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A Vision for Human-Model Interaction in Interactive Model-Centric Systems Engineering

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Interactive Model-Centric Systems Engineering (IMCSE) Research Program

Not be confused with Model-based Systems Engineering (MBSE)…

IMCSE is a research program that seeks to encourage development of augmented complex systems thinking and analysis to support data-driven decision making

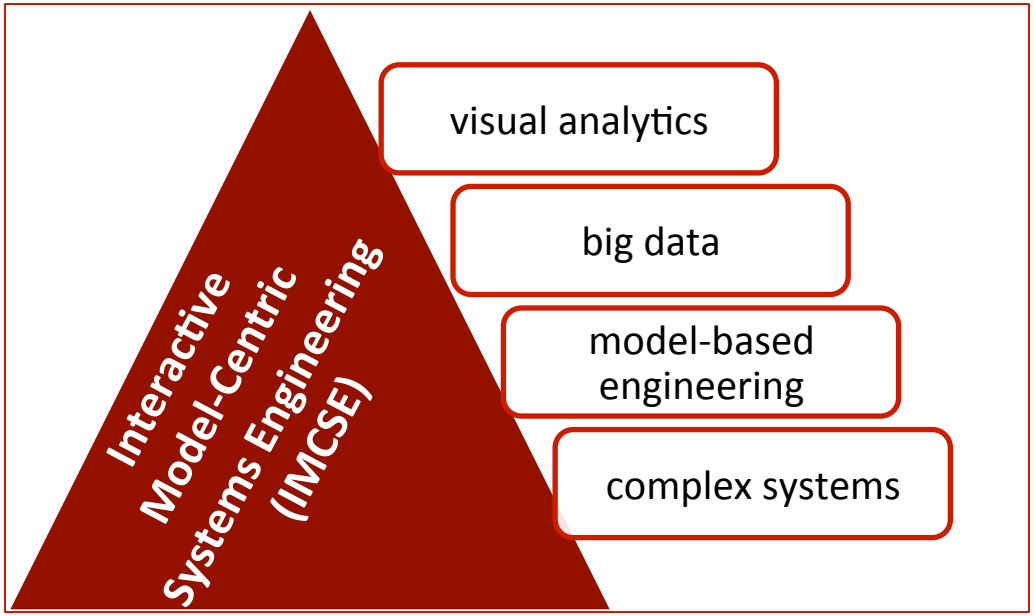
- Initiated by MIT in May 2014, sponsorship by *US Department of Defense Systems Engineering Research Center (SERC)*
- First step was to undertake a pathfinder project to identify areas of investigation
- Several areas of investigation at MIT
- Many relevant research initiatives taking place across the larger systems community (academia, government, industry)

Motivation for IMCSE Research Program

Models are "abstractions of reality" … gap between model and system is narrowing

Higher probability errors and omissions in a model lead to system failures

Humans need to be endogenous to interactive model-centric environments



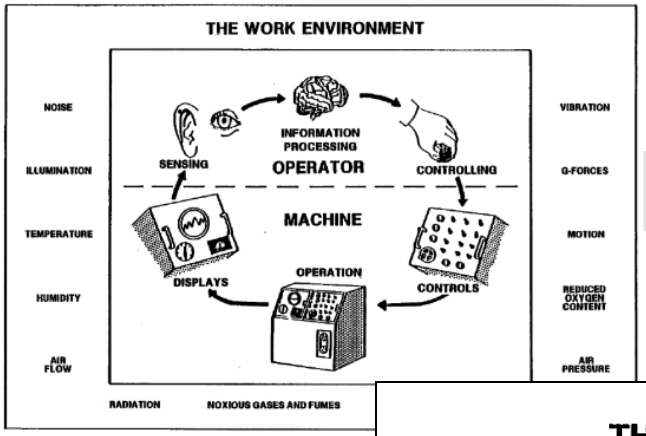
While progress has been made on model-based engineering … there has been **relatively little investigation of the complexities of human-model interaction**

Rhodes, D.H., and Ross, A.M., IMCSE SERC Reports: Phase 1, Phase 2, Phase 3, www.sercuarc.org

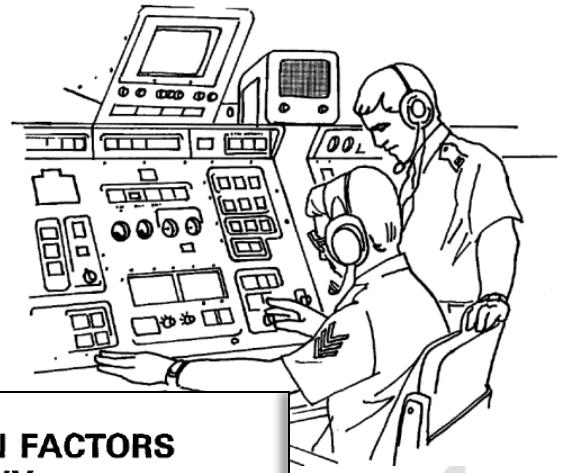
Evolution of Human Factors Design

source: 1990 Systems Engineering Course

THE OPERATOR — MACHINE MODEL



THE OPERATOR IN THE SYSTEM



THE EVOLUTION OF HUMAN FACTORS DESIGN PHILOSOPHY

- MACHINE ORIENTATION
  - THE MACHINE, JOB, AND ENVIRONMENT ARE ASSUMED TO BE FIXED
  - SELECT AND TRAIN PEOPLE TO DO THE JOB, OPERATE THE EQUIPMENT
    RESULT: POSSIBILITIES OF MODIFYING THE EQUIPMENT, JOB OR ENVIRONMENT IGNORED

- SYSTEM ORIENTATION
  - DESIGN
    - PERSONNEL
    - TRAINING
    - EQUIPMENT
    - JOB
    - ENVIRONMENT

    AS SYSTEM ELEMENTS, RECOGNIZING THE TRADE-OFFS POSSIBLE AMONG THESE ELEMENTS

Who interacts with models?

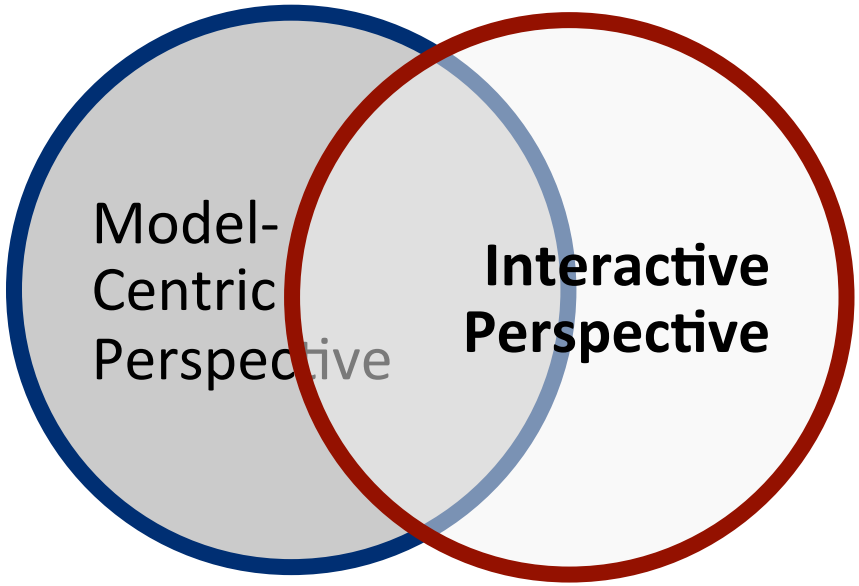
multitude of users, models used for many purposes

- model developers
- architects
- engineers/designers
- analysts
- system testers
- program managers
- senior decision makers
- developers of model-based toolsets

Interact with models individually and in teams

Why interact with models?

- explore data
- find patterns
- judge uncertainty
- make design choices
- validate decisions made
- develop trust in a model
- perceive truthfulness of a model
- ….



What are some key questions?

Significant progress on theory/practice of model-based systems engineering

… insufficient focus on ***human-model interaction***

How do humans interact with models and model-generated information?

How do humans interact with each other through using models?

How can systems decisions be improved through model interaction?

What cognitive challenges exist for model-informed decision-making?

What are essential human roles in model-centric environments?

Toward a Vision for Human-Model Interaction

imagine an ideal world…

An intuitive experience that generates deep insights across the area of relevant decisions that balances time, resources and the desired confidence in the decision outcome

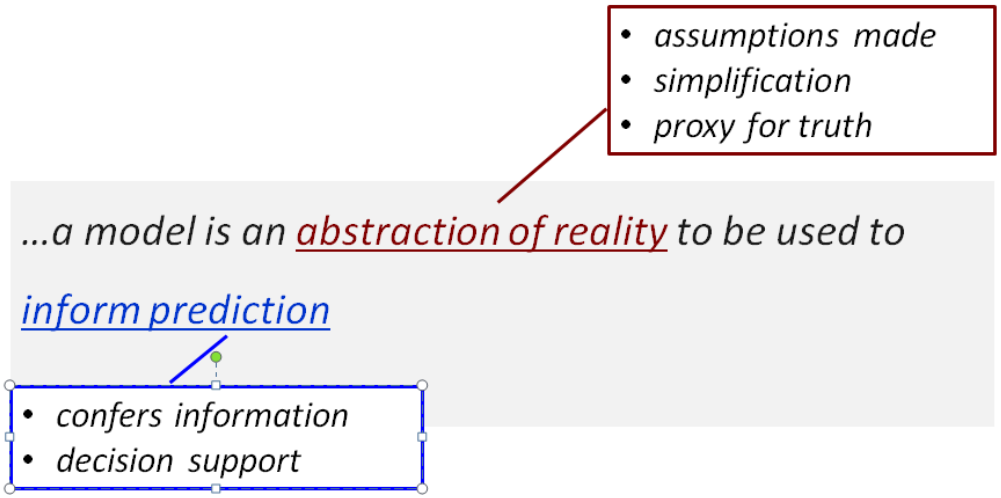
Key Emergent Themes

- ease of interaction
- enabling informed decisions
- human-human interaction
- guided interaction
- model re-usability
- trust in models
- curation of models

IMCSE Pathfinder Workshop Report (Feb 2015)

MIT IMCSE Research Highlights

1. Analogy studies
2. Empirical study of model-centric decisions
3. Interactive visualization prototypes
4. Model trade-off and choice
5. Curation of model-centric environments



1. Analogy studies

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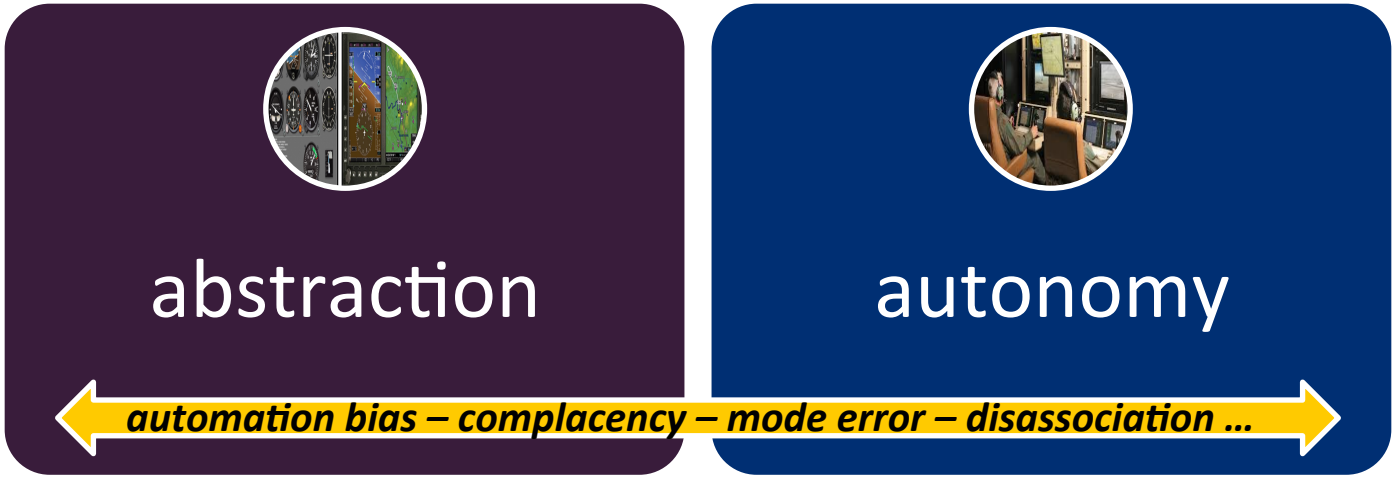
Research Question: How can interactive model-centric environments be designed to address cognitive and perceptual challenges?

Human-Model Interaction

learning from analogy cases



Glass Cockpit -- Analogy Case Study

Study shows 55% of pilots encountered “automation surprises” after a year of flying with glass cockpits due to mode errors (NASA)

Pilot error in air crash rooted in accepting wrong system waypoint by choosing initial item in dropdown list (Mosier & Skitka)

Users greatly preferred glass cockpit displays to traditional but performed demonstratively worse (Wright & O’Hare)

German, E.S., and Rhodes, D.H., "Human-Model Interactivity: What Can Be Learned from the Experience of Pilots Transitioning to Glass Cockpit?," 14th Conference on Systems Engineering Research, Huntsville, AL, March 2016

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1. Analogy studies
2. **Empirical study of model-centric decisions**
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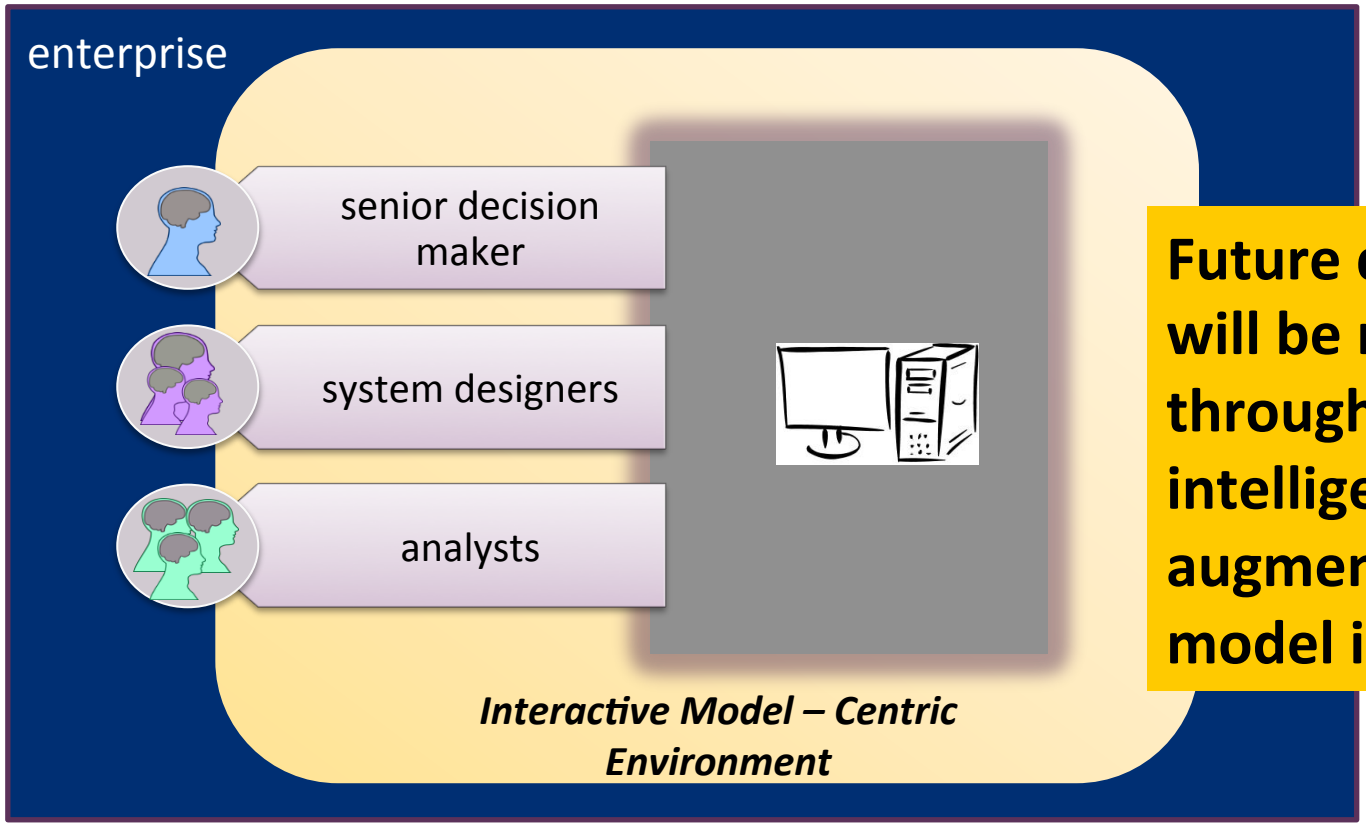
Research Question: How do model-users make decisions with models (e.g., develop trust in models, assess truthfulness of model)?

Model-Centric Environment



Future decisions will be made through human intelligence augmented with model intelligence

Empirical Study
decisions with models

Exploratory study underway to gain insight into how various types of decision-makers interact with and perceive models

- Expert interviews will focus on four primary questions:
  - —How and why do you interact with models?
  - —How do you develop trust in models?
  - —How do you perceive truthfulness of models?
  - —To what degree/which decisions are made based on models?
- Results will inform design principles and heuristics on design and use of models/model-centric environments
  - —Interview results will be supplemented with current/emerging knowledge on decision-making, heuristics and biases, situational awareness, trust, human-automation interaction, etc.

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3. **Interactive visualization prototypes**
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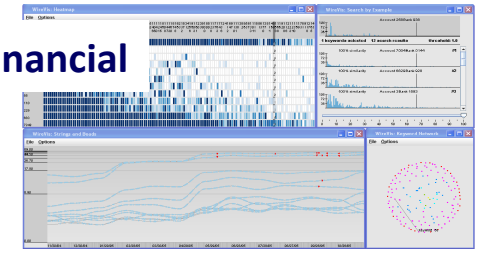
Research Question: How can visual analytics be used in systems decisions involving complexity and large volumes of data?

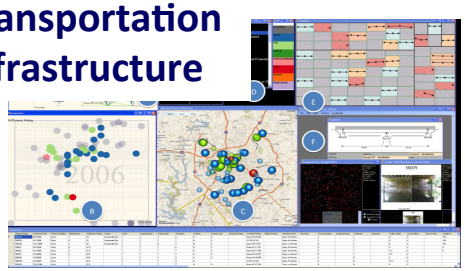
Visual Analytics and Big Data

- Visual analytics is "the science of analytical reasoning facilitated by **visual interactive interfaces**." (Thomas and Cook, 2005)
- Focuses on collaboration between **human and computer** to solve complex problems
- Visual analytics has shown significant promise **addressing challenges in other domains where data volume and complexity are issues**
  - —Financial fraud detection
  - —Transportation infrastructure planning
  - —Healthcare decision making

Financial



Transportation Infrastructure

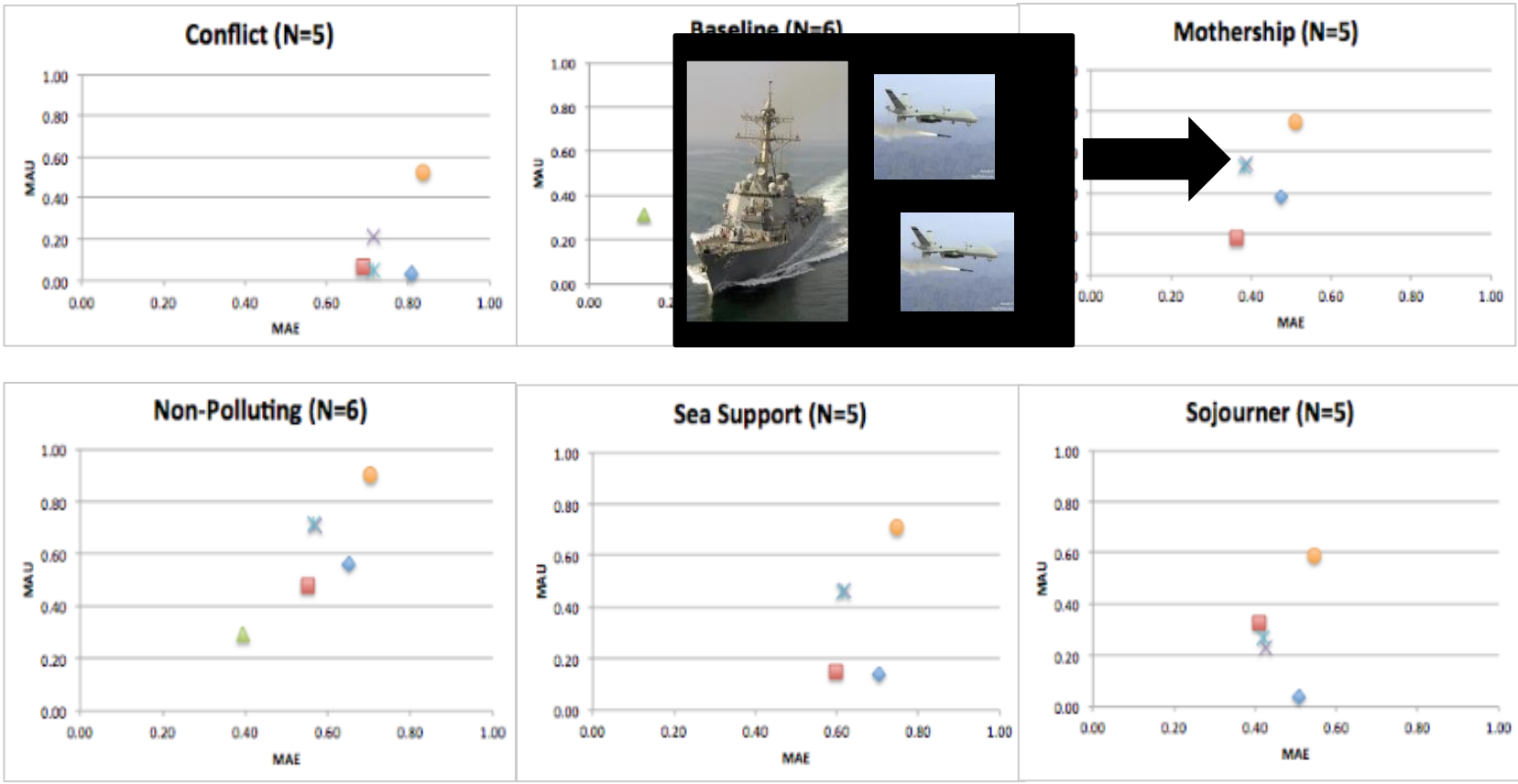


Healthcare

Tradespace Exploration

challenges of analyzing large data sets

Simplified example: six point designs evaluated under six "scenarios"
(vs computationally-derived scenarios based on uncertainty factors)

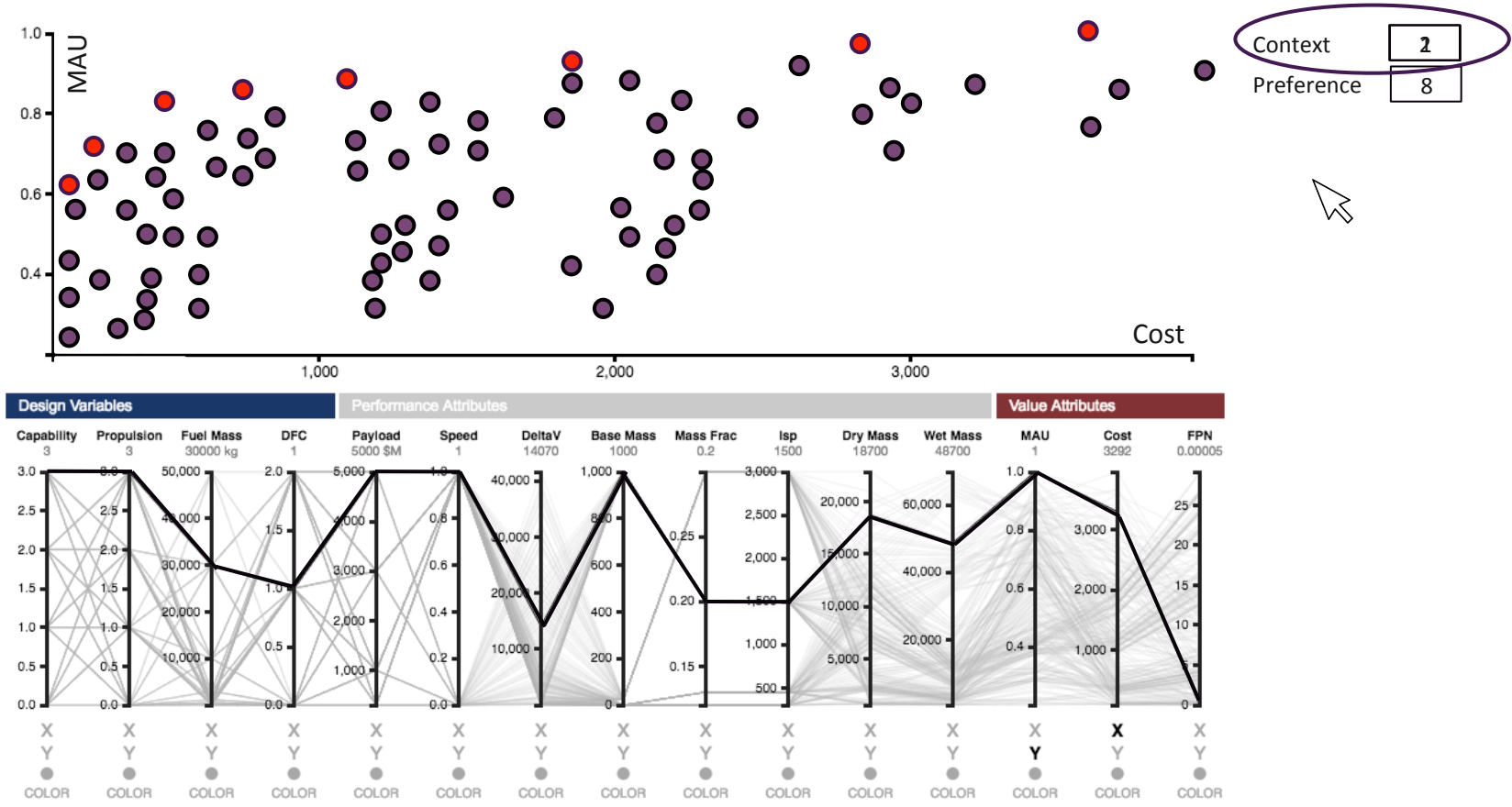


Schaffner, M.A., Ross, A.M., and Rhodes, D.H., "A Method for Selecting Affordable System Concepts: A Case Application to Naval Ship Design," 12th Conference on Systems Engineering Research, Redondo Beach, CA, March 2014

Applying Visual Analytics to Explore Impact of Changing Context

prototype visualization tool

http://seari.mit.edu/ieea-single_epoch.html



Curry, M, and Ross, A.M., "Designing System Value Sustainment using Interactive Epoch Era Analysis: A Case Study for On-orbit Servicing Vehicles," 14th Conference on Systems Engineering Research, Huntsville, AL, March 2016

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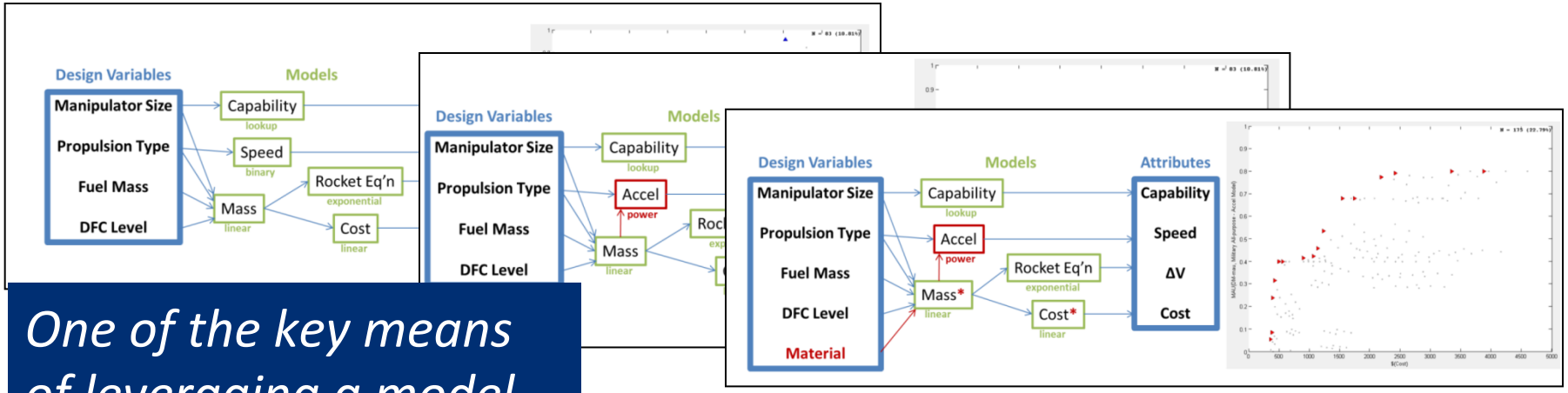
Research Question: How can interactive model trading enable resilient systems decisions?

Interactive Model Trading

value models and evaluative models



One of the key means of leveraging a model-centric environment is the trading of models, which can reveal insights about the system that are difficult or impossible to see when considering only a single model.

Design ID (Aluminum)	Model 1	Model 2	Model 3	Model 4	Design ID (Carbon)	Model 3	Model 4
52	√	√	√	√	436	√	√
53	√	√	√	√	437	√	√
63	√	√	√	√	447	√	√
54	√	√	√	√	438		√
87	√	√	√	√	471		√
119	√	√	√	√	503		√
86		√		√	470		√
120		√		√	504		√
96	√		√		480	√	
128	√		√		512	√	
127	√				511		
95	√	√	√		479	√	

Ross, A.M., Fitzgerald, M.E., and Rhodes, D.H., "Interactive Evaluative Model Trading for Resilient Systems Decisions," 14th Conference on Systems Engineering Research, Huntsville, AL, March 2016 (MITRE BEST SE RESEARCH TRANSITION AWARD)

MIT IMCSE Research Highlights

1. Analogy studies
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5. **Curation of model-centric environments**

Research Question: Would a model curation role address key challenges and needs? What competencies are needed?

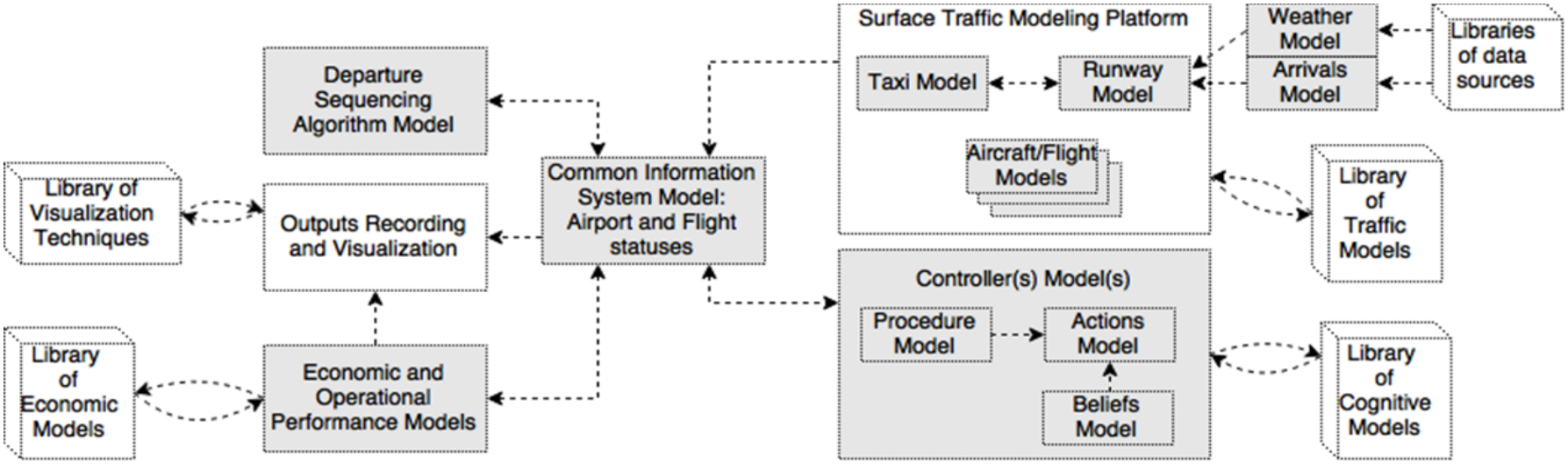
Challenges and Drivers

- Legacy models not widely used beyond their original purpose
- Modeling efforts duplicated across programs
- Re-use suffers from a lack of access, trust and legitimacy
- Modeling competency distributed across individuals/ organizations, not leveraged at enterprise level
- Transforming to digital engineering paradigm

Decisions Involved in Using/Managing Model-Centric Environments

Architect an airport collaborative decision making system (CDM)

"share real-time flight information and delegate authority to sequence departures, in order to maximize capacity use and reduce congestion"

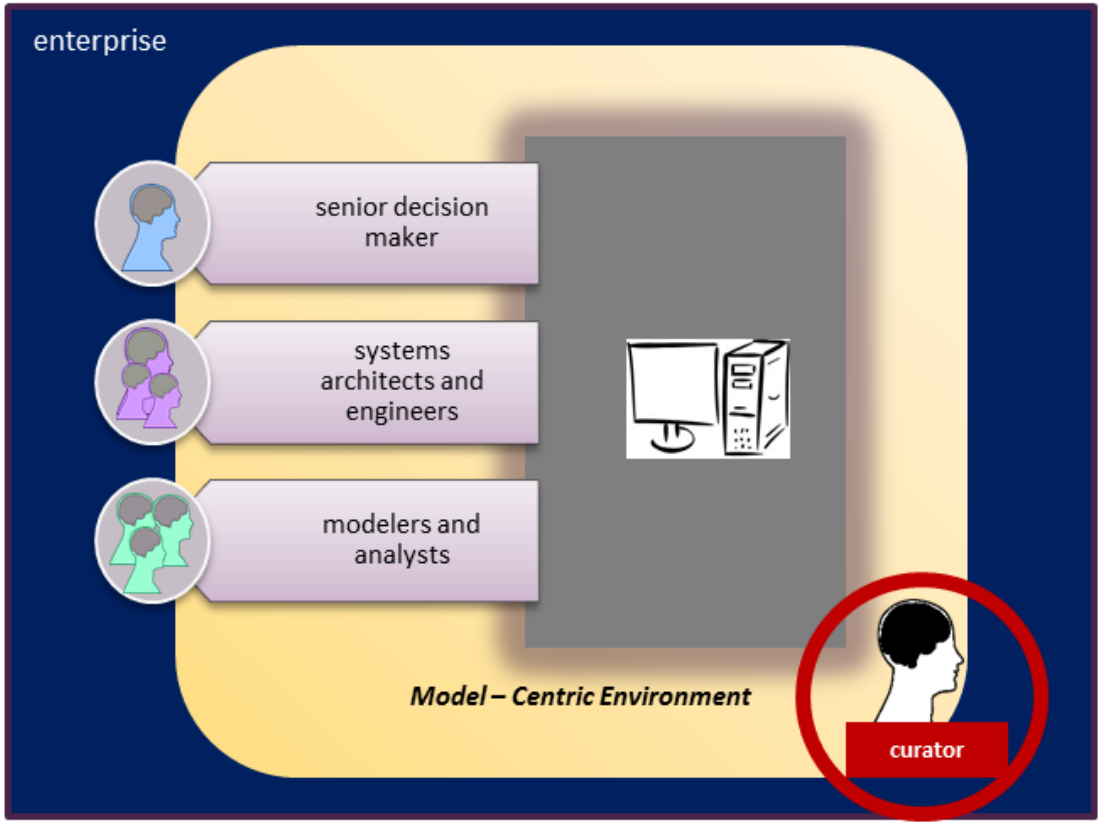


- What models? what platforms? analysis techniques?
- What model trades? Where are data sources?
- What about composability of my models?

Reymondet, L., Rhodes, D.H. and Ross, A.M., Considerations for Model Curation in Model-Centric Systems Engineering, IEEE SysCon 2016

DoD Digital Engineering Working Group SE Digital Engineering Fundamentals (2016)

The responsibility of planning and coordinating programs' use of models, simulations, tools, data, data rights, and the engineering environment belongs to the program manager; the performance of the actual may be delegated to the program systems engineer and other program staff as appropriate



Model Curator as Leadership Role

Envisioned role includes…

- Process-owner for model-centric environments
- Manage data/model repositories, data rights, IP
- Protect model 'pedigree'
- Guide selection of models and modeling platforms
- Own model risk/opportunity
- Negotiate borrowing/loan

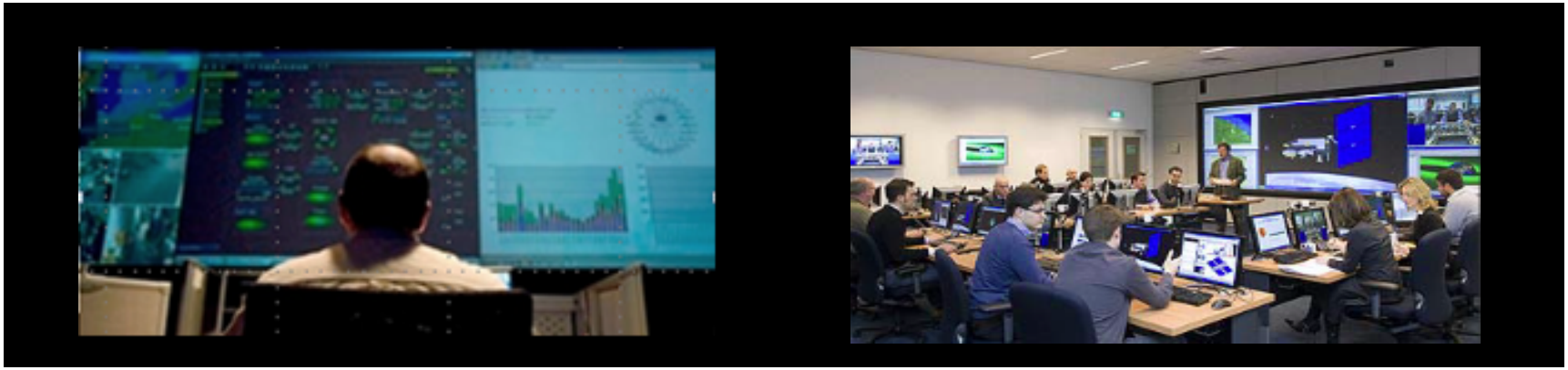
Goals
Competency profile and role definition
Standard for "model pedigree"

Reymondet, L., Rhodes, D.H., and Ross, A.M., "Considerations for Model Curation in Model-Centric Systems Engineering," 10th Annual IEEE Systems Conference, Orlando, FL, April 201

Summary

research goal and underlying premises

*Develop transformative results through **enabling intense human-model interaction**, to rapidly conceive of systems and interact with models in order to make rapid trades to decide on what is most effective given present knowledge and future uncertainties, and practical given resources and constraints*



Successful systems acquisition, development and sustainment depends upon effective **"human-model teaming"**

Interactive model-centric environments necessitate **specialized leadership and competencies**

Human-Model Interaction

achieving the vision

Significant progress on theory/practice of model-based systems engineering

… insufficient focus on ***human-model interaction***

Three imperatives:

(1) identify synergies between research projects and initiatives

(2) connect clusters of researchers and practitioners around research threads

(3) engage practitioner community in piloting and validating research outcomes as they unfold

Questions?

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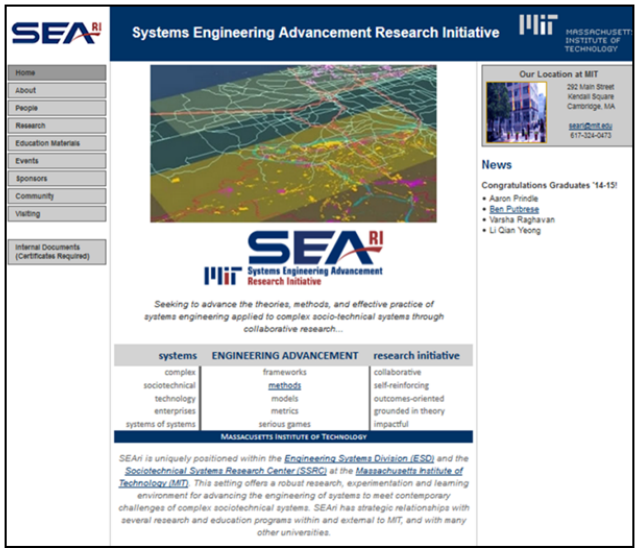

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