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

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

- **2007**
  - Socrates
  - MPC
  - FAEWSET
  - Browser-based strategic portfolio planning tool for USAF

- **2010**
  - FACT
  - Genesis of extending prior work into a web-based Systems Engineering tool for collaborative use

- **2011**
  - ITAP
  - Initial workshop support extended into MPT concept maturation for evaluation of -ilities

- **2012**
  - FACT 2.0
  - Refactoring to enable greater extensibility and provide more integrated workflow

- **2013**
  - OpenSEAT Initiative
  - ERS TRADESPACE
  - Non-vehicle centric collaborative analysis tool under development for greater extensibility and higher-level interoperability to support future needs of DoD ERS

- **2014**
  - CORTEX ...
  - New backend concept and framework based on lessons learned from other efforts to support ongoing and future developments including FACT 2.0 and ERS

- **2015**
  - Excel-based series of tools for configuring the Marine Personnel Carrier, and supporting source selection

- **2016**
  - Browser-based tool for pre-AoA JCIDS analysis to configure Integrated Electronic Warfare System architecting options
Multi-Level Modeling: Methodology


1. Agree on Central Questions of Interest
2. Identify System Structure & Phenomena
3. Visualize Relationships
4. Identify Areas of Exploration
5. Identify Data Sets to Parameterize
6. Identify Relevant Computational Models
7. Agree on Context & Boundaries
8. Conceptualize Models and abstractions
9. Develop Systemigrams
10. Develop Data Models
11. Integrate Computational Models
12. Test/Verify
The Landscape of a Complex System

- 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
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 as 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

- 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

Starting Point: Descriptive System architecture model

Complete Prescriptive System Architecture model

Select contexts

Baseline classification of existing data relationships

Structured Graph Network Analysis

Unstructured Graph Data Analysis

Workshops

“Virtual Think-Tank”

Synthesized scenarios

Computational Models

Updated Formal System Architecture model

Executable Meta-model

Data Model

Conceptual Model

System Boundaries

Data Aggregation Constructs

Data Ontology

Network Connections

Entities & Relationships

Conceptual and Multi-Level Modeling Architectural Framework
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
• 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 complex systems
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

Notebook Example

Narrative + Semantic ‘Anchoring’

Aggregation Model

Text Analytics

A community of people have opportunities to hold jobs associated with job availability, their access to the job (mobility & health); their knowledge, skill, abilities, and other characteristics (KSAs); and their personal outlook (beliefs, desires, intents or BDIs) on the relative worth of a job.

Job Satisfaction is associated with person-job-environment fit, their personal characteristics, along with compensation as an ongoing and personal outlook. Key environment fit include location, work schedule, personal job characteristics and BDIs. Job characteristics include security, workload, and personal characteristics.
Cortex Common Backend Framework

MotorCortex
“Execute Models”
Purpose: Execute Analyses
Based on: Multi-Disciplinary Analysis and Optimization

FrontalCortex
“Visualize Data”
Purpose: Decision Making
Based on: Utility Theory and Machine Learning

Broca
“Communicate”
Purpose: Facilitate Collaboration
Based on: Natural Language, Publish-Subscribe Patterns

ArchiCortex
“Enable Collaboration”
Purpose: Archive and Version Data
Based on: JSON Patch

Descriptive System architecture model

OpenSEAT Notebook
“Capture Concepts”
Purpose: Project Narratives
Based on: Jupyter Notebooks

CerebralCortex
“Capture Knowledge”
Purpose: Conceptual Modeling
Based on: SysML

Prescriptive System Architecture model

Data Entity-Relationship model

Computational models

Shared Knowledge

Shared Workflow
Cortex Computing Architecture

Collaborative
Browser-based
workflow

Standard Web
API and Linked-
data structure

Document-relational
database stores model
instances

Jupyter notebooks combine text,
models, and data relationships

Pluggable Meta-
model definition
& execution
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
• **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

Emerging Technologies & Use
- Signals of the future in the present
- Emerging Technology Studies
- Narratives of emergence

Horizon Scanning

Narratives
The power of the narrative to address complexity

Conceptual Models
Formal design capture of conceptual (white-board) models into SE design tradespace tools

Study briefing, CONOPS, etc.

Data Models

Design Models

Human Decisions

Machine Decisions

Evaluation

V&V

GTRI Cortex Environment

Qualitative Methods
• Questions?