SYSTEMS ENGINEERING RESEARCH CENTER

SERC TALKS

WELCOME

Why is Human-Model Interactivity Important to the Future of Model-Centric Systems Engineering?

Drs. Donna Rhodes & Adam Ross, MIT

December 7, 2016 | 1:00 pm ET

- ❑ Today's session will be recorded.
- ❑ An archive of today's talk will be available at: www.SERCuarc.org
- ❑ Use the Q&A box to queue questions, reserving the chat box for comments, and questions will be answered during the last 5-10 minutes of the session.
- ❑ If you are connected via the dial-in information only, please email questions or comments to Ms. Mimi Marcus at mmarcus@stevens.edu.
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Why is Human-Model Interactivity Important to the Future of Model-Centric Engineering?

Dr. Donna H. Rhodes and Dr. Adam M. Ross
Massachusetts Institute of Technology

www.sercuarc.org

Addressing complex systems problems requires both human intelligence and use of models

- Models are useful for generating data that can be used in human decision making
- Human cognitive limits drive necessity of using models and computational resources
- Models can "automatically" perform certain human functions but humans provide the context: under which conditions is the model appropriate and useful?

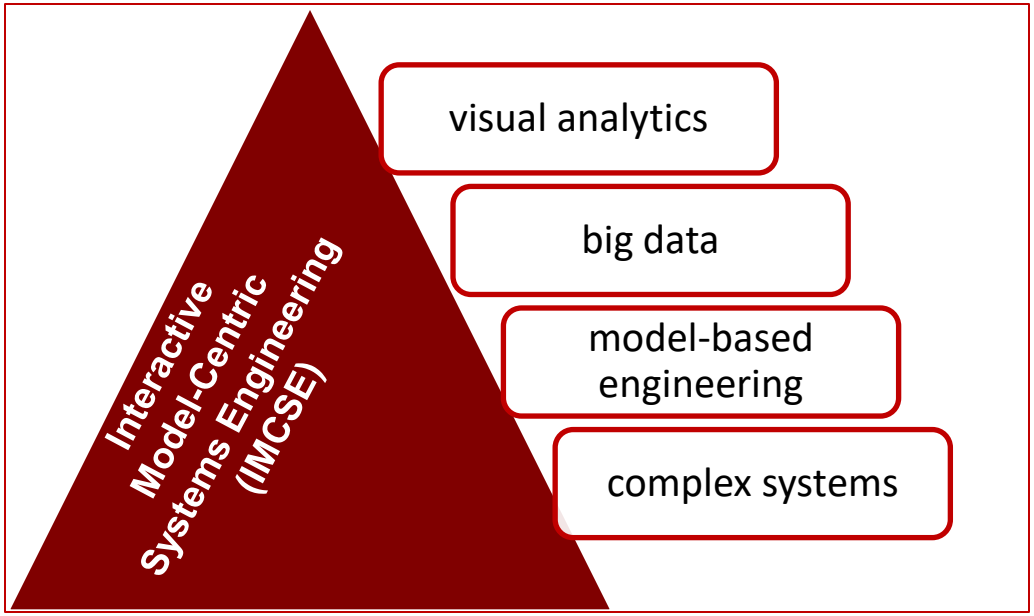
Effective interactivity makes models useful at the speed of human decision making

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

Toward a "Science" of Human – Model Interaction

- Previous investigation of human-model interaction mostly limited to "mechanistic" aspects

- Related areas
  - —Science of ***human-systems integration*** **(HSI)** has emerged (Pew and Mavor, 2007), but focuses on humans and operational systems, while models are abstractions of reality.
  - —Science of ***human-computer interaction*** **(HCI)** is relatively mature and offers valuable insights for the future (Harper et al., 2008); however its focus is on designing computer interfaces for effective human use.
  - —Science of ***visual analytics*** is emerging

Areas of Inquiry

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 using models?

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

What are essential human roles in model-centric environments?

How can interactivitity of humans and models be made more effective?

Research Highlights

INVESTIGATING HUMAN-MODEL INTERACTION

Expected Outcome: Impactful studies on key topics leading to heuristics and prescriptive guidance

SYSTEMS ENGINEERING Research Center

Toward a Vision for Human-Model Interaction

SEA RI Systems Engineering Advancement Research Initiative

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

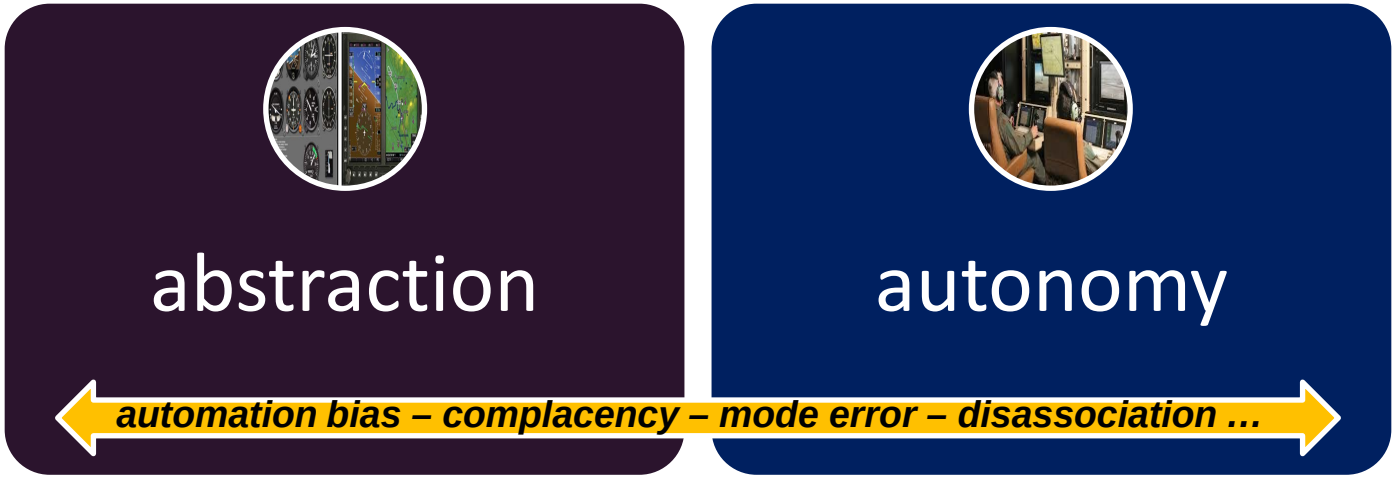
- ease of interaction
- enabling informed decisions
- human-human interaction
- guided interaction
- model re-usability
- trust in models
- curation of models

IMCSE Pathfinder Workshop Report (Feb 2015) has informed our research activities

Human-Model Interaction

learning from analogy cases

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



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)

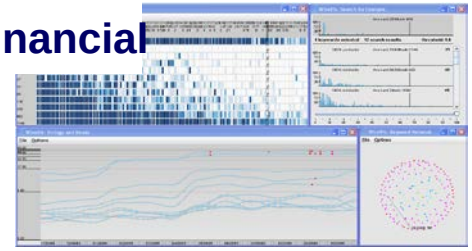
German, E.S., and Rhodes, D.H., "Human-Model Interactivity: What Can Be Learned from the Experience of Pilots Transitioning to Glass Cockpit?," 14th Conference on Systems Engineering Research, Huntsville, AL, March 2016

Visual Analytics and Big Data

Research Question: How can visual analytics be used in systems decisions involving complexity and large volumes of 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 maintenance planning
  - Healthcare decision making

Financial



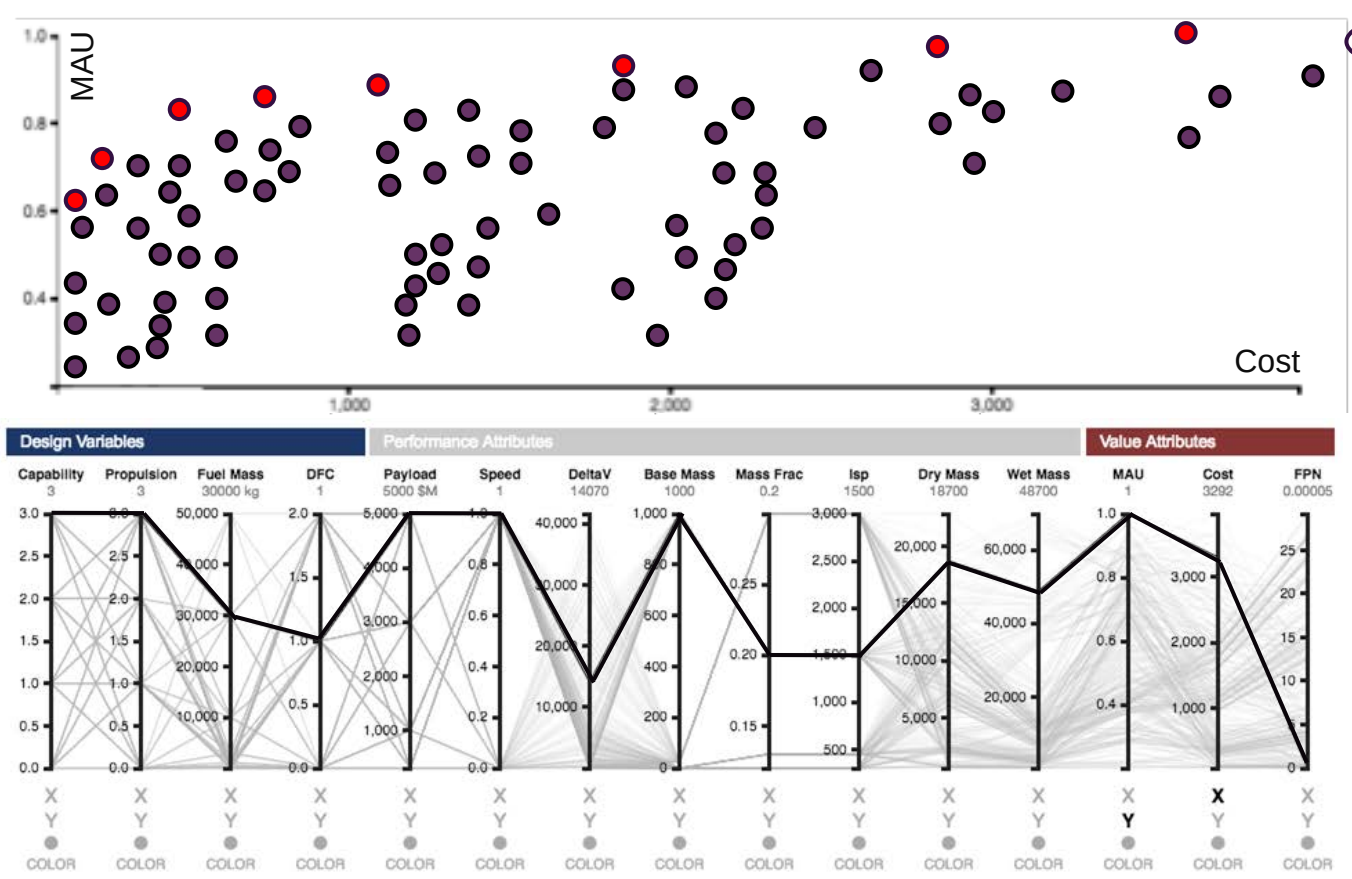
Transportation Infrastructure

Healthcare

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

Impacts of Visualization and Interaction on Human Performance

Ongoing exploratory human-subjects experiment:

- **Purpose:** *Decouple and evaluate impacts of visualization and interaction on human performance when performing surrogate design tasks*

- **Two cohorts:** (1) MIT graduate students and (2) volunteers using Amazon's Mechanical Turk crowdsourcing marketplace
  - Data to be analyzed separately

- **Three parts:** Personality traits, standard test of spatial ability, surrogate engineering design tasks
  - Subjects answer several questions about the surrogate engineering design tasks using one of four web-based interfaces (randomly assigned)
    - Plain text table of data
    - MS Excel-like interactive table of data
    - Static graph or visualization of the data
    - Interactive visualization of the data

- *MIT and DoD IRB Approved*
- *Investigators: Curry and Rhodes*

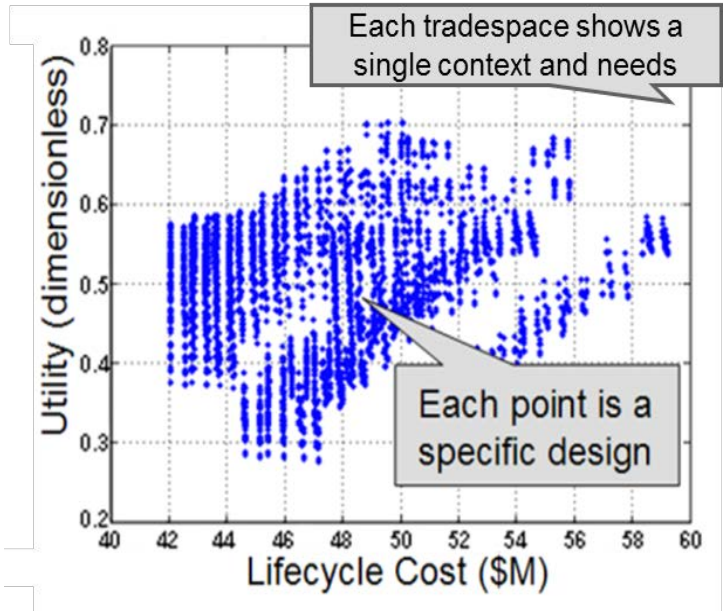
Research Highlights

Framing Multi-Stakeholder Tradespace Exploration

Expected Outcome: Recommendations for framing tradespace exploration to enhance multi-stakeholder decision making

Tradespace Exploration

- TSE design paradigm
  - —Many alternatives
  - —Observe trends in outcome space
  - —Generate problem insight / knowledge
  - —Use to enable confident decisions

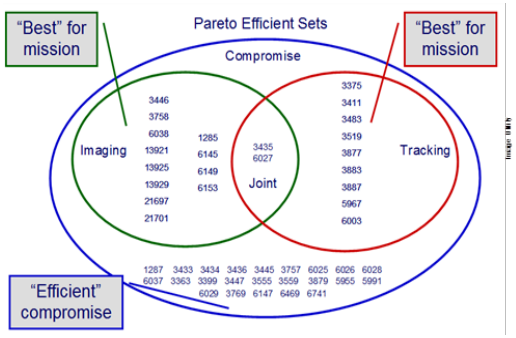


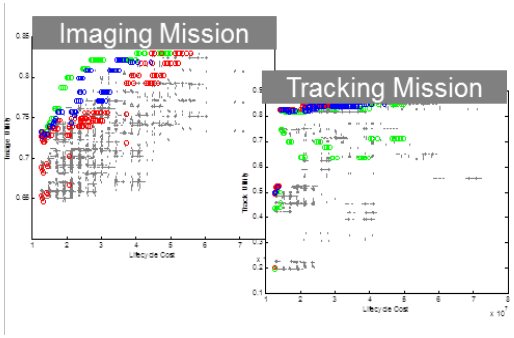
- MSTSE - to assist in negotiation
  - —Observe trends between stakeholders
  - —Use to find good group decisions
  - —Applied heuristically with some success
  - —Identified as key component of TSE and Resilient Systems research agenda

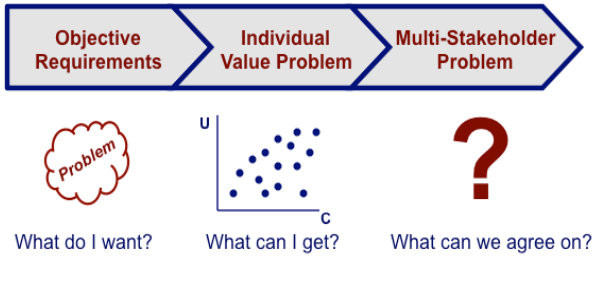
Multi-Stakeholder Negotiation in Tradespace Exploration

Vision: creating, using and sharing tradespace data with multiple, diverse decision makers

Method and metrics guide TSE to identify efficient tradeoffs and support negotiation



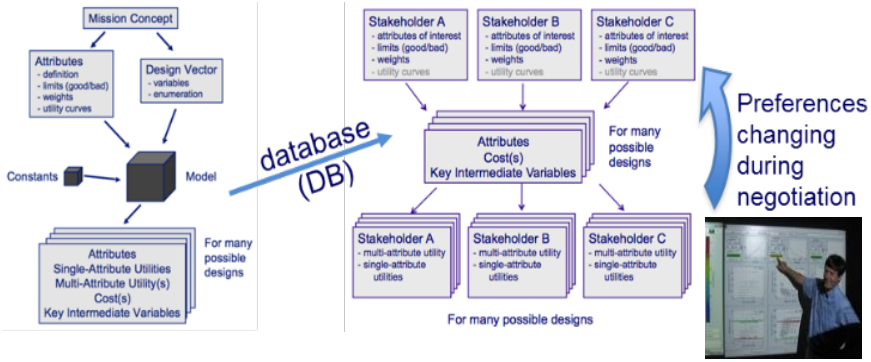




Ross et al., "Responsive Systems Comparison Method: Dynamic Insights into Designing a Satellite Radar System," *AIAA Space 2009*, Pasadena, CA, Sep 2009.
Fitzgerald, M.E., and Ross, A.M., "Controlling for Framing Effects in Multi-Stakeholder Tradespace Exploration," *12th Conference on Systems Engineering Research*, Redondo Beach, CA, Mar 2014.

Human-in-the-loop tradespace exploration to update knowledge and beliefs

1) Find "best" designs per mission, 2) Seek "compromise" solutions across missions, 3) Vary mission priorities (weights) and repeat, 4) Vary mission acceptance ranges, 5) Vary mission contexts



Method provides quantitative approach for discovering "best" mission-specific designs, as well as "efficient" (benefit at cost) compromises across missions and stakeholders

Real-time database interaction using tradespace with multiple, simultaneous decision makers allows for feedback between preference updating and "favorite" solutions, allowing for better compromises

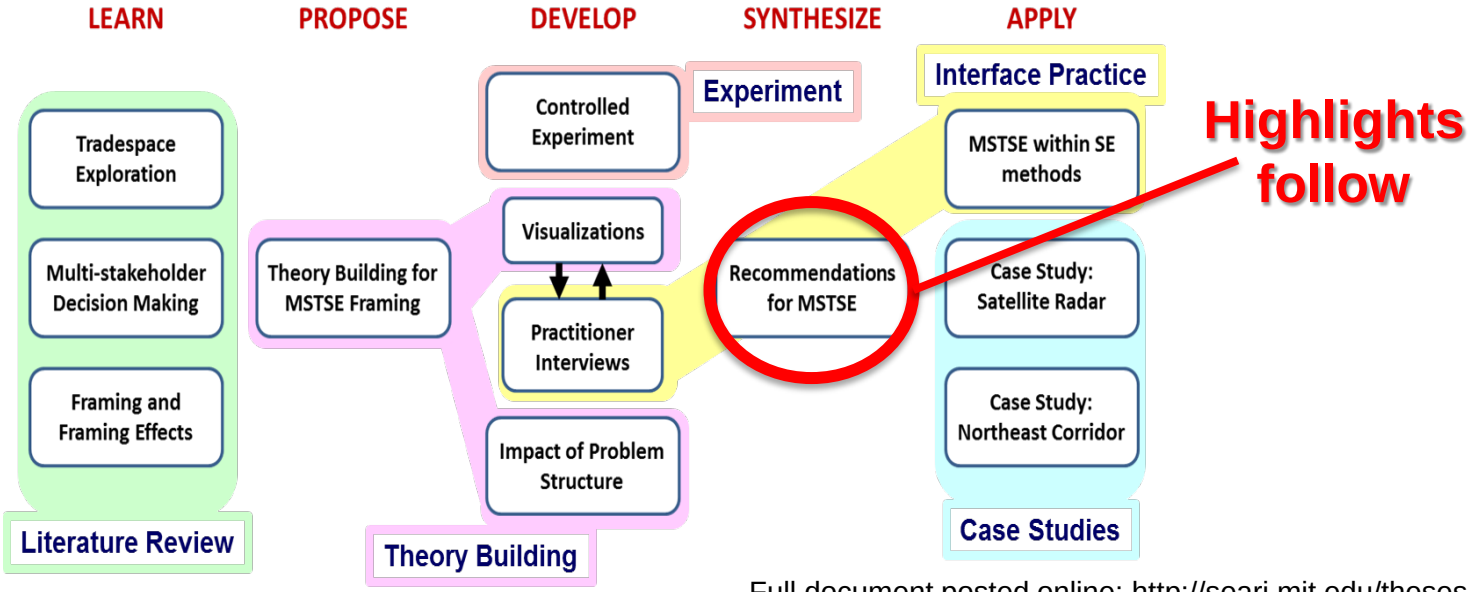
Ross, A.M., McManus, H.L., Rhodes, D.H., and Hastings, D.E., "A Role for Interactive Tradespace Exploration in Multi-Stakeholder Negotiations," *AIAA Space 2010*, Anaheim, CA, Sep 2010.

Framing Tradespace Exploration to Improve Support for Multiple-Stakeholder Decision Making

Research Questions

Matthew E. Fitzgerald, Ph.D. Dissertation, MIT June 2016

1. Are the principles of tradespace exploration (TSE) fundamentally aligned with those of complex, sociotechnical negotiations?
2. Has the evolution of multi-stakeholder tradespace exploration (MSTSE), as an offshoot of single-stakeholder TSE, resulted in unintentional framing effects impacting decision making, and can those effects be controlled?
3. How can MSTSE be effectively incorporated into a design process, such that it best complements the tasks required by practicing engineers and the needs of decision makers?
4. Can –ilities contribute to MSTSE as a potential avenue for creating mutual value and breaking impasses?



Full document posted online: http://seari.mit.edu/theses

Two Types of Framing that Matter

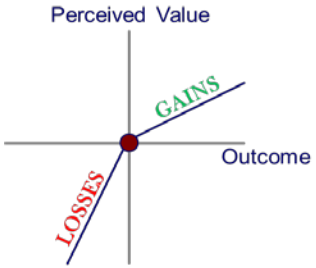
Macro Framing

- Stakeholders may disagree on fundamental purpose for working together
- Communication challenge
  - "Talking past" each other
- Explicit reflection on assumptions that frame decision making can resolve conflicts

Why are we doing this?
What is "fair"?
Do I have interests beyond performance attributes?

Micro Framing

- Cognitive limitations can lead to bad or counterintuitive decisions
  - Bounded rationality
  - Prospect theory
- Framing can also affect the mental decision process
  - Matching mental and constructed models
  - Two-path information processing



Personal beliefs and perspectives

Presentation of information and tasks

Framing Recommendations

Problem Formulation

Structuring the problem and scoping the decision

- Capture Macro Frames
- Create Many Alternatives
- Record Key Elements of Problem Structure
- Determine Each Stakeholder's BATNA

Modeling / Evaluation

Developing and using models to assess designs

- Joint Fact Finding and Collaborative Modeling
- Private Information

Exploration / Analysis

Generating insights from model outputs

- Limit Individual Analysis
- Emphasize the BATNA
- Analyze Relationships
- Refer Back to Macro Frames
- Allow Stakeholders to Change Their Minds

Key Insights

- This research uncovered the importance of social aspects of negotiation (e.g. *the **process** by which decisions are made*, including framing)
- Tradespaces (i.e. large sets of data) can help to generate insights, but the way in which information is interpreted and acted upon requires trust
- The "models," and the interactive exploration of their results, provided an opportunity for targeted collaboration between stakeholders using a common reference (e.g. model/data as boundary object)

Phase	Recommendation	Informal MSTSE
Problem Formulation	Capture macro frames	All of these apply except for capturing macro frames of other stakeholders. Make best estimates for stakeholders' BATNAs and value models.
	Create many alternatives	
	Record key elements of problem structure	
	Determine each stakeholder's BATNA	
Modeling / Evaluation	Joint Fact Finding	Treat modeling as normal TSE
	Private information	
Exploration / Analysis	Emphasize the BATNA	Continue to use BATNA-centric visualizations and analyze relationships, but limit activities related to changing stakeholder value models without their participation.
	Limit strictly individual analysis	
	Analyze relationships	
	Allow stakeholders to change their mind	
	Refer back to macro frames	

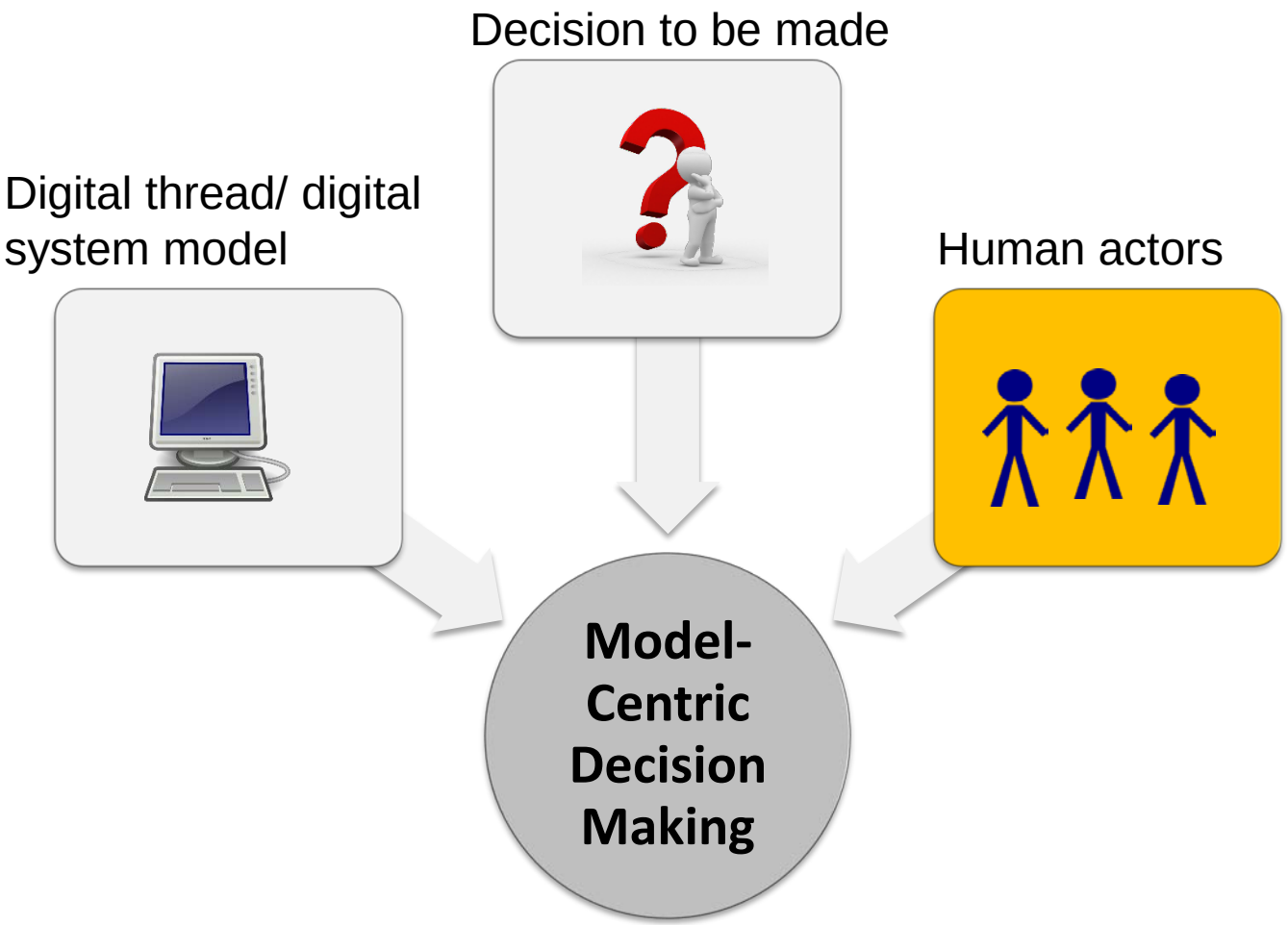
See dissertation for further information

Research Highlights

Model-Centric Decision Making Study

Expected Outcome: Empirical findings on how models inform decisions and how trust in models is engendered

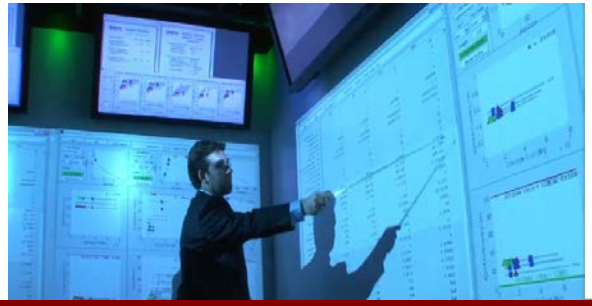
Elements of Model-Centric Decision Making



Who Interacts with Models?

multitude of users, models used for many purposes

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



Interact with models individually and in teams

Interview-Based Study

model-centric decision making

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

- Motivated by increasing need for individuals and teams to make decisions with models and model-generated information
- Examines how decision-makers build trust in models and to what degree models are used to make decisions
- While anecdotal stories of success and failure exist, empirical studies are needed to truly understand the many facets of human decision-making in model-centric engineering
- Expected to generate key insights that may inform current and future practice, and determine areas for more extensive study

- *MIT and DoD IRB Approved*
- *Investigators: German and Rhodes (PI)*

Transparency and Trust

- Variation in how much interaction is desired
- Varied opinions on how much transparency others need/want
- Everyone cares about transparency …but personally may not need to “see the code” , rely on others to do that

I like to be able to get way down in my code…to see the algorithms doing the calculation

I never look at the lowest levels…I have associates working on that

If I have somebody who I trust, as I know their expertise, background … I will trust their model

INTERIM FINDINGS: Common Biases in Model-Centric Decision Making

- **Confirmation Bias**

  Decision makers use models to confirm their preconceived answers ….long hard battle to convince them the model is giving insights into other things that should be considered

- **Model Investment Bias**

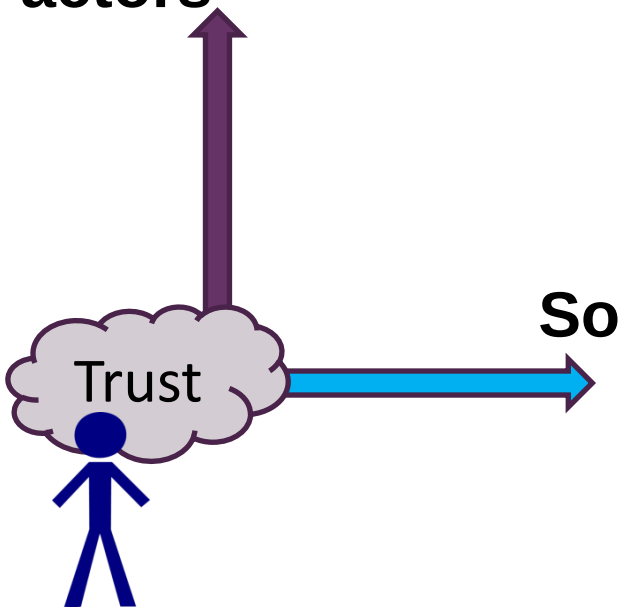
  The more money and time invested in developing the model, the more people have that false sense of security that whatever the model comes up with must be correct

  …we have no choice but to believe the model

INTERIM FINDINGS: Trust Based on Combination of Technological and Social Factors

Technological Factors

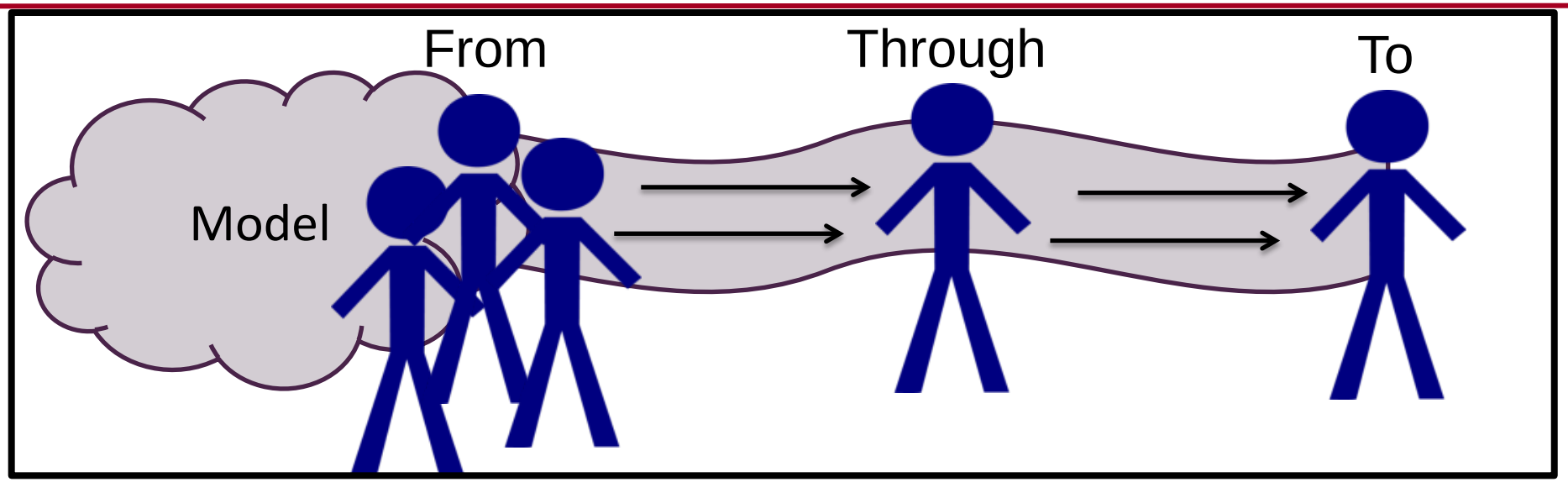
Transparency
Documentation
Uncertainty
Referent Data
Model Code
…

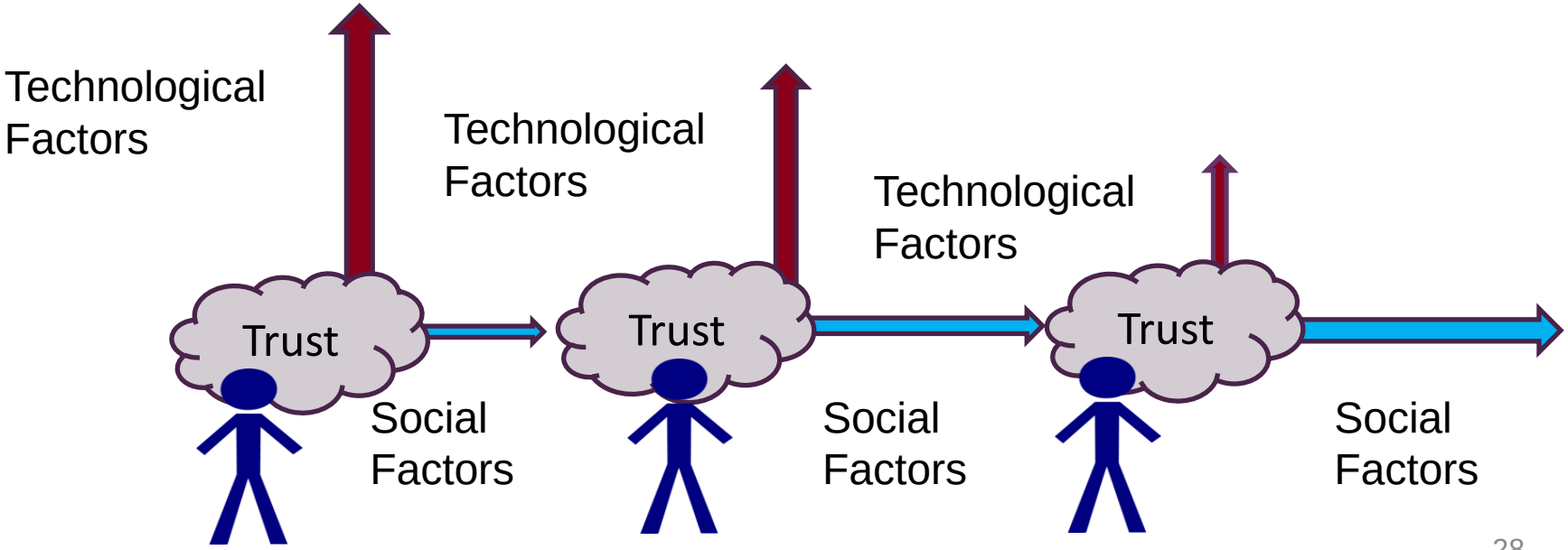


Social Factors

Credibility
Personal Relationships
Word of Mouth
Model Origin
Expert Opinion
…

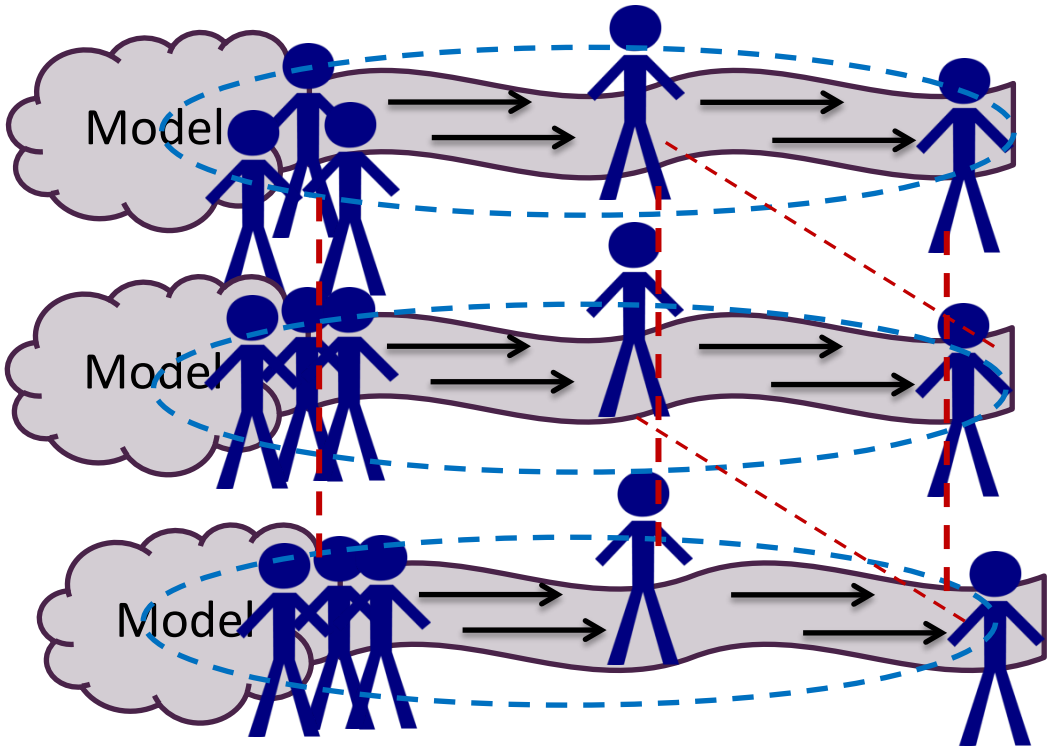
INTERIM FINDINGS: Data suggests many decision flows with three actors





INTERIM FINDINGS : Essential Need for High Interactivity of Human Actors

Buy-in and trust emerge as a result of back-and-forth interactivity between human actors within a decision flow and human actors across layers of decision flows



Research Highlights

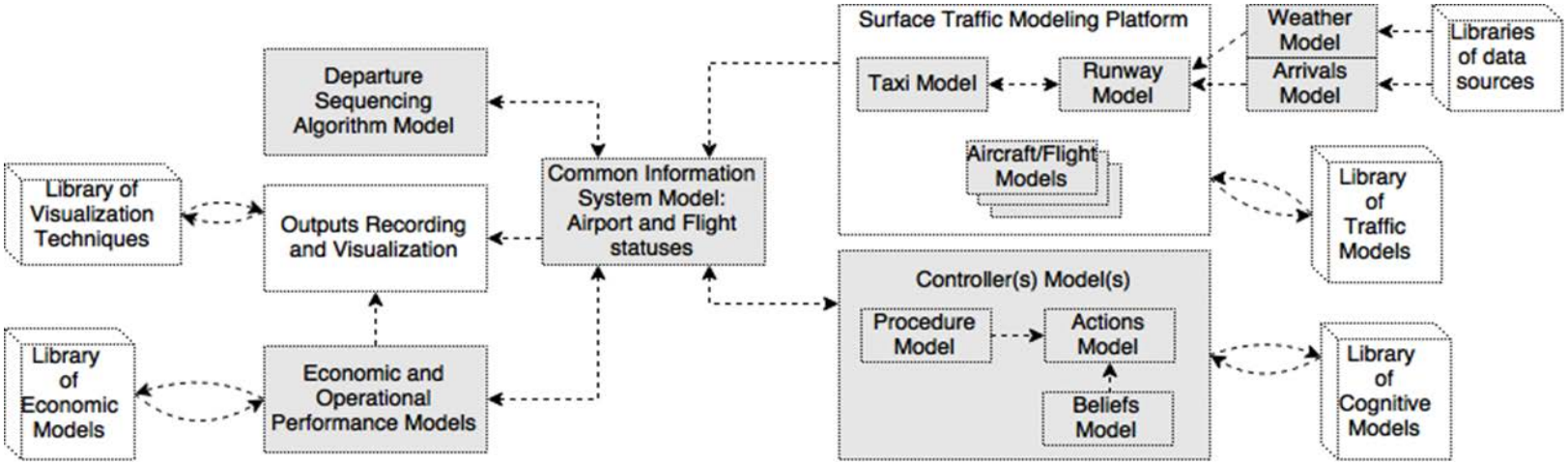
Curation of Model-Centric Environments

Expected Outcome: Recommendations for a model curation leadership role and content for “model pedigree”

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 sources of data? Sources of models?
- What about composability of my models?

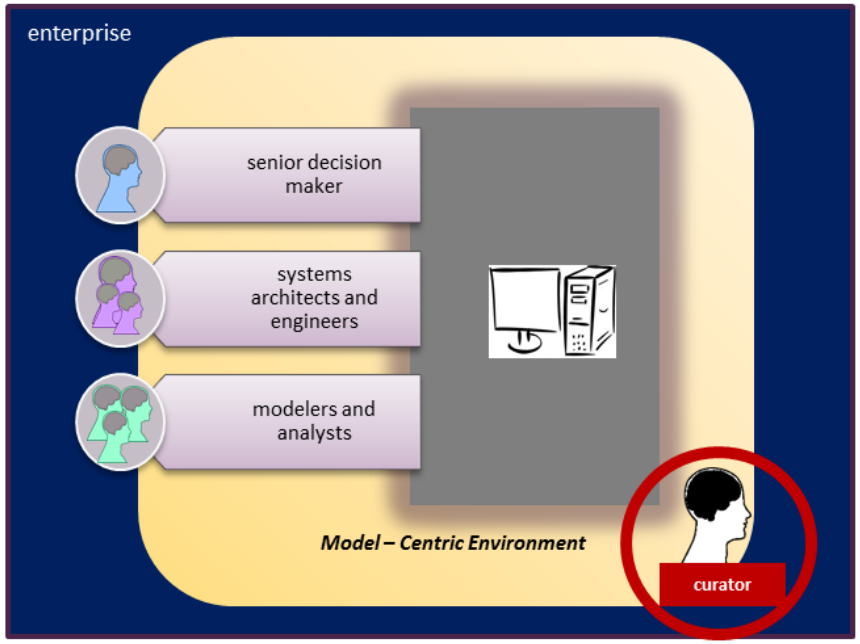
Reymondet, L., Rhodes, D.H. and Ross, A.M., Considerations for Model Curation in Model-Centric Systems Engineering, IEEE SysCon 2016

Model-Centric Environments

specialized role and competencies?

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

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



- Selecting/composing models requires specialized knowledge
- Humans need to be an integral part of the model-centric environment but largely considered as exogenous 'customers'

Model Curation 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/manage model risk and opportunity
- Negotiate borrowing and loan of model assets
- Have deep knowledge of models, model trades, composability...

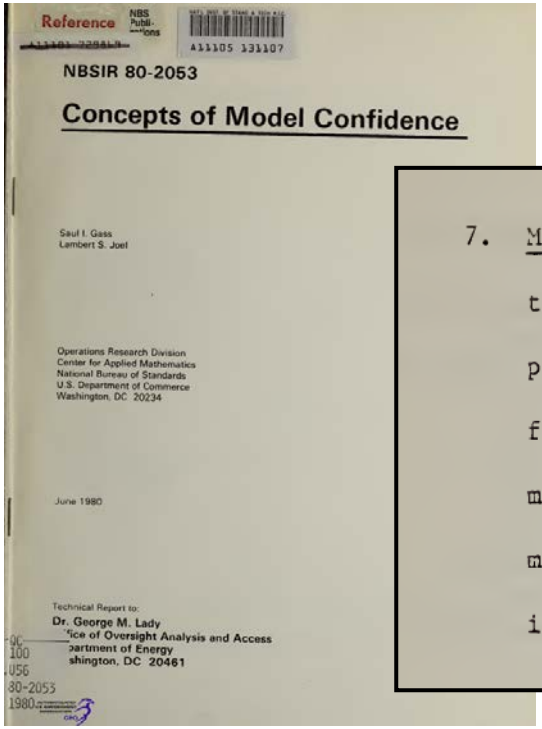
DoD Digital Engineering Working Group SE Digital Engineering Fundamentals (2016)

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

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 2016

Need for Standard Model Pedigree

- Model pedigree not a new idea but little attention in our field
- Gathering information from literature and current discussions
- Plan to engage larger community in standardizing a pedigree



7. Model Demographics--an abstract and description of the model antecedents and developmental process, originators and developers, past users, cost, and current developmental activities. This information should enable the decision maker to determine the model's status with respect to past achievements, theoretical and methodological state-of-the-art, and the expert advice that went into its development.

IMPLICATIONS FOR PRACTICE

Implications for Practice

Humans in Model-Centric Environments

- Ensure awareness/mitigations for cognitive and perceptual biases
- Recognize that trust in models needs to be earned, in context of its use and associated assumptions
- Preserve the "triad" – whether humans or proxy actors (AI/automation)

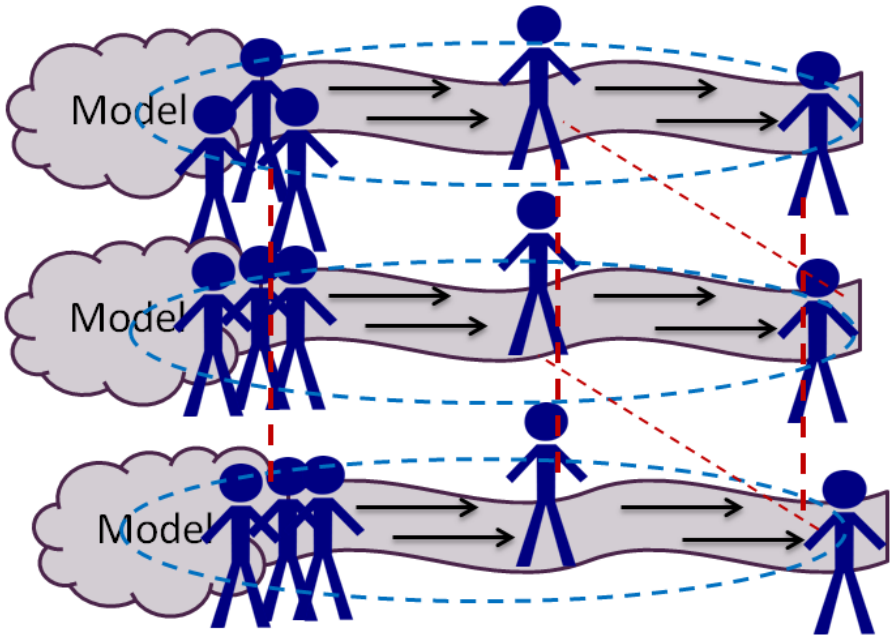
The merging of the user and modeler should cause cautionary alarms to go off

S. Gass, 1990

Implications for Practice

Enabling Human-Model "Teaming"

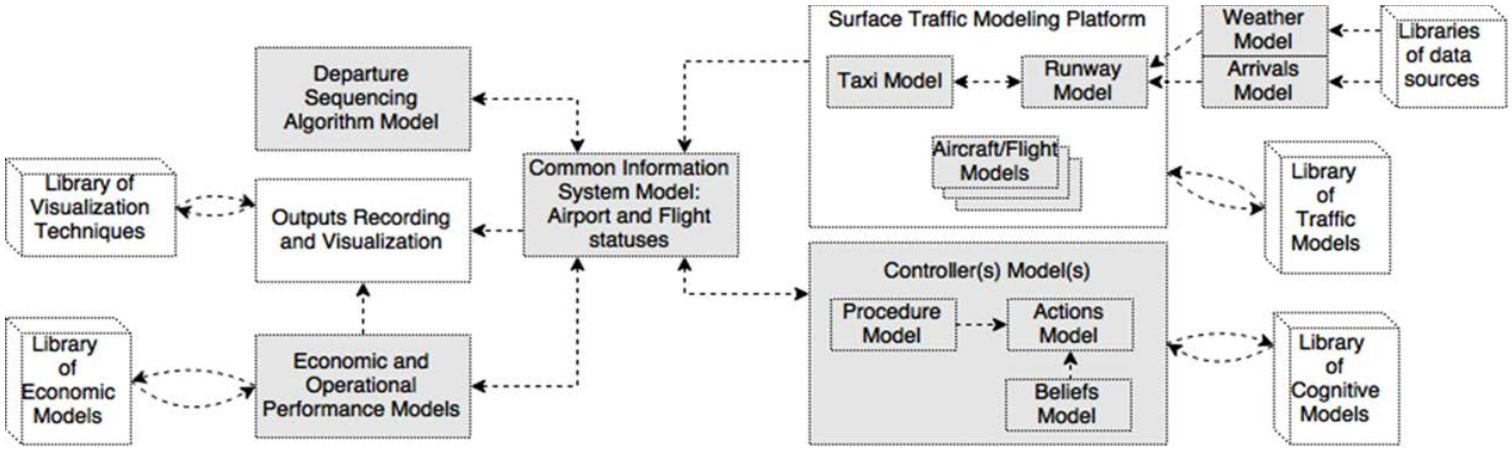
- Eliminate barriers for multi-layer, back-and-forth communications
- Develop immersive, collaboration-enabling methods and tools
- Promote culture of openness and questioning assumptions



Implications for Practice

Curation Leadership Role and "Science"

- Establish strategic enterprise leadership role (beyond CM)
- Mature practices (e.g., model certification/recertification) and specialized competencies (e.g., model composability)
- Standardize and protect model pedigree
- Preserve artifacts and 'voice of experts'



Summary

research goal and underlying assumptions

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*

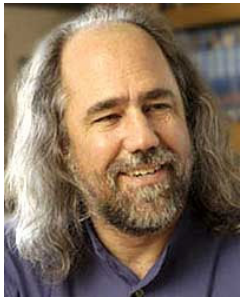
Successful systems acquisition, development and sustainment depends upon effective "human-model teaming"

Interactive model-centric environments necessitate specialized leadership and competencies

Questions?

SERC TALKS

UPCOMING TOPICS:



What is the Self?

Grady Booch, IBM Almaden Research Laboratory

February 1, 2017 | 1:00 pm ET

Can Graphical Models Provide a Sufficient Basis for General Intelligence?

Dr. Paul S. Rosenbloom, Institute for Creative Technologies, University of Southern California

April 5, 2017 | 1:00 pm ET

Thank you for joining us!

Please check back on the SERC website for today's recording and future SERC Talks information!