SYSTEMS ENGINEERING Research Center

SEAri Systems Engineering Advancement Research Initiative

Model-Centric Decision Making

INCOSE IW MBSE Workshop 2017

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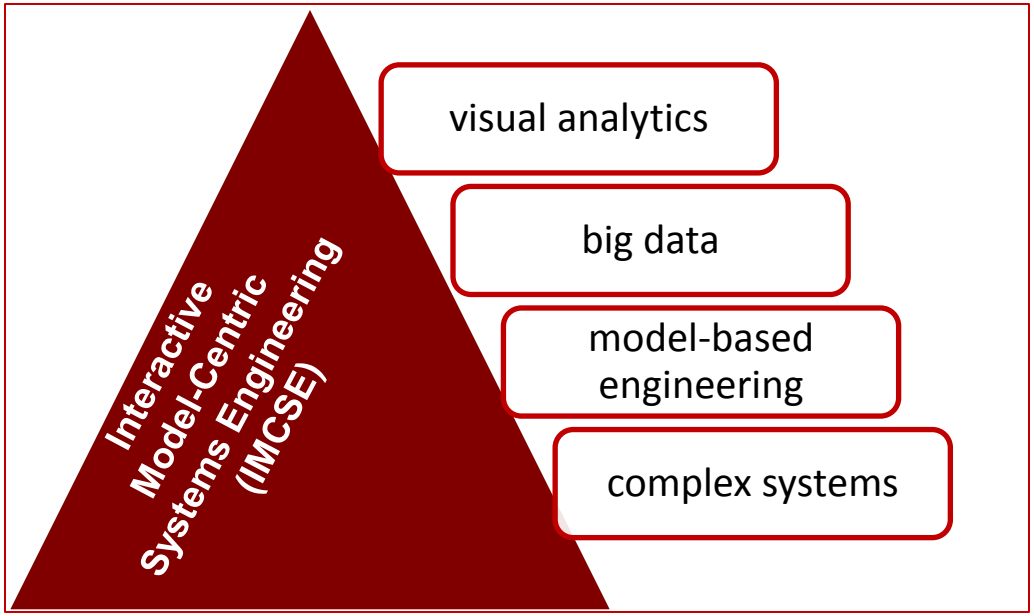
IMCSE Research Program

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

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



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, www.sercuarc.org

Areas of Inquiry

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?

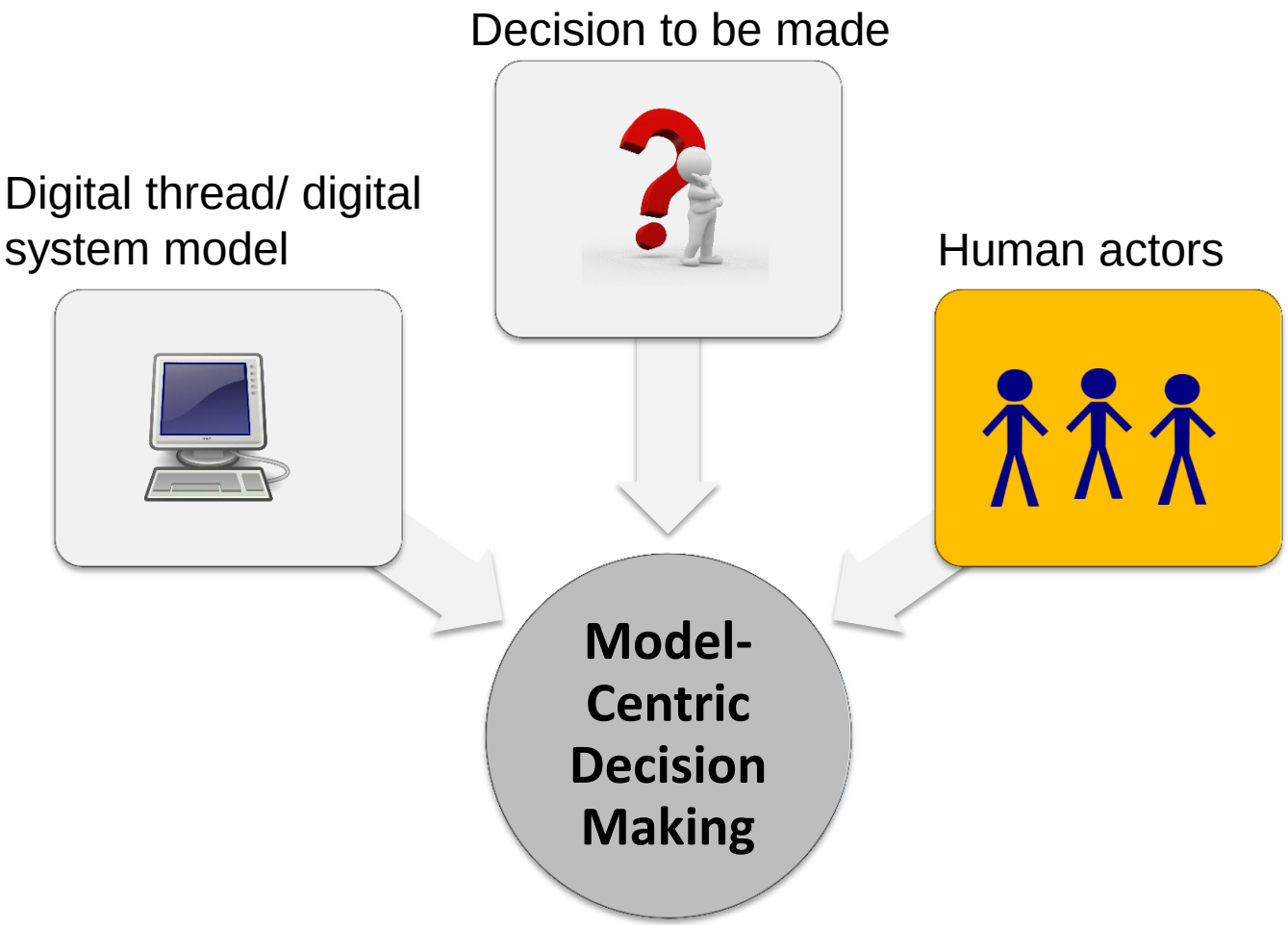
- **Human-Systems Integration (HSI)** focuses on humans and operational systems, while models are abstractions of reality.
- **Human-Computer Interaction (HCI)** focuses on designing computer interfaces for effective human use.
- **Visual Analytics** is the science of analytical reasoning facilitated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

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



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)*

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

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

INTERIM FINDING:

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 FINDING: 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**

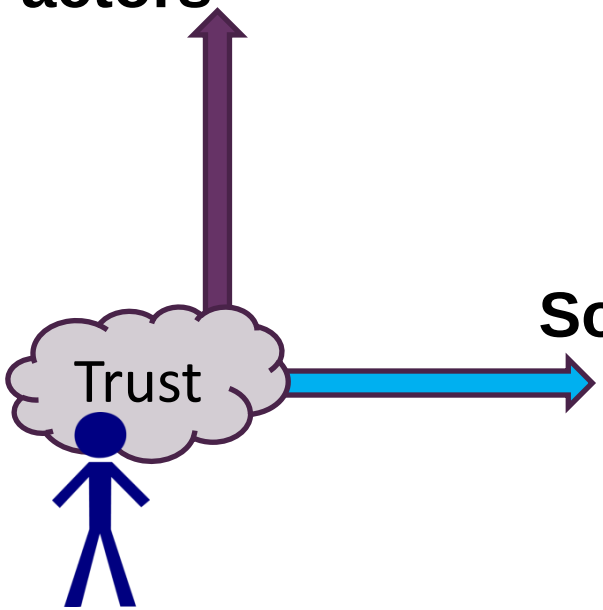
  The more money and time invested in developing the model, the more people have that false sense of security that whatever the model comes up with must be correct

  …we have no choice but to believe the model

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

Technological Factors

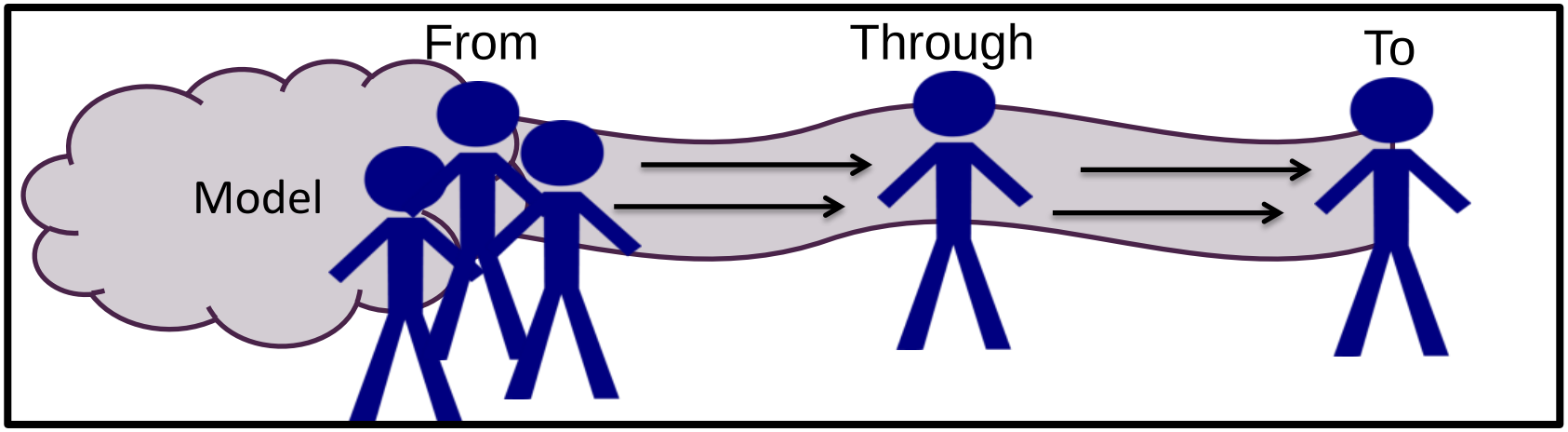
Transparency
Documentation
Uncertainty
Referent Data
Model Code
…

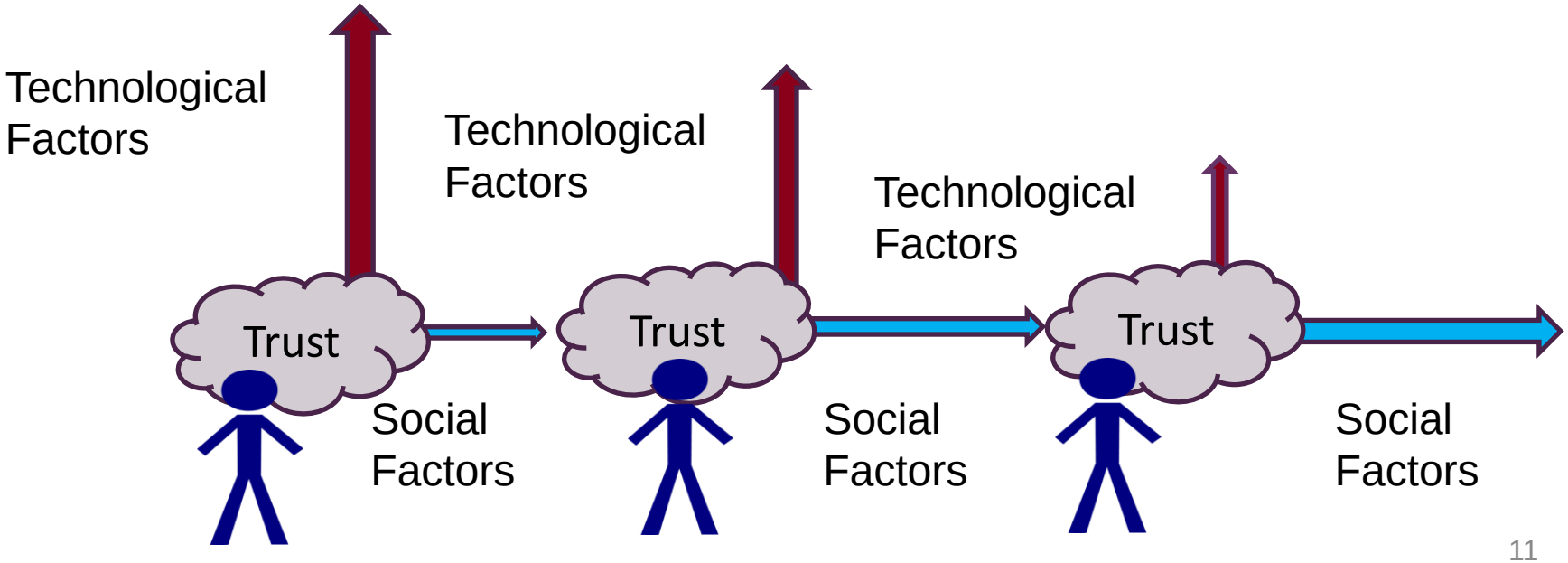


Social Factors

Credibility
Personal Relationships
Word of Mouth
Model Origin
Expert Opinion
…

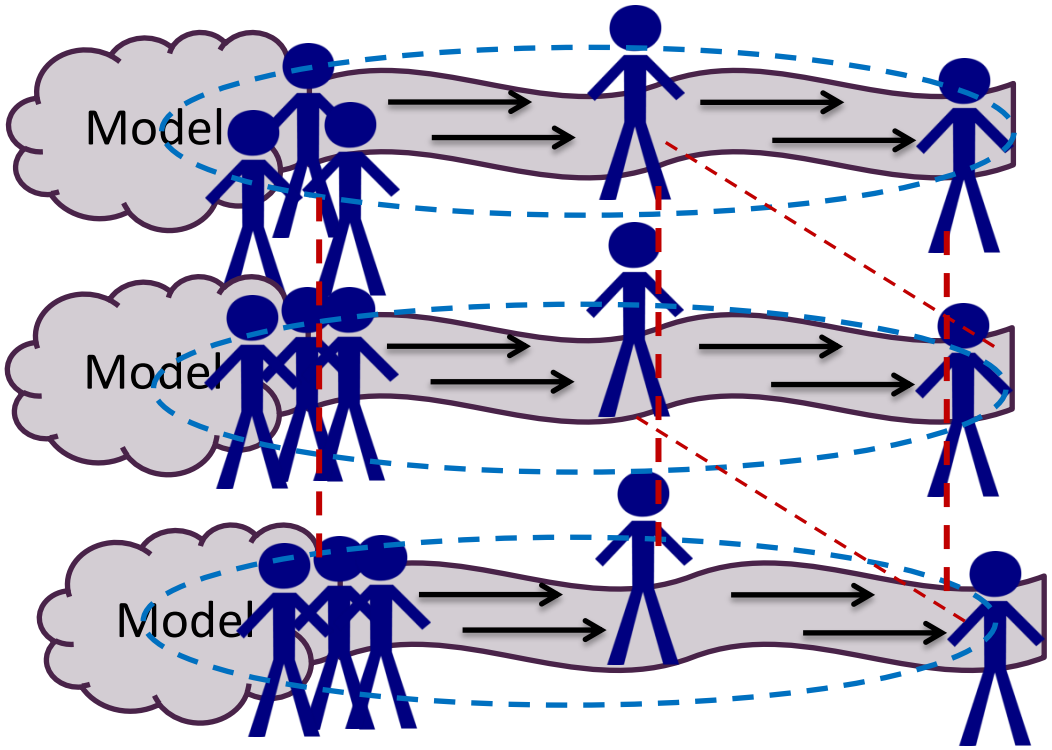
INTERIM FINDING: Data suggests decision flows with three actors





INTERIM FINDING: 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



INTERIM FINDING: Preference for Human Knowledge over Encoded Knowledge

Why did I name my model "Fred"?

No, it's not an acronym… I named it Fred because whenever I built this model everybody still said go ask Fred, we trust Fred to have the right answer.

I was tired of people questioning my model, so I named it Fred.

Now I say "well, Fred says …." and people stopped asking questions about the information, but I was really taking about my model.

Research Highlights

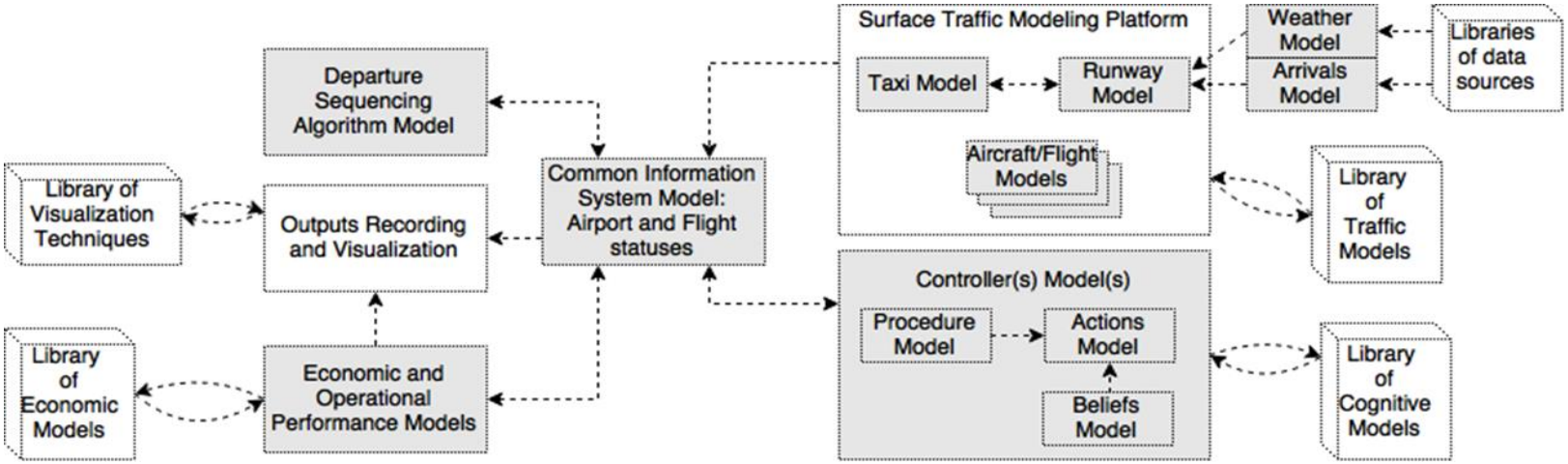
Curation of Model-Centric Environments

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?

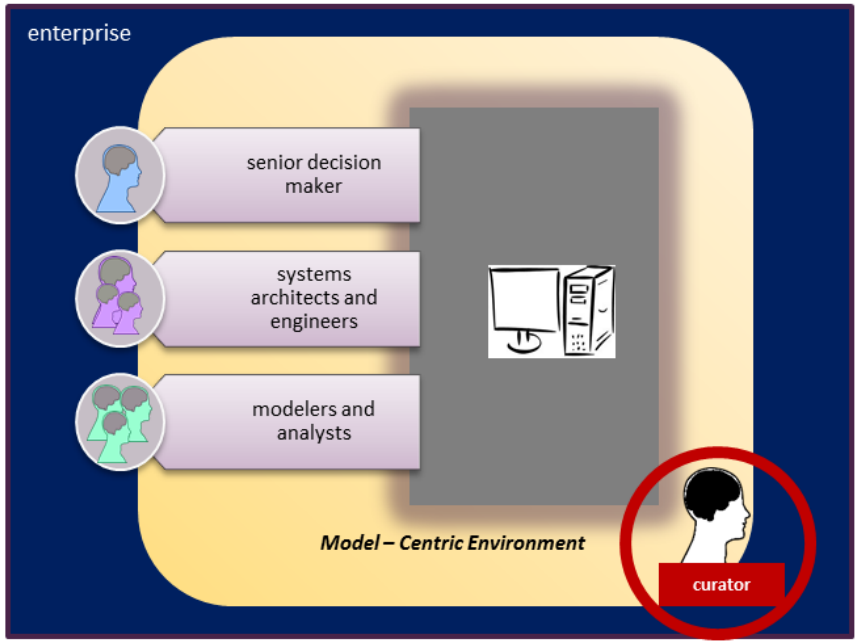
Reymondet, L., Rhodes, D.H. and Ross, A.M., Considerations for Model Curation in Model-Centric Systems Engineering, IEEE SysCon 2016

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
- 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…

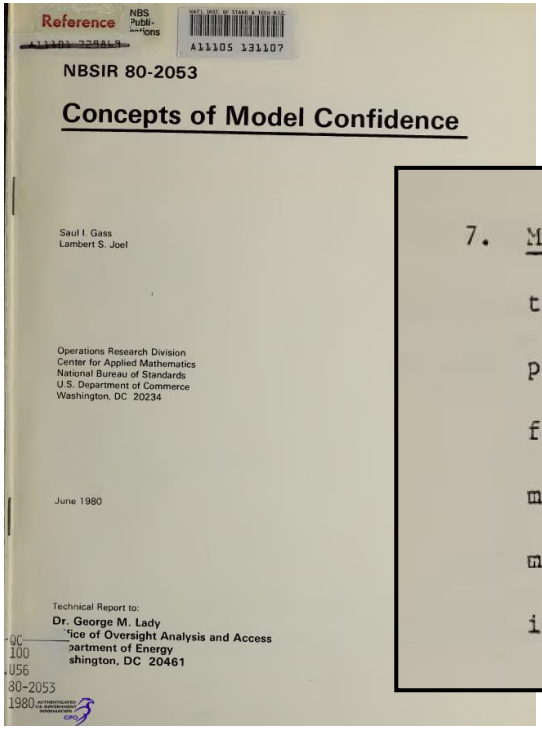
DoD Digital Engineering Working Group SE Digital Engineering Fundamentals (2016)

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



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…

Implications for Practice

Humans in Model-Centric Environments

- Ensure awareness/mitigations for cognitive and perceptual biases
- Preserve the "triad" – whether humans or proxy actors (AI/automation)

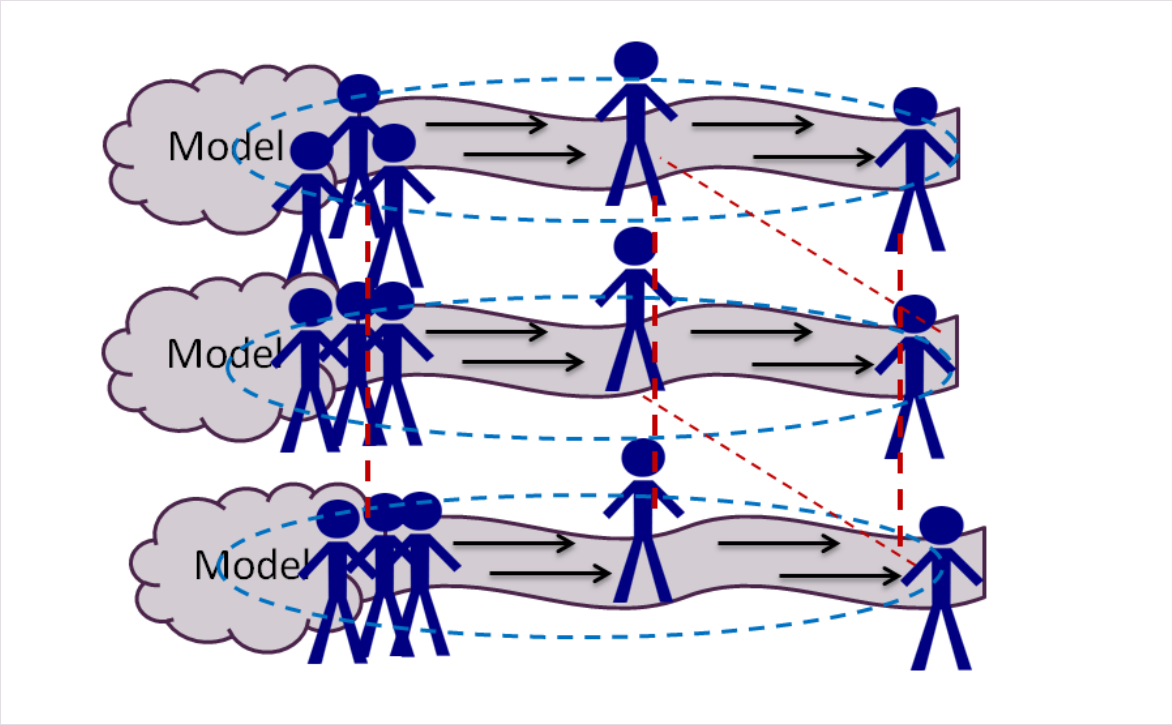
The merging of the user and modeler should cause cautionary alarms to go off

S. Gass, 1990

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

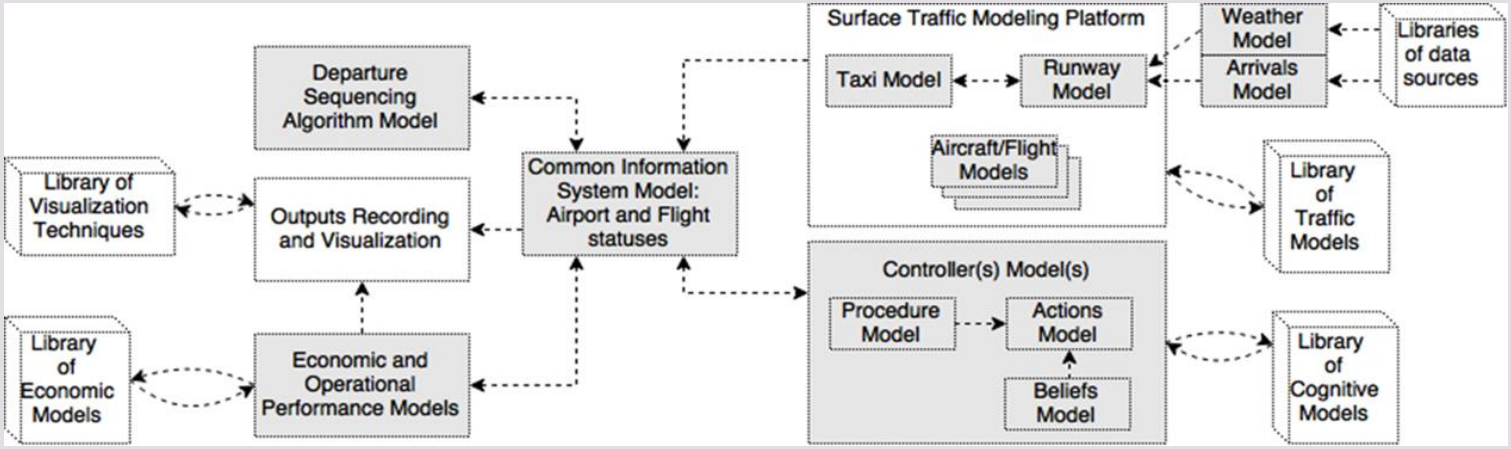


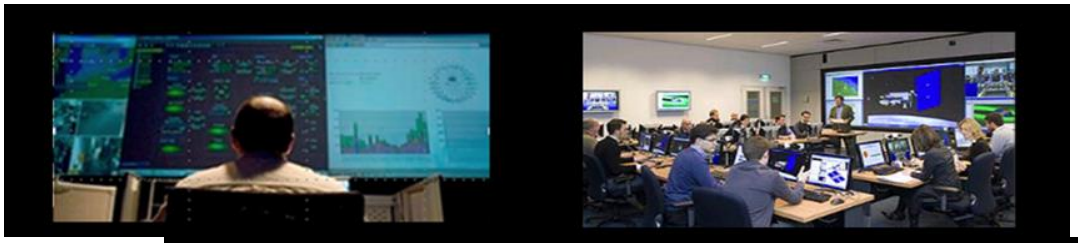
Implications for Practice

Curation Leadership Role and "Science"

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'





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

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