26th annual INCOSE international symposium

Edinburgh, UK
July 18 - 21, 2016

An Integral Approach to Risk Management

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Finger Lakes Chapter

Agenda

- Introduction
- Current approach
- An integral approach
- Conclusions

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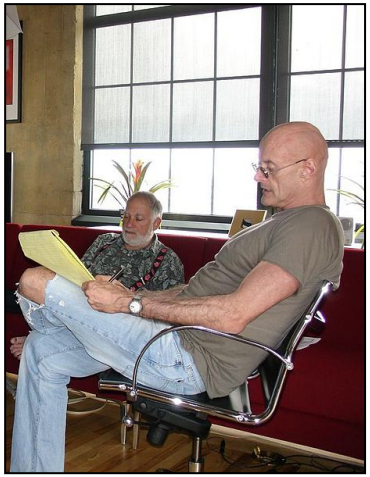
Integral Theory

- Integral Theory
  - School of philosophy founded by Ken Wilber
  - Integrate all human knowledge into a single framework
  - Applied to over 35 domains
- Integral Theory models are useful for SE
  - Broaden the perspective of SE
  - Improve how SE is practiced
  - Develop better solutions



Ken Wilber

Integral Theory Models

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	Interior	Exterior
Individual	Upper Left (UL) I Intentional (Subjective)	Upper Right (UR) IT Behavioral (Objective)
Collective	Lower Left (LL) WE Cultural (Intersubjective)	Lower Right (LR) ITS Social (Interobjective)

Four Quadrant Model

Level	Color	Perspective
Post Integral	Turquoise	Kosmocentric
Integral	Teal	Planetcentric
Post Modern	Green	Worldcentric
Modern	Orange	Sociocentric
Traditional	Amber	Ethnocentric
Tribal	Red	Egocentric

Levels of Development Model

Four Quadrant Model

	Interior	Exterior
Individual	Upper Left (UL) I Intentional (Subjective)	Upper Right (UR) IT Behavioral (Objective)
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Integral View of Systems Engineering

	Interior	Exterior
Individual	Upper Left (UL) I Intentional Subjective	Upper Right (UR) IT Behavioral (Objective)
Collective	Lower Left (LL) We Cultural (Interobjective)	Lower Right (LR) ITS Social (Interobjective)

Use All Four Quadrants

	Interior	Exterior
Individual	Upper Left (UL) I Intentional (Subjective)	Upper Right (UR) IT Behavioral (Objective)
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Levels of Development Model

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- Mankind moving to higher levels of consciousness or development
- Moving up - increasing perspective and decreasing egocentrism

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INCOSE Vision 2025

Current Systems Engineering Practices and Challenges

1. Mission complexity is growing faster than our ability to manage it . . . increasing mission risk from inadequate specifications and incomplete verification.

2. System design emerges from pieces, rather than from architecture . . . resulting in systems that are brittle, difficult to test, and complex and expensive to operate.

3. Knowledge and investment are lost at project life cycle phase boundaries . . . increasing development cost and risk of late discovery of design problems

4. Knowledge and investment are lost between projects . . . increasing cost and risk: dampening the potential for true product lines.

5. Technical and programmatic sides of projects are poorly coupled . . . hampering effective project risk-based decision making.

6. Most major disasters such as Challenger and Columbia have resulted from failure to recognize and deal with risks. The Columbia Accident Investigation Board determined that the preferred approach is an "independent technical authority".

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INCOSE Vision 2025

Current Systems Engineering Practices and Challenges

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A Challenge Area – Risk Management

6 Most major disasters such as Challenger and Columbia have resulted from failure to recognize and deal with risks. The Columbia Accident Investigation Board determined that the preferred approach is an "independent technical authority".

Image credit: NASA/ Public domain

Image credit: INCOSE

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Risk Assessment

- Dominant approach is objective and quantitative
  - Lean toward formal methods
  - “Human judgment is seriously flawed and that methodology and technique should serve as bulwarks against its fallibilities and limitations”
    - *Risk Assessment as a Subjective Process,* RAND P-8640, Ralph Strauch, 1980

Risk Assessment

- The standard approach to risk assessment and management has six steps:
  1. Risk identification
  2. Risk modeling, quantification, and measurement
  3. Risk evaluation
  4. Risk acceptance and avoidance
  5. Risk management
  6. Risk communication
- From *Risk Modeling, Assessment and Management (Fourth Edition), Yacov Haimes, 2016*

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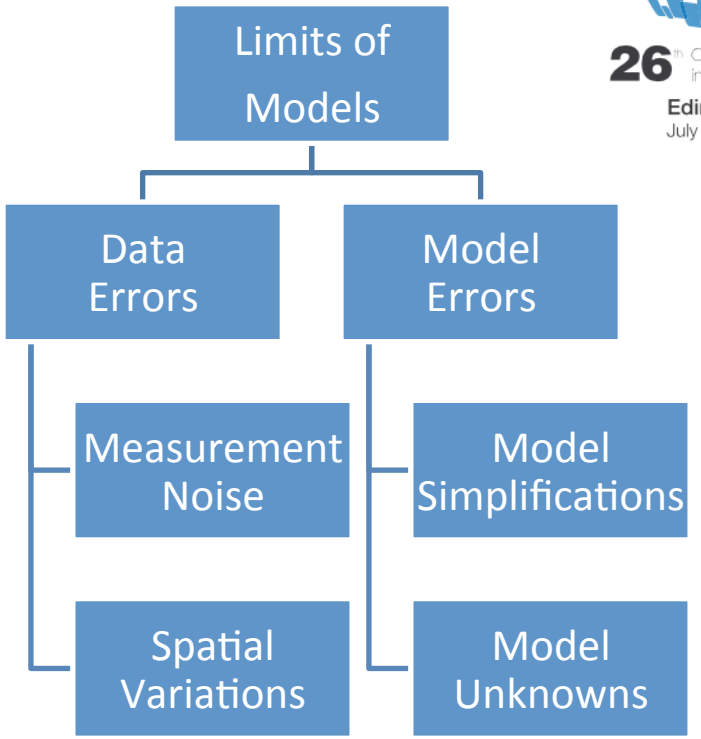
Limits of Models

- Model uncertainty
  - The way the actual system works is not completely known
- Model inaccuracies
  - There are some differences between the model and reality



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Space Shuttle Challenger Disaster
January 28, 1986

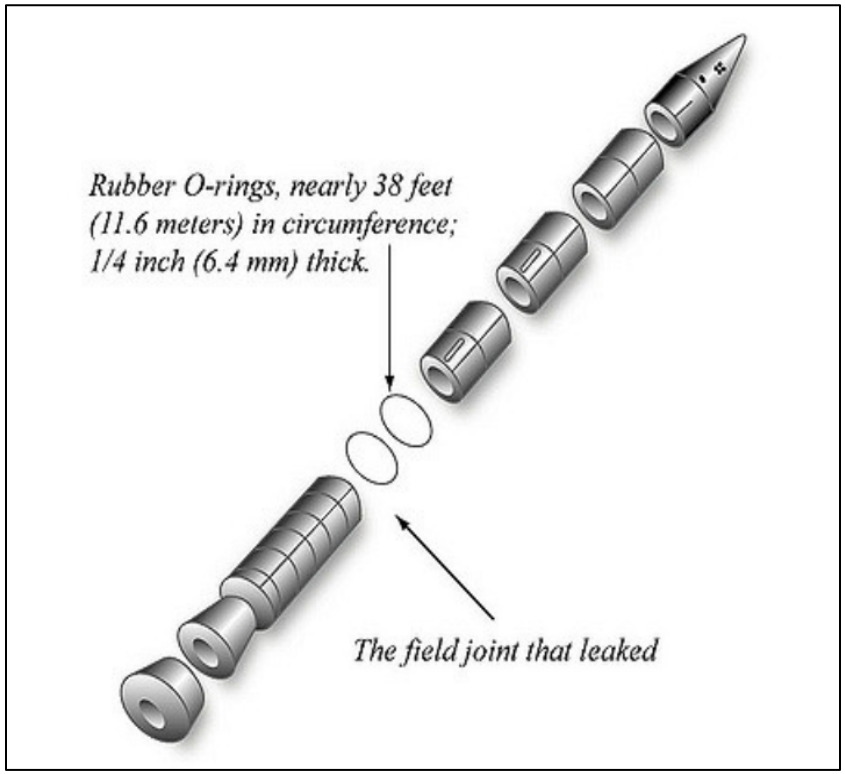
- Useful example
  - Limits of purely objective approach
  - Limits of models
  - Need for judgment, allowance of subjectivity in risk assessment

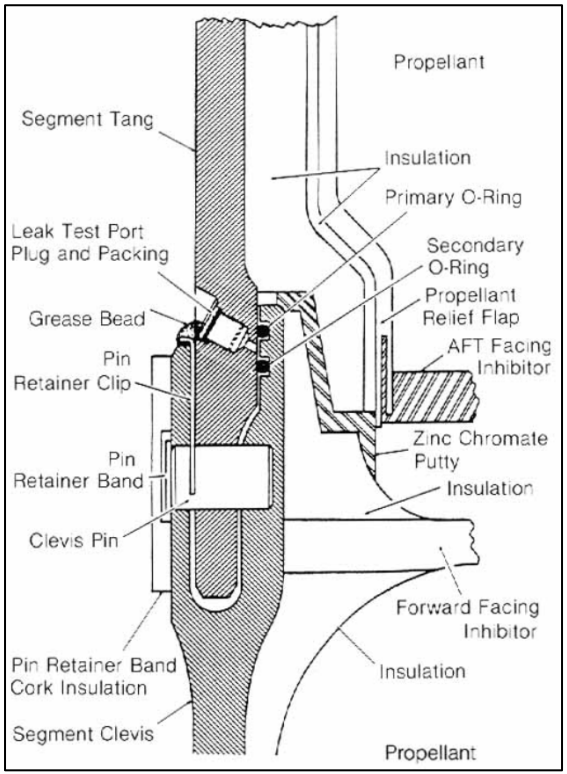
Photo credits: NASA / Public domain

Key Events – Challenger Disaster

- 1977-1985
  - O-ring seen as a risk area, critical design item
- January 27, 1986
  - Engineers recommend postponing launch (cold)
  - Managers push for launch
  - Engineers give in, make launch recommendation
- January 28, 1986
  - Shuttle launches, explodes

Solid Rocket Booster, O-Rings





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Rejection of Subjectivity

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- Initial Thiokol recommendation – postpone launch
  - Based on subjective evidence
- Thiokol engineers acknowledge
  - Not adequately supported by the data
  - Subjective, based on intuition, engineering feel
- NASA challenges Thiokol to “prove it”
  - Quantify their concerns, show data to support their position
  - Show how their position fits with the accepted model

Models Become Institutionalized

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- Over time, becomes harder to question the model
- Requires rejection of the previous paradigm
- Gave the go-ahead to launch for 8 years, hard to say it's unsafe now
  - Occupational risk, professional integrity, lose face
- NASA manager quote:
  - "Wait a minute. You've seen that before and you told us it was OK. And you saw it before, and you said it was OK. Now what are you? Are you a wimp? Are you liar?"

SRB Joint Design Warning Signs

Year	Event	Significance
1977	During a hydroburst test, failure occurred in the joint seals. Both the primary and secondary O-rings leaked.	Joint opening was contrary to expectations.
1980	A shuttle oversight committee expressed concerns about leaks in the joints. Designate joint as criticality 1R (redundant system - failure could cause loss of life)	Committee – it is unknown if secondary O-ring would reseal if primary O-ring failed
1981	STS-2 flight resulted in blow-by through the putty around the joint. There was one scorched primary O-ring.	First sign of O-ring failure.
1984	STS-41B flight had erosion on 3 O-ring joints. The erosion in one case was 0.050" of the 0.250" diameter.	Significant erosion.
1985	STS-51C flight was coldest launch to date (51° F). Two O-rings had erosion, two joints had blow-by.	Cold temperatures, significant erosion and blow-by.
1985	Morton Thiokol performed bench tests to evaluate temperature effects on O-ring and metal contact. At 75° F, the O-ring lost contact for 2.4 seconds. At 50° F, the O-ring did not re-establish contact after 10 min.	Shows significant effect of cold temperatures on joint operation.

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Errors in the SRB Joint Model

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- Did not fully understand temperature effects
- Did not account for potential for ice in the joint
- Did not understand putty behavior
- Did not understand wind shear effects
- Did not understand overcompression effects (focused on undercompression effects)
- Did not question the model for 8 years, until the Challenger disaster

Limits of Models

- Many areas where models are limited
  - The science is not well understood
  - Cannot run experiments to test models
- Examples
  - Geoengineering (e.g., dams), nuclear power, petrochemical plants, air traffic control systems
- Problem is getting worse
  - Increasing complexity
  - Unpredictable emergent behaviors
  - Influence of large, complex software systems

Image credit: Princeton University Press

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Integral Approach to Risk Mgmt

- Embrace subjectivity
- Acknowledge uncertainty
- Integrate objective and subjective info
- Use heuristics for resilient design
- Expand the system boundaries

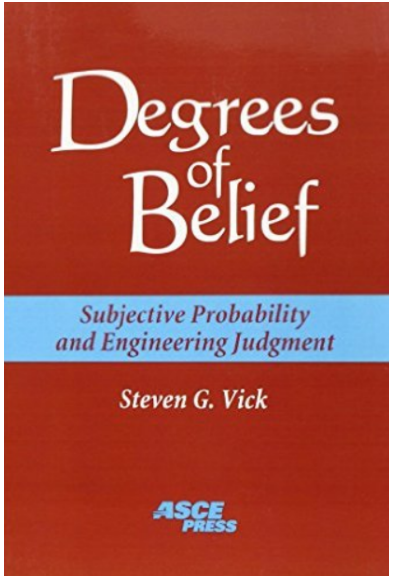


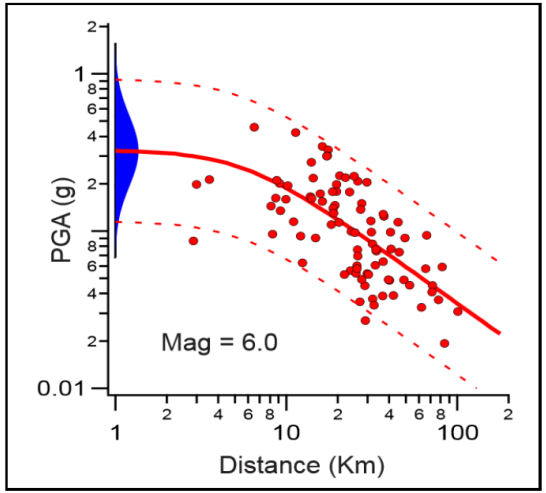
Image credit: ASCE Press

Embrace Subjectivity

- Use a synthesis of objective and subjective methods
  - “Methodology and judgment aid and support each other instead of competing” (Strauch, 1980)
- Models inform judgment
  - Use all available information
  - Data quality, personal experience, case-history information

Acknowledge Uncertainty

- Avoid purely objective assessments
- Acknowledge and characterize the uncertainty in the assessments
- Example: seismic hazard analysis
  - Assign high, low and best-estimate probabilities to an event
  - Predicted attenuation relationship for earthquake events and soil conditions
  - Dashed line is 95% confidence region



Seismic Analysis Chart Showing Second-Order Probabilities

Image credit: ASCE Press

Integrate Subjective and Objective Info

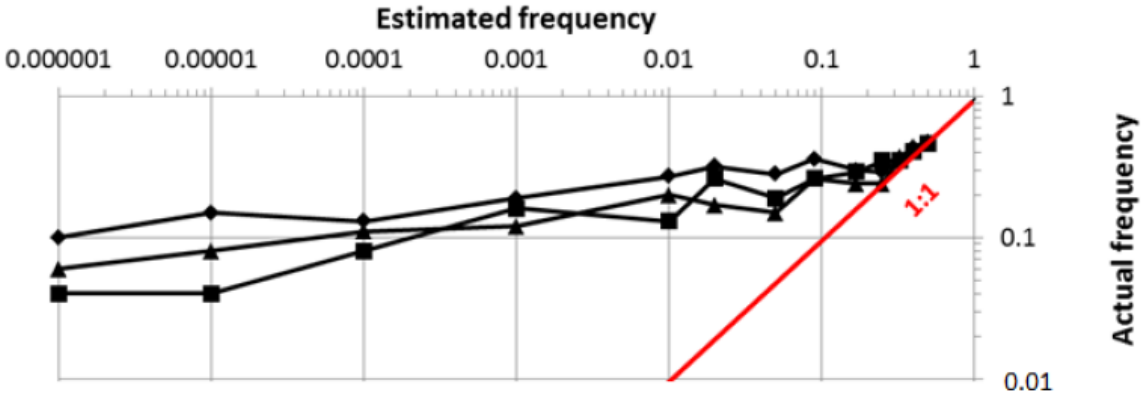
- Vick's framework – reduce effects of biases

Type	Biases			
Cognitive	Availability Bias	Confirmation Bias	Hindsight Bias	Insufficient Adjustment
	Conjunctive Distortion	Insufficient Adjustment	Representative Bias	Insensitivity to Predictability
	Base-rate Neglect	Insensitivity to Sample Size	Overconfidence Bias	Underconfidence Bias
Motivational	Personal Bias	Organizational Bias		

One Example of Bias

- Conjunctive distortion
  - Specific conditions more probable than a single general one
  - *Linda is 31 years old, single, outspoken, and very bright. She majored in philosophy. As a student, she was deeply concerned with issues of discrimination and social justice, and also participated in anti-nuclear demonstrations.*
  - Which is more probable?
    - Linda is a bank teller
    - Linda is a bank teller and is active in the feminist movement

Another Example of Bias



- Not very good at estimating small probabilities
- Tend to underestimate small probabilities
  - Example – NASA shuttle managers – failure 1 in 100,000
- Tend to be overconfident in our ability to estimate these
- Decomposition can help – “divide and conquer”

Image credit: Steven Vick

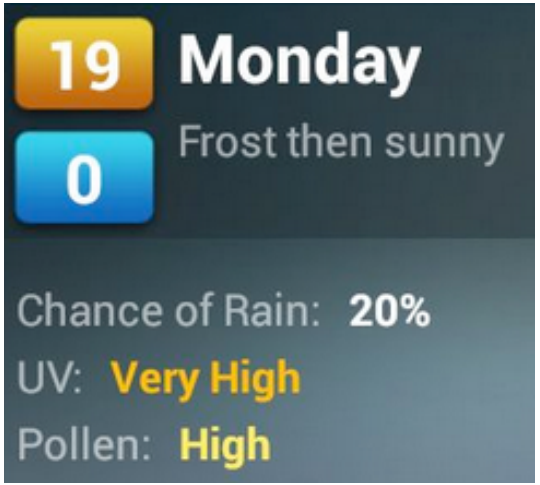
Vick's Framework

- Four stages
  - Assemble information
  - Synthesize information
  - Numerical assignment
  - Confirmation

Process Stage	Applicable Techniques
Assembling information and evidence	Search memory
	Search original information and data sources
	Identify and review "type case" histories
	Identify frequency information
	List information and evidence
Synthesizing information and evidence	Adopt a "weight-of-evidence" perspective
	Be introspective and self-questioning
	Use all information of all types
	Account for simple methods and observations
	Incorporate base-rate frequencies
	Question quantity and quality of data
	Question analysis assumptions
	Avoid conservative interpretations
	Use judgment attributes
Numerical assignment	Converge on the value from both ends
	Avoid insufficient adjustment
	Use visual devices
	Use verbal transformations
	Limit extreme values by further decomposition
Confirmation	Check for mathematical coherence
	Adopt different perspectives
	Prompt for disconfirming evidence
	Review for changes
	Confirm that values make sense collectively
	Do a reality check

Feedback

- Feedback is helpful in improving performance in subjective probability
  - Can help reduce biases over time
- Example – weather forecasters
  - Provide subjective probability of rain (on a given day, or a given hour)
  - Feedback helps them to be pretty accurate in their judgments



Resilient Design Heuristics

- Reduce risk of system failure by adopting resilient design heuristics
  - Heuristics – rules of thumb
  - As opposed to objective, measurable requirements
- Jackson proposes resilient design heuristics in four areas
  - Capacity, flexibility, tolerance, inter-element collaboration

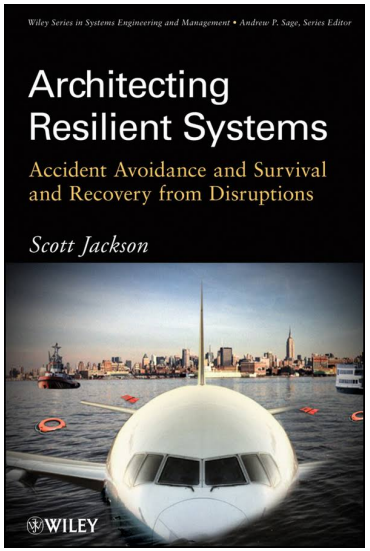
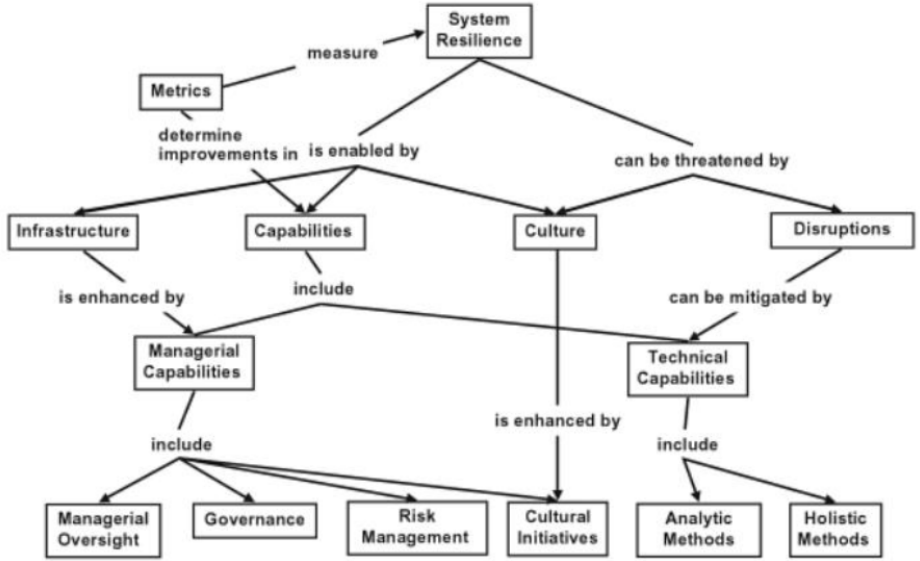


Image credit: Wiley

Expand the Boundaries of the System



- Consider the organization –
  - The organization is often the most critical part of the system

Image credit: Scott Jackson / Wiley

Organizational Issues - Culture

- Culture is often identified as a primary cause in man-made disasters
  - An issue in NASA shuttle accidents
- Culture is the most challenging aspect of managing risk
  - Neither technical nor quantifiable
  - Jackson describes positive and negative paradigms for risk management culture

Positive Paradigms

Preoccupation with failure
Reluctance to simplify interpretations
Sensitivity to operations and a reporting culture
Commitment to resilience and a learning culture
Deference to expertise and a flexible culture
A just culture

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Summary

- Risk management is a major area of focus for INCOSE
  - *Vision 2025* acknowledges the need to improve methods for risk management
- Current risk techniques are limited
  - Models have limits (uncertainties and inaccuracies)
  - Models can constrain our thinking and perceptions

Integral Approach

- Take an integral approach
  - Integrate both objective and subjective information
  - Use judgment and heuristics
  - Include organizational aspects of risk (e.g., culture, leadership)
- A more complete approach, leads to better solutions

Thank You

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