The Business Case for Using a Numbered Logarithmic Risk Severity Scale

Donald W. Swallom

U.S. Army Aviation and Missile Command

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Abstract

By the way they are structured, the severity scales of both U.S. Department of Defense (DoD) Instruction 6055.07 dealing with actual accidents, and Military Standard 882 (MIL-STD-882) dealing with potential accidents, do not adequately address accidents with extremely high dollar or fatality loss. While the threshold for the highest classification of damage loss has been increased by 6055.07 to $2 million and 882 to $10 million, both up from $1 million, some DoD systems exceed those values by up to three orders of magnitude. The threshold for the highest injury classification is unchanged at one fatality. A numbered logarithmic severity scale similar to the Richter Scale used for earthquakes would resolve this deficiency and support classifying and assessing the risk of high-loss accidents. The new scale would not only improve the risk management of accidents but also would enhance the Department of Defense application of risk management. It could be further applied on a national basis in support of Presidential Policy Directive 8 which aims to strengthen the security and resilience of the nation through systematic preparation for the threats and hazards that pose the greatest risk to U.S. security and well being.

Introduction

Problem. Currently the DoD's accident classification structure is delineated in DoD Instruction 6055.07, *Mishap Notification, Investigation, Reporting, and Record Keeping*, as follows:

> Class A mishap. The resulting total cost of damages to Government and other property is $2 million or more, a DoD aircraft is destroyed (excluding UAS Groups 1, 2, or 3), or an injury or occupational illness results in a fatality or permanent total disability.
>
> Class B mishap. The resulting total cost of damages to Government and other property is $500,000 or more, but less than $2 million. An injury or occupational illness results in permanent partial disability, or when three or more personnel are hospitalized for inpatient care (which, for mishap reporting purposes only, does not include just observation or diagnostic care) as a result of a single mishap.
>
> Class C mishap. The resulting total cost of property damages to Government and other property is $50,000 or more, but less than $500,000; or a nonfatal injury or illness that results in 1 or more days away from work, not including the day of the injury.
>
> Class D mishap. The resulting total cost of property damage is $20,000 or more, but less than $50,000; or a recordable injury or illness not otherwise classified as a Class A, B, or C mishap. (ref. 1)

In Military Standard 882E (MIL-STD-882E), the severity categories used to assess potential mishaps due to hazard are as listed in Table 1. The problem with these severity scales is that the top thresholds of each are so much less than the value of the DoD's most expensive systems. Figure 1 shows these thresholds compared to the most expensive systems. The threshold barely registers on the chart compared to these systems. Figure 2 shows how much less the fatality thresholds are than the populations of Nimitz and Ford-Class aircraft carriers and again the thresholds barely show on the chart.

Table 1 — MIL-STD-882E Severity Categories. (ref. 2)

Description	Severity Category	Mishap Result Criteria
Catastrophic	1	Could result in one or more of the following: death, permanent total disability, irreversible significant environmental impact, or monetary loss equal to or exceeding $10M.
Critical	2	Could result in one or more of the following: permanent partial disability, injuries or occupational illness that may result in hospitalization of at least three personnel, reversible significant environmental impact, or monetary loss equal to or exceeding $1M but less than $10M.
Marginal	3	Could result in one or more of the following: injury or occupational illness resulting in one or more lost work day(s), reversible moderate environmental impact, or monetary loss equal to or exceeding $100K but less than $1M.
Negligible	4	Could result in one or more of the following: injury or occupational illness not resulting in a lost work day, minimal environmental impact, or monetary loss less than $100K.

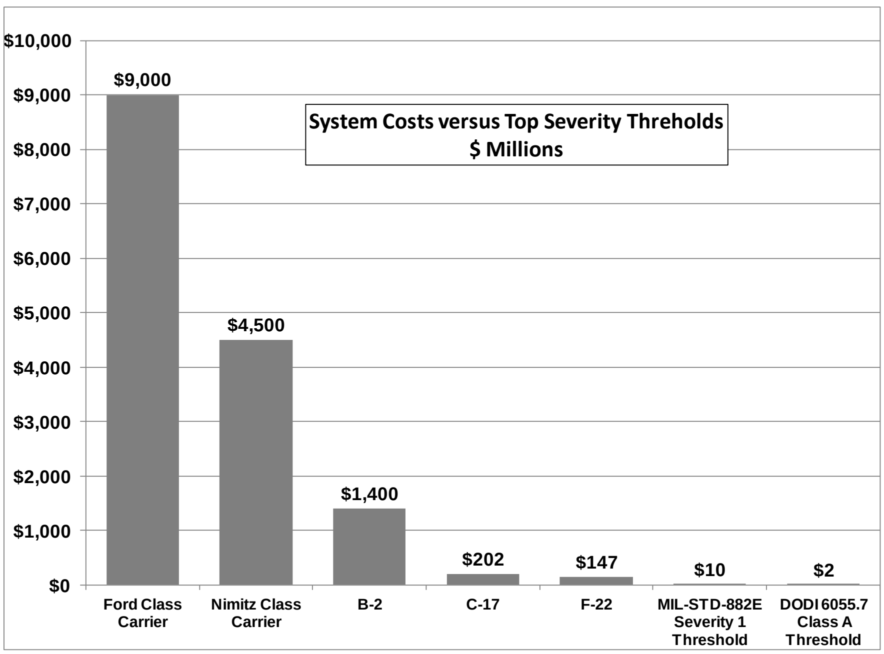

Figure 1 — System costs versus top severity thresholds

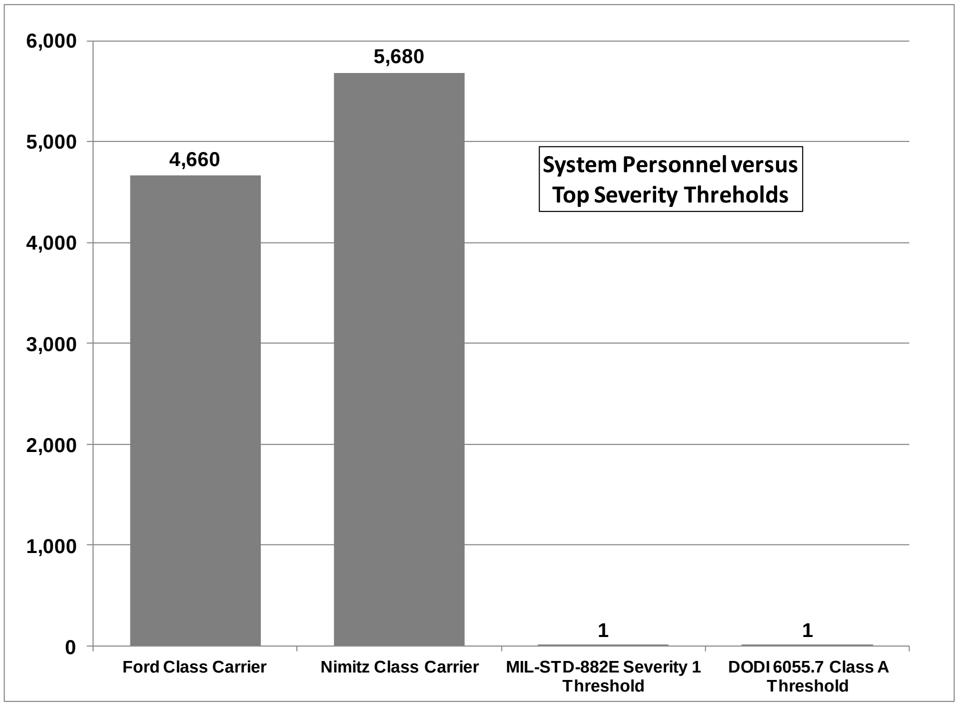

Figure 2 — System personnel versus top severity threshold

This problem is further exacerbated in that both the 6055.07 and 882 scale labels increase in the opposite direction to increasing severity. This means they must be rescaled in order to accommodate increases because is that there is no number before "1" and no letter before "A." Had they been numbered or lettered in the same direction as increasing severity they would only require the addition of a number or letter increment to increase the range of severity covered. In addition, for both scales there are only 4 levels of severity. In keeping 4 levels, MIL-STD-882E, when it increased the Severity 1 threshold from $1 million to $10 million, also increased the top value of its lowest severity category, Category 4, from $10,000 to $100,000 which seems to be rather high for a loss described by its label as "Negligible." With numbering of the severity categories in the same direction, one could increase the range of severity of the scale by adding one more level, Severity Category 5, and leaving the original category ranges unchanged.

Background. Before 1989, the threshold for a Class A accident was $500,000. From 1989 to 2009, the threshold for a Class A mishap was $1 million (ref. 3). Prior to 2000, no dollar values were included with the severity categories in MIL-STD-882. With MIL-STD-882D, published in 2000, the threshold for a Severity Category 1 was also $1million (ref. 4). In fact, the suggested mishap severity categories incorporated all the thresholds of the DODI 6055.7. These thresholds made sense because they were already well known by all those familiar with accident data in the DoD.

After work began in 2004 on a revision to MIL-STD-882D, the attributes of a good risk assessment matrix were discussed in some detail in a panel discussion held at the 2004 International System Safety Conference. The results of this discussion were published in the Journal of System Safety in 2005 (ref.5). Also in 2005, the author of this paper submitted a paper to the 23rd International System Safety Conference (ref. 6) proposing a common risk matrix for all DoD aircraft. Key to this matrix, shown in Figure 3, was reversing the numbering of the severity scale from that used in MIL-STD-882D enabling the ability to tailor it to the dollar value and number occupants of a specific aircraft. The various aircraft are depicted on the matrix by the different patterned lines. This matrix was incorporated as an example matrix in the February 2006 draft of MIL-STD-882E which eventually was developed by the TechAmerica G48 Committee into ANSI/GEIA-STD-0010-2009 (ref. 7). Also included in the author's 2005 paper (ref. 6) was a matrix tailored in this same manner for "Spaceship Earth" (Figure 4). This matrix used only 13 categories of severity to assess hazards up and including those hazards that could end life on this planet.

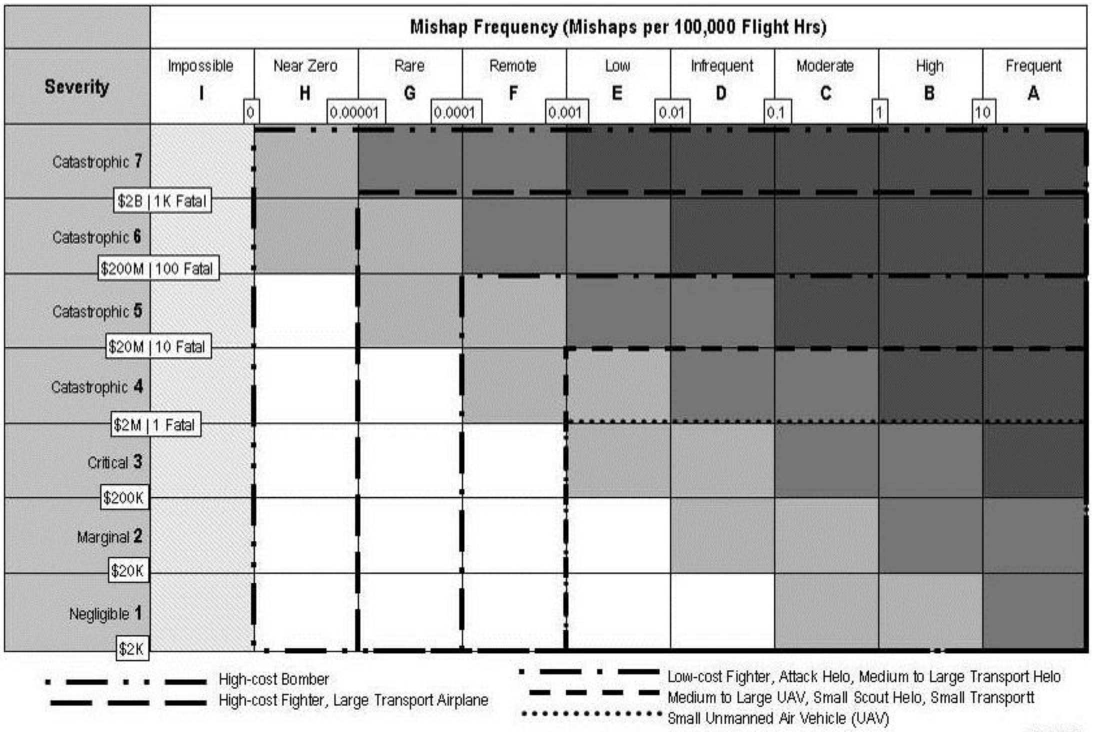

Figure 3 — A common mishap risk assessment matrix for DoD aircraft systems. (ref. 8)

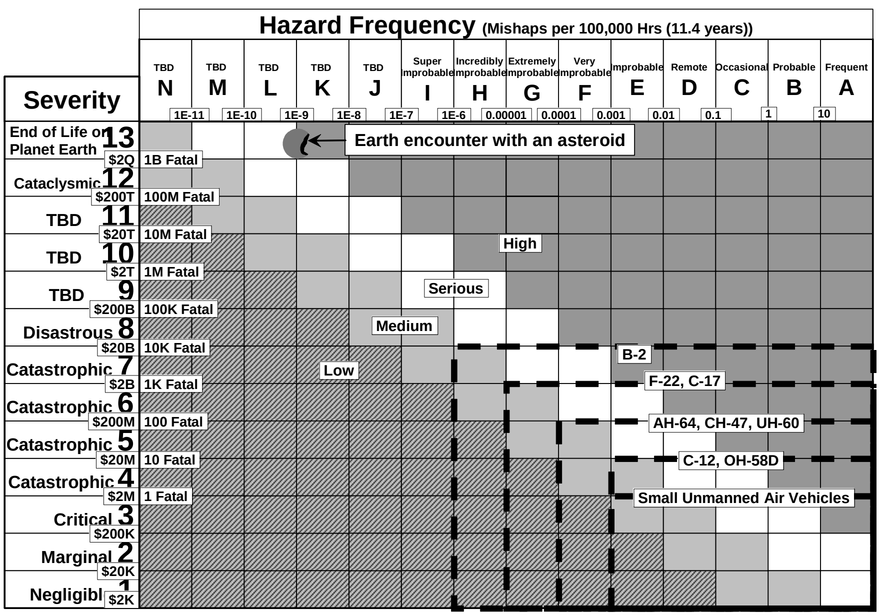

Figure 4 — A Risk Assessment Matrix Tailored for Spaceship Earth (ref. 9)

Scope. There are four arenas where a numbered logarithmic risk severity scale has benefits. First is the arena discussed above, DoD accident classification and system safety risk assessment.

Second is the arena of risk management. The U.S. Army's composite risk management, described in Department of the Army Pamphlet 385–30, is "a continuous process applied across the full spectrum of Army training and operations, individual and collective day-to-day activities and events, and base operations functions to identify and assess hazards, develop and implement controls, and evaluate outcomes." (ref. 10). Table 2 is the Standardized Army risk matrix. The severity categories used by U.S. Army Pamphlet 385-30, are the same as those in MIL-STD-882D with 1 fatality and $1 million as the top category threshold. Table 3 is the risk acceptance matrix setting risk categories against the duration of exposure to determine which authority should accept the risk. Figure 5 shows the numbers of soldiers at each level.

Table 2 — DA Pam 385–30 Standardized Army risk matrix (ref. 11)

	Probability					
Severity	**Frequent A**	**Likely B**	**Occasional C**	**Seldom D**	**Unlikely E**	
Catastrophic	I	E (1)	E (1)	H (2)	H (2)	M (3)
Critical	II	E (1)	H (2)	H (2)	M (3)	L (4)
Marginal	III	H (2)	M (3)	M (3)	L (4)	L (5)
Negligible	IV	M (3)	L (4)	L (4)	L (5)	L (5)

Table 3 — DA Pam 385–30 Risk acceptance matrix (ref. 12)

	Duration of risk				
Category of risk	**1 month or less**	**Greater than 1 month, less than 1 year**	**Greater than 1 year, less than 5 years**	**Permanent or greater than 5 years**	**Chartered system development programs**
Extremely high risk	General officer	MSC CG – General officer	Army Headquarters CG	ASA(I&E)	Component Acquisition Executive (CAE)
High risk	Brigade CO or responsible O-6	General officer[1]	MSC CG – General officer	Army Headquarters CG	Program Executive Officer (PEO)
Moderate risk	Battalion CO[1] or responsible O-5	Brigade CO[1] or responsible O-6	General officer[1]	General officer[1]	Program manager
Low risk	Company CO[2] or responsible O-3	Battalion CO[2] or responsible O-5	Brigade CO[1] or responsible O-6	Brigade CO[1] or responsible O-6	Program manager
Tolerable risk	Not required	Not required	Not required	Not required	Not required

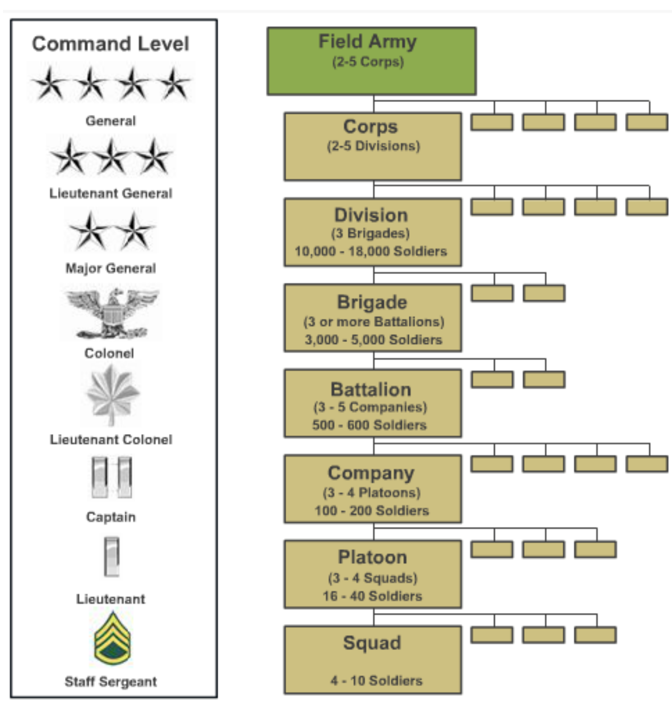

Figure 5 — U.S. Army Operational Units (ref. 13)

The lowest risk acceptance authorities are company commanding officers (CO) . Companies are composed of 100 to 200 soldiers. This progresses to battalion COs (500 to 600 soldiers) and brigade COs (3,000 to 5,000 soldiers). But what if an entire Army division (10,000 to18,000 soldiers) is exposed to an operational threat or hazard? How does a scale dealing with only one or more fatalities handle that? Scenarios like this have occurred. For example, in June, 1991, Clark Air Base in the Philippines was devastated by the eruption of Mount Pinatubo necessitating a massive evacuation of aircraft, equipment, and about 15,000 personnel to other bases in the Pacific just prior to the event.

Third is the arena of national preparedness. On March 30, 2011 President Obama released Presidential Policy Directive 8 (PPD-8): National Preparedness, which is "aimed at strengthening the security and resilience of the United States through systematic preparation for the threats that pose the greatest risk to the security of the Nation, including acts of terrorism, cyber attacks, pandemics, and catastrophic natural disasters (ref. 14)." A new severity scale would be useful in support of PPD-8 which aims to strengthen the security and resilience of the nation through systematic preparation for the threats and hazards that pose the greatest risk to U.S. security and well being. As part of the effort, the Secretary of Homeland Security led an effort to conduct a strategic national risk assessment (SNRA) to help identify the types of incidents that pose the greatest threat to the Nation's homeland security. The SNRA evaluated the risk from known threats and hazards that have the potential to significantly impact the Nation's homeland security. These threats and hazards were grouped into a series of national-level events with the potential to test the Nation's preparedness. The report identified 23 of these events listed in Table 4.

Table 4 — Strategic National Risk Assessment (SNRA) National-Level Events (ref. 15)

Threat/ Hazard Group	**Threat/Hazard Type**
Natural	Animal Disease Outbreak
	Earthquake
	Flood
	Human Pandemic Outbreak
	Hurricane
	Space Weather
	Tsunami
	Volcanic Eruption
	Wildfire
Technological/ Accidental	Biological Food Contamination
	Chemical Substance Spill or Release
	Dam Failure
	Radiological Substance Release
Adversarial/ Human-Caused	Aircraft as a Weapon
	Armed Assault
	Biological Terrorism Attack (non-food)
	Chemical/Biological Food Contamination Terrorism Attack
	Chemical Terrorism Attack (non-food)
	Cyber Attack against Data
	Cyber Attack against Physical Infrastructure
	Explosives Terrorism Attack
	Nuclear Terrorism Attack
	Radiological Terrorism Attack

Fourth is the arena of global preparedness. Many of the hazards listed in Table 4 also have the potential for global impact. A pandemic has historically been a source of world-wide risk with such diseases as cholera, influenza, typhus, smallpox, measles, tuberculosis, leprosy, malaria, yellow fever, and AIDS. Potential pandemic diseases include viral hemorrhagic fever, previously controlled antibiotic-resistant microorganisms, severe acute respiratory syndrome (SARS), and H5N1 Influenza (Avian Flu). Some hazards such as earthquake and tsunami can affect multiple countries and even multiple continents in one event and a collision with a large extraterrestrial object would destroy all life on our planet.

Desired Outcomes

There are four desired outcomes of implementing a numbered logarithmic risk severity scale corresponding to the four arenas described above.

Outcome 1. It must support DoD policy regarding the investigation of mishaps and the assessment of environmental, safety, and occupational health hazards for DoD systems.

Outcome 2. It must be a useful tool to all levels of DoD leadership in employing composite (operational) risk management for the full range of DoD operations.

Outcome 3. It must be useful in support of national preparedness to include managing the risk of all of the 23events listed in Table 4.

Outcome 4. It must be useful in support of global preparedness.

Alternatives to be Analyzed

Alternative 1. Keep the current DODI 6055.07 structure for accident classification (A, B, C, D) and MIL-STD-882 severity categories (1, 2, 3, 4) which are not aligned to increase with increasing severity. Continue the current practice of increasing the severity thresholds every 10 to 20 years making incremental changes that do not approach the magnitude of the costs of systems in terms of damage or injury.

Alternative 2. Renumber the severity scales using numbers going in the same direction as the increase in severity. Start numbering with Severity Category 1 for the lowest range of severity and add one severity category for each 10-fold increase in severity. Add categories until the full range of potential loss is covered for a specific system. Do this for the dollar value of damage and for injuries and fatalities. Eliminate the use of one-word labels (Catastrophic, Critical, Marginal, Negligible) for each severity category. Descriptions in terms of dollar value of damage and injuries and fatalities are more meaningful and do not carry any preconceived notions of their meaning as is the case with one-word labels.

Analysis of Alternatives

Alternative 1. The argument for Alternative 1, as far at DODI 6055.07 is concerned, is that the current system works adequately for its intended purposes. One purpose of the accident classes is to determine the level of effort required to investigate an accident. Any additional effort over and above that required by the instruction to investigate high value or high interest accidents will be ordered by the appropriate level of authority anyway. However, what the current system lacks is a means to differentiate high value Class A accidents from Class A accidents which are barely in the Class A range. For example, in February, 2008, a B-2 crashed on the runway shortly after takeoff from Andersen Air Force Base in Guam. As shown in Figure 1, the cost was $1.4 billion. It was just one Class A accident so the overall Class A accident rate for Fiscal Year 2008 did not increase much. But in terms of dollars lost to Class A accidents it must have caused a significant jump. In the realm of U.S. Navy aircraft carriers, an accident is a Class A if one sailor is killed, one aircraft is lost, or the entire ship and its company is lost. There is no differentiation between them.

In terms of managing risk, the same issue is true; the severity categories do not differentiate between lower value Class A accidents and truly high value losses in the arena of managing the operational risk to a large installation or formation of troops.

Alternative 2. The proposed renumbered logarithmic risk severity scale, shown in Figure 6, can easily be expanded to the size needed for the application. When used in conjunction with a probability scale, one can create a matrix that can assess hazards with the potential for lost up to and including the entire world population. In this age of nuclear weapons and other weapons of mass destruction, an accidental or intentional use of such a weapon can easily impact millions, and in extreme cases, billions. If, for example, the cost of the Ford class aircraft carrier were to increase significantly the new risk scale can easily accommodate the increase. And the new scale can be used to create a risk matrix on the scale demonstrated in Figure 4 which can be applied to any of the 23 events in Table 4 plus any threat or hazard on a global scale. When the world population exceeds 10 billion the scale is easily expandable to 14 levels. Figures 6 and 7 show how some potential or historic "big" events plot against the new severity scale.

Equally beneficial is the way the new scale makes a risk matrix totally tailorable has illustrated in Figures 3 and 4. The new scale enables the Figure 3 matrix to expand in Figure 4 to cover the entire risk space of planet Earth, that is, the full range of severity possible and the full range of probability. The recent changes to the severity scales of both DODI 6055.07 and MIL-STD-882 only move them up on the severity scale without expanding their range of coverage very much.

The cost of converting to Alternative 2 in the short term is the same as Alternative 1. The severity scales of both DODI 6055.07 and MIL-STD-882 have recently changed and will have to change again in the future to keep up with increased costs of accidents. Implementing Alternative 2 would cost no more than this recent change. But in the long term would cost much less since there is no adjustment needed except for inflation. It would be no cost for additional data because the cost, injury, and fatality data in the accident databases of the services would not change. The change would be in the reports generated and initially in such things as describing which severity categories of accident require a particular level of effort to investigate.

What would change is an improved comprehension for leadership at all levels of the government and for the public, as well, of the significance of all actual or potential high loss events in the same way that the Richter scale aids in the comprehension of the severity of earthquake. As shown in Figures 6 and 7, the new scale truly differentiates between such events.

Also note that the new scale does not use labels such as "catastrophic," "critical," "marginal," or "negligible." As mentioned earlier, the term "Negligible" as currently defined is inappropriately used to describe severities of loss up to $100,000. Also, as illustrated in Figure 4, there are not enough words to label 13 levels of severity adequately and, as today's Richter scale demonstrates, there will be no need for them once the new severity scale becomes commonly used.

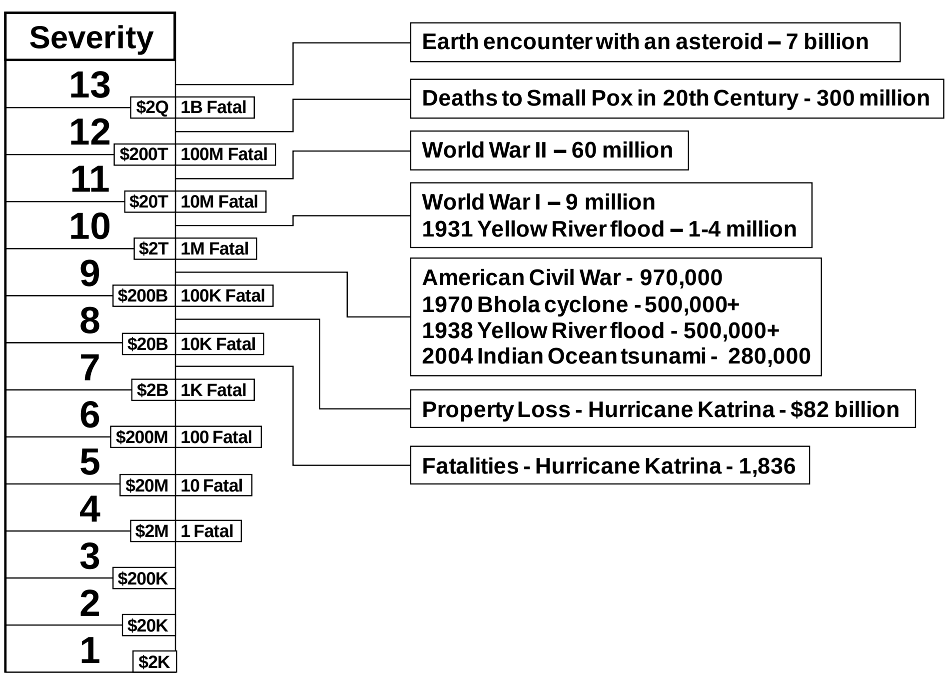

Figure 6 — Severity Categories of Potential or Historic Big Events (ref. 16)

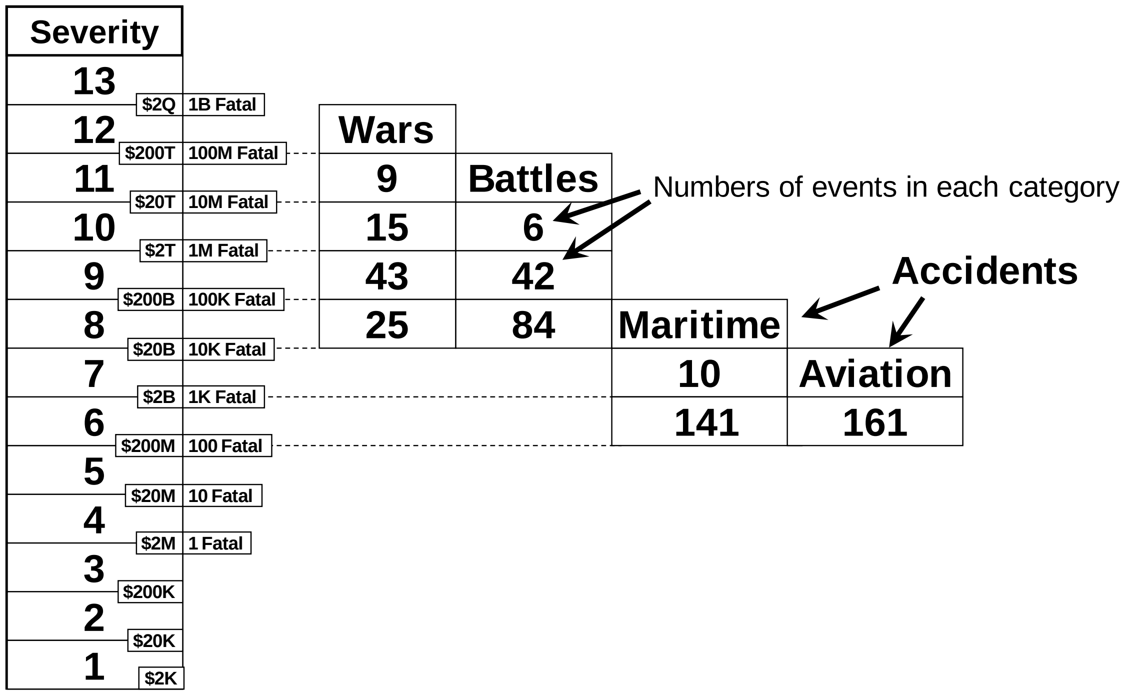

Figure 7 — Severity of Historic Events Based on Fatalities (ref. 17)

Conclusion

The current severity scales used in DODI 6055.07 and MIL-STD-882E are not structured to deal with the large costs of the DoD's systems. Top thresholds are too low and the current reversed letters and numbers used to designate the accident classes and severity categories make it difficult to adjust the scales to reflect the cost realities of our present and future systems. However, if we adopt a logarithmic risk severity scale numbered to increase in the same direction as increasing severity, we can use it for the full range of environmental, safety and occupational health risk management challenges to include even global worst case scenarios for the full range of natural and man-made disasters.

Recommendation

Begin the transition to the new scale by developing reports and risk assessments based on existing accident and other disastrous event data. This will help to educate today's environmental, safety and occupational health risk management personnel and others dealing with these kinds of events on the utility of this tool. It will also help calibrate the thinking of all government leaders on the meaning of risk assessment in the same way that the Richter Scale helped the scientific community and general public of the 1930s to comprehend the nature of earthquake severity data.

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Biography

Donald W. “Don” Swallom, Safety Engineer, U.S. Army Aviation and Missile Command, ATTN AMSAM-SFA, Redstone Arsenal, AL 35898-5000, telephone (256) 842-8641, fax (256) 313-2111, email: donald.w.swallom.civ@mail.mil.

Donald W. “Don” Swallom is a safety engineer with the U.S. Army Aviation and Missile Command Safety Office. Don holds a Bachelor of Science in Engineering Sciences from the United States Air Force Academy and a Master of Science in Systems Management from the University of Southern California. Prior to his current position, he served as a helicopter pilot, staff officer, and developmental engineer in the United States Air Force. His last Air Force assignment was as the chief of safety for the Arnold Engineering Development Center, the world's largest complex of aerospace ground testing facilities. He collaborated on the system safety chapter of the *Handbook of Human Systems Integration* (John Wiley and Son, 2003). Don is a Fellow member of the International System Safety Society and a past president of the Tennessee Valley Chapter.