NATO OTAN Advanced Research Workshop

PREDICTING, RANKING, AND PRIORITIZING PROBABLE ENVIRONMENTAL HAZARDS AND RISKS





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ENVIRON International
San Francisco, California USA

Venice, ITALY
16-19 March 2006

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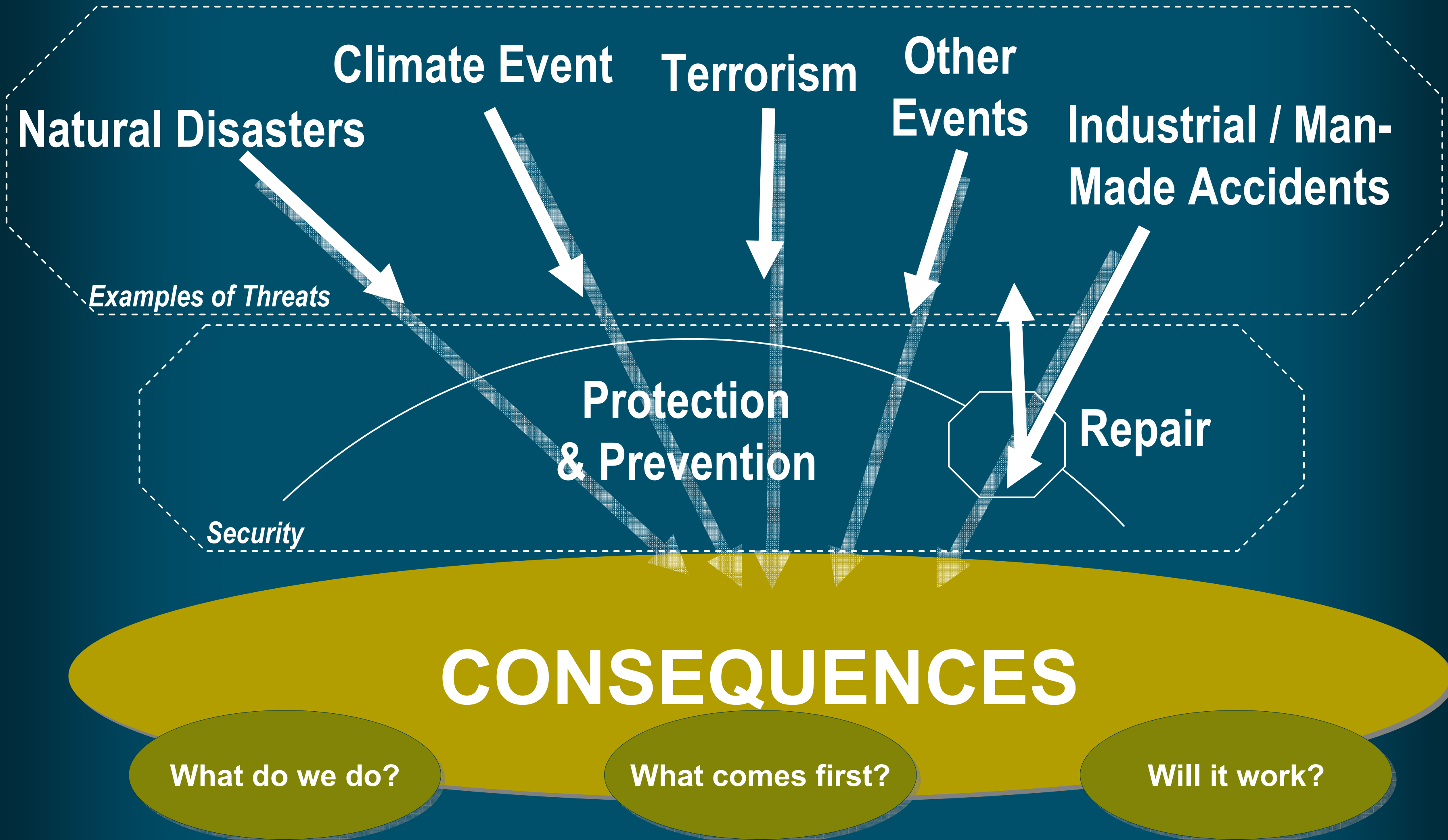
Abstract

- In a perfect world, on some regular basis, regulatory agencies and organizations would review and prioritize environmental challenges facing society systematically. That process would begin by listing all the possible risks, and ordering them according to the threat posed by each. It would continue by listing each option for controlling each risk, characterized by some estimate of effectiveness and cost. The process would conclude by identifying the best set of options or course of action for risk avoidance or risk reduction; i.e., strategies that achieve the greatest reductions at the least cost. Those costs might be measured in dollars, time, or whatever other resources needed to invest in risk management. As a by-product, this process would also identify residual risks, which cannot be reduced at any reasonable price, but which may continue to be of concern.
- In reality, though, systematic reviews of environmental risk are rare. Risks are so diverse that it is hard to compile either the list of threats or the set of possible control strategies. Environmental regulators and managers seldom have access to credible estimates of the sizes of the risks, the chances for control, or the costs of amelioration. A successful risk-ranking method faces many simultaneous demands. It must reflect the underlying science faithfully, capture the critical dimensions of that science, present that information comprehensibly, secure the input of citizens' values, reach a stable conclusion and convey it credibly to the broad public.
- This presentation explores how industrial ports and other organizations might respond to the challenges of ranking and prioritizing environmental risks and strategies for addressing risks cost-effectively. One strategy is to make as few assumptions as possible, reporting the results in something approaching raw form, assembling the data without digesting them. The work product might include weakly comparable estimates, expressed in different units and accompanied by frank discussions of the sources, assumptions and limitations and without any integration of the data. A second strategy is to integrate the evidence in several different ways, each reflecting an alternative value system; doing so would not prejudge which values are appropriate (among those that are considered). A third strategy is to elicit values from citizens or citizen panels, then derive the analytically appropriate rankings implied by them. Its success depends on the individuals' or groups' ability to express their values in the abstract form required by analytical models. Each strategy presumes a basic six step process, which may be applicable for industrial ports: (1) define and categorize environmental risks; (2) identify the relevant attributes of risk; (3) quantify the risks; (4) rank risks using several stakeholder groups; (5) compare risk rankings across different groups; and (6) prioritize risks based on most common set of attributes and concerns.

Aftermath of Security Failure



Aftermath of Security Failure

Answering the threat means we have to understand it's risks to different sectors:

Environmental Risk After Security Failure

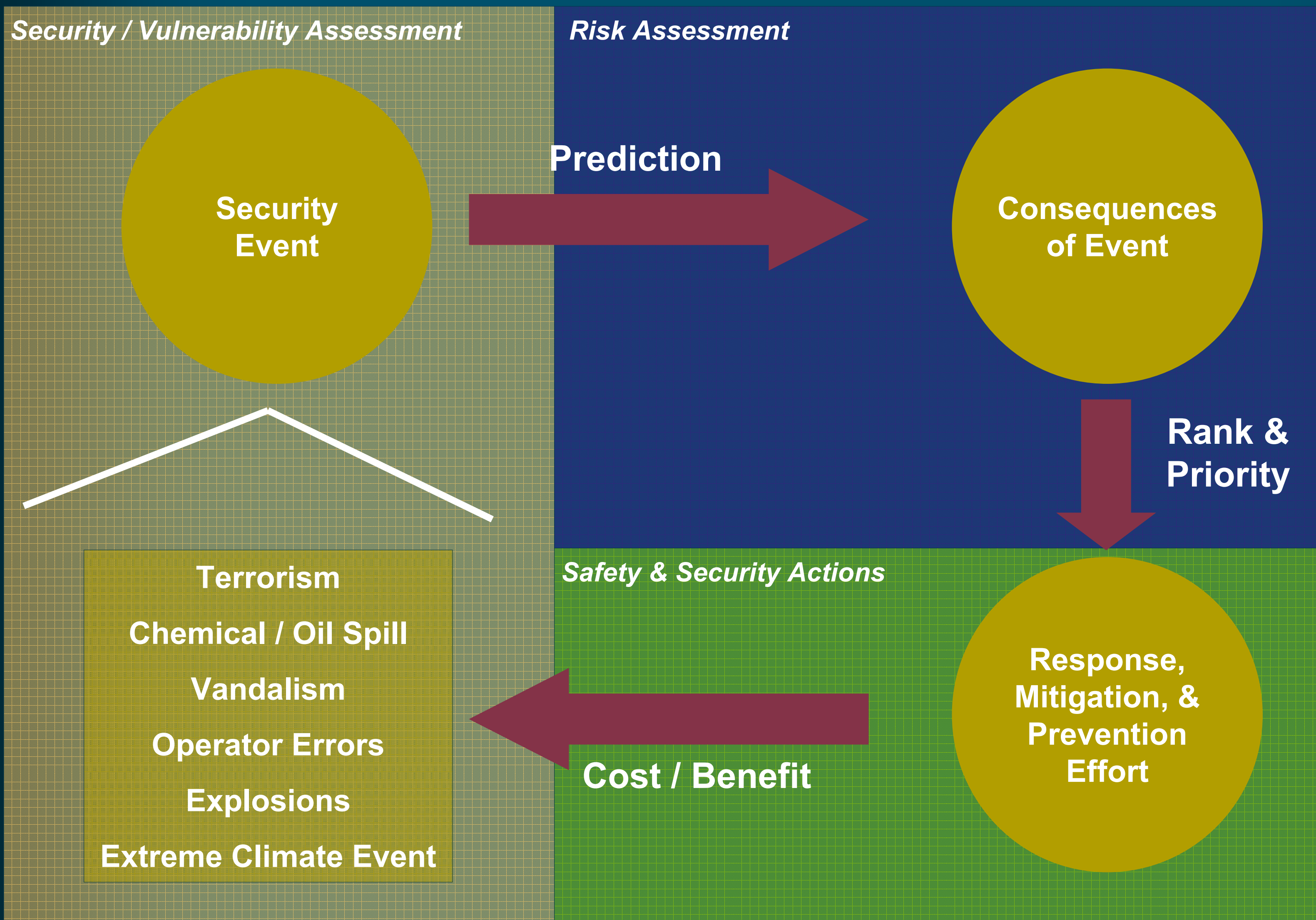
- Chemical / Oil Spills
- Contaminated Fish
- Degraded Water Quality
- Loss of Life
- Sediment Contamination
- Air Pollution
- Radiological Hazards
- Wildlife Habitat Loss

Health & Ecological Risk Assessment

Other Considerations (Cost, Economy, Social, etc.)

Multi-Criteria Decision Analysis (MCDA)

Security, Risk, & Action



Evaluating "Environmental Security"

Belluck et al (2005) definition:

- *"environmental security involves actions that guard against environmental degradation in order to preserve or protect human, material, and natural resources at scales ranging from global to local"*

- 3 evaluation elements:
  - (1) **understanding** basic human, ecological & environmental conditions
  - (2) **predicting** various opportunities whereby security might be compromised
  - (3) **analyzing range of options** to enhance, prevent, or minimize the contingency for adverse events to occur

Formulating Responses

Risk Ranking

- A risk management tool for comparing and prioritizing ecological, health, economic, and other risks.
- Formal risk ranking uses an analytical process to:
  - pose a risk question;
  - identify potential hazards and risks;
  - characterize factors that can be used as variables for quantifying risk; and
  - mathematically combine variables to yield *risk scores*.
- U.S. agencies that regularly use risk-ranking methods:
  - NASA, Department of Defense, EPA, & Nuclear Regulatory Commission
- Approaches have been well-described
  - Haimes (1998), Ayyub (2003), Finkel and Golding (1994)
  - Davies (1996), Konisky (1999),
  - Health and Safety Executive (1999).

Attributes of Risk Ranking Categories

- **Logically consistent:**
  - Exhaustive, so no relevant risks are overlooked
  - Mutually exclusive, so risks are not double counted
  - Homogeneous, so all risk categories are evaluated on the same set of attributes
- **Administratively Compatible:**
  - Compatible with existing organizational structures and legislative mandates, so lines of authority are clear and management actions at cross purposes avoided
  - Relevant to management, so risk priorities can be mapped into risk-management actions.
  - Assigned large weighting criteria, so decision-making can be understood with minimal interpretation.
  - Compatible with existing databases, to make best use of available information in any analysis leading to ranking.
- **Equitable:**
  - Fairly drawn, so interests of various stakeholders are balanced.
- **Compatible with cognitive constraints and biases:**
  - Chosen with awareness of inevitable framing biases.
  - Simple and compatible with people's existing mental models, so risk categories are easy to communicate.
  - Few enough in number so that the ranking task is tractable.
  - Free of the "lamp-post" effect, in which better understood risks are categorized more finely than less understood risks.

Morgan, M.G., et al., *Risk Analysis* 20:49-58 (2000)

Risk Matrix for Human Health Risks

Severity Scale	Probability of Occurrence				
	Very Low	Low	Medium	High	Very High
Death	*Medium*	*Medium*	*High*	*High*	*High*
Hospitalization	*Low*	*Medium*	*Medium*	*High*	*High*
Acute Illness	*Low*	*Medium*	*Medium*	*High*	*High*
Worry	*Low*	*Low*	*Low*	*Medium*	*Medium*

For example: *Is botulism poisoning possible from canned food?*
- Contemporary food packaging standards reduce the probability of occurrence to Low-Very Low; however, the consequence of poisoning is sometimes death. Thus, the overall risk might be scored as Medium.

Example: Assigning "Weight" to Oil Release

Table 7-4 Workshop consensus on exposure thresholds of concern in parts per million (ppm) for dispersed oil in the water column (Pond et al., 2000b)

Exposure	Level of Concern	Protective of Sensitive Life Stages	More Protective Criteria	Protective of Adult Fish	More Protective Criteria	Adult Crustacea/ Invertebrates	More Protective Criteria
0-3 hours	Low	<5	<1-5	<10	<10	<5	<5
	Medium	5-10	5-10	10-100	10-100	5-50	5-50
	High	>10	>10	>100	>100	>50	>50
0-24 hours	Low	<1	<0.5	<2	<0.5	<2	<0.5
	Medium	1-5	.5-5	2-10	.5-10	2-5	.5-5
	High	>5	>5	>10	>10	>5	>5
0-96 hours	Low	<1	<0.5	<1	<0.5	<1	<0.5
	Medium			1-5	.0-5	1-5	.5-1
	High	>1	>0.5	>5	>5	>5	>1

Numbers in parts per million (ppm).
Values indicate thresholds of ecological concern following an oil release. For example, if adult fish are exposed to a dispersed oil plume >100 ppm for 3 hours, concern should be high. If they are exposed to <10-ppm plume for 3 hours, concern should be low (because there is little or no potential for acute effects).

Assigning Weight to Oil Release Cleanup

Zones:	Terrestrial					Water Surface				Intertidal				
Habitats: / Sub-Habitats:	Upland and Supratidal									Marsh				
RESOURCES:	Vegetation	Mammals	Birds	Reptiles/Amphibians	Insects	Mammals	Birds	Reptiles/Amphibians	Vegetation	Mammals	Birds	Fish	Crustaceans	Mollusks
STRESSORS:														
Natural Recovery	7	1,7	1,7	1,7	1,7	1,4,7	1,4,7	1,4,7	2,4	1,4,7	1,4,7	2,7	2,4,7	2,4,7
On-Water Recovery	3	3,6	3,6	3,6	3,6	3	3	3	3	3	3	3	3	3
Shoreline cleanup	3,4,6	3,4,6	3,4,6	3,4,6	3,4,6	4,7	4,7	4	3,4	3,4	3,4	3,4	3,4	3,4
Oil + Dispersant	NA	NA	NA	NA	NA	7	7	NA	2	4,7	4,7	2,7	2,7	2,7
ISB	1	1	1	1	1	1,5	1,5	1,5	4,5	1,4,5,7	1,4,5,7	5,7	4,5,7	4,5,7

Hazard Path:

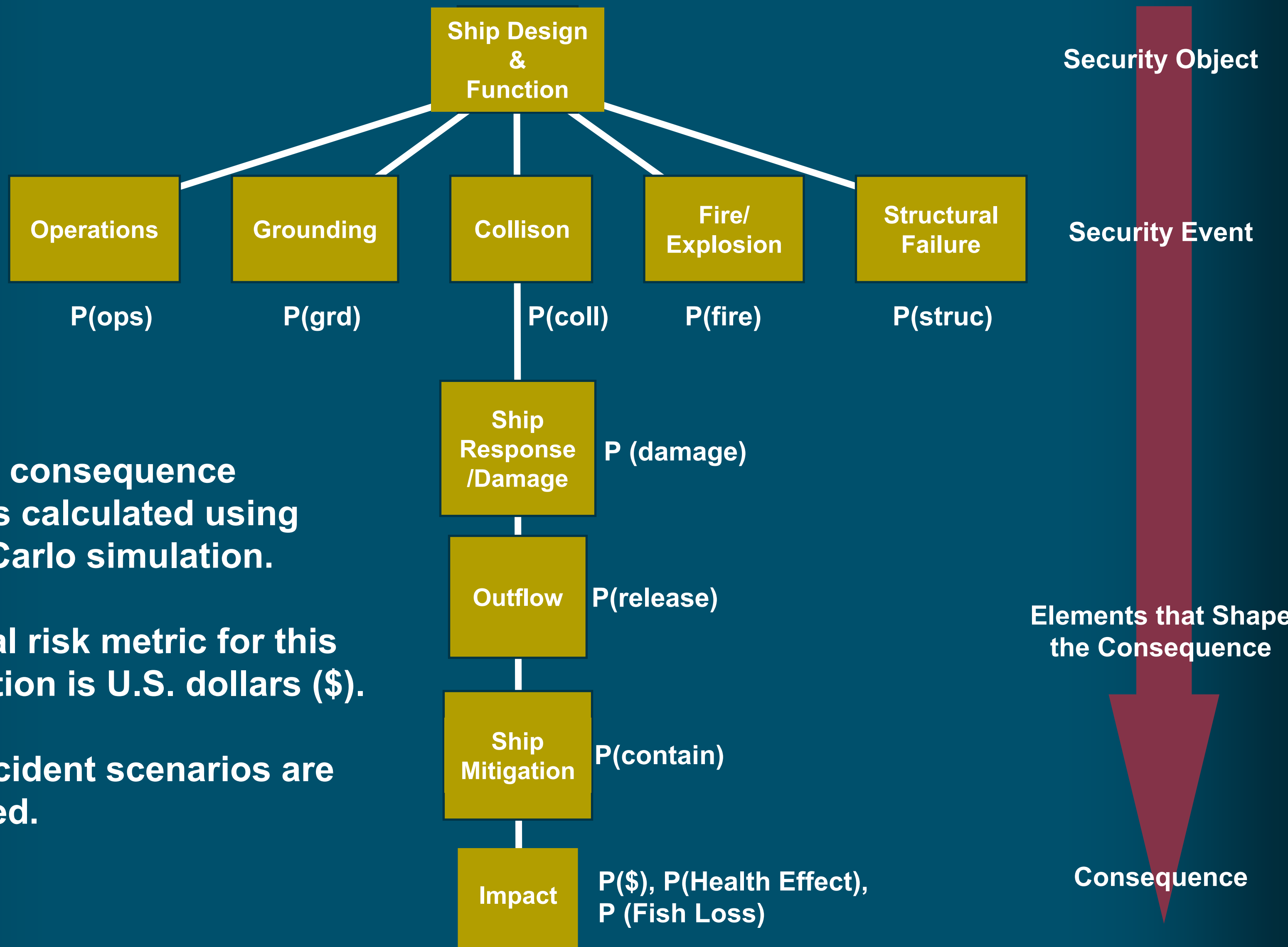
1. Air exposure
2. Aqueous exposure
3. Physical trauma
4. Physical oiling/smothering
5. Thermal
6. Waste
7. Indirect (food chain)

Summary of how possible impacts of an oil spill and cleanup activities might affect ecology. The numbers in the matrix represent the path by which stressors affect the resource. For example, on-water recovery activities may affect vegetation through (3) physical trauma.

Other Tools for Estimating Risks

- Several tools for estimation and ranking of risks are available to use in conjunction with, or in place of, risk matrices:
  - Fault tree analysis (FTA)
  - Probabilistic risk analysis (PRA)
  - Event trees (ET)
  - Failure mode and effects analysis (FMEA)
  - Expert elicitation
- In general, any method that can estimate the probability of occurrence of an event.

Calculating Oil Tanker Spill Risks



- Oil spill consequence analysis calculated using Monte Carlo simulation.
- The final risk metric for this calculation is U.S. dollars ($).
- Five accident scenarios are identified.

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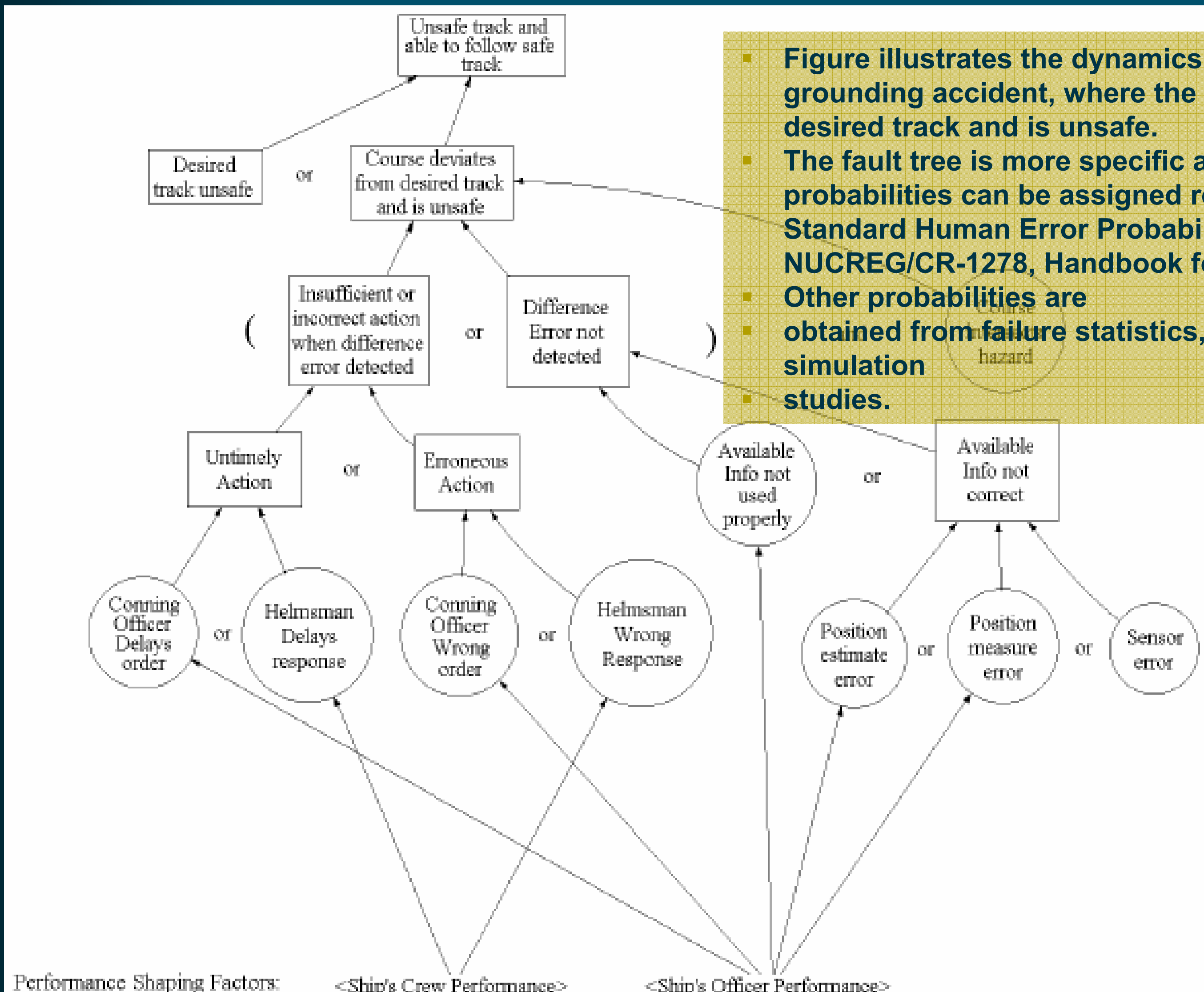
Fault Tree for Oil Tanker Grounding

- Figure illustrates the dynamics of a powered and drift grounding accident, where the vessel deviates from the desired track and is unsafe.
- The fault tree is more specific at lower levels where probabilities can be assigned reflecting human error using Standard Human Error Probabilities (HEP's) obtained from NUCREG/CR-1278, Handbook for Human Reliability Analysis.
- Other probabilities are
- obtained from failure statistics, expert opinion and simulation
- studies.



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Risk Management Tools For Port Environmental Security, Critical Infrastructure, and Sustainability

NATO Advanced Research Workshop
16 – 19 March 2006, Venice, Italy
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