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Problem. Solved.

Tradespace Analysis for Policy: the OpenSEAT approach

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The OpenSEAT Initiative

- Open-source Systems Engineering and Architecting Toolset (OpenSEAT)
  - A GTRI internal effort to explore alternative use cases for model-based tradespace exploration and decision analysis
    - Engineered Resilient Systems: Context-driven tradespace and decision analysis tools
    - Data Analytics: Model-based data organization & visualization
    - Complex Systems: Conceptual modeling and Multi-model integration
    - Knowledge Management: organizing scientific or design knowledge as a conceptual model over time
- Specific application to Policy implications in complex multi-level sociotechnical enterprises

Historical Development Context

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Approximate Timeline showing historical context for the development and maturation from Desktop to Browser to Web Applications for GTRI's ***Systems Engineering Frameworks***

2007 2010 2011 2012 2013 2014 2015

Socrates — Browser-based strategic portfolio planning tool for USAF

MPC — Excel-based series of tools for configuring the Marine Personnel Carrier, and supporting source selection

FAEWSET — Browser-based tool for pre-AoA JCIDS analysis to configure Integrated Electronic Warfare System architecting options

FACT — Genesis of extending prior work into a web-based Systems Engineering tool for collaborative use

ITAP — Initial workshop support extended into MPT concept maturation for evaluation of -ilities

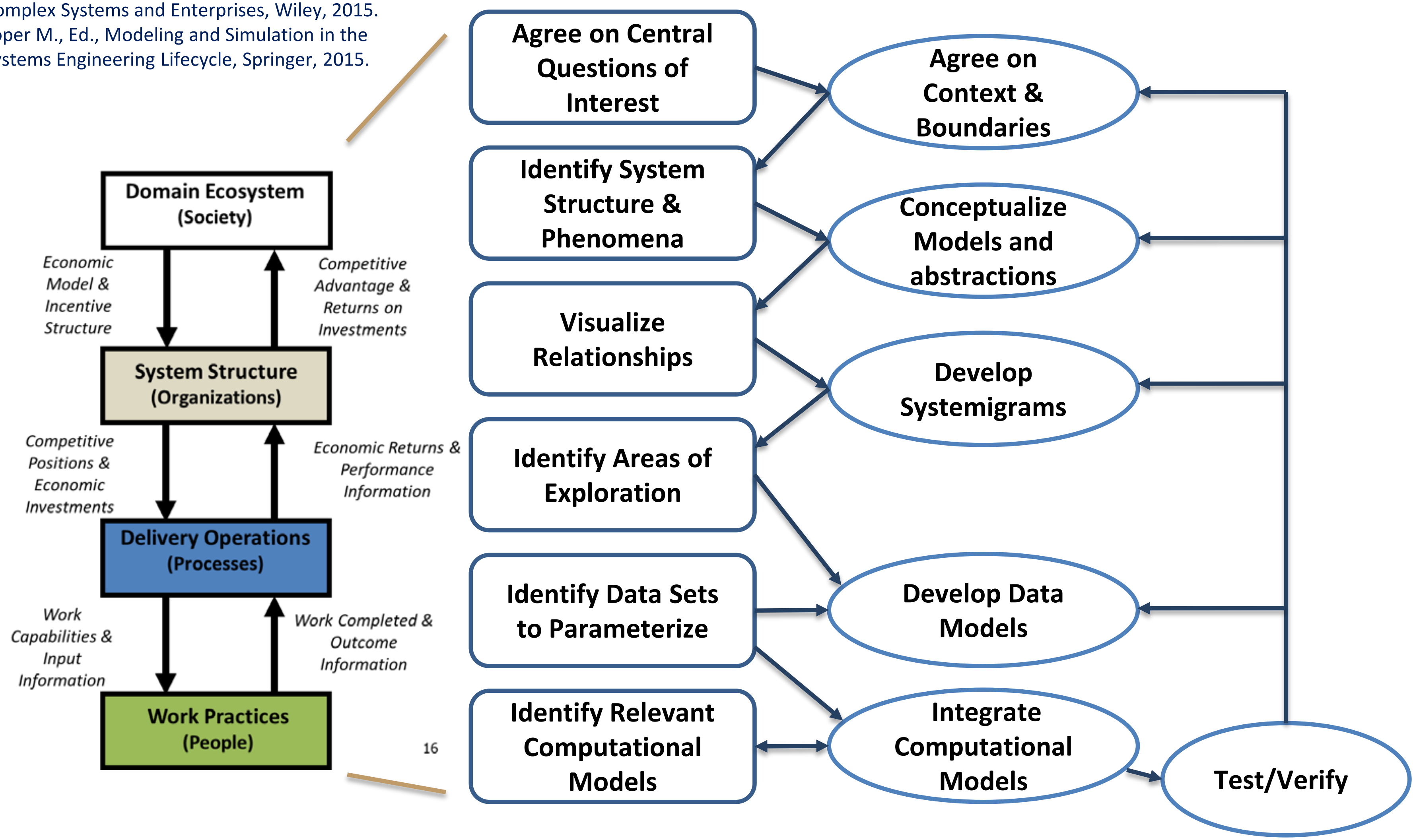
FACT 2.0 — Refactoring to enable greater extensibility and provide more integrated workflow

ERS TRADESPACE — Non-vehicle centric collaborative analysis tool under development for greater extensibility and higher-level interoperability to support future needs of DoD ERS

CORTEX … — OpenSEAT Initiative — New backend concept and framework based on lessons learned from other efforts to support ongoing and future developments including FACT 2.0 and ERS

Multi-Level Modeling: Methodology

Rouse, W.B, Modeling and Visualization of Complex Systems and Enterprises, Wiley, 2015.
Loper M., Ed., Modeling and Simulation in the Systems Engineering Lifecycle, Springer, 2015.



The Landscape of a Complex System

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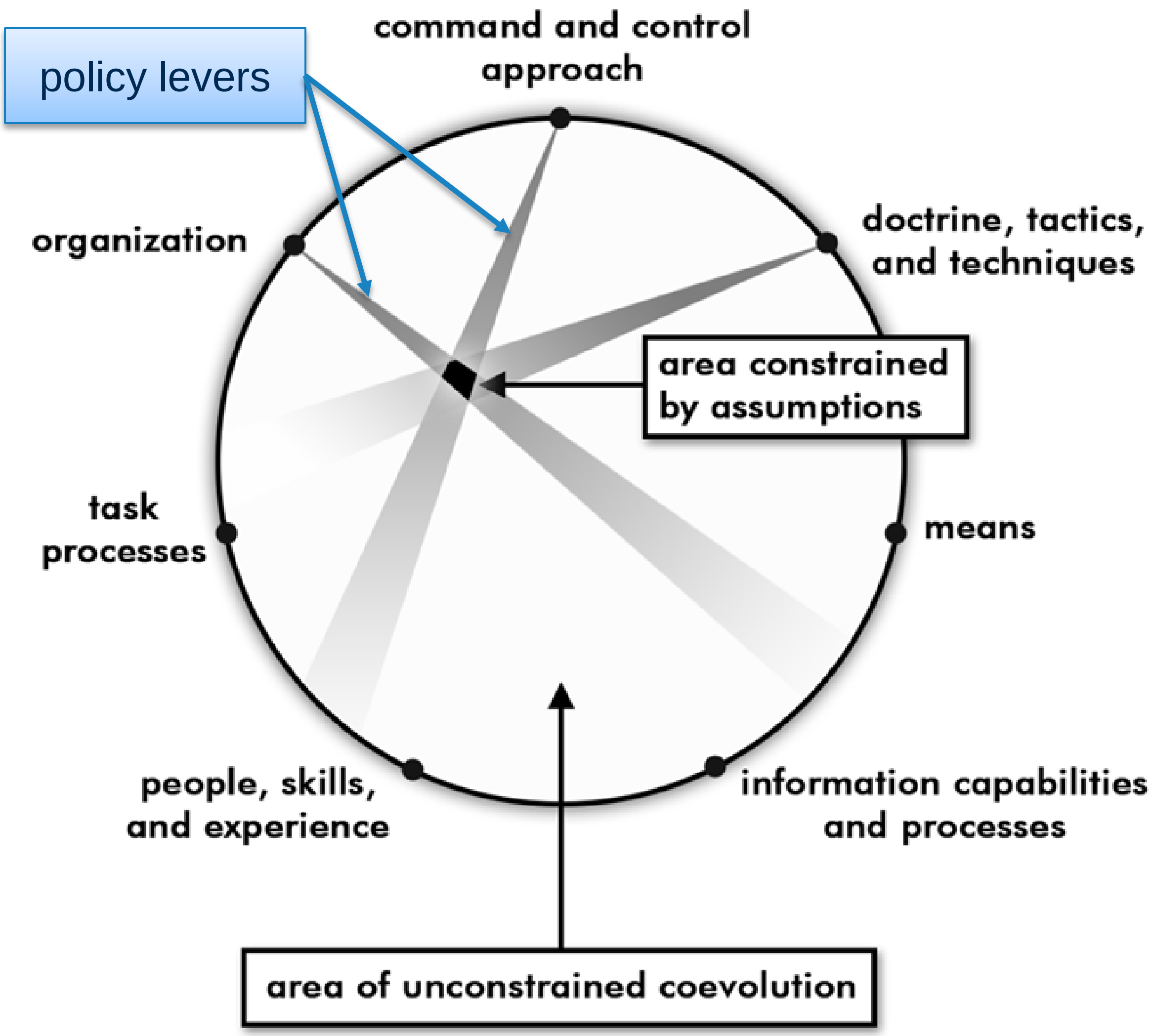

- **System level experimentation** evaluates existing approaches and disruptive change of parts with respect to the whole
- Each set of **assumptions** creates a hypothesis of how the system will evolve
- Evaluating many sets of assumptions is a **campaign of experiments**
- Each experiment contributes back to **theories of the whole**

Alberts and Hayes, Campaigns of Experimentation: Pathways to Innovation and Transformation, CCRP Publications

Defining System Constructs

- **System Constructs** are variables which are themselves not observable but can be derived from aggregated measures of observable elements which have a causal relationship to the construct.
- Although a staple of psychology and social science, constructs are seldom considered as important aggregation variables in systems engineering*
  - *Referred to a architectural attributes for derived requirements, but seldom defined or measured at aggregate levels.
- They may have numerous causal factors which are **context dependent**.
- Measurement of system constructs assumes long-term **evaluation** of a data model within a contextual architecture.

Example System Constructs for Cities

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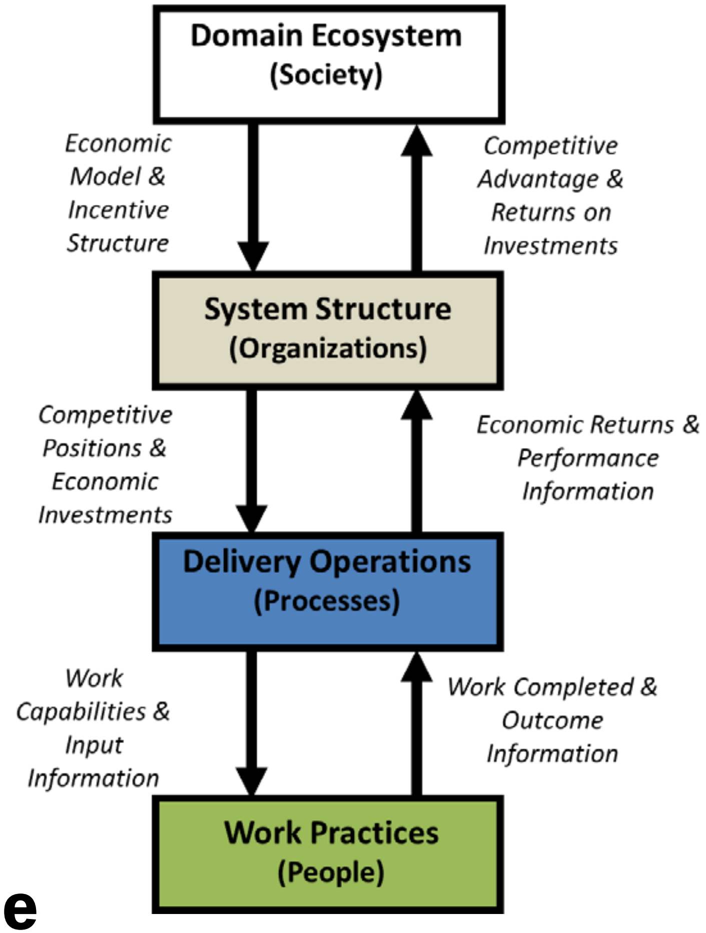
- Sustainability
- Vulnerability
- Efficiency
- Diversity
- Scale
- Safety
- Trust
- Standard of Living
- Well-being
- Experience

- Capacity
- Resilience
- Access
- Equity
- Satisfaction
- Stability



Measures are different at each level

Qualitative/Quantitative Approach

- **System Engineering: *quantitative approach***
  - Driven by **needs** and envisioned **system**
  - Multi-attribute design **optimization**
  - Functional decomposition of lower level behaviors from system level
  - Design verification/ validation strategies
- **Engineering Design: *qualitative approach***
  - Driven by **goals** and envisioned **outcomes**
  - Multi-attribute design **evaluation**
  - Aggregate system behaviors not predictable by lower level behaviors
  - Outcome-based evaluation strategies

MBSE Connectivity

Conceptual and Multi-Level Modeling Architectural Framework

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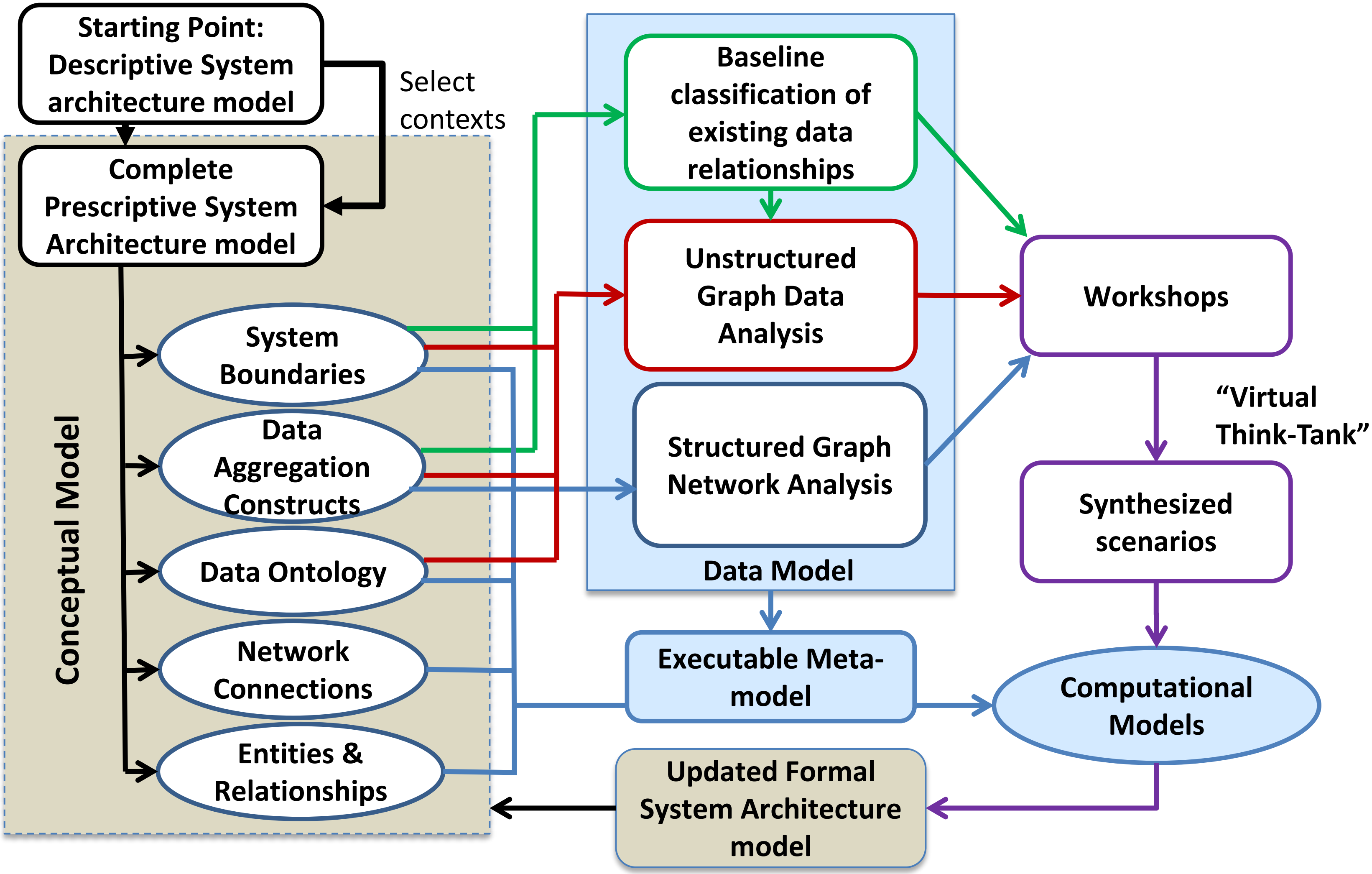

Conceptual Model as an Enduring Asset

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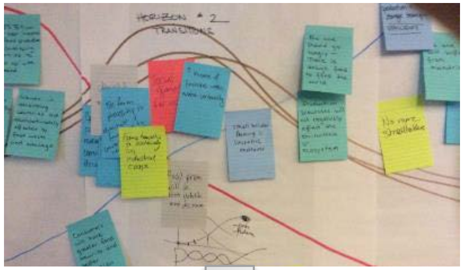
Why a conceptual model?

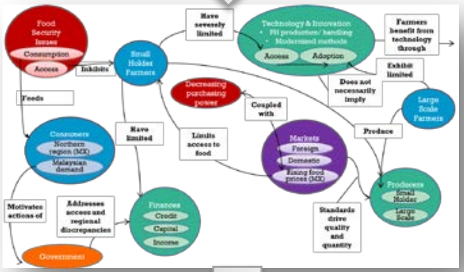
- Capture mental pictures of the system – converting tacit knowledge to explicit knowledge
- Dual-channel processing: greater understanding via both textual and visual formalism
- Interactive use of text and visuals to represent system and context
- Communicate concepts at various levels of abstraction
- Develop an ontological agreement of the system in question

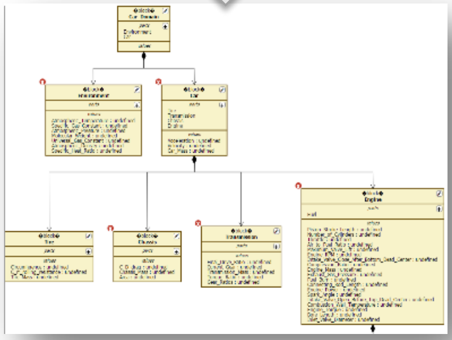
Issues to address:

- Majority of conceptual models consist of sketches that are not captured into computer aided tools
  - Thus, not adding to the knowledge base
- Conceptual modelers look for tools that preserve as much freedom of expression as possible
  - Most formal conceptual modeling tools are too restrictive

Workflow:







Concept Facilitation Toolset

GLOBAL KNOWLEDGE INITIATIVE

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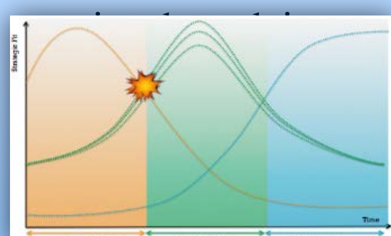
- Futures Map:
  - Adopted from International Futures Forum (Scotland): "3 Horizons" methodology
- Context Analysis:
  - GTRI/GKI developed Taxonomy
- Systems Map:
  - Using the "Systemigram" tool to map relationships and phenomena

Futures Map

- Captures evidence about current problem space, desired future, and possible transitions in between
- Helps users identify innovation paths

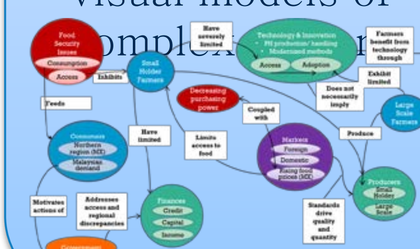


Context Analysis

- A Sociotechnical Systems Taxonomy
- Captures Entities & Relationships & Outcomes at multiple levels
- Helps users identify general and contextual relationships

Systems Map

- Visualizes entities, environment, interactions, and phenomena / patterns in the system at any level
- Integrates semantic and visual models of



There are many useful Conceptual Modeling Approaches

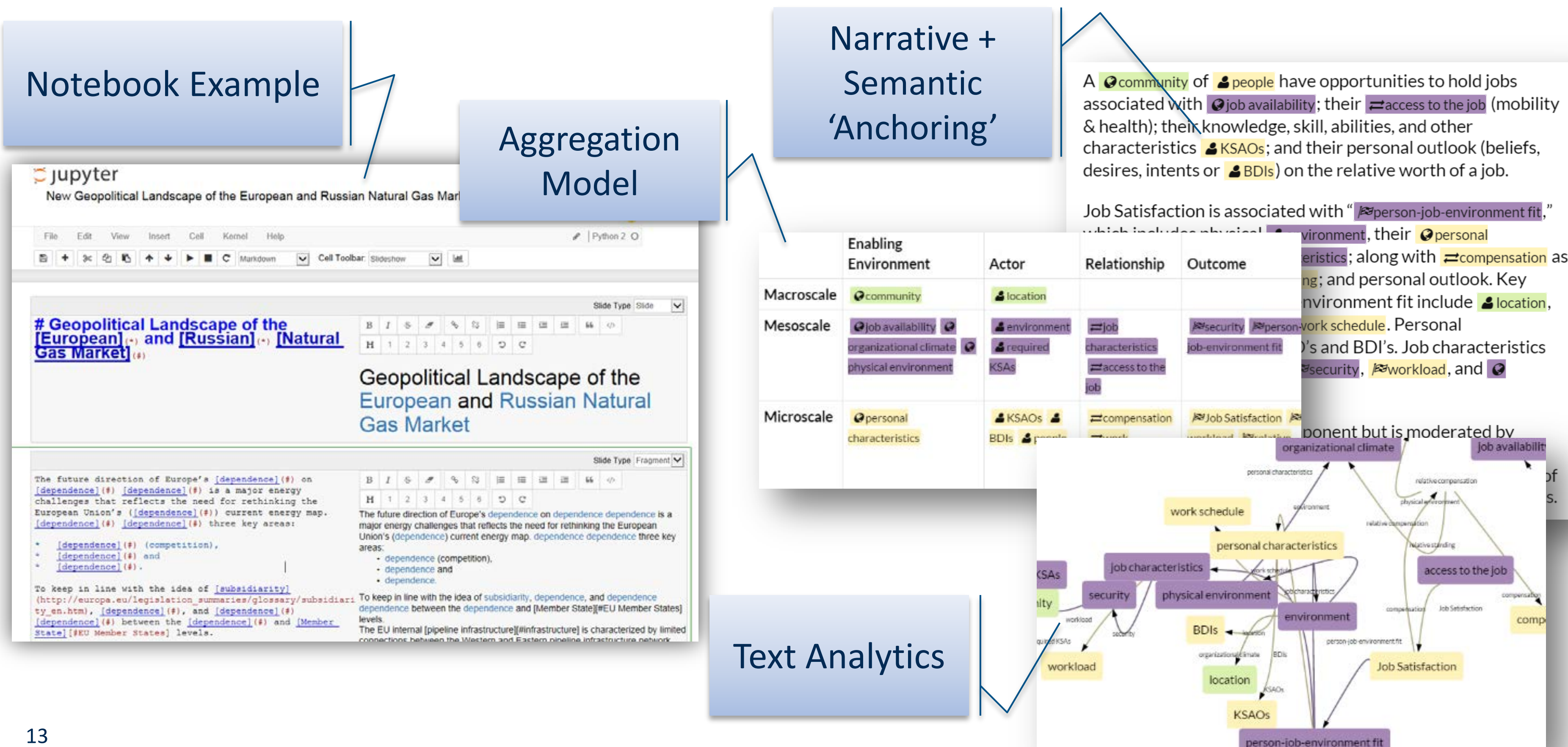
- Mindmaps & Tree Diagrams
- Morphological Matrices
- Systemigrams (Boardman & Sauser)
- Object Process Modeling (OPM) (Dori)
- Fundamental Modeling Concepts (FMC Consortium)
- Factor Trees (Davis)
- Acyclic Graphs
- Block Diagrams & Use Cases
- Constraint or N2 Diagrams

The Challenge is to integrate them into the Framework:

- **Semantics – need Natural Language Capability**
- **Symbology – need Common Diagrammatic forms**

OpenSEAT Notebook

- Extension to open source Jupyter Notebook project
- Semantic linkage of narrative & visual diagrams for model consistency
- Descriptive briefings and interactive model execution



Cortex Common Backend Framework

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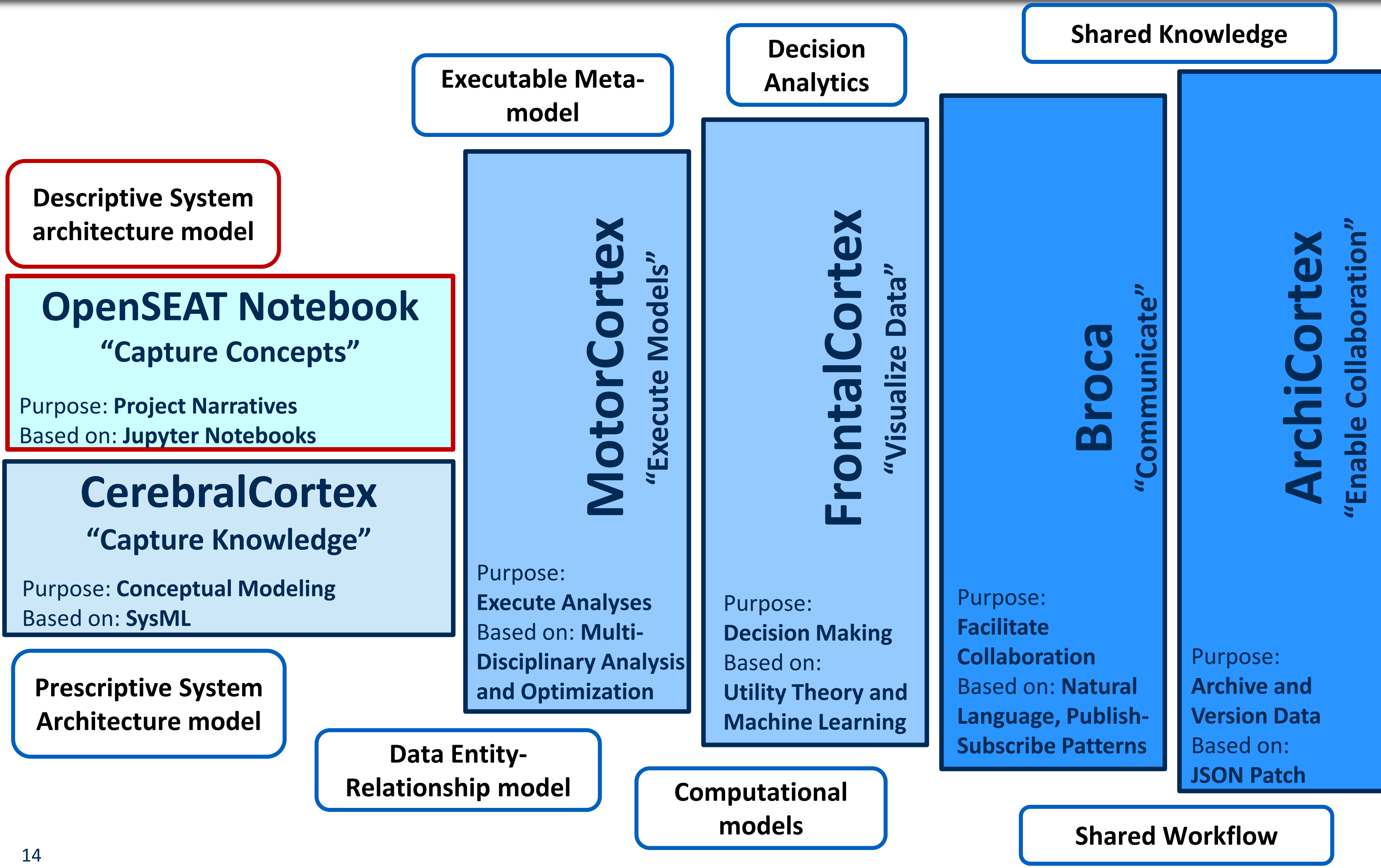
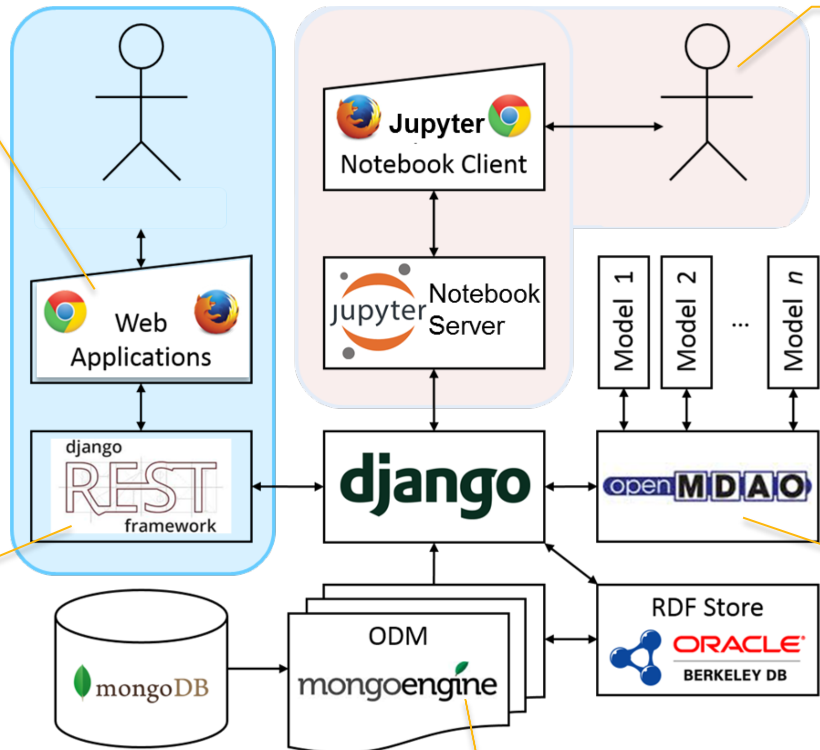


Cortex Computing Architecture

Collaborative Browser-based workflow

Standard Web API and Linked-data structure



Jupyter notebooks combine text, models, and data relationships

Pluggable Meta-model definition & execution

Document-relational database stores model instances

Transitioning the High-Level Conceptual Model to the OpenSEAT Framework

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- The Three Horizons map, related scenarios, and Systemigram narratives/diagrams capture concepts
  - Free form modeling tools providing mainly descriptive form
- Transition to Prescriptive form is a System Architecting process
  - Ontological form
  - Formal conceptual modeling & modeling language
  - Causal models, correlative and causal relationship analysis
  - Data model design
  - Multi-level computational model design(s)
  - Measures of performance/interest and visualization
- Results should be disseminated with Descriptive and Prescriptive forms intact

Conceptual Modeling Research

- Research effort exploring "right" level of abstraction and tool form for conceptual modeling
  - For insight into complexity, must engender **creativity** in stakeholder viewpoints
- "**Systemigram**" forms a useful free-form tool
  - Combined narrative and diagram, and is powerful for articulating system structure and emergent phenomena
- **SysML** based diagrams capture details of system architecture, data models, and parametrics
  - Engineering level of detail not interpretable by high level stakeholders
- Intermediate forms under exploration:
  - **Natural language support** is required
  - Levels of **abstraction and aggregation** are critical to design
  - **Number of views** acceptable to stakeholders
  - Research on **cognitive bases** for stimulating stakeholder response

OpenSEAT – Open-source System Engineering and Architecting Toolset

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- A holistic environment:
  - using emerging MBSE concepts, the framework is designed to maintain the knowledge base of the "whole" – as a conceptual model – while teams conduct exploration of the parts. The conceptual model becomes a durable component of the design environment, not just a design artifact.
- Managing context:
  - different studies, hypotheses, or projects can be explored against a common data set that represents the system in multiple contexts. A common workflow and configuration management environment supports parallel exploration of system trades.
- Multi-model integration:
  - analytical inputs and results of different algorithms, static models, and dynamic simulations are maintained in a common data model. Pluggable interfaces to different M&S environments supports long-term evolution of M&S capabilities.
- Composable visualization tools:
  - pluggable interfaces to different visualization tools and a common data model allow flexible real-time exploration of design trades and measures of performance. Integration of data visualizations and narrative text provides for interactive presentation or reporting of model results.
- Collaboration:
  - different teams can use all the data and related models in a collaborative browser-based environment to share model exploration, analysis, and results visualization.

Merging Qualitative and Quantitative Research into a Single Framework

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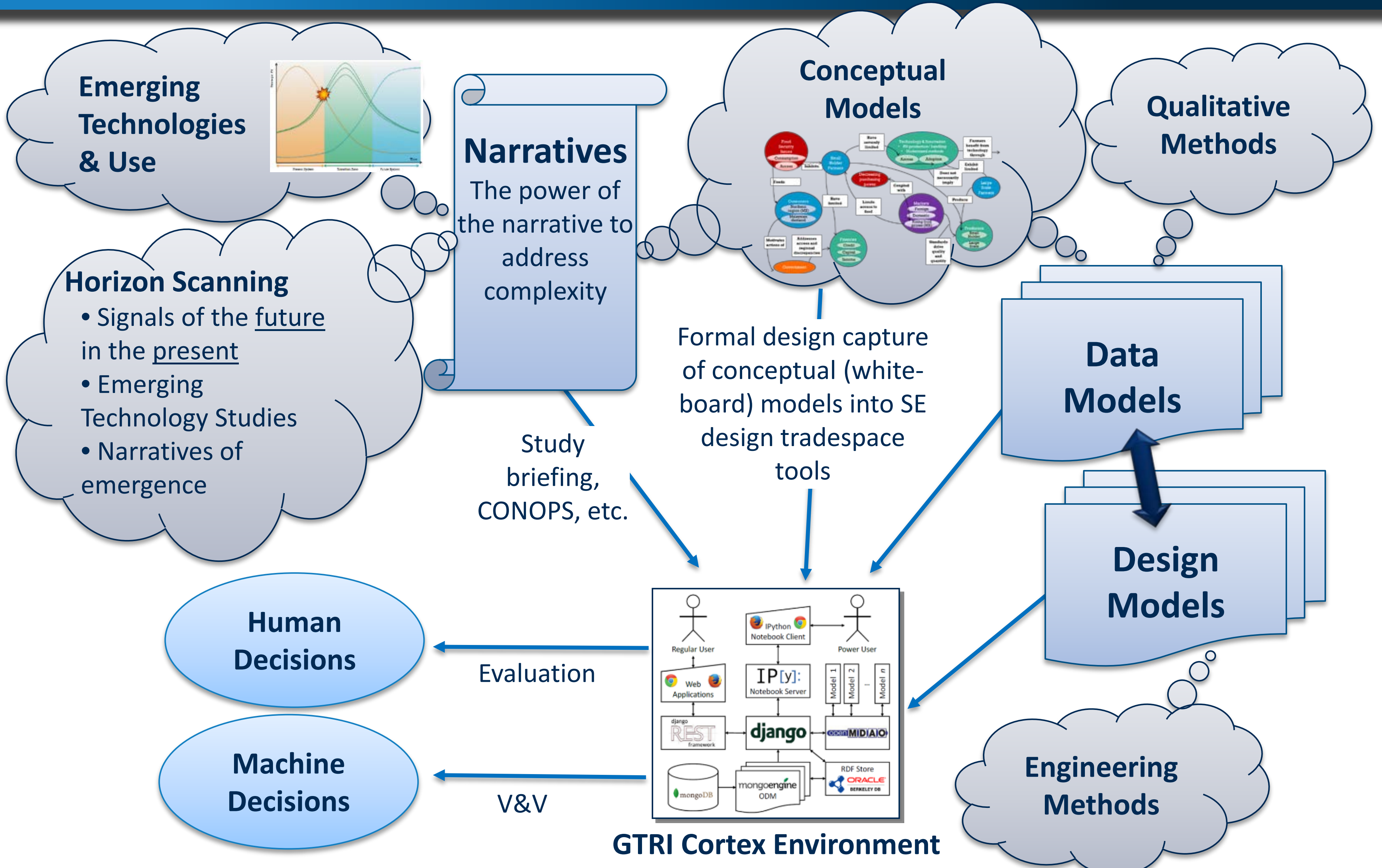

- Questions?