Research & Education Challenges in Risk Analysis & Risk Management

Improved Understanding of Risk Management

Type Matching Risks, Risk Analysis & Risk Response

Maritime Risk Symposium 2011

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Chair, Security and Defense Specialty Group, Society for Risk Analysis

The views presented here are those of the presenter and are not to be taken as necessarily reflecting the official views of the Department of Homeland Security or any other agency of the federal government

Risk Management is Not Meeting Expectations

Observed   – Risk Management is failing in the face of 21st Century Threats and Hazards

Hazards   – Terrorism, Climate Change, Global Supply Chain Disruption, others

Evidence   – Financial System Meltdown
   – Deepwater Horizon
   – "The Failure of Risk Management" by Douglas Hubbard

Diagnosis– Cause in three parts

1. Managers/Risk Managers who don't understand risk management

2. Risk Analysts who don't understand risk management

3. Analytic approaches and risk responses that are ill-suited to the risks to which they are applied, esp. true for newly emergent, newly recognized risks

Recommended Treatment

1. Risk Managers and Risk Analysts both need a better, more complete understanding of risk management

2. Analytic methods and risk responses must be compatible with fundamental characteristics of the risk in question – we especially need new approaches better suited to complex and complex adaptive systems

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Background

1981 – Kaplan & Garrick's Risk Assessment Triplet

• What can happen?

• How likely is it that it will happen?

• If it does happen, what are the consequences?

Kaplan S, Garrick B. J. "On the Quantitative Definition of Risk" *Risk Analysis*, 1981: Vol. 1 No. 1

Background

1991 – Haimes' "Total Risk Management" Triplet

- What can be done and what options are available?

- What are their associated trade-offs in terms of all costs, benefits and risks?

- What are the impacts of current management decisions on future options?

Haimes Y. Y. "Total Risk Management"
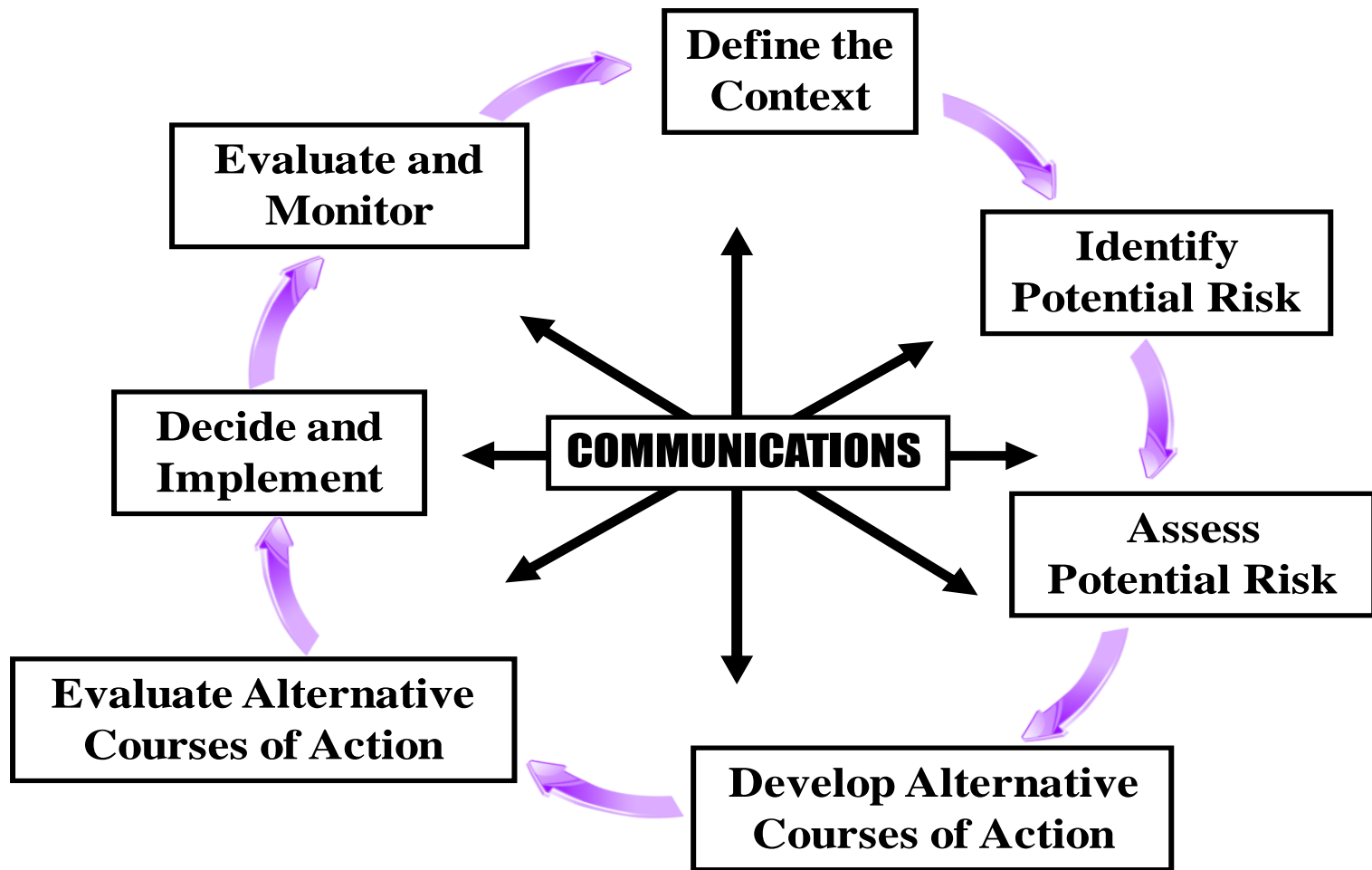*Risk Analysis*, 1991: Vol. 11 No. 2

Background

2009 – Haimes suggests adding 4th RA Question to Kaplan & Garrick's original triplet

- Over what time frame?

Haimes, Y. Y., ""On the Complex Definition of Risk:
A Systems-Based Approach"
Risk Analysis, 2009: *Vol. 29, No. 12*

The Total Risk Management Cycle

Figure 1

The 5 Question Triplets in Risk Management

1. Risk Context

1-1. *What are my risk management responsibilities?* *
1-2. *What is my risk management environment?* *
1-3. *What outcomes and objectives am I expected to achieve?* *

2. Risk Assessment

2-1. *What can happen?* *
2-2. *How likely is it that it will happen?* *
2-3. *If it does happen, what are the consequences?* *

3. Risk Response

3-1. *What could I do about it?* *
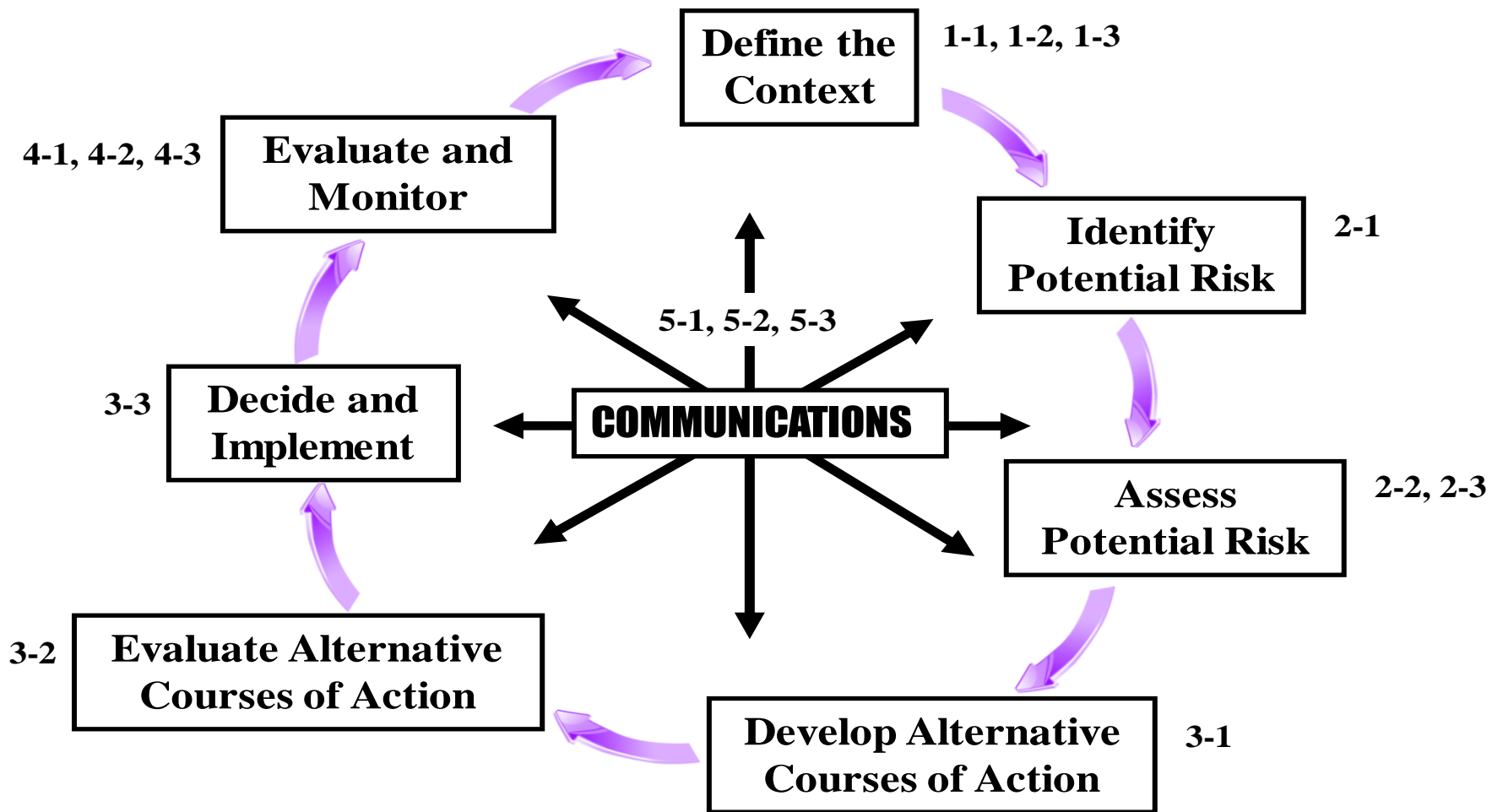3-2. *What should I do about it?* *
3-3. *What am I going to do about it?* *

4. Risk & Response Monitoring & Evaluation

4-1. *How well is my chosen course of action working?* *
4-2. *Has anything changed that requires altering my existing risk management measures?* *
4-3. *Are there current trends and/or potential future developments that could require altering my existing risk management measures?* *

5. Risk Communication

5-1. *What risk information needs to be communicated?* *
5-2. *Between whom does it need to be communicated?* *
5-3. *How can necessary risk information be most effectively communicated?* *

* "And when?" or "Over what timeframe?" should be added when appropriate

The Total Risk Management Cycle

Figure 2

Risk Context

1-1. What are my risk management responsibilities? *

What is the nature of the risk(s) for which I am responsible?
What is the scope of my risk?

1-2. What is my risk management environment? *

1-3. What outcomes and objectives am I expected to achieve? *

* "And when?" or "Over what timeframe?" should be added when appropriate

Risk Assessment

2-1. What can happen? *

2-2. How likely is it that it will happen? *

2-3. If it does happen, what are the consequences? *

* "And when?" or "Over what timeframe?" should be added when appropriate

Risk Response

3-1.   What could I do about it? *

What can be done and what options are available?

3-2.   What should I do about it? *

What are their associated trade-offs in terms of all costs, benefits and risks?

What are the impacts of current management decisions on future options?

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2 Propositions and a Question

P1 - Risk Management includes Risk Identification, Risk Assessment, other Risk Analyses, chosing Risk Management Strategies & specific Interventions, and Risk Communications.

P2 - To be effective, these elements of Risk Management must be appropriate to the fundamental characteristics of the risk in question.

Q – Can risks be usefully typed by fundamental characteristics to aid in selecting analytic methods and risk management strategies?

Risk Typing by Hazard

Six Classes of Hazards

(1) Infectious and degenerative diseases

(2) natural catastrophes

(3)failure of large technological systems

(4) discrete, small-scale hazards

(5)low-level, delayed-effect hazards

(6) sociopolitical disruptions

William W. Lowrance
"The Nature of Risk,"
in *Societal Risk Assessment: How Safe is Safe Enough?*
Richard C. Schwing and Walter A. Albers, Jr., eds.
(Plenum Press, New York and London, 1980). pp. 5-17.

Risk Typing by Weight & Color of Tail Feathers

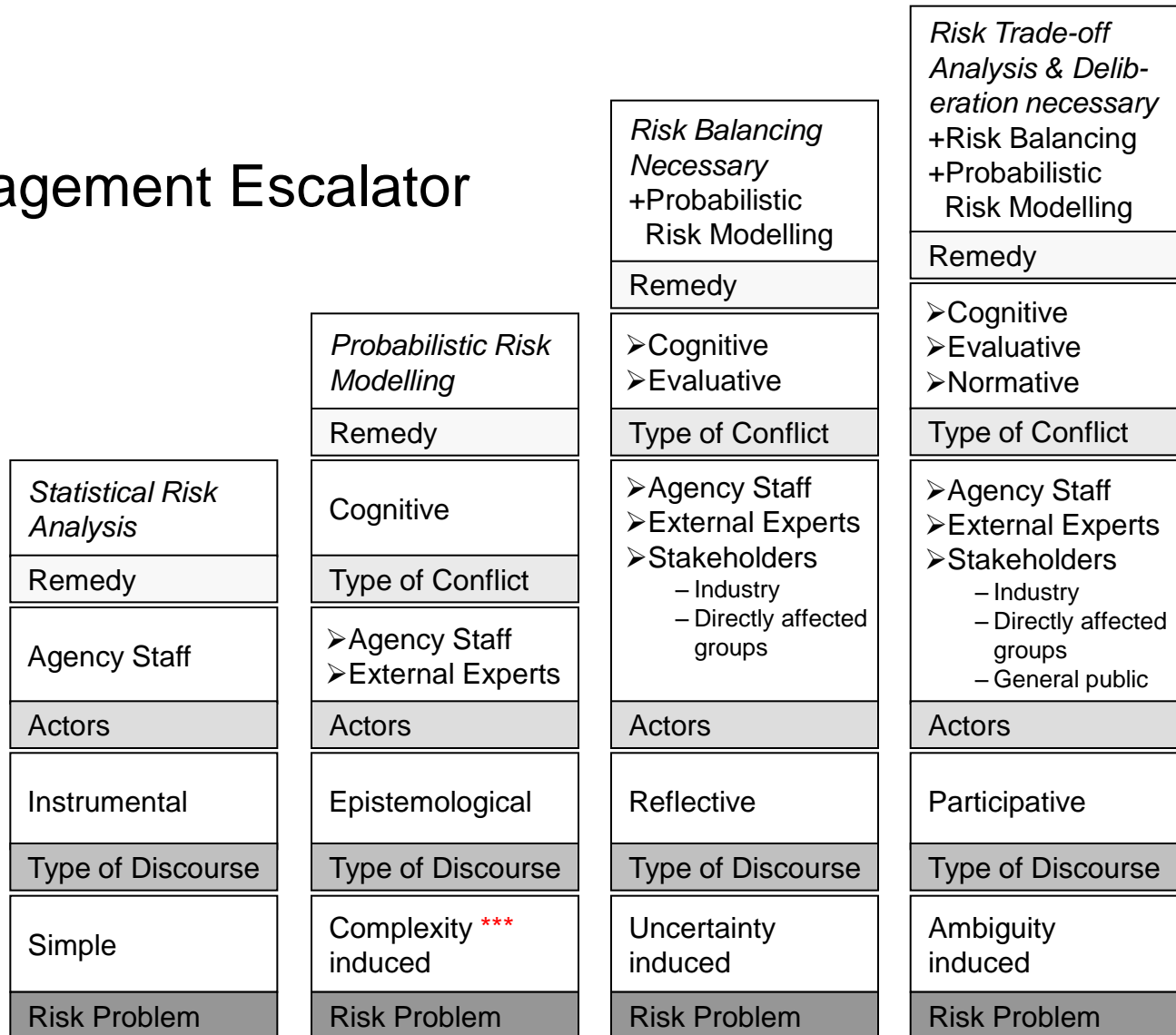| APPLICATION DOMAIN	Simple payoffs	Complex payoffs
Distribution 1 ("thin tailed")	Extremely robust to Black Swans	Quite robust to Black Swans
Distribution 2 ("heavy" and/or unknown tails, no or unknown characteristic scale)	Quite robust to Black Swans	LIMITS of Statistics – extreme fragility to Black Swans

Risk Typing by Decision Support Needs & Modes

IRGC Risk Management Escalator

*** "Complexity" used here to mean "complicated but understandable and bounded" – not in the CAS sense

Statistical Risk Analysis	*Probabilistic Risk Modelling*	*Risk Balancing Necessary* +Probabilistic Risk Modelling	*Risk Trade-off Analysis & Deliberation necessary* +Risk Balancing +Probabilistic Risk Modelling
Remedy	**Remedy**	**Remedy**	**Remedy**
	Cognitive	➢Cognitive ➢Evaluative	➢Cognitive ➢Evaluative ➢Normative
	Type of Conflict	**Type of Conflict**	**Type of Conflict**
Agency Staff	➢Agency Staff ➢External Experts	➢Agency Staff ➢External Experts ➢Stakeholders – Industry – Directly affected groups	➢Agency Staff ➢External Experts ➢Stakeholders – Industry – Directly affected groups – General public
Actors	**Actors**	**Actors**	**Actors**
Instrumental	Epistemological	Reflective	Participative
Type of Discourse	**Type of Discourse**	**Type of Discourse**	**Type of Discourse**
Simple	Complexity *** induced	Uncertainty induced	Ambiguity induced
Risk Problem	**Risk Problem**	**Risk Problem**	**Risk Problem**

Typing Risk to Facilitate Analysis and Action

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First Distinction – Stable vs. Dynamic

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Stable Risk

- Neither the hazard nor the systemic context in which the hazard resides change in ***direct response*** to risk management actions

- Hazards and their systemic contexts change relatively slowly

- Cause-effect pairs tightly coupled, isolable

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- **Second distinction** – "Natural" vs. Adversarial

Proposed Risk Typology

Type 1 – Stable Easily Discerned Risk

Type 2 – Stable Difficult to Discern Risk

Type 3 – Dynamic Natural Risk (includes human error)

Type 4 – Dynamic Adversarial Risk

Type 1 Risks – Stable Easily Discerned

Example – Marine Steam Boilers (1807 to 1852)

- What can happen?
- How likely is it to happen?
- What are the consequences?

Kaplan & Garrick's Risk Assessment Triplet

Type 1 Risks – Stable Easily Discerned

Example – Marine Steam Boilers (1807 to 1852)

- What can happen? **Exploding Boilers**
- How likely is it to happen? **Very Likely**
- What are the consequences? **Bad! Really, really bad!!!**

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Solution Set – Primarily Prevention based on

- Science & Engineering – first ever federal grant for scientific research
- Standards– design, licensing, inspections, periodic testing
- Law – creation of first federal public welfare (safety) regulatory agency
- Based on analysis of cause (engineering & operational) & interventions
- Well-suited to "Fix and Forget" mentality (but frequently requires enforcement)

Type 2 Risks – Stable Difficult to Discern

Why difficult to discern?

- Inability to directly discern answers (gambling, actuarial/insurance)
- Scale and complicated nature of engineered systems (nuclear power)
- Latency between cause and effect (carcinogenic chemicals at work)
- Low signal to noise ratio in cause and effect (pollution impacts)

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- Statistics, Probabilistic Risk Analysis, Epidemiologic Studies, Modeling and other methods to answer K&G's Risk Assessment Triplet

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Solution Set very similar to Type 1 solution set - standards, regulations, engineering controls, enforcement, "Fix and Forget," plus Consequence Mitigation, insurance …

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The last 50+ years – The Golden Age of Risk Analysis

Type 3 Risks – Dynamic "Natural" Risk

Example – Vessel Traffic in Ports

- Fixed physical parameters – bridges, wharves, channels

- Dynamic physical parameters – wind, water depth, current, visibility, etc.

- Dynamic, variable mix of vessels – types, locations, courses & speeds, human operators – general patterns but also near-infinite variety

- Very Complex Adaptive System (nested/overlapping systems of systems)

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Assessment of Vessel Traffic Risk

- What can happen? Many different scenarios – near-infinite variety
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Difficult Risk Management Context

- Multiple "Risk Managers" – Multiple Tools – Ongoing, ever-changing problem – Requires Constant Attention – No "Fix and Forget"

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Example – Terrorism

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Difficult Risk Management Context

- Multiple "Risk Managers" – Multiple Tools – Ongoing, ever-changing problem
- Risk Reduction Measures, if known to adversary, can be bypassed or overcome, or even exploited if unanticipated vulnerabilities are created
- Strategic vs. Tactical Mismatch

Proposed Risk Typology

Type 1 – Stable Easily Discerned Risk

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Each type possesses fundamentally different characteristics

Each type requires fundamentally different approaches to Risk Assessment, Risk Analysis and Risk Management Strategies & Interventions

Mixed Risk Types

A given risk context or source can exhibit multiple risk types

- Example: Marine Boilers
  - Type 1 – Engineering Deficiencies
  - Type 3 – Human Error – inadequate maintenance, operator error
  - Type 4 – Misconduct – gagging relief valves to boost pressure & speed
  - Type 2 – Asbestos – used in insulation, pipe lagging

- Example: Biological Threats
  - Type 1 – Traditional "Normal" Diseases
  - Type 2 – Emergent Zoonotic Disease – e.g., "Flying Pig Flu"
  - Type 3 – Human Error – e.g., accidental lab release
  - Type 3 – Drug Resistant Bacteria – e.g., MRSA, bacillus gonnakillus
  - Type 4 – Biological Attack – e.g., 2001 anthrax, synthetic smallpox

Type 3 & 4 Risks – Complex Adaptive Systems

Complex Adaptive Systems

- Many interdependent components
- Behaviors and interdependencies unknown, possibly variable
- Non-linear stimulus-response relationships, also possibly variable

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Suggestions for New Approaches

- Look at the system rather than at individual elements or factors
- Focus on understanding system dynamics rather than predicting specific events or outcomes
- Intervene to affect component behaviors and system responses to inputs and changes rather than to prevent specific events or outcomes

Lessons from High Reliability Organizations

99.999999+% Success ➡ Catastrophic Failure & Public Outrage

These situations demands High Reliability Organizations (HROs)

HROs exhibit:
- Preoccupation with failure
- Reluctance to simplify interpretations
- Sensitivity to operations
- Commitment to resilience
- Deference to expertise

Reward rather than punish problem identification & reporting

HROs results from organizational culture & real behavior, not from slogans on the walls or analyses done to satisfy a checklist

Research Needs in CAS Risk Management

New Ways of Conceptualizing CAS Risk & CAS Risk Management

Analytic Methods Appropriate for CAS Risks

Risk Management Strategies Appropriate for CAS Risks

Risk Interventions Appropriate for specific CAS Risks

Decision-Making Processes Appropriate for when RM Responsibilities are Shared

How to achieve "HRO" results in environments with high uncertainty, dynamic risks, multiple risk managers and stakeholders with competing agendas, some of which may be malicious

"Not everything that can be counted counts, and not everything that counts can be counted."
- Albert Einstein (1879-1955)

Questions?

National Academy of Science

"Rarely is there a single 'right' risk analysis tool, method or model to provide 'correct' analysis to support decision making…"

Committee to Review the Department of Homeland Security's Approach to Risk Analysis.
Review of the Department of Homeland Security's Approach to Risk Analysis.
Washington DC: National Academies Press, 2010.

More from the NAS Report

For terrorism risk analysis, neither threats nor consequences are well characterized by data.

…terrorism involves an open rather than a closed system…

Terrorists observe and respond to defenses and to changing political conditions…

…it will rarely be possible to develop statistically valid estimates of attack frequencies (threat) or success probabilities (vulnerability)…

…better methods need to be found for incorporating the intentional nature of terrorist attacks into risk analyses…

A Note of Caution on PRA

- "…it is simply not possible to validate predictive models of rare events that have not occurred, and unvalidated models cannot be relied upon."

- "…distinction between models for ***probabilistic risk assessment*** on long time scales…vs. ***specific point prediction*** of individual rare events."

- Models for prediction vs. models for insight

Source – "*Rare Events*"; JASON (DOD Advisory Group); October 2009
http://www.fas.org/irp/agency/dod/jason/rare.pdf

Words of Wisdom

"Unlike the position that exists in the physical sciences, in… disciplines that deal with essentially complex phenomena, the aspects of the events to be accounted for about which we can get quantitative data are necessarily limited and may not include the important ones. While in the physical sciences it is generally assumed… that any important factor which determines the observed events will itself be directly observable and measurable...in…complex phenomena…which depend on the actions of many individuals, all the circumstances which will determine the outcome of a process…will hardly ever be fully known or measurable."

Words of Wisdom (cont'd.)

"It is an approach which has come to be described as the "scientistic" attitude - an attitude which, as I defined it some thirty years ago, "is decidedly unscientific in the true sense of the word, since it involves a mechanical and uncritical application of habits of thought to fields different from those in which they have been formed.""

Friedrich August von Hayek

First Nobel Laureate in Economics

"The Pretence of Knowledge"

Lecture to the memory of Alfred Nobel

December 11, 1974

Risk Management Strategies/Responses

You can

- Accept Risk

- Avoid Risk

- Transfer Risk

- Reduce Risk

Risk Management Strategies/Responses

You can

- Accept Risk
- Avoid Risk

Substitute one risk for another

- Transfer Risk

- Reduce Risk

Challenging Orthodoxy

"Risk analysis is broadly defined to include risk assessment, risk characterization, risk communication, risk management, and policy relating to risk…,"

Society for Risk Analysis Vision Statement

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Risk Management is the superior construct, not Risk Analysis

Challenging Orthodoxy

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Society for Risk Analysis Vision Statement

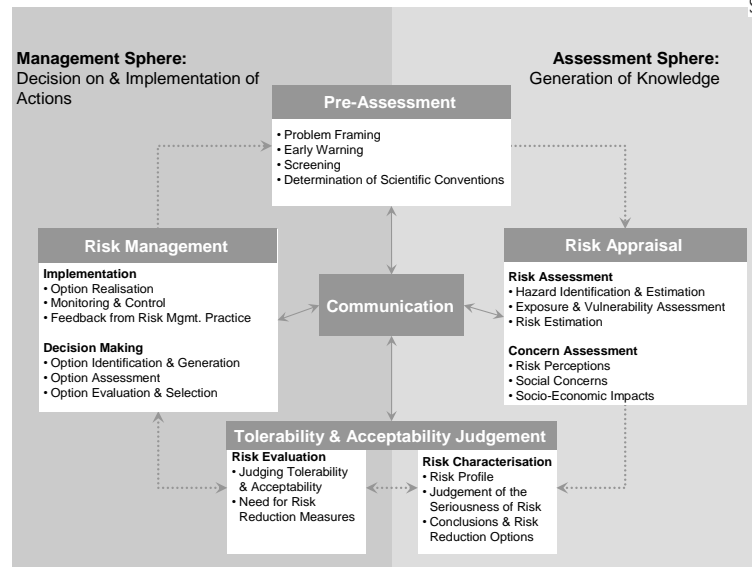Risk Management is the superior construct, not Risk Analysis

Risk Analysis is only one of several subordinate supporting components of Risk Management

Background

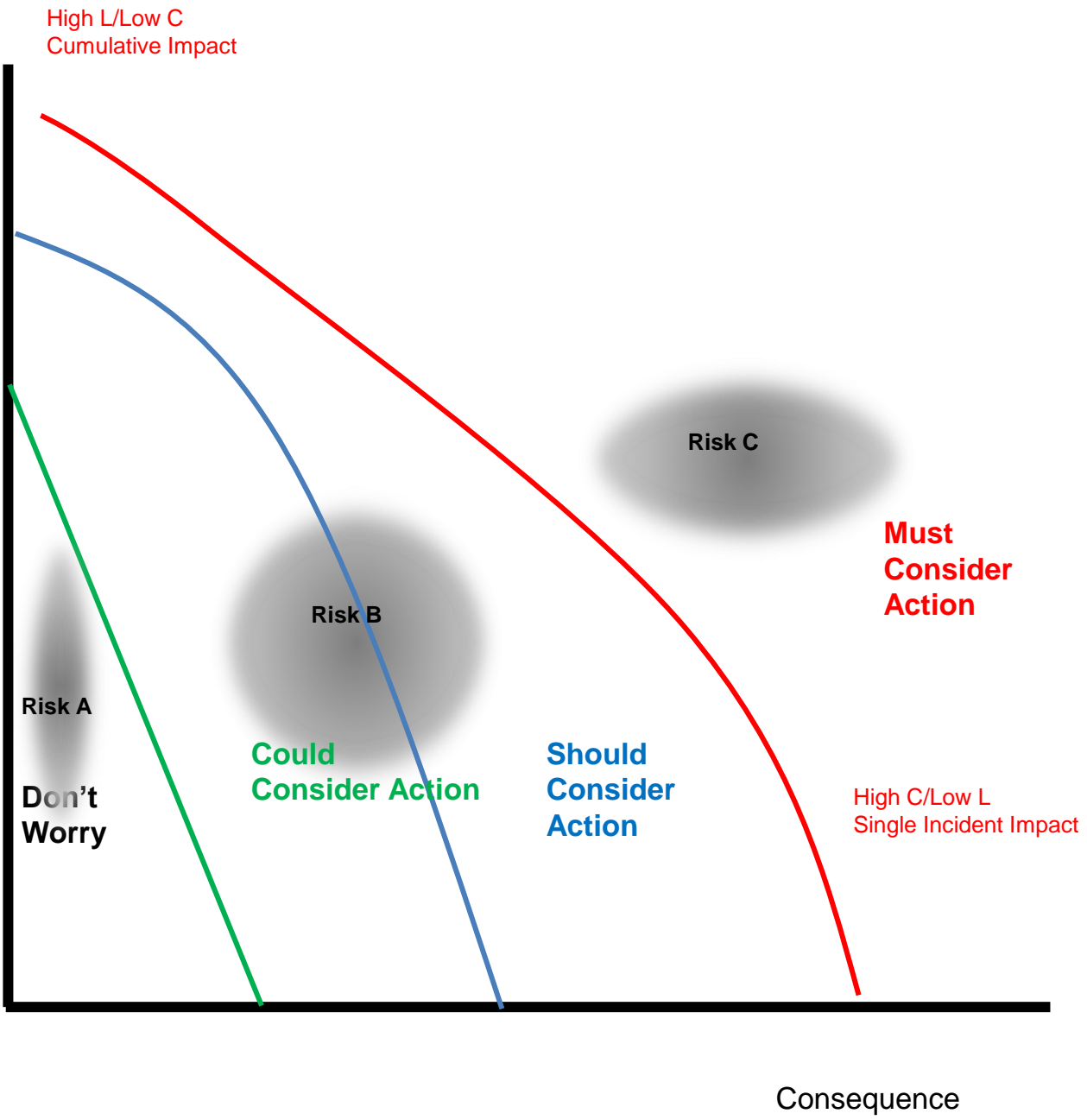Various Risk Management Cycles/Frameworks – GAO, IRGC, DHS, numerous others
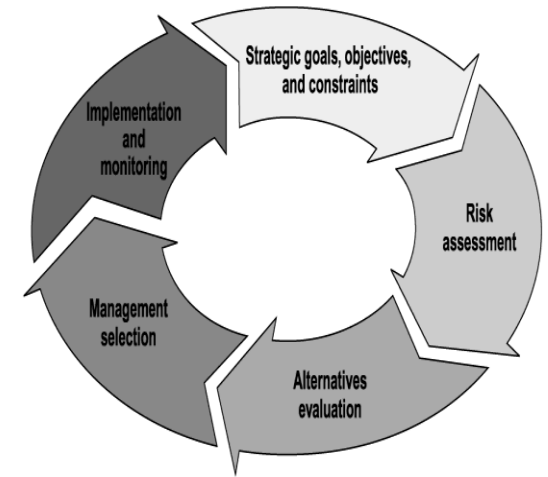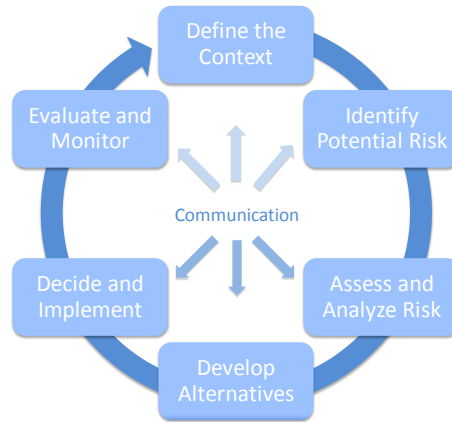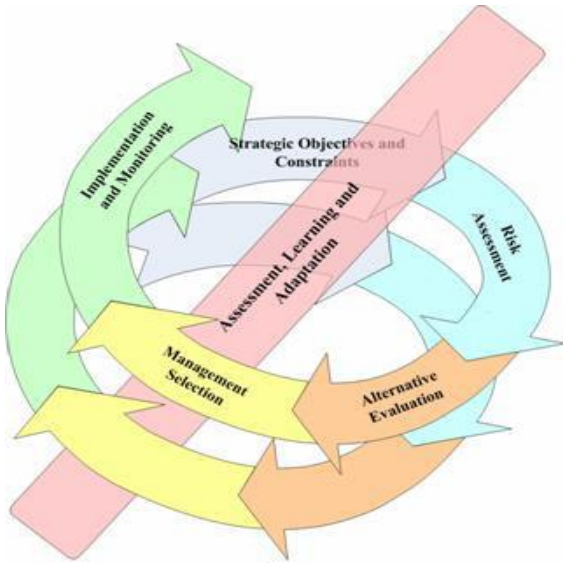
Source: GAO.

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Likelihood

High L/Low C
Cumulative Impact

Risk C

**Must
Consider
Action**

Risk B

Risk A

**Could
Consider Action**

**Should
Consider
Action**

**Don't
Worry**

High C/Low L
Single Incident Impact

Consequence

Risk Response

3-1.   What could I do about it? *

3-2.   What should I do about it? *

3-3.   What am I going to do about it? *

* "And when?" or "Over what timeframe?" should be added when appropriate

Risk Typing by Nature and Scale of Consequence

Scope

	ENDURABLE	TERMINAL
GLOBAL	Thinning of the ozone layer	X
LOCAL	Recession in a country	Genocide
PERSONAL	Your car is stolen	Death

Intensity

Six risk categories

Existential Risks
Analyzing Human Extinction Scenarios and Related Hazards

Nick Bostrom
Faculty of Philosophy, Oxford University

Research & Education Challenges in Risk Analysis & Risk Management

Improved Understanding of Risk Management

Type Matching Risks, Risk Analysis & Risk Response

Maritime Risk Symposium 2011

Rutgers University
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DHS Science and Technology Directorate
Chair, Security and Defense Specialty Group, Society for Risk Analysis

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2. Risk Analysts who don't understand risk management

3. Analytic approaches and risk responses that are ill-suited to the risks to which they are applied, esp. true for newly emergent, newly recognized risks

Recommended Treatment

1. Risk Managers and Risk Analysts both need a better, more complete understanding of risk management

2. Analytic methods and risk responses must be compatible with fundamental characteristics of the risk in question – we especially need new approaches better suited to complex and complex adaptive systems

The 5 Question Triplets in Risk Management

1. **Risk Context**
   - *1-1. What are my risk management responsibilities? ***
   - *1-2. What is my risk management environment? ***
   - *1-3. What outcomes and objectives am I expected to achieve? ***

2. **Risk Assessment**
   - *2-1. What can happen? ***
   - *2-2. How likely is it that it will happen? ***
   - *2-3. If it does happen, what are the consequences? ***

3. **Risk Response**
   - *3-1. What could I do about it? ***
   - *3-2. What should I do about it? ***
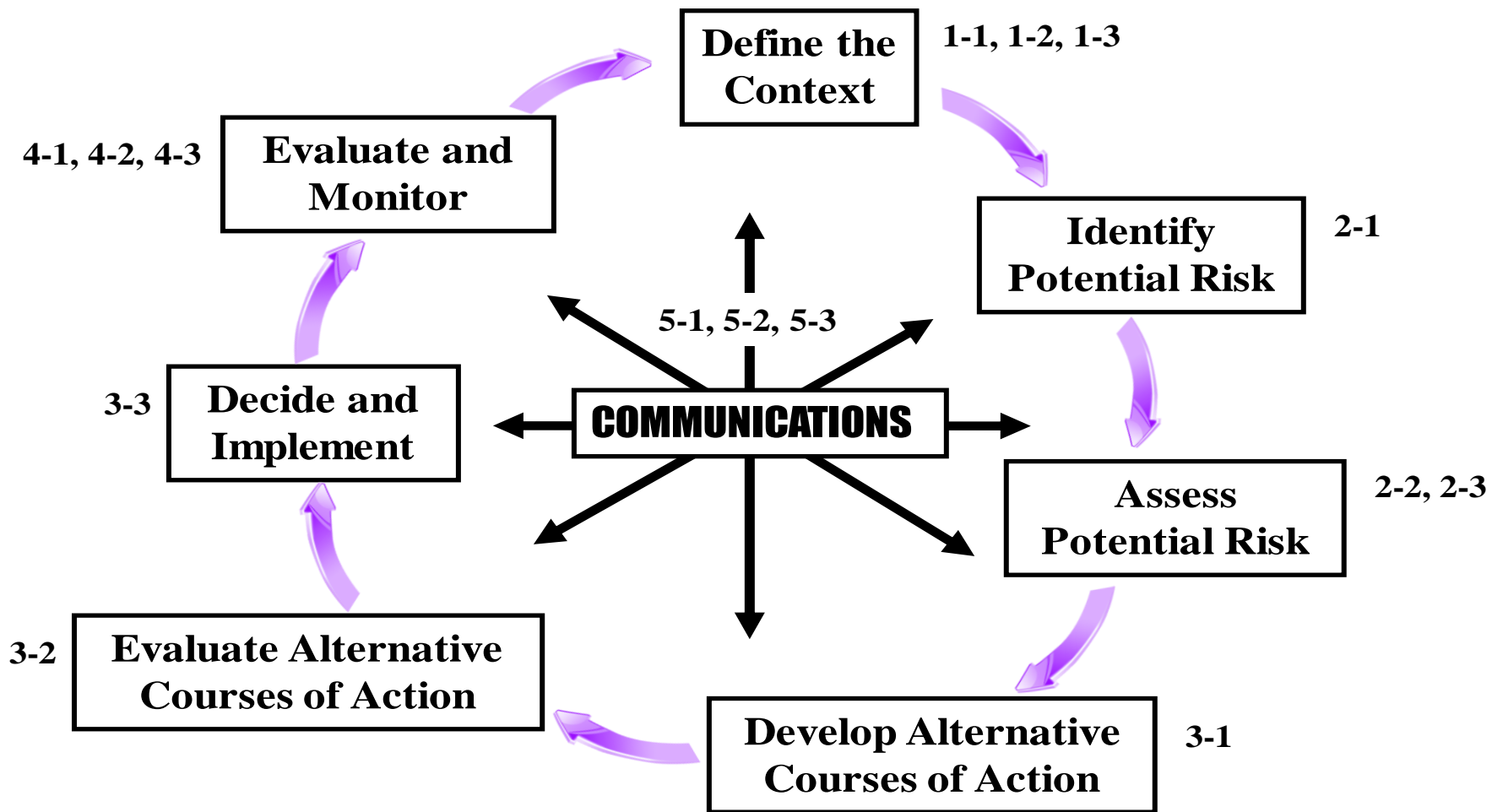   - *3-3. What am I going to do about it? ***

4. **Risk & Response Monitoring & Evaluation**
   - *4-1. How well is my chosen course of action working? ***
   - *4-2. Has anything changed that requires altering my existing risk management measures? ***
   - *4-3. Are there current trends and/or potential future developments that could require altering my existing risk management measures? ***

5. **Risk Communication**
   - *5-1. What risk information needs to be communicated? ***
   - *5-2. Between whom does it need to be communicated? ***
   - *5-3. How can necessary risk information be most effectively communicated? ***

* "And when?" or "Over what timeframe?" should be added when appropriate

The Total Risk Management Cycle

Figure 2

Typing Risk to Facilitate Analysis and Action

First Distinction – Stable vs. Dynamic

Stable Risk

- Neither the hazard nor the systemic context in which the hazard resides change in ***direct response*** to risk management actions

- Hazards and their systemic contexts change relatively slowly

- Cause-effect pairs tightly coupled, isolable

- **Second distinction** – Easily Discerned vs. Difficult to Discern

Dynamic Risk

- The hazard and/or the systemic context change, either in direct response to risk management actions **or** spontaneously and unpredictably…. or both

- Hazards and/or systemic context can change very quickly

- Cause-effect pairs neither tightly coupled nor isolable

- **Second distinction** – "Natural" vs. Adversarial

Proposed Risk Typology

Type 1 – Stable Easily Discerned Risk

Type 2 – Stable Difficult to Discern Risk

Type 3 – Dynamic Natural Risk

Type 4 – Dynamic Adversarial Risk

Each type possesses fundamentally different characteristics

Each type requires fundamentally different approaches to Risk Assessment, Risk Analysis and Risk Management Strategies & Interventions

Type 3 & 4 Risks – Complex Adaptive Systems

Complex Adaptive Systems

- Many interdependent components
- Behaviors and interdependencies unknown, possibly variable
- Non-linear stimulus-response relationships, also possibly variable

Type 2 Analytic Methods Potentially Useful but Always Inadequate

Type 1 & 2 Interventions Probably Necessary but Never Sufficient

- Continuous attention & adaptation required - "Fix and Forget" guaranteed to fail

Suggestions for New Approaches

- Look at the system rather than at individual elements or factors
- Focus on understanding system dynamics rather than predicting specific events or outcomes
- Intervene to affect component behaviors and system responses to inputs and changes rather than to prevent specific events or outcomes

Lessons from High Reliability Organizations

99.999999+% Success ➡️ Catastrophic Failure & Public Outrage

These situations demands High Reliability Organizations (HROs)

HROs exhibit:

- Preoccupation with failure
- Reluctance to simplify interpretations
- Sensitivity to operations
- Commitment to resilience
- Deference to expertise

Reward rather than punish problem identification & reporting

HROs results from organizational culture & real behavior, not from slogans on the walls or analyses done to satisfy a checklist

Research Needs in CAS Risk Management

New Ways of Conceptualizing CAS Risk & CAS Risk Management

Analytic Methods Appropriate for CAS Risks

Risk Management Strategies Appropriate for CAS Risks

Risk Interventions Appropriate for specific CAS Risks

Decision-Making Processes Appropriate for when RM Responsibilities are Shared

How to achieve "HRO" results in environments with high uncertainty, dynamic risks, multiple risk managers and stakeholders with competing agendas, some of which may be malicious