presidential Commission, was astonished at the very concept of 'acceptable risk'. What, after all, constitutes taking an "acceptable" risk to human life? Vision Zero is a policy for traffic safety that was adopted by the Swedish Parliament in 1997. The policy states that it is ethically unacceptable for people to die or be seriously injured in the road transport system.[21] This emphasis on ethical premises is new to the field of traffic safety and may serve as a principle that can be exported to the field of disaster prevention in general.

When one is considering what constitutes an acceptable risk, one must take epistemological and ethical responsibility. This responsibility is not abrogated even if a flight is considered experimental. It is crucial to consider the point that consent must be obtained prior to risk distribution. It is also crucial to consider that known risk (e.g., known avoidable danger with the O-rings) must be communicated to the risk-takers if consent obtained is to be informed. Indeed, in this case, since the dangers

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[20] The U.S. government is currently teaching the terms and definitions for the proper understanding of risk that the present author originated in its educational training courses for FEMA, the Federal Emergency Management Association.

[21] *Cf.*, Jessica Nihlen Fahlquist, 'Responsibility ascriptions and Vision Zero,' *Accident Analysis & Prevention*,' 38 (2006), pp. 1113-1118. Norway adopted a similar version of Vision Zero in 2001.

with the O-rings were red-flagged, under these conditions consent should not even be sought in the first place. Finally, safety systems such as escape bolt hatches, space pressure suits, parachute descent systems, must be provided to make even informed consent a viable option.

Epistemological responsibility for risk assessment entails taking proper scientific measurements regarding the quantitative part of risk assessment. Ethical responsibility for risk assessment *made with the consequence of being the criterion of placing others at lethal risk* requires the evaluation of whether a risk is morally acceptable and falls outside the domain of scientific method proper. Scientific method when applied to human beings is not ethically neutral; decisions to apply the results of scientific method to impact upon human life do require moral judgments. Truth is a value and scientific truth is the value that is intrinsic to scientific inquiry. Ethical value is the kind of value which must be taken into account whenever scientific method or the results of that method in terms of scientific technology is applied to human beings. The calculation of the risk is purely quantitative and does not take into account the qualitative nature of the factors in the equation. Since the calculation of the risk is mathematical with respect to the factors calculated, the decision to take risks (without consent) with the human lives in question is an extra-scientific decision. While the calculation of the risk is purely scientific, it can become ethically relevant. It becomes ethically relevant when one decides to apply the calculation to take risks with the human lives in question without their consent. This decision makes use of scientific calculation, but the decision to go ahead with the engineering is not a scientific decision; it is a moral one.

Much of the discussion concerning risk assessment and risk management appears to treat the quantitative measurement of risk assessment as relatively unproblematic whereas the qualitative assessment of risk assessment is treated as highly problematic. But, is even the quantitative measurement of risk assessment unproblematic?[22] How does one carry out the quantitative part of risk assessment?[23] In the specific case from

[22] *Cf.*, Sheila Jasanoff, 'Bridging the Two Cultures of Risk Analysis,' *Risk Analysis*, 3, (2), 1993, pp. 123-129.

[23] Leaded gas was announced as toxic by the assistant surgeon general of the United States in 1922, but it was not outlawed until 1996. *Cf.*, Rosner and Markowitz, 'A Gift of G-d', *The Public Health Controversy over Lead-Additives*,' American Journal of Public Health 75, pp. 344-352.

which we will draw most of our information here, the launching of the U. S. space shuttle, *Challenger*, the action to be taken was considered to be an "acceptable risk". The question of "acceptable risk" was applied to the action to be taken, not to the decision to take the action. Had the notion of "acceptable risk" been applied to the decision to launch, ethical responsibility for the *decision* would have fallen more directly on the shoulders of the decision makers. When one of the four managers who overrode the unanimous decision of 14 engineers and managers not to launch was asked at the Presidential Commission hearings, whether the phrase 'loss of mission and life' had a negative connotation, the answer given by the manager, Larry Mulloy, was that such a description had no negative connotation and simply meant that you have a single point failure with no back-up and the failure of that single system is catastrophic.[24] Mulloy's answer is limited to the failure of the mission and is not fully ethically responsible since it does not take into account the loss of life.

EPISTEMOLOGICAL BASIS OF RISK ASSESSMENT: SUBJECTIVE JUDGMENT VERSUS PERFORMANCE DATA

Risk assessment in the case of the decision to launch the *Challenger* was based on using a failure modes effects analysis. Cook, one of the few if not the only source on the *Challenger* who goes into detail on this point, points to one study, conducted in 1984, which concluded that the chance of a Solid Rocket Booster explosion was one in thirty-five launches.[25] Nevertheless, the Marshall managers spoke of "acceptable risk". If you "lost" one astronaut, that was "data" in the risk equation. *Some loss of a human life was thus considered acceptable*. A team of statisticians formed by the National Research Council to follow up on the commission report analyzed the same data and estimated a "gambling probability" of 14 per cent for a catastrophic O-ring failure at a temperature of 31 degrees.[26] It is not as if one can design a system in which there is ab-

[24] Richard C. Cook, *Challenger Revealed, An Insider's Account of How the Reagan Administration Caused the Greatest Tragedy of the Space Age*, New York: Avalon, 2006, p. 243.

[25] *Ibid*., p. 356.

[26] *Ibid*., p. 171.

solutely no risk. The point is to design a system in which precautions are taken with the view that a loss of life is unacceptable.

In 1977, NASA commissioned a group called the Wiggins Group to study the possibility of flight failures and by examining data for all previous space launches, a likely failure rate of one in fifty-seven was derived. According to Cook, NASA complained that many of the launch vehicles the Wiggins group included were not similar enough to the *Challenger* shuttle to be part of the data base. So, Wiggins changed the probable failure rate to one in 100. Professor Feynman, a member of the Rogers Commission, calculated the odds at one in 100. Another study conducted by the Air Force placed the likely failure rate for the shuttle in a similar range to the Wiggins analysis. According to Cook, none of these studies were publicized and most of the newspaper reporters who covered NASA most likely had never heard of them. When NASA was forced to arrive at an official number, their chief engineer came up with the infamous and arbitrary estimate of one in 100,000. As Cook put it, 'At a rate of twenty-four launches per year, this meant that NASA expected the shuttle to fail catastrophically only once every 4,167 years.[27] The possible incidence of occurrence was therefore negligible. By presenting, not calculating, the *incidence* of risk as virtually non-existent, it was possible to immunize oneself against the realities of the *consequences* of the risk. One could then make a decision to risk other people's lives, because statistical probability had eliminated the problematic dimension of the risk factor, the consequences, from the equation. When a figure is used, such as one in 100,000, one might assume that this is a calculated risk since it is put in the mathematical language of percentages and statistics. But, this was not a "calculated risk" at all, but fantasy parading as mathematics. A figure picked out of thin air had granted the decision makers moral immunity. Of course, the space shuttle program was considered experimental. However, this does not imply that the astronauts should not have been informed of the *known* risks that they were taking.

The Nobel laureate physicist Richard Feynman, was shocked to learn that NASA management had claimed that the risk factor of a launch crash was 1 in 100,000 which they had arrived at without relying upon any actual past performance data. If one calculated risk based upon actual past performance data, the risk was, according to Professor Feynman, a mem-

[27] *Ibid.*, pp. 126-7.

ber of the Rogers Commission, 1 in 100.[28] According to Professor Feynman, while management, in defending its decision to launch, pointed to the risk involved as being 1 in 100,000, this figure of 1 in 100,000 was not based on previous performance data. If one took the actual performance data of rocket engines in the past, as Professor Feynman did, the risk was far greater. When one does this, one can more clearly consider the case of the possibility of incidence versus the actuality of consequence. Does one wish to risk the lives of the astronauts and the civilians when the chance of their death is 1 in 100? Unless the risk estimates are based on past performance data as a data base, according to Feynman, 'it's all tomfoolery'.[29] There is no reason why we should not learn from the lessons of the *Challenger* disaster to generalize sound conclusions concerning the method we should employ when engaging in risk assessment. Even if we take under consideration that the shuttle was conceived of as experimental, it does not follow that the possibility of loss of life due to risk factors not known by those placed under the risk is acceptable. Being informed of the risk and being provided with technology that provided escape from the risk would go far to making risk more acceptable. It is possible for a manned space program to exist, as it did prior to the launch of the *Challenger*, with escape systems in place to safeguard the lives of the astronauts.

In 1991, the probability for a meltdown in a nuclear plant was calculated by some scholars to be one in 10,000 years.[30] The quantitative and hence scientific appearance of probability figures may disguise the fact that such figures may lack any sound scientific basis. In 1974, nearly twenty years earlier, the Atomic Energy Commission had stated that "The most likely core melt accident would occur on the average of one every 17,000 years per plant."[31] The AEC stated that "While the study has presented the estimated risks from nuclear power plant accidents and compared them with other risks in our society, it has made no judgment on the acceptability of nuclear risks. Although the study believes nuclear accident risks are very small, the judgment as to what level of risk society should accept is a broader one than can be made here."[32] A probabil-

[28] *Ibid*., p. 183.

[29] *Ibid*., p. 183.

[30] Alvira Kreimer and Mohan Munasinghe, eds., *Managing Natural Disasters and the Environment*, World Bank, 1991, p. 109.

[31] William W. Lowrance, Of Acceptable Risk: Science and the Determination of Safety, Los Altos, Ca.,1976, William Kaufmann, Inc., p. 73.

[32] Ibid., p. 77.

ity figure by itself does not carry with it ethical acceptability. That is a separate judgment altogether. The AEC went on to state that "For accidents involving 1,000 or more fatalities the number is 1 in 1,000,000 or once in a million years. Interestingly, this is just the probability that a meteor would strike a U.S. population center and cause 1,000 fatalities."[33]

EPISTEMOLOGICAL AND ETHICAL RESPONSIBILITY FOR RISK MANAGEMENT SAFETY MARGINS

Major General Kutnya, Director of Space Systems and Command Control, USAF, Air Force General and Presidential Commission member, argued that the O-ring evidence was analogous to evidence that an airliner wing was about to fall off. Professor Feynman pointed out with respect to Diane Vaughan's contention that there was a 'safety factor of three', that because in previous cases the O-ring had burned only one third of the way through, that did not prove that there was a safety factor of three. If we merge the O-ring and the airplane wing examples, the argument of General Kutnya, and Professor Feynman, is that if the wings of an aircraft have burned one-third of the way through, that did not mean that they had a two-thirds safety margin. If a part that is designed to hold back inflammatory gases is weakened by one-third, then its capacity to hold those gases back is diminished by one-third. In such a weakened state, the margin between its holding up and its caving in to the pressure of the gases is seriously undermined. It is not that it possesses a two-thirds safety margin; it is that one-third of its capacity is diminished. It may not be capable of standing up to a heavy load. Its safety margin at that point may be zero.

In Professor Feynman's words:

> If a bridge is designed to withstand a certain load ... it may be designed for the materials used to actually stand up under three times the load ... But if the expected load comes on to the new bridge and a crack appears in a beam, this is a failure of the design. The O-rings of the solid rocket boosters were not designed to erode. Erosion was a clue that something was wrong. Erosion was not something from which safety could be inferred.[34]

[33] Ibid., p. 73.
[34] *Ibid.*, p. 183.

If we are to generalize from these arguments to future scenarios of risk assessment, we must be careful never to consider problems that develop as evidence that the design is still basically sound. Problems are danger signals, not signals that everything is fine. When safety is compromised, it does not signify that there is still a viable margin of safety. When safety is weakened, what we have left is not a state of safety conditions which are a little less than perfect; we have conditions which are not safe. At the very least, one needs to be informed of unsafe effects just as possible side effects are listed for medicines so that the risks taken are known rather than unknown. When one takes those medicines for which side-effects are made known to the patient, one is aware of the risk factors.

Professor Feynman, in his famous, improvised experiment during the televised hearings, dropped a piece of the rubber O-ring into a glass of ice water obtained from a waiter and demonstrated that it had no resiliency left to it at a freezing temperature and therefore could not expand to contain the superhot inflammable gases. Considering the intriguing discussion of different definitions of 'resilience', Professor Feynman appears to be integrating notions borrowed from ecological and engineering definitions. The adaptive qualities of resilience are essential in this case to providing strong, stable and consistent containment. In this case, resilience is closer to the engineering definition of resilience, focusing on efficiency, constancy and predictability. On the other hand, the qualities of ecological resistance are also involved since the reaction to change is crucial in that it was discovered that though the O-rings were not initially designed to expand that under pressure, in previous launches the metal bent and the rubber expanded (a process known as extrusion) to seal the O-ring. While this was not how the O-rings were designed to function, this is how they functioned in flight conditions. This is analogous to the need to absorb disturbance and reorganize while undergoing change.[35]

The above examples make it clear that the primary problem of risk lies in the *choices* to be made by the risk decision makers, not in the *management* of risk already taken. By focusing on the term "management", one takes for granted that a risk must exist in the first place and needs only to be managed. In the case of the O-rings, and the escape systems, there was no need for this risk to exist in the first place. There are important lessons to be learned for the management of other wide-risk technological systems.

[35] *Cf.*, Mary Comerio, *Resilience*.

RISK HEEDING: EPISTEMOLOGICAL AND ETHICAL FALLACIES

In the case of any possible locus of disaster, warnings and the heeding of notifications of risk are of paramount importance.[36] It is important to take note of epistemological and ethical fallacies when it comes to arguments of why warnings are not sufficiently heeded. In the case of the *Challenger* disaster, nothing should blind us to the point that the most senior engineer involved was keenly aware of the fatal risk involved and sent red-flagged warnings to this effect. That these warnings were not heeded is sometimes obscured with the "argument" that one cannot hold up actions to be taken on the basis of warnings since every possible action will always have risks and it is next to impossible to take note of every single warning that comes across one's desk. The existence of warnings that cannot supposedly be noticed is referred to under the hypothesis of "weak signals".[37] *The hypothesis of "weak signals" is offered up as a rationale why warnings cannot always be heeded*.

This "weak signals" hypothesis is easily refuted when one considers the *source*, the *content* and the *form* of the signals. One *source* of the signal in this case is the most senior engineer who knows the most about the O-rings. (Other well-informed engineers joined in.) It is not a crank call made by a tourist to the information center at the space center. The source in this case was the project's senior engineer himself. It was a warning from the inside, by an insider, who knew the most about the technology about which he was issuing the warning.

The *content of the signal* warns of the danger being fatal to all aboard. There is no weakness in terms of the content of the message. In Boisjoly's famous memorandum of July 31, 1985, he warned before the fact that if there were a launch, "The result would be a catastrophe of the highest order – loss of human life." In his earlier warning of July 22, 1985, he warned of a horrifying flight failure unless a solution were implemented

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[36] A useful site for hazard early warning information is available from the "Disaster Risk Management for Health Fact Sheets," Global Platform, May 2011, accessed September 15, 2015, http://www.who.int/hac/events/drm_fact_sheet_early_warning_natural_hazards.pdf

[37] The hypothesis of "weak signals" to describe the warnings of the failure of the O-rings was put forward by Diane Vaughan in her book, *The Challenger Launch Decision: Risky Technology, Culture and Deviance at NASA*.

to prevent O-ring erosion.[38] One can readily see that there is no mincing of words to minimize the possibility that the danger might be understood to be less than absolutely extraordinary. The consequences in terms of life and death danger are spelled out in detail. The specific risk factor is named. One could not possibly ask for a stronger signal.

In terms of the form of the "weak signals" hypothesis, it should be noted that when it came to the timing of the launch, 14 managers and engineers alike *unanimously* voted against it.[39] One could not conceive of a stronger signal than this. That this decision was overturned in an off-line thirty-five minute caucus by 4 Morton Thiokol managers (with no engineers on line who were not managers i.e., Lund, who was both manager and engineer, allowed to participate in the closed off-line caucus) does not take away from the fact that these 4 managers were fully aware of the previous signal of unanimous vote of 14 engineers and managers against the launch.[40] There is no possibility that the signals sent were not the strongest possible signals available. It is important to remember that while all 14 were privy to most of the teleconference, that the fateful decision to launch was made during the thirty-five minute off-net caucus to which only the 4 managers were privy. The engineers who were not privy to this decision had no part in writing the recommendation to launch and refused to sign it. These engineers did not change from their original recommendation not to launch. *During this long passage of time, changes in the content of the putty were implemented.*

THE RIGHT TO MAKE DECISIONS OVER OTHERS' LIFE AND DEATH

What if we leave the decision to launch to the astronauts themselves and make sure that they are fully informed of the dangers? (For the sake of this discussion, we omit the fact that there were two civilian passengers aboard). The crew, who perceive themselves as heroes, are likely to decide

[38] *Saving Human Lives: Lessons in Management Ethics*, p. 170. *Cf.*, *Investigation of the Challenger Accident, Report of the Committee on Science and Technology*, House of Representatives, Ninety-Ninth Congress, 2nd Session, Union Calendar No. 600, House Report 99-1016, Washington, D. C., GPO, 1986, p. 285. This memorandum is blotted out so as to be virtually illegible.

[39] *Ibid*., pp. 174, 195.

[40] *Ibid*., for an extended analysis of the unsound and unethical decision making process engaged in by the four middle managers.

to launch. When I had the privilege to personally interview Kathyrn Cordell Thornton, the celebrated astronaut who was part of the 100 strong astronaut corps at the time of the *Challenger*, and then Director of the Center for Science, Mathematics and Engineering Education at the University of Virginia, we discussed this very issue. I recall her saying that, 'if these astronauts had refused to go up, there would be 100 others behind them waiting to take their place.' This is not surprising when one considers the peer expectations of that kind of group. There is a psychological expectation that they should be fearless. This is no different from football players going into the field with a head injury. The question now has become, does one have a right to take a risk with one's own life? One could say that this is a matter of individual choice. But, is it? One must take into account the circumstances that make up the context in which the choice is to be made. Such circumstances include peer pressure, job pressure, expectations of the kind of risk the risk taker is "supposed" to be taking in the concrete situation. The real problem lies with the risk makers, those who place the risk takers in the situations in which lethal risks are being taken. The shuffle of responsibility to those who take the risks from those who create the risks relieves the risk makers of ethical responsibility.

Ultimately, the deciders, those who are taking the risk of other people's lives in their own hands, have the responsibility of *not risking other people's lives*. It is as simple as this. *There is no such thing as an ethical choice to risk another person's life when it is not necessary in the service of life without first obtaining prior consent.* If managers do so on account of cost-saving, they are making unethical choices if we define the basic principle of ethics to value human life as the highest priority. Needless to say, matters are different in the case of the military in which case prior consent has been implicitly given when one has become a soldier. Then, a general can order soldiers into combat zones in which their lives are placed in jeopardy. But, in these cases, prior consent has been obtained. In these cases, in any case, the general's commands are in the service of life in the sense that the war or battle being fought is, presumably in the service of the lives whom the soldiers are fighting to protect.

We should not leave the discussion of this one classic example without mentioning that the astronauts and the civilians aboard could have easily been provided with proper space suits, parachutes and ejection chairs had the shuttle been designed for them. No one died as a result of the explosion. Horrifically, all died because of too fast a collision with the ocean. All were breathing until ocean contact. *It is important to emphasize that the crew and the passengers were alive, were conscious after the spectacular explosion.* During their three minute descent, some crew members had actually activated and used their emergency air packs. One can only ponder the living terror that those horrifying three minutes gave to those seven people, fully aware of their imminent death. What mental suffering those human beings endured! That such a provision of space suits, parachutes and ejection chairs were considered and then rejected by management is another unethical decision that resulted not in the safe abortion of the mission, but in the unimaginably horrific deaths of every person aboard. Earlier spacecraft had been equipped with launch escape systems, thus proving that escape systems were not only possible, but were actual. *The decision not to equip the Challenger with an abort system was not a decision based on possibility, but a decision based on policy.* This death, or should it be said, manslaughter of the astronauts and passengers, was not the result of high-risk technology, but the result of a cost-benefit analysis that did not follow a safety first priority. This horrific outcome was the result of risky and unethical decision making, of unethical risk assessment. This risk did not have to exist in the first place. It was a management decision that decided not to include these safety precautions: *it was risk assessment that did not take into account the value of human life*. (All earlier and all later missions were equipped with abort systems).

FINAL CONSIDERATIONS

THE RIGHT TO MAKE DECISIONS OVER OTHER'S LIFE AND DEATH

We are normative beings. What this means is that we are capable of analyzing our behavior in moral terms. It is difficult to provide an example of when we are not aware of when we or others are operating in ways which we consider to be unethical. If such an example could be found, it is always possible to argue that we should have been so aware. For example, while much has been made of the idea that moral norms are culturally variable, it is difficult if not impossible to find an example of a culture that does not follow some version of the Golden Rule, that harm-doing to others is not acceptable except in certain specialized cases, such as selfdefense.[41] While what constitutes harm to others may involve some cultural variance, in fact, it is easier to find commonalities of what is considered harm-doing than it is to find differences.[42] When we are considering the countries in which man-made disasters occur, especially those involving wide-risk technologies, there is a basic agreement about what constitutes harm-doing/harm-allowing and hence unethical behavior.

There is some degree of resistance to the introduction of humanistic concerns to what have traditionally been conceived of as technologically driven organizations. What is needed is more adaptive resilience on the part of technocrats and bureaucrats to allow the soft data of ethics to penetrate into the engineering, political or management arena. When the decision of whether or not one should locate the Fukushima Daiichi Nuclear Reactor near to the Ocean was being made, what was lacking was not the hard data of science, but the soft data of ethics.

We have also learned that the alleged hard data of risk assessment is sometimes based on fantasy such as the odds predicting the failure of the loss of a space shuttle and the odds of a nuclear core melt disaster. One of the problems is that risk assessment has not been scientific enough in its methodology. It is hoped that some of these ideas can also be applied to the important area of reducing the risks of the harmful consequences of disasters.[43] In addition, according to the International Red Cross, the traditional focus of the health sector has been on response and recovery and there is a need to broaden that focus to include prevention and mitigation and to develop community capacities.[44] Thus, when calculating the risks of the movement of elderly populations in the case of the Fukushima Daiichi nuclear reactor disaster, one can take soft data into account.

[41] Robert Elliott Allinson, 'The Negative Formulation of the Golden Rule in Confucius', *Journal of Chinese Philosophy*, Vol. 12, no. 3, September, 1985.

[42] 1988: (ed. with Shu-hsien Liu), *Harmony and Strife: Contemporary Perspectives, East and West*, cloth-bound, Chinese University Press, 1988, pp. 336.

[43] A useful example of such an application is found in Muhammed Tariq, Saif Ullah Khan and Zahid Pahman, 'Evaluation of Disaster Prevention and Management: A Comprehensive Case of Haiti and Pakistan,' *Interdisciplinary Journal of Contemporary Research in Business*,' Vol 3, No 5, September 2011, China has also made significant improvement in their disaster management approach. *Cf.*, accessed September 15, 2015, http://news.xinhuanet.com/english/2009-05/11/content_11351284.htm

[44] "Humanitarian Health Action: Disaster Risk Management for Health Facts Sheet," World Health Organization, accessed September 15, 2015, http://www.who.int/hac/techguidance/preparedness/factsheets/en/

One must ethically assess that it will be more difficult to move elderly people to new homes without harmful effects. Shashnawa Ali, head of climate change and disaster resilience for Islamic relief Bangladesh, emphasizes the need to give poorer countries a fighting chance by taking measures such as rebuilding flood-prone houses on higher grounds.[45] This demonstrates the importance of prior ethical calculations which reveals the importance of applying the ideas developed here to the important areas of risk reduction management to cope with the situations that arise once a disaster has occurred.[46] In terms of monetary factors, research from the U.S. government shows that one dollar of money spent on risk reduction saves fifteen dollars in disaster relief.[47]

It is a pity that it takes a great disaster to awaken the need for prevention. Thailand now has the best tsunami warning system in Asia but it took the horrific toll of human lives to bring this about.[48] Ethics, which represents the core of the soft data of the humanities, is at the bottom of

[45] Mark Tran, "UN urged to create global fund for disaster prevention," *The Guardian*, October 1, 2012, accessed September 15, 2015, http://www.theguardian.com/global-development/2012/oct/01/call-for-global-fund-disaster-prevention

[46] A clear account of the approach of reducing the consequences of disasters is given in the United Nations Development Programme for Indonesia. This is important since Indonesia is one of the most disaster prone areas in the world. *Cf.*, accessed September 15, 2015, http://www.undp.or.id/programme/cpr/, The Government of India/United Nations Development Programme on Natural Disaster Risk Management includes specifics such as training masons and engineers to construct earthquake resistant houses. *Cf.*, accessed September 15, 2015, http://saarc-sdmc.nic.in/pdf/india/file5.pdf

Vietnam is another example of one of the most disaster prone areas in the world. Their handbook on disaster management shows an awareness of the need to extend communication down to village and commune levels. *Cf.*, accessed September 15, 2015, http://www.coe-dmha.org/Publications/cdr_handbooks/Vietnam_DisasterResponse_Handbook2012.pdf.Thailand is also making progress especially after the 2004 Tsunami. *Cf.*, accessed September 15, 2015, http://www.jica.go.jp/english/our_work/evaluation/tech_and_grant/project/term/asia/c8h0vm000001rr8t-att/thai_2008_02.pdf

[47] Mark Tran, "UN urged to create global fund for disaster prevention," *The Guardian*, October 1, 2012, accessed September 15, 2015, http://www.theguardian.com/global-development/2012/oct/01/call-for-global-fund-disaster-prevention

[48] "Survivors of 2004 tsunami left horrified after being 'ambushed' by trailer for movie about Boxing Day tragedy," *Daily Mail*, December 25, 2012, accessed September 15, 2015, http://www.dailymail.co.uk/news/article-2253133/Boxing-Day-Tsunami-Survivors-2004-tsunami-left-horrified-ambushed-trailer-movie-Boxing-Day-tragedy.html

and motivates all efforts at reducing the harmful effects of disasters, for what we are all most concerned about is preventing and reducing harm to our fellow human beings. This analysis has underscored the importance of preventing disasters from occurring in the first place. This notion of prior prevention is key especially when one considers the prospect of mega-disasters in the face of which even the best of risk reduction management measures may prove ineffective. The Fukushima Daiichi nuclear reactor disaster may only be an early warning signal of such mega-disasters that might be on the horizon. In the end, prevention may be our only answer. The ethical behavior of human beings is not a luxury; in today's world, it is a necessity.

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