27th annual INCOSE international symposium

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July 15 - 20, 2017


A Research Agenda

# Warranting System Validity Through a Holistic Validation Framework

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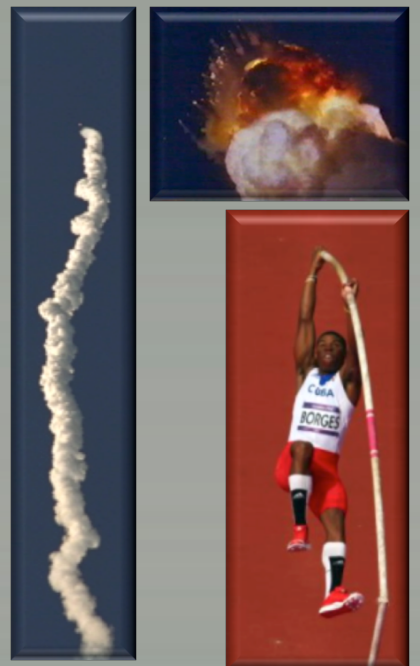
# GAO reports[1,2] significant risk to launch reliability when validation in SE is missing

## Expendable Launch Vehicle Acquisition – form and reform

Titans, Atlas, Delta
1960-1997

Government "Oversight"

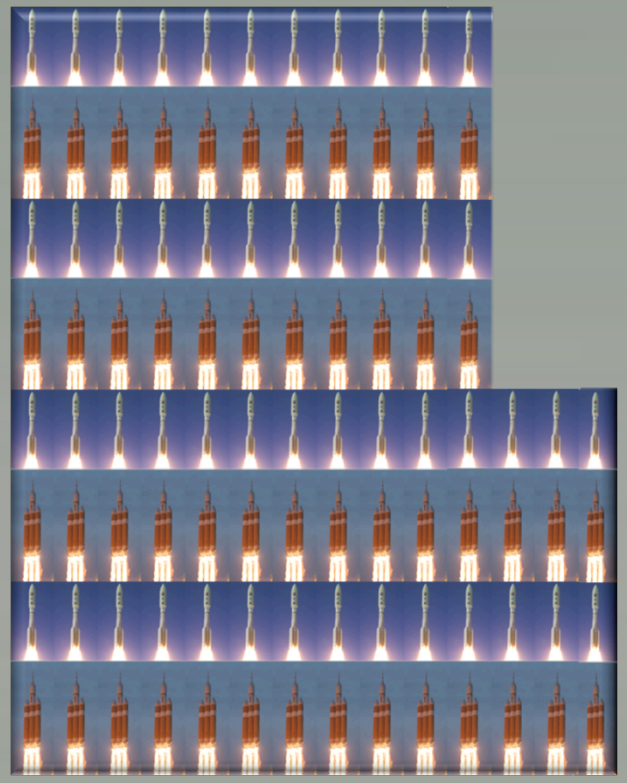
"Partnershi0p"



1998-1999

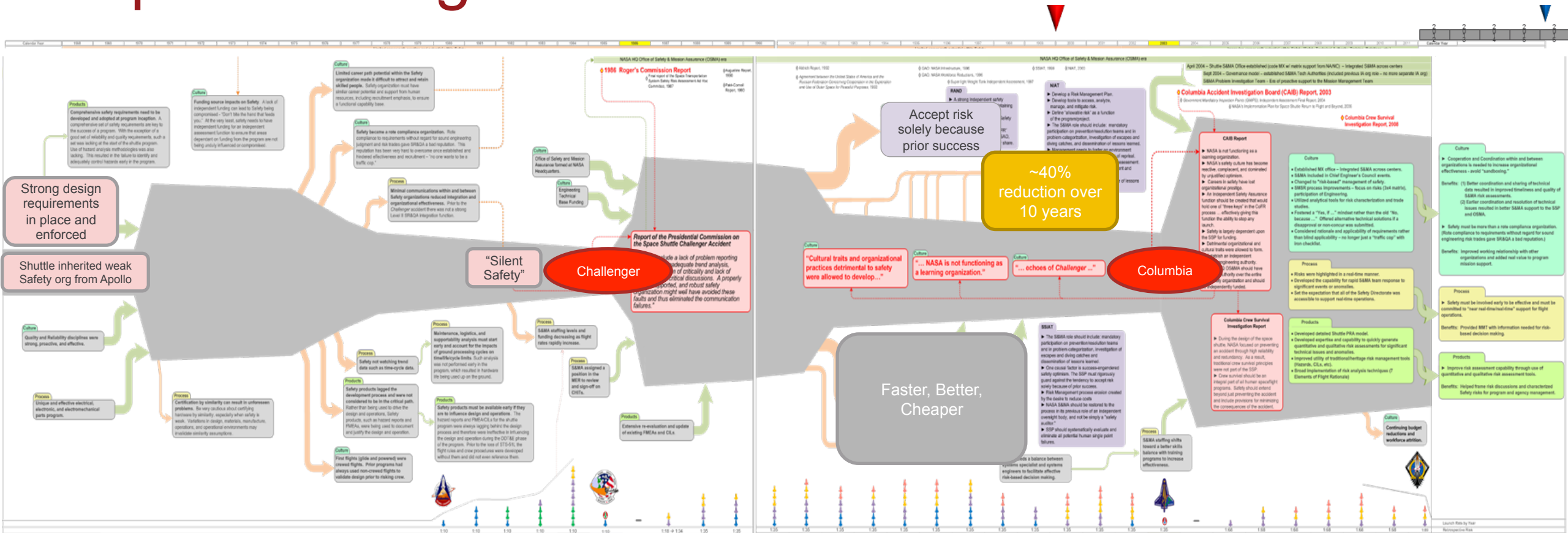
"Partnershi0p"

Government "Oversight"



Atlas V, Delta IV
ULA 100+ successes 2000-present

# Reduction of SE leaves systems acquirers open to a high risk of loss of mission




**NOTIONAL Relative expenditure on Safety and Mission Assurance over the Space Transportation System Life Cycle**

Source: NASA Safety and Mission Assurance, 2016

http://jsc-sma-missp.jsc.nasa.gov/FSO/Lists/Assessment%20List/Attachments/3920/Shuttle_Legacy_Handout_RevA%20-%20main%20foldouts%20only.pdf

# Waiting until you have a launch failure is a poor method for justifying more validation

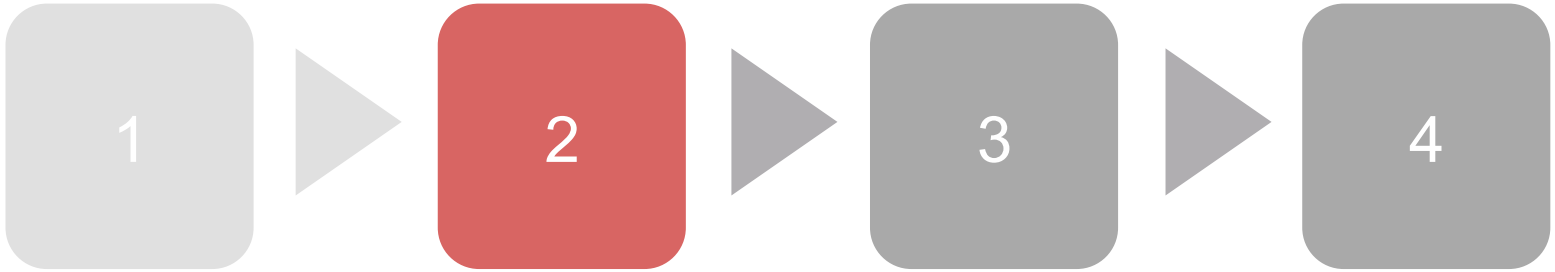
Houston, we have a problem.

Commercial Resupply Service Missions
Falcon 9, Antares, Soyuz Russian)
2014-2015

H-II (HTV-6) Resupply
Mission (JAXA), 2015
Success

**Is there some particular logic to Validation in SE to justify validation criteria?**

# Agenda




US Space Launch System Validation Need

Validation in Systems Engineering

Research Theory Base

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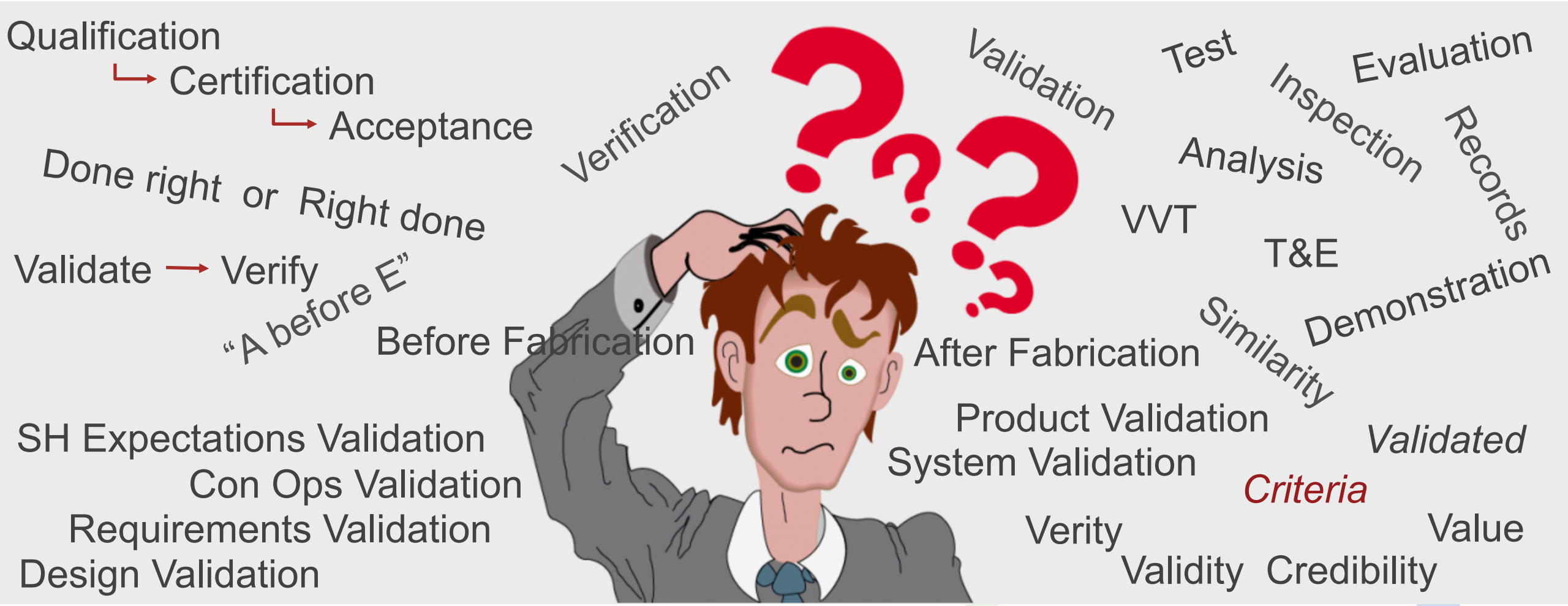
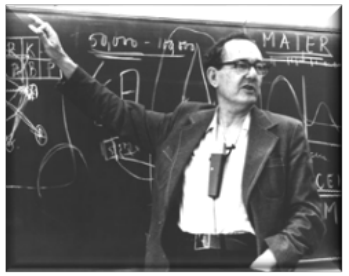
# Confusion regarding validation in systems engineering ..no definitive definitions



# Artificial systems have artificial validity criteria

- Engineered systems = Artificial systems
  - The engineered system will cause predefined alterations of effects
  - Effects would not manifest without existence and action of system
- Validation in Systems Engineering
  - Confirming through examination of objective evidence
  - Justification of belief that the novel pattern has some repeatable, predictable truth
  - Boundary validity negotiated
- A human process of involving human activity on human-created systems
  - Physical interrogation
  - Mental rationalization
  - Dialectical reasoning
    - Shared reasoning



Herb Simon
Sciences of the Artificial

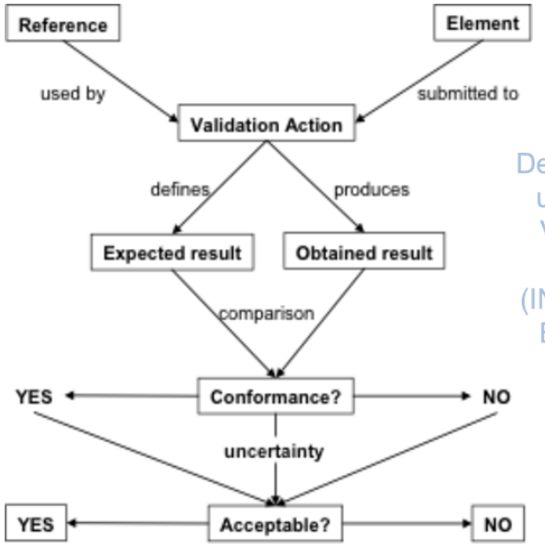



Figure: Definition and usage of a Validation Action (INCOSE SE BKCASE)

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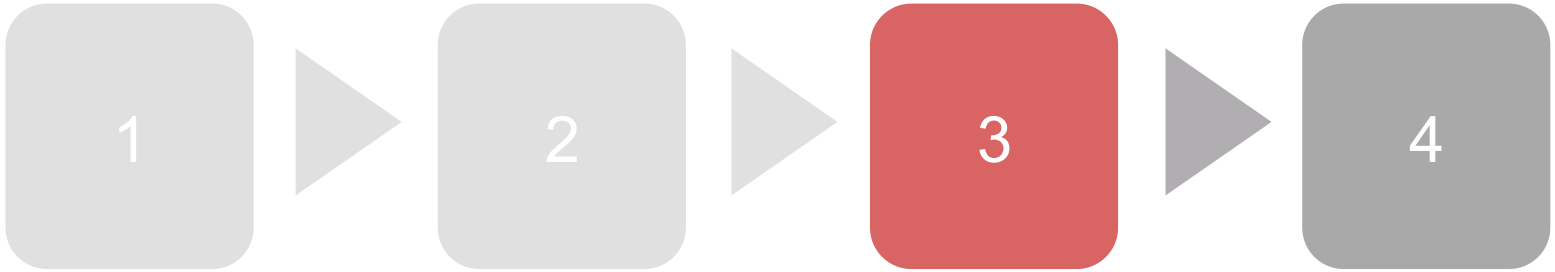


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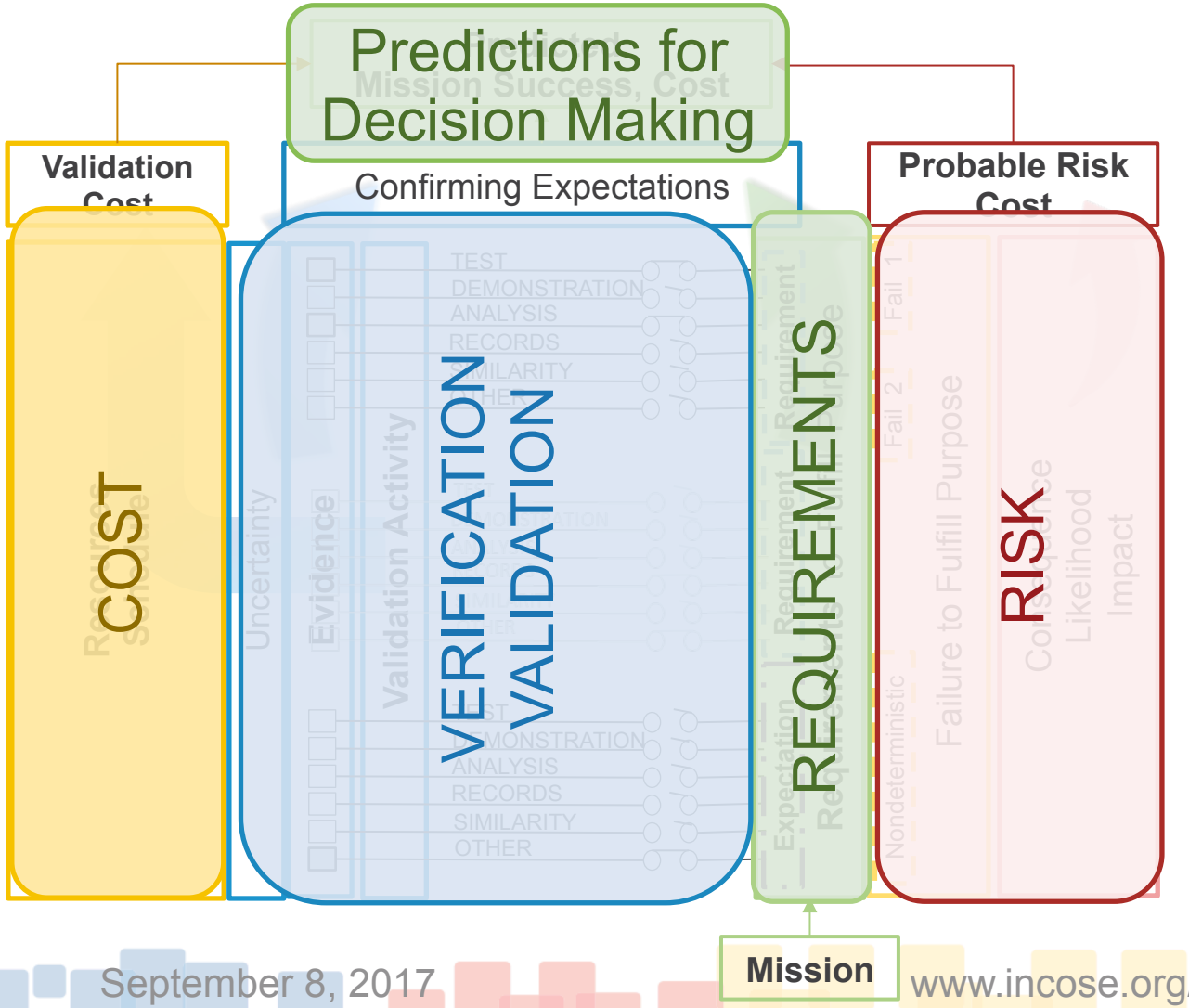
# Focus on risk mitigation to determine validation strategy ignores  a key validation question..



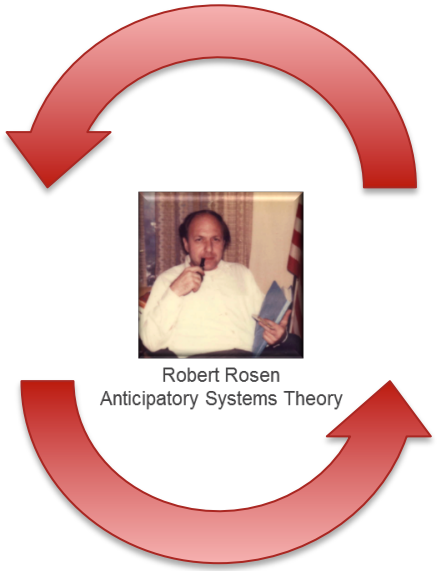

**How do you know?**

# Interrogating a model to reason about the system

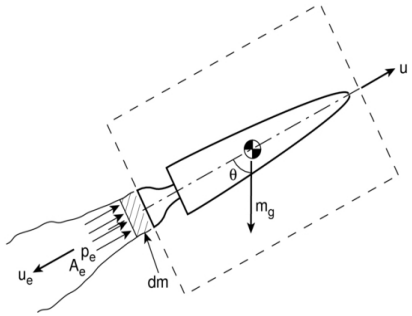
# Modeling relations in anticipatory systems is fundamental for engineered systems

Information encoding

Phenomenal
Actual
"Entity"




Contextual
Pattern-al
"Model"




$$u = g\left[\mathrm{Isp}\ln\left(\frac{m_{v_0}}{m_v}\right) - t\right]$$

$$h_b = g\left[-t_b\mathrm{Isp}\frac{\ln\left(\frac{m_{v_0}}{m_{v,\mathrm{final}}}\right)}{\left(\frac{m_{v_0}}{m_{v,\mathrm{final}}} - 1\right)} + t_b\mathrm{Isp} - \frac{1}{2}t_b^2\right]$$

Information decoding

Mental Modeling Theory
Johnson-Laird, 1983;
Johnson-Laird & Khemlani, 2014

Expert Systems
O'Keefe et al, 1987

Systems Thinking
Senge, 1990

Systems Engineering,
Hall, 1999;
Sage & Armstrong, 2000;
Buede, 2000;
Roda, 2013

Artificial Systems Science
Simon, 1983

Model Validation
Sargent in Pace, 2001

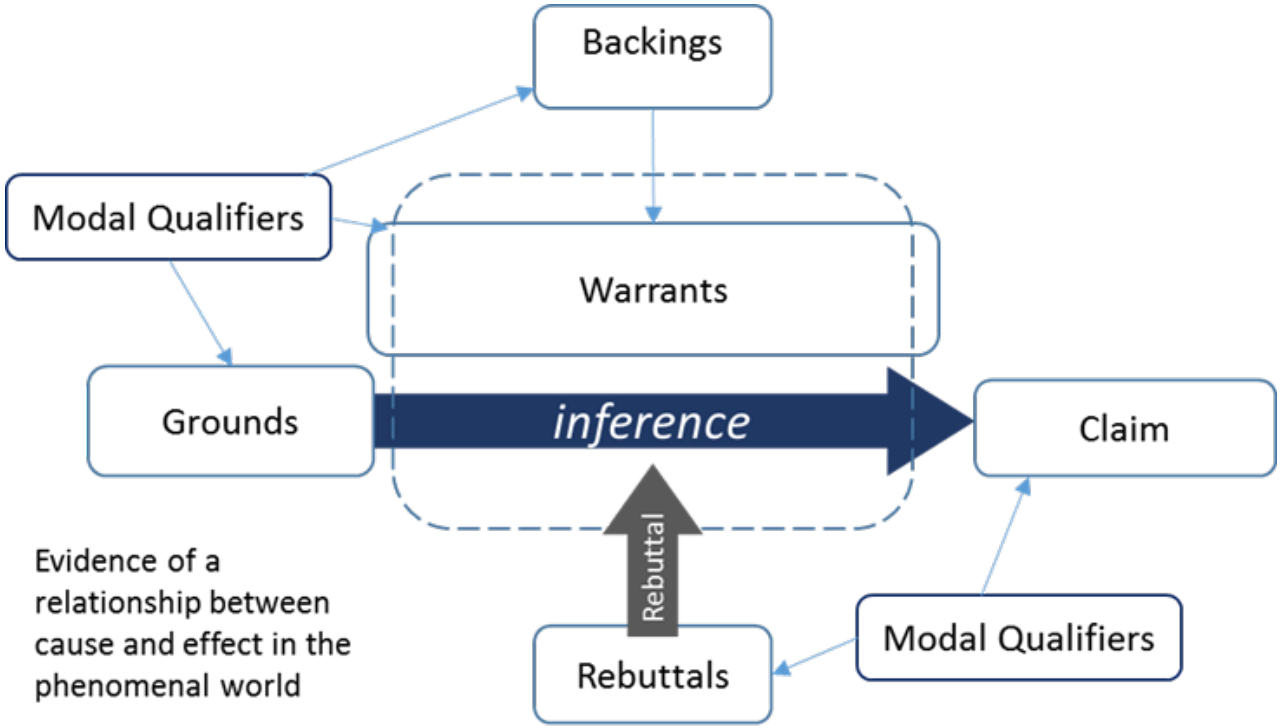
IS Design Theory
Gregor, 2006;
Gregor and Jones, 2007;
many more

Ecological Systems, Policy
Kineman, 2007

Physics Pedagogy
Hestenes, 2010

Cognitive Science
Nersessian, 2012

# Contextual models do not exist on evidence alone; An inferential structure is necessary




Stephen Toulmin
Model of Argumentation

Jansson and Sage, 1998 – Argument and Inference in SE

Sage and Armstrong, 2000 – Argument and Inference in SE

Metcalfe and, Sastrowardoyo, 2013 – Argument Mapping

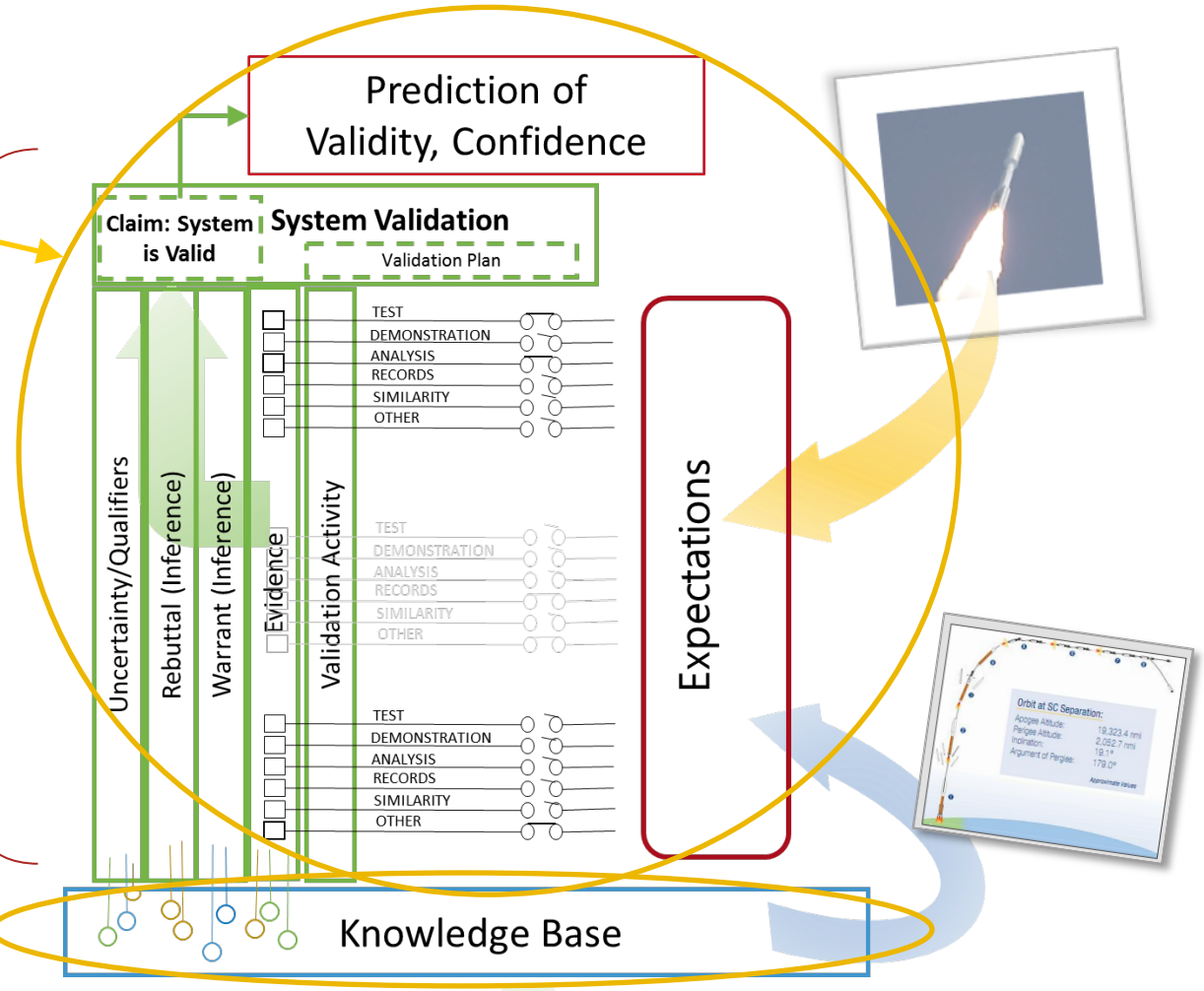
Graydon and Holloway, 2016 – Confidence in Assurance Arguments

Toulmin's model of argumentation links "Grounds" to the "Claim" by "Warrants"

# Warranting system validity needs a holistic validation framework

Step 1: Recognize the Core

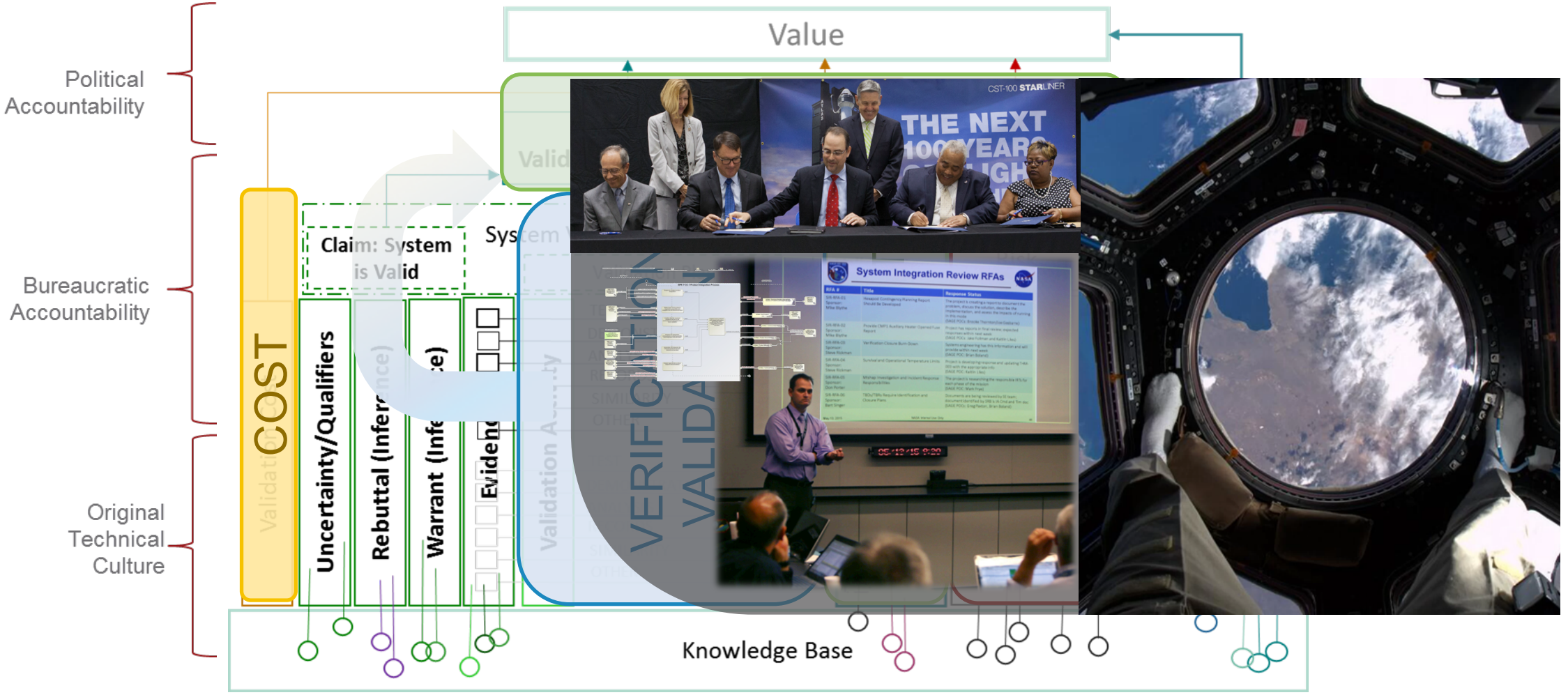
Elements of Toulmin's model of argumentation



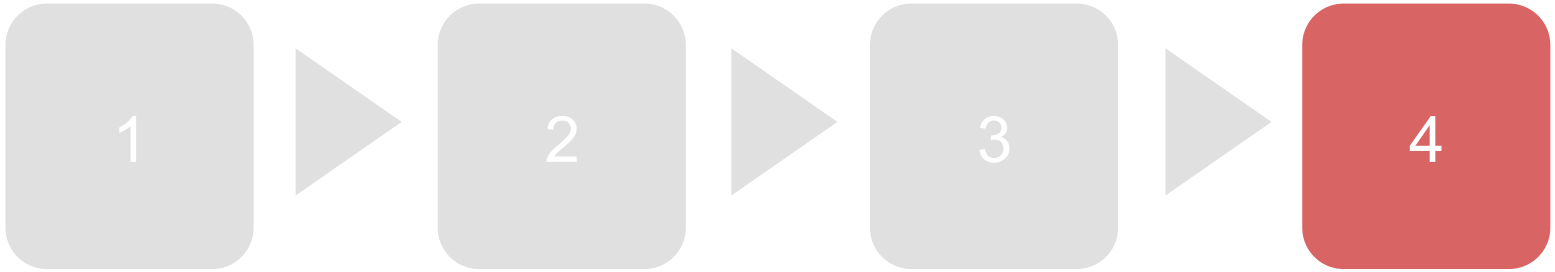

Step 2: Recognize the Knowledge Base

and..

# A holistic framework of validation draws on the knowledge base in ways that affect value



# Agenda

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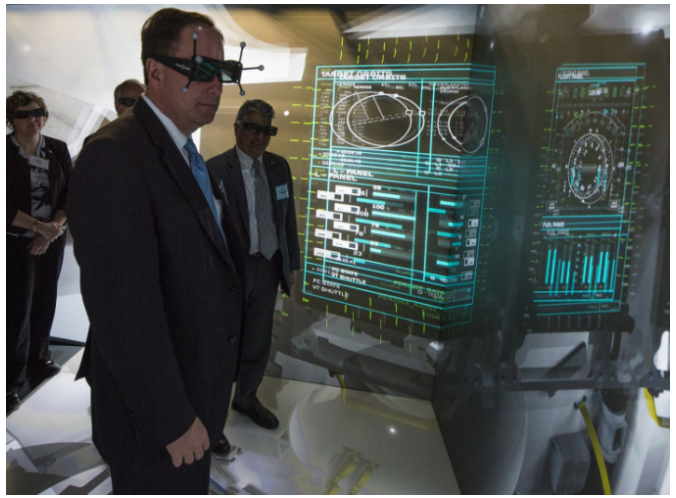
# Opportunities for research are everywhere

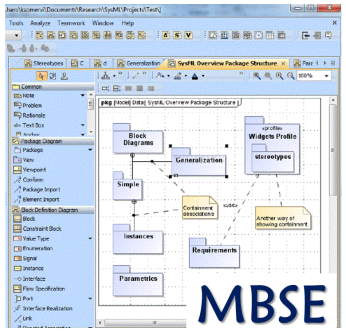

***Systems of Systems of Agents*** – Values frame judgments and commitment agreements between players, establishing the ultimate "truth" by which validity is judged

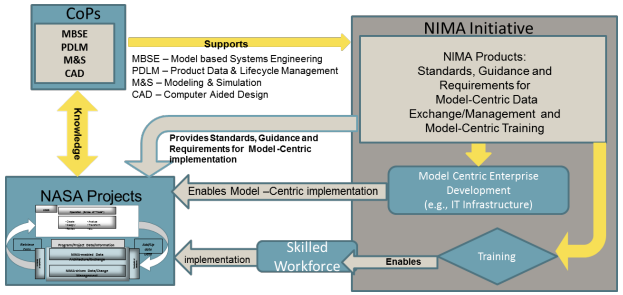


***Online & Wired*** – Technology and sociality are changing how to communicate models and need to enable discernment of truth

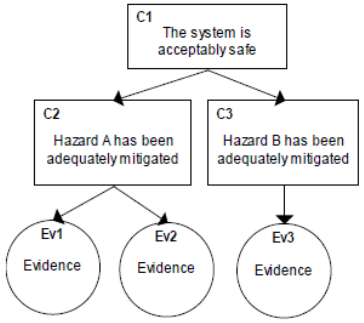
(credit: NASA/Joel Kowsky)

***Model Based Systems Engineering*** changes how to communicate models and establish agreement regarding the single source of "truth"



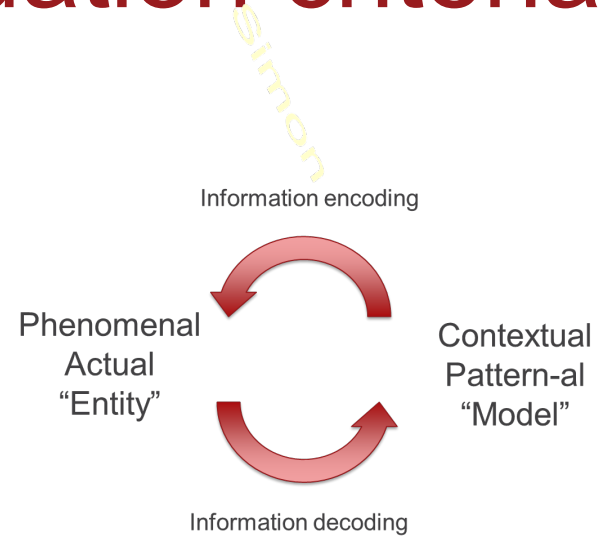

NASA Integrated Modeling Architecture for MBE (Gill 2013)

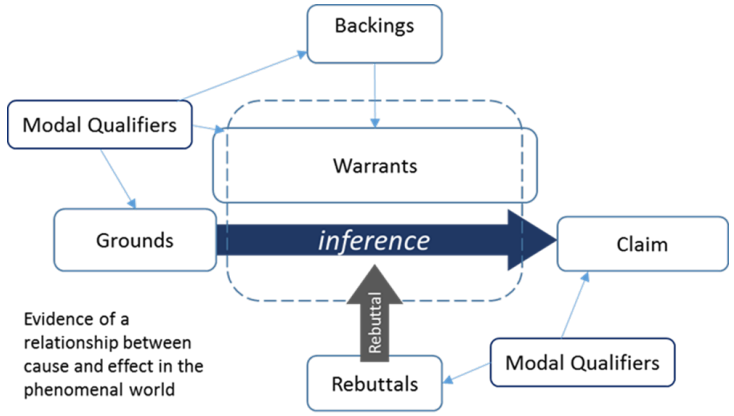



Notional Eliminative Argumentation structure (Goodenough, Weinstock, and Klein, 2015)

***Safety and Mission Assurance*** , risk and hazards analysis organizes key information but probabilistic methods have yet to be developed to produce justified expert assessment of confidence in assurance arguments (Graydon & Holloway, 2016)

# Research goal: Develop the theory that justifies validation criteria in systems engineering




Robert Rosen

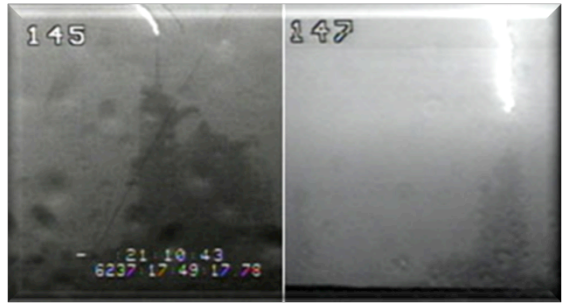
Imre Lakatos

Stephen Toulmin

# Research Validation Criteria

- Traditional qualitative research validation criteria

- Illustration by well-documented case studies
  - NASA case studies
    - Challenger
    - Post-Columbia Return to Flight
    - STS-115 Launch Stand Down Decision

# Class of 2017

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