A Few Words First

Courtesy – Please mute your phone (*6 toggle).

Upcoming Chapter Meetings:

- **2018 Chapter Officer/Director election ballots have been sent – please vote**

- **Nov 9, Architecting Cyber Physical Systems**
  (**THURSDAY not Wednesday, but usual time**)
  Dr. Cihan Dagli, Missouri University of Science & Technology

- **Dec 8, Holiday Social, St. Clair Winery/Bistro, 5:00pm-7:30pm, can bring guest**
  FREE, but register for head count, see Event Listing on Chapter home page

- **Jan 10, System-Aware Security for Cyber Physical Systems**
  Dr. Barry Horowitz, University of Virginia

CSEP Courses by *Certification Training International:*
  Course details | Course brochure
  2017 Course Schedule (close by, but many more locations and dates):
  Oct 30-Nov 3 | Las Vegas, NV
  Feb 26-Mar 2 | Las Vegas, NV
  Apr 02-Apr 5 | Denver

First slide, not recorded but retained in pdf presentation.

And Now - Introductions

Enchantment Chapter Monthly Meeting

INCOSE
ENCHANTMENT CHAPTER

11 October 2017 – 4:45-6:00 pm:

Why is Human-Model Interactivity Important to the Future of Model-Centric Systems Engineering?
  Dr. Donna Rhodes, Massachusetts Institute of Technology, rhodes@mit.edu

Abstract: In our envisioned future, we see engineers, analysts, and decision makers immersed in highly interactive model-centric environments using digital system models as a primary basis for system decisions. While significant progress on modeling languages, modeling practices, and modeling methods has been achieved, insufficient attention has been given to the necessary interactivity between humans and models. Given emerging modeling toolsets, availability of powerful computational resources, and autonomous decision-aiding, the human role in relationship to models must be re-examined. In this talk, Dr. Rhodes will share findings and insights from ongoing research on human-model interactivity. The research is motivated by the need to better understand and enable effective "human-model teaming", while drawing from advancements in data science, visual analytics, and growing knowledge of complex systems. Ongoing areas of inquiry include: how and why individuals interact within model-centric environments, facets of human interaction with visualization tools and large data sets, and underlying fundamentals such as the role of trust in model-centric decision making. Emerging implications for practice extending from the interim findings are discussed.

Download slides today-only from GlobalMeetSeven file library or anytime from the Library at www.incose.org/enchantment
NOTE: This meeting will be recorded

Today's Presentation

Things to Think About

How can this be applied in your work environment?

What did you hear that will influence your thinking?

What is your take away from this presentation?

Speaker Bio

Donna Rhodes is a principal research scientist in the MIT Sociotechnical Systems Research Center, and co-founder and director of MIT's Systems Engineering Advancement Initiative (SEAri).

She teaches and advises graduate students across multiple programs at MIT, and is principal investigator for numerous sponsored research projects.

Her research includes innovative methods for architecting and design of complex systems and enterprises, human-model interaction, model-centric decision making, and empirical studies of engineering systems practice.

Prior to MIT, Dr. Rhodes held technical and senior management positions at IBM Federal Systems, Lockheed Martin, and Lucent.

She has been very involved in the evolution of the systems engineering field, and is a Past President and Fellow of the International Council on Systems Engineering (INCOSE).

She received her M.S. and Ph.D. in Systems Science from the T.J. Watson School of Engineering at Binghamton University.

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

October 11, 2017

Dr. Donna H. Rhodes

Systems Engineering Advancement Research Initiative (SEAri)
Massachusetts Institute of Technology
rhodes@mit.edu

**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?

Humans need to be endogenous to interactive model-centric environments …

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

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

Interactive Model-Centric Systems Engineering (IMCSE)

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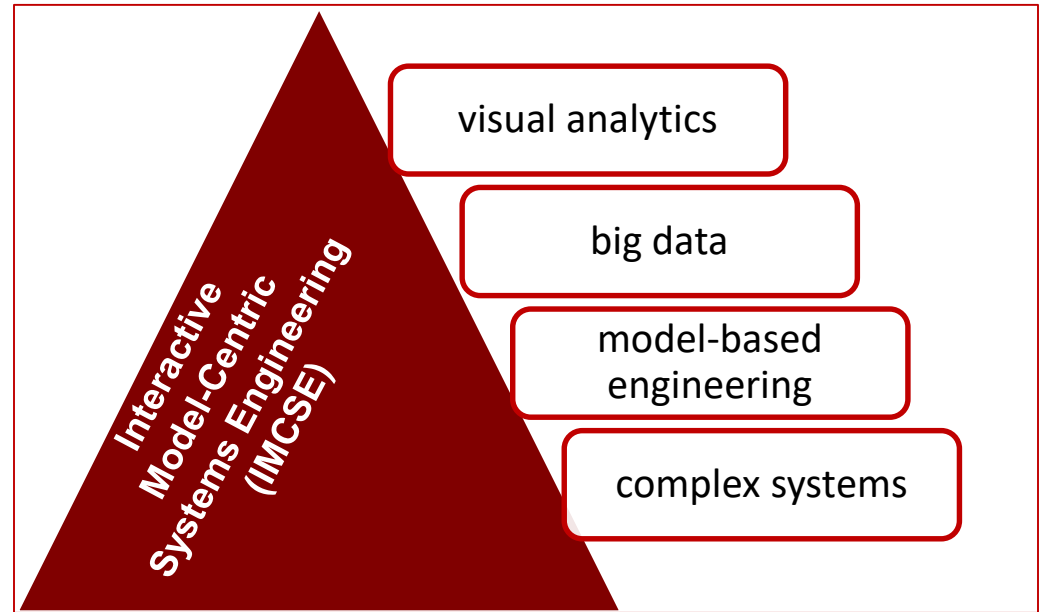
Develop transformative results through
enabling intense human-model interaction, *to rapidly conceive of systems and interact with models in order to make rapid trades to decide on what is most effective given present knowledge and future uncertainties, and practical given resources and constraints*

Rhodes, D.H., and Ross, A.M., IMCSE **SERC Reports**: Phase 1, Phase 2, Phase 3, Phase 4, www.sercuarc.org

While progress has been made on model-based engineering

… there has been relatively little investigation of the complexities of **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 interactivity of humans and models be made more effective?

- **Human-Systems Integration (HSI)** focuses on humans and operational systems, while models are abstractions of reality.
- **Human-Computer Interaction (HCI)** focuses on designing computer interfaces for effective human use.
- **Visual Analytics** is the science of analytical reasoning facilitated by visual interactive interfaces." (Thomas and Cook, 2005)

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) has informed our research activities

Research Highlights
INVESTIGATING HUMAN-MODEL INTERACTION

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

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

abstraction

autonomy

automation bias – complacency – mode error – disassociation …
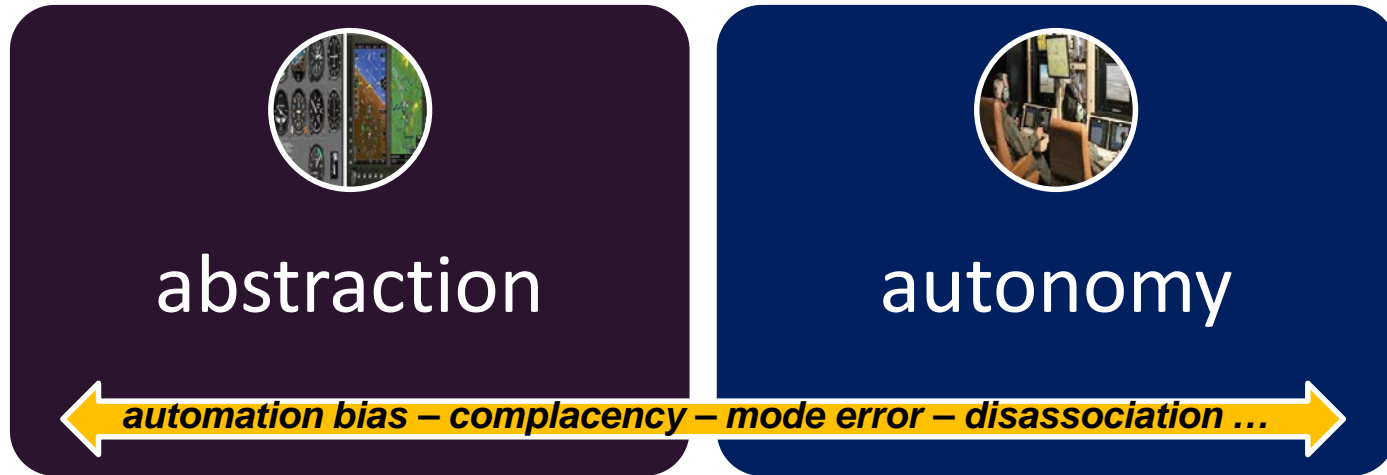
Glass Cockpit -- Analogy Case Study

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

prototype visualization tool

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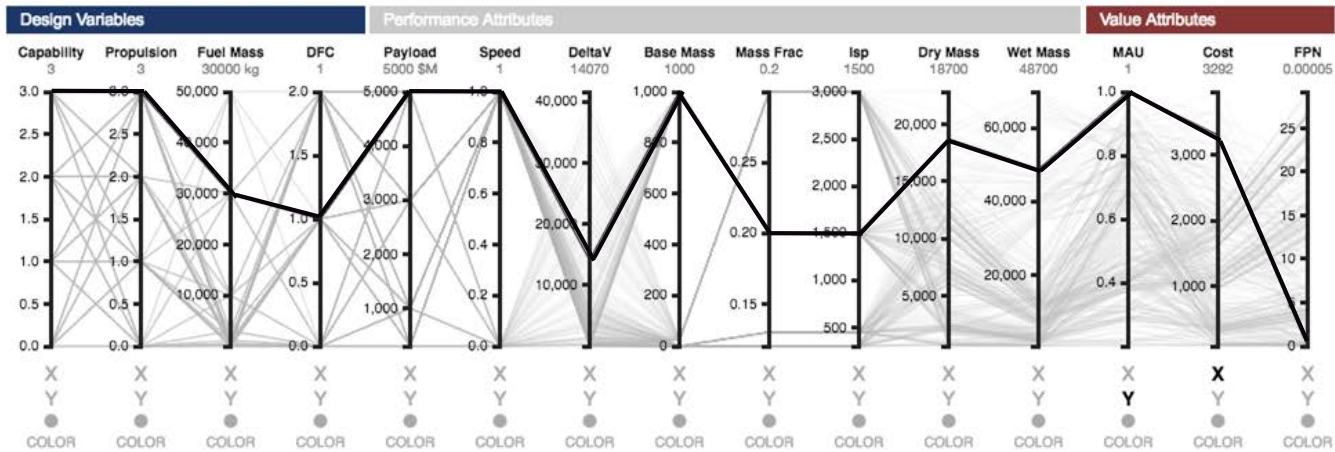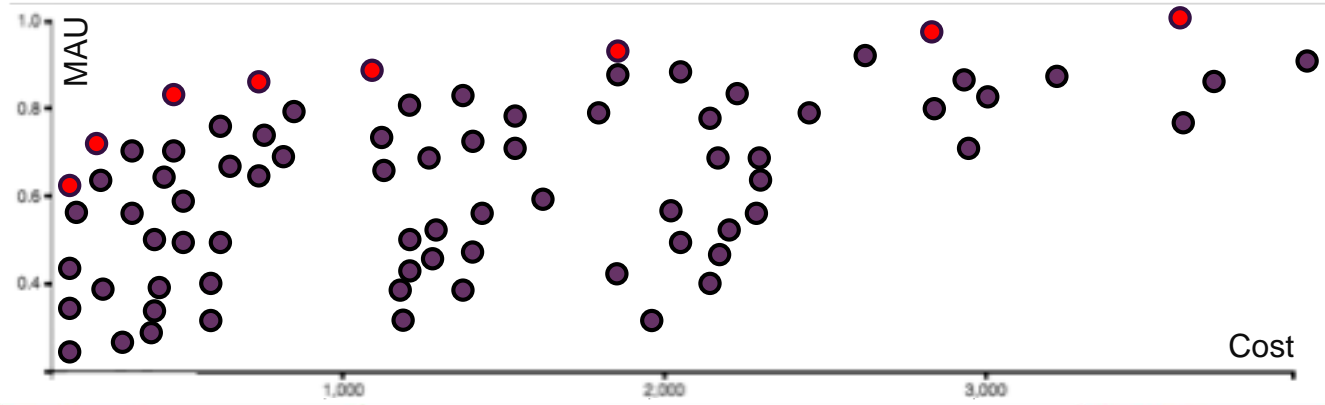
Curry, M, and Ross, A.M., "Designing System Value Sustainment using Interactive Epoch Era Analysis: A Case Study for On-orbit Servicing Vehicles," 14th Conference on Systems Engineering Research, Huntsville, AL, March 2016

Curry (2017) MIT Doctoral Thesis

Q#3: Does interactive visualization improve design problem decision-making and, if so, what are the relative contributions of representation, interaction or other factors to user performance?

Examples of results:

- **Accuracy**
  - Graphs improve accuracy on trend observation tasks
  - Interaction improves accuracy on sorting tasks

- **Speed**
  - Adding interaction decreases completion time
  - Adding a graph decreases completion time for trend tasks

- Objective of experiment to determine how well subjects complete tasks for a simplified car design problem
  - Must compromise on optimality to satisfy 4 customer segments
  - Emulates a typical multi-epoch analysis problem

- 104 subjects recruited via Amazon's Mechanical Turk (Mturk) online crowd sourcing marketplace
  - 26 participants per treatment group

		Visualization	
		No	Yes
Interaction	No	A	B
	Yes	C	D
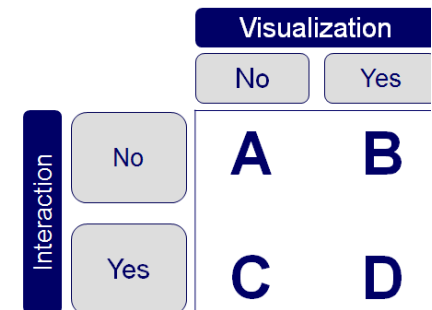
4 Experimental treatment groups

amazon mechanical turk

For full results of the experiment, see MIT Doctoral Thesis of Michael Curry, 2017 (seari.mit.edu)

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**MIT
Course Experiment**

Objective
compare how individuals make decisions when presented with similar information from computer models and human experts

(ref: German, 2017)

When faced with conflicting recommendations from human and computer sources of roughly equivalent efficacy, which recommendation are you more likely to trust?
(40 responses)

- Human recommendation
- Computer recommendation
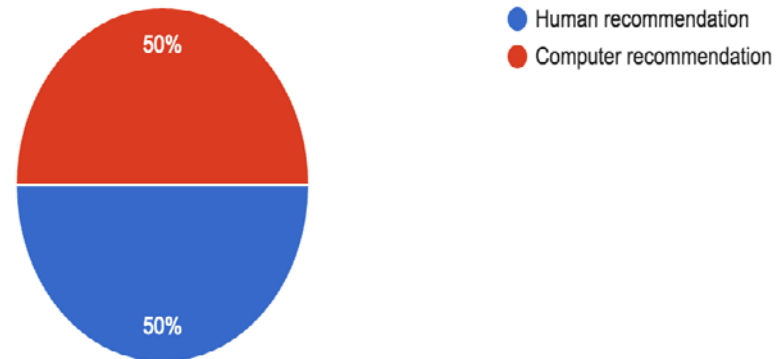
Small studies and discussions with experts suggest trust as a central theme for investigation

Model-Centric Decision Making Study

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

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

SYSTEMS ENGINEERING
Research Center

SEA RI
Systems Engineering Advancement
Research Initiative

Exploratory study 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)*

German, E.S., and Rhodes, D.H., "Model-centric decision-making: exploring decision-maker trust and perception of models" 15th Conference on Systems Engineering Research, Torrance, CA 2017

- Three actor decision flow

- Importance of intercommunication

- Transparency and trust

- Understanding of assumptions and uncertainty

- Technological and social factors influencing trust

- Importance of model-related documentation

- Factors limiting model-centric decisions

- Using models as primary versus supplementary

- Model pedigree

- Non-advocate role in reviews

- Model investment bias and confirmation bias

- Real-time interaction with models

- Viewing humans as endogenous

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

- **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

Technological Factors
Transparency
Documentation
Uncertainty
Referent Data
Model Code
…

Trust
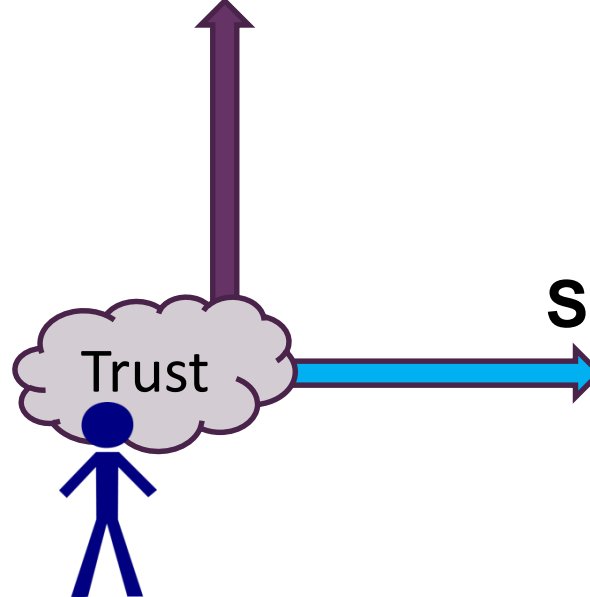
Social Factors
Credibility
Personal Relationships
Word of Mouth
Model Origin
Expert Opinion
…
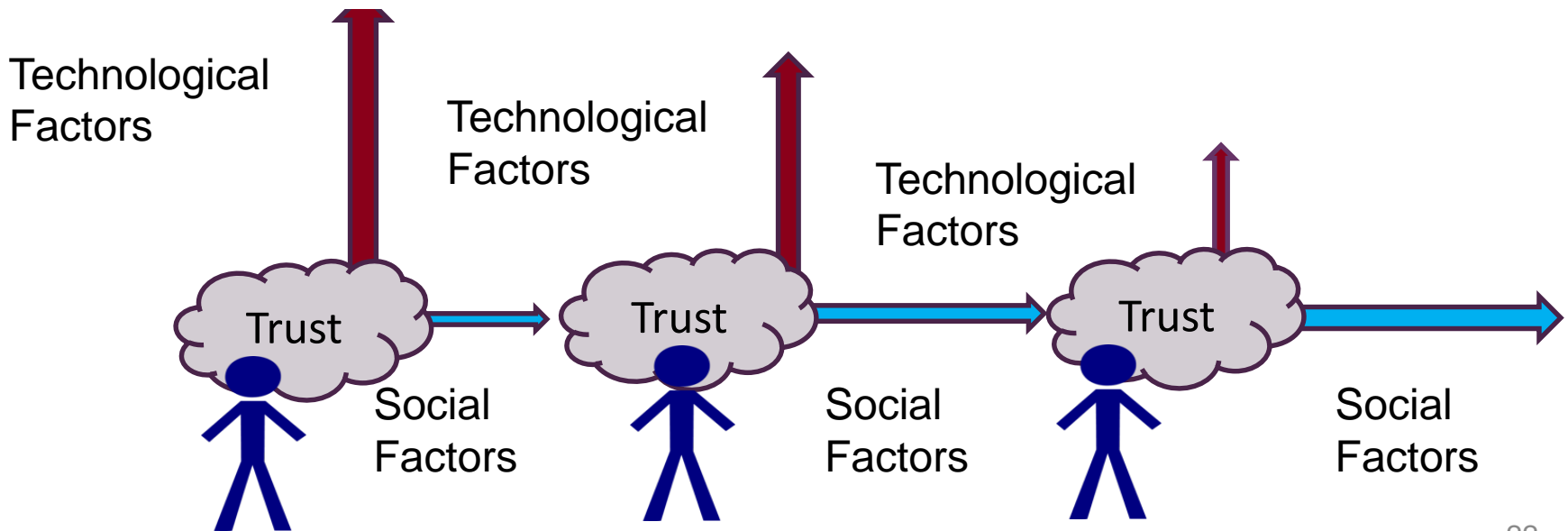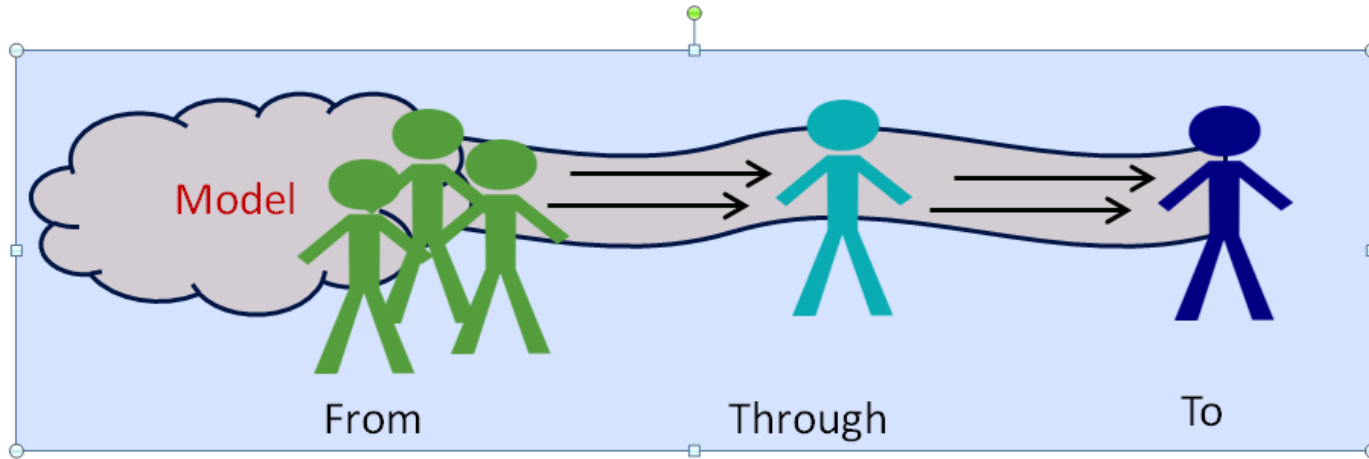
Buy-in and trust emerge as a result of back-and-forth interactivity between human actors within a decision flow and human actors across layers of decision flows
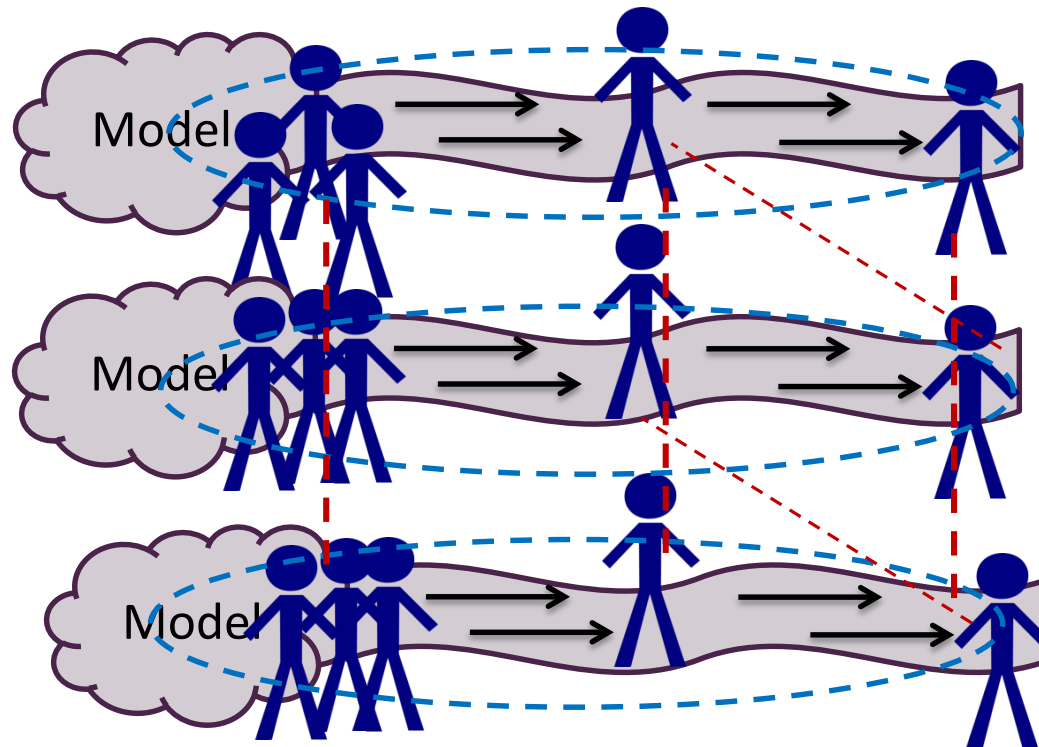
1. designing models for human use

2. using models in decision-making

3. sociotechnical considerations

4. context and assumptions

5. transparency and trust

6. mitigating biases

- *Heuristics encapsulate insights and strategies discovered by experts though experience*

- *Experts apply these intuitively*

- *Heuristics can be used to educate and guide practice of novices, as they learn through their own experiences*

- *Validated heuristics inform the development of policy and practices*

Mitigating Biases

Increasing speed of decision-making implies a decrease in time spent analyzing a problem that in turn increases chance of biased judgment

- Model-centric environments enable interaction to build intuition and speed decision-making, but may increase bias (e.g., automation bias)

- Complex problems may require focused attention and analysis that take time to fully understand in order to develop an accurate mental model of the situation

- While faster decisions are desired if effective, speed itself may set people up for failure by encouraging them to rely upon fast and intuitive, yet bias-susceptible, judgment, rather than more cognitively demanding rational and analytical thought processes

Research Highlights
Curation of Model-Centric Environments

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

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"
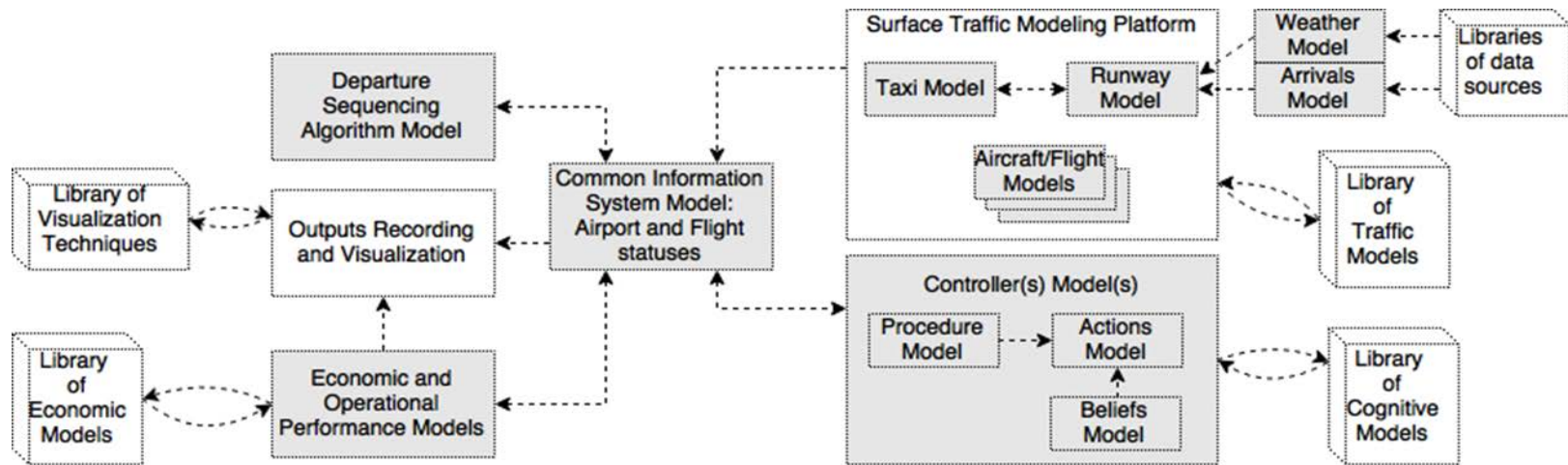

- What models? what platforms? analysis techniques?
- What model trades?
- Where are sources of data? Sources of models?
- What about composability of my models?

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'
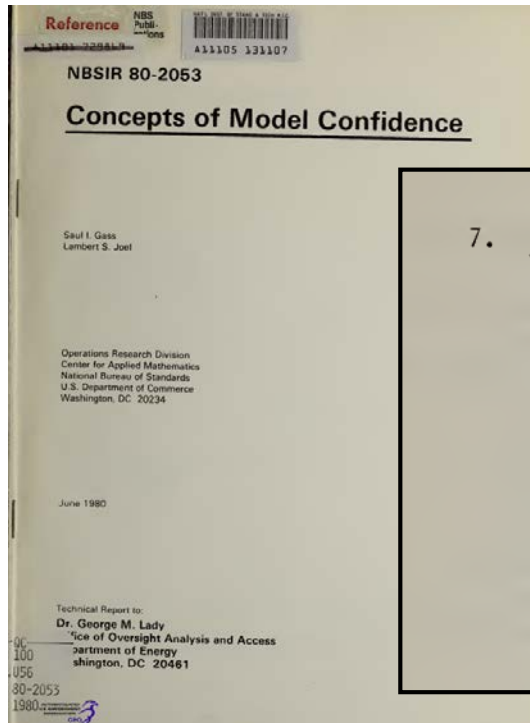
Model Curation Leadership Role
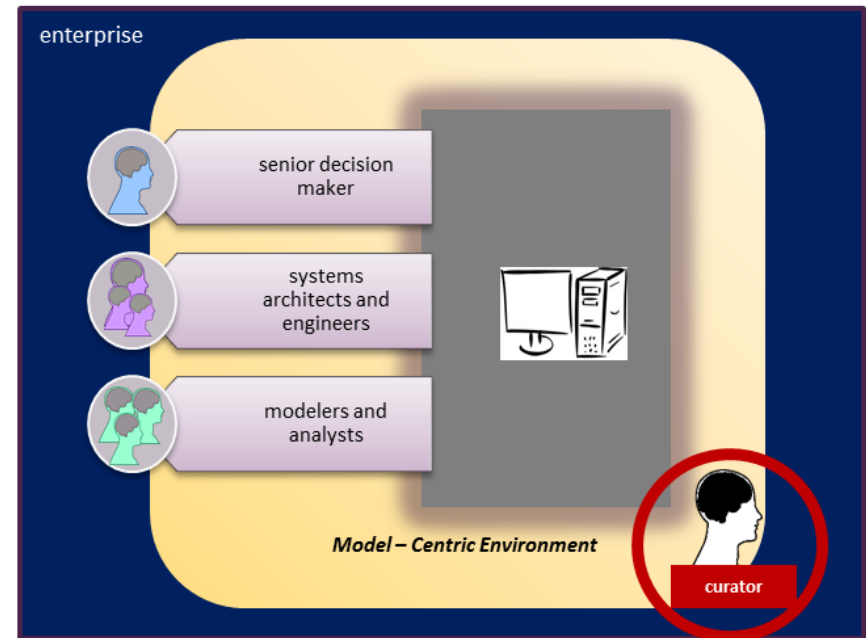
Envisioned role includes...

- Process-owner for model-centric environments
- Manages data/model repositories, data rights, IP
- Protects model 'pedigree'
- Guide selection of models and modeling platforms
- Owns/manages model risk and opportunity
- Negotiates borrowing and loan of model assets
- 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

Reference
NBS Publications

A11105 131107

NBSIR 80-2053

Concepts of Model Confidence

Saul I. Gass
Lambert S. Joel

Operations Research Division
Center for Applied Mathematics
National Bureau of Standards
U.S. Department of Commerce
Washington, DC 20234

June 1980

Technical Report to:
Dr. George M. Lady
Office of Oversight Analysis and Access
Department of Energy
Washington, DC 20461

QC
100
.U56
80-2053
1980

> 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.
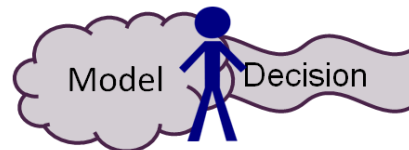
Some Implications for Practice…

- Ensure awareness/mitigations for cognitive and perceptual biases

- 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

Model   Decision

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
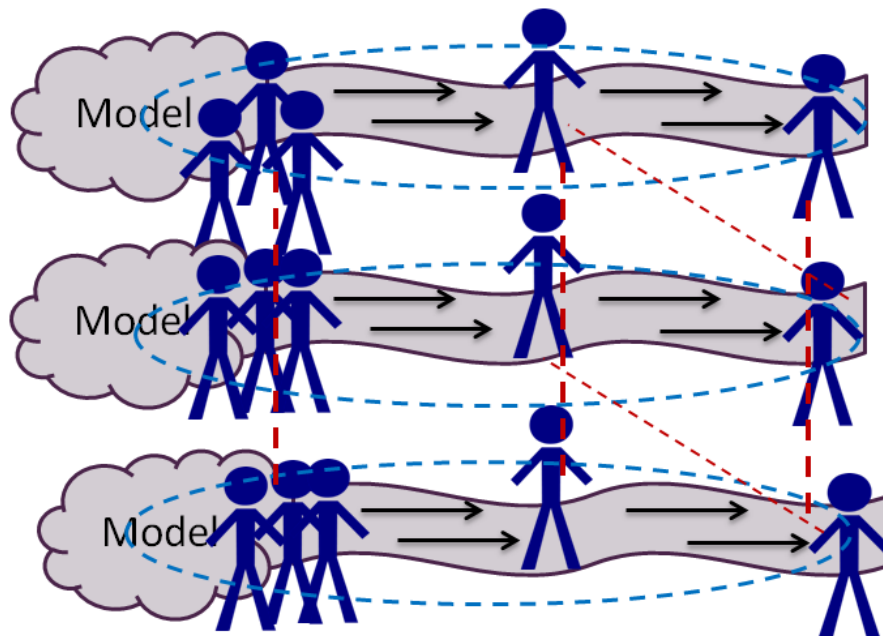
## *Model-centric environments require special leadership and skills*

- 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'
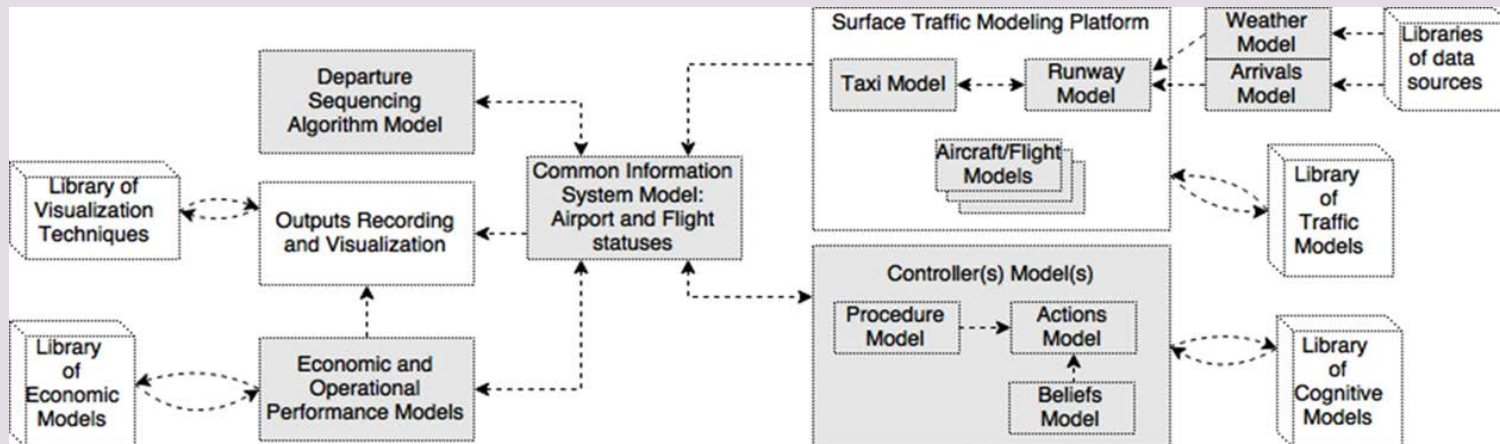
- Empirical data (vs anecdotal evidence) on human-model interaction "state of practice" (based on 30 expert interviews)

- Heuristics encapsulate human-model interaction strategies for use in education, training and practice guidelines

Confirms need for further investigation ….

—Patterns of why, when and how various stakeholders interact with models

—Understanding critical touchpoints for human to interact with model in decision process

—Determining where human interaction is preferred over augmented intelligence
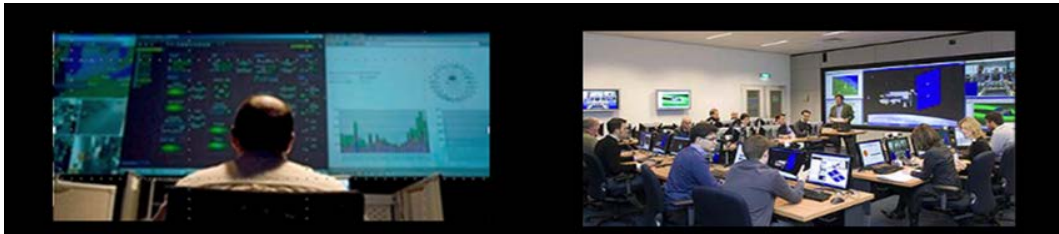
Effective interactivity makes models useful at the speed of human decision making

rhodes@mit.edu

seari.mit.edu   www.sercuarc.org

Today's Presentation

Things to Think About

How can this be applied in your work environment?

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What is your take away from this presentation?

Please

The link for the online survey for this meeting is

www.surveymonkey.com/r/2017_10_MeetingEval

www.surveymonkey.com/r/2017_10_MeetingEval

Look in GlobalMeet chat box for cut & paste link.

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The library page at: **www.incose.org/enchantment**.

Recording will be there in the library tomorrow.