

Transforming Systems Engineering Through Model-based Systems Engineering

ART-022

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UMassAmherst



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Organization

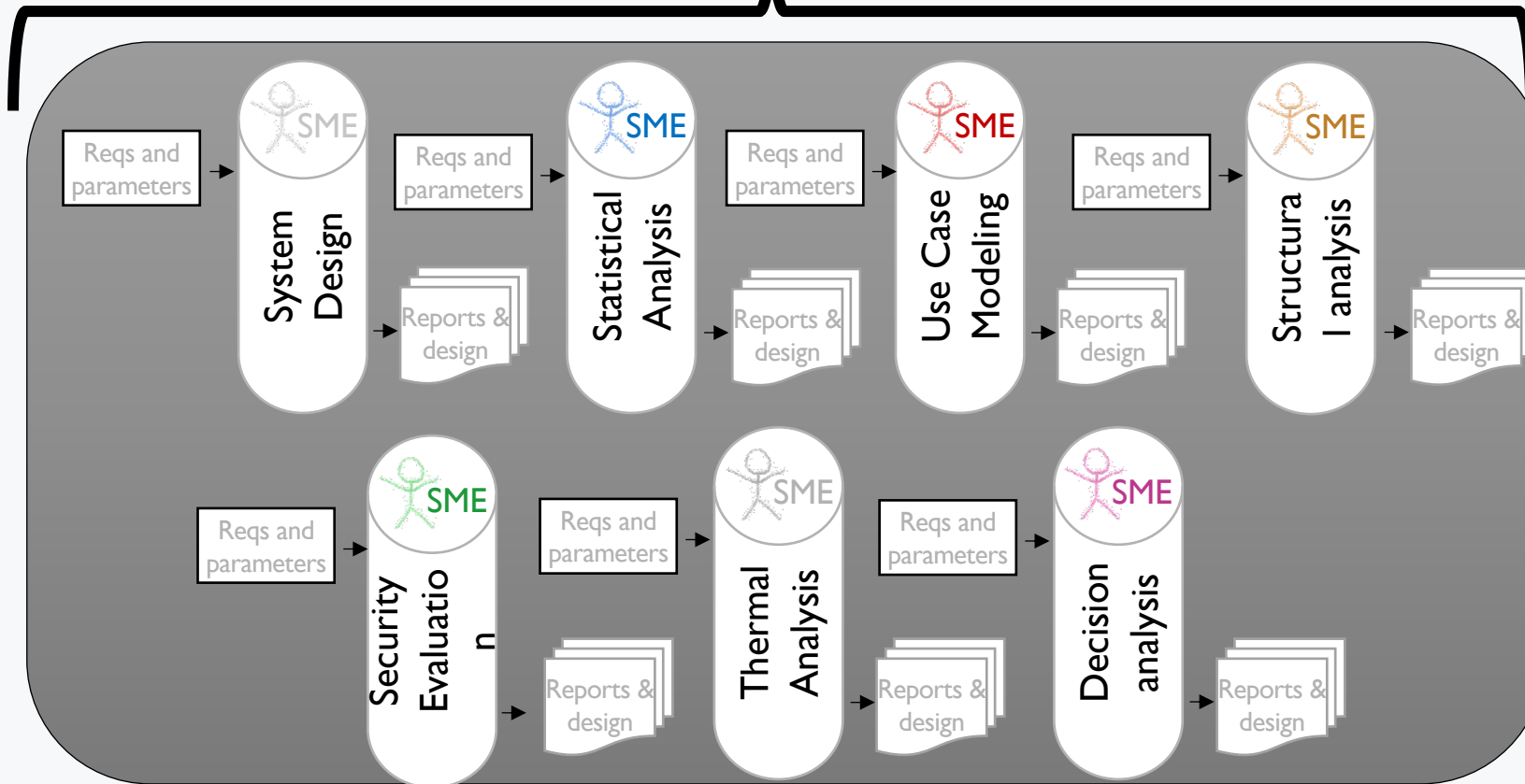
- **INTRO (WHY):** Context/Motivation – How did we get here?
- **WHAT:** Digital Engineering Enabling Technologies and Methods
- **HOW:** “Full Stack” of Models with Integrated Workflows Coordinated using Armaments Interoperability and Integration Framework (IoIF)
- **HOW WELL:** Transitioning research using two different training courses for two different use cases

Motivation: Transform Beyond Stove Piped Analyses



Systems Engineer

- Communicating
- Translating
- Facilitating data flow

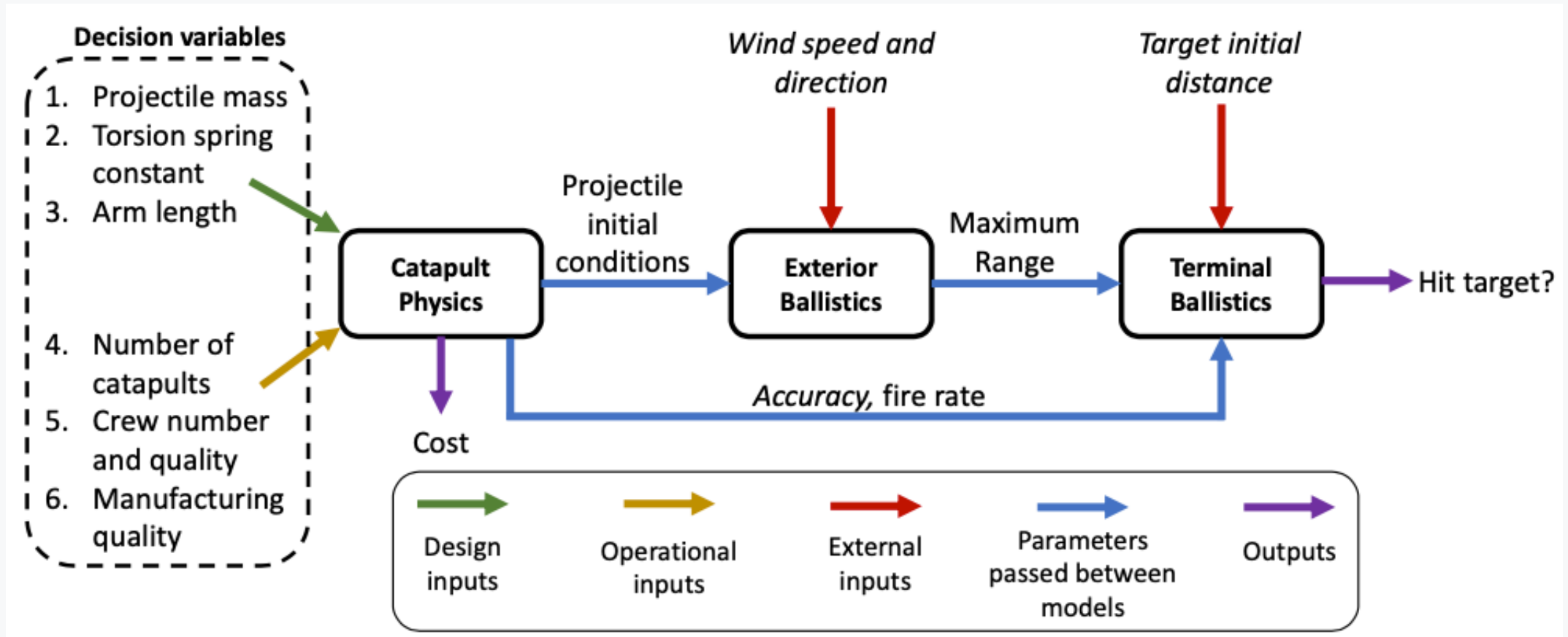


Example: Cross Domain Relationships Needed for System Trades, Analysis and Design

- Mission objective: continuous surveillance
- Capability Refueling UAV
- Systems: UAV and Refueler
- Valve – Cross-domain Object
- Mechanical Domain
 - Valve connects to Pipe
- Electrical Domain
 - Switch opens/closes Value
 - Maybe software
- Operator Domain
 - Pilot remotely sends message to control value
- Communication Domain
 - Message sent through network
- Fire control Domain
 - Independent detection to shut off valve
- Safety Domain

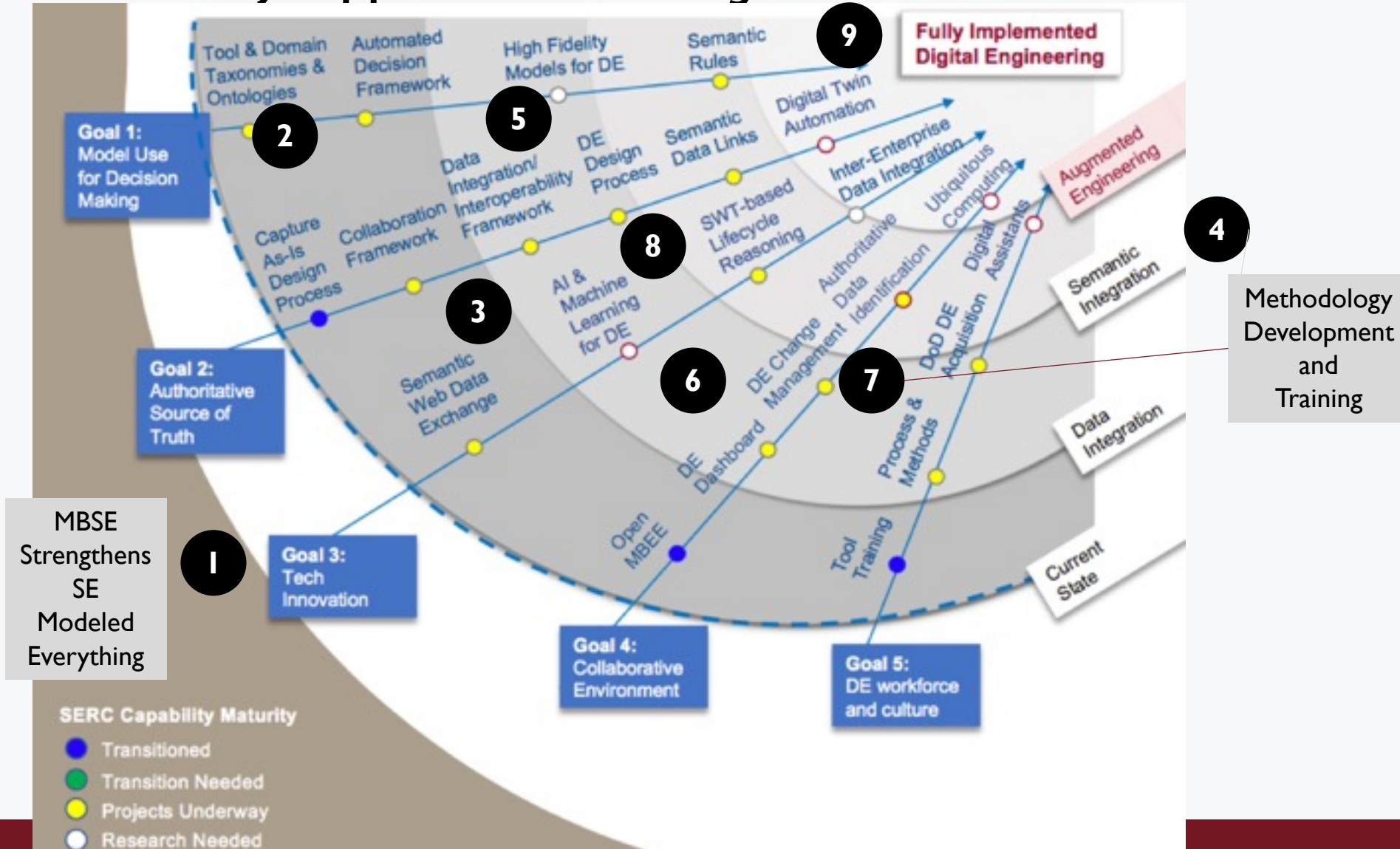


Example (alternative): Model and Simulation Interactions for Mission Level Optimization*



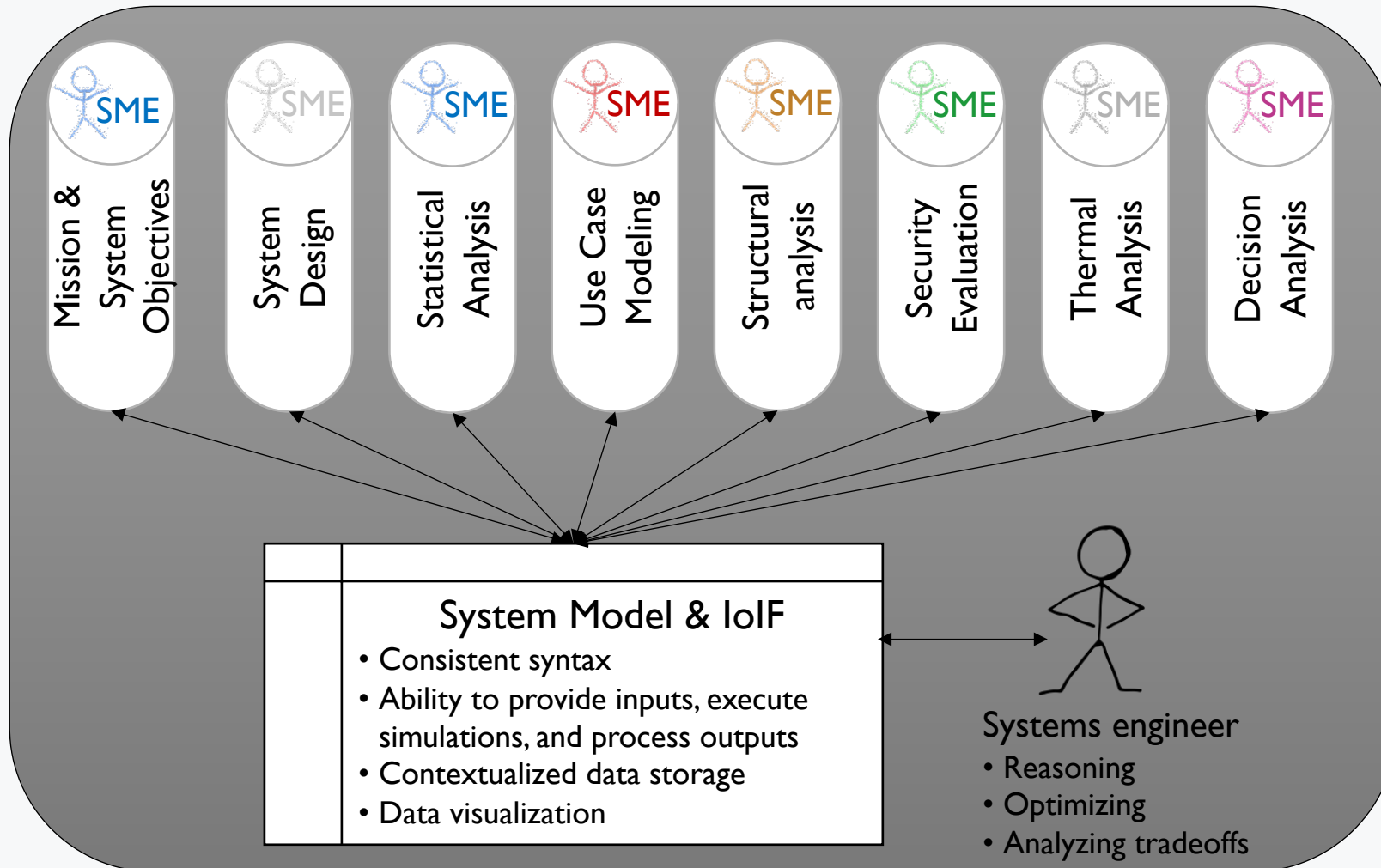
*Chell, B., Multidisciplinary System and Mission Design Optimization, Dissertation Stevens Institute of Technology, May 30, 2021.

Tracking Digital Engineering for Systems Engineering Roadmap: Goals are Mutually Supportive not Orthogonal

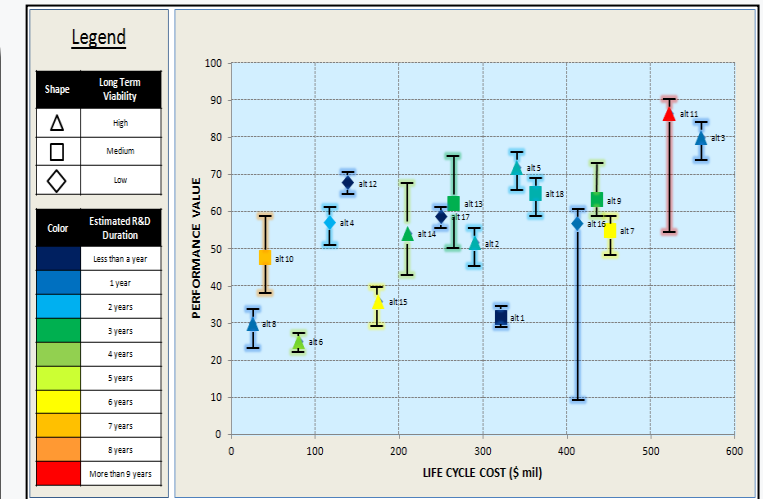


* https://sercuarc.org/wp-content/uploads/2020/01/ROADMAPS_2.3.pdf

Enabling Technologies of Ontologies and Semantic Technologies Support Cross-Domain Model “Integration” through Interoperability



Scatter Plot Dashboard for Decision Making related to Objectives

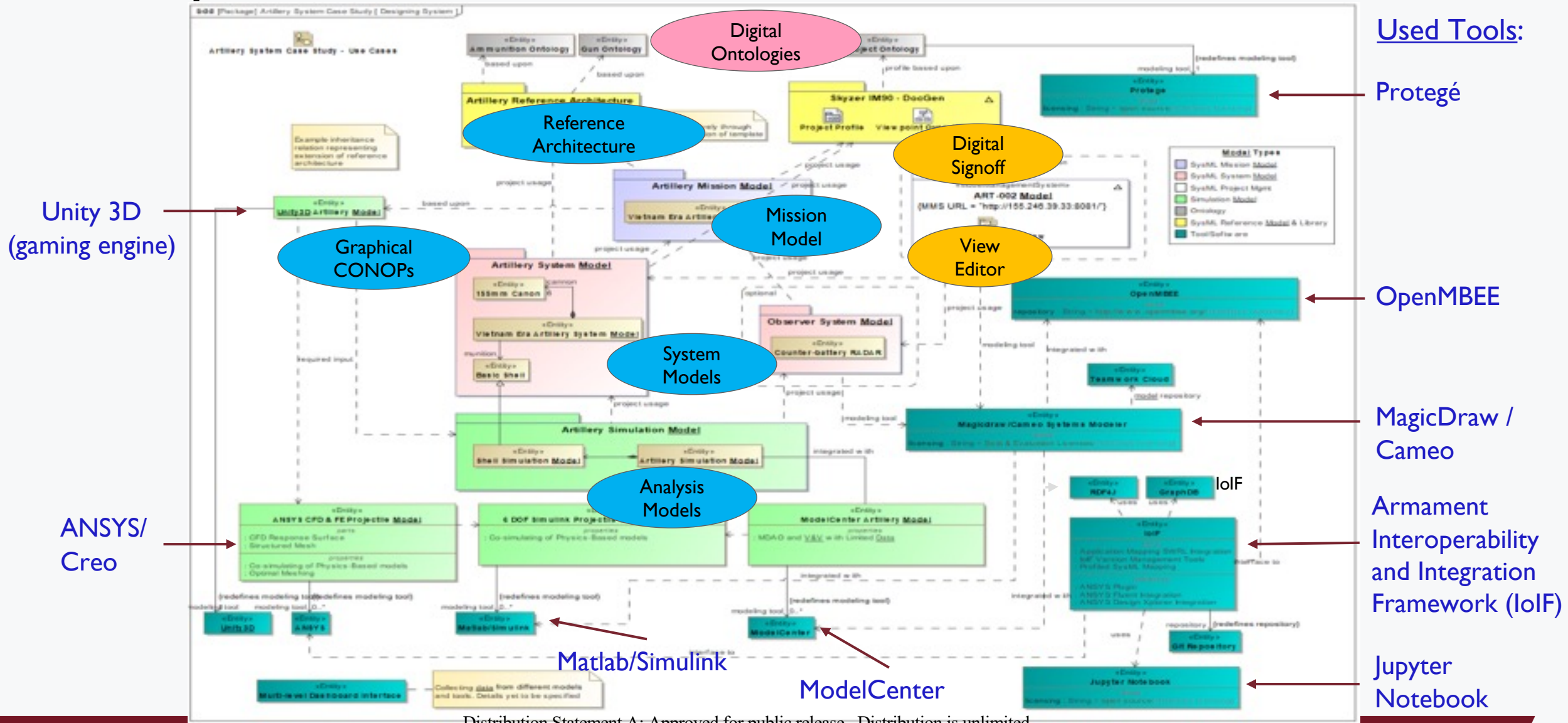


Strategic/mission-level decision-maker

- Setting requirements & objectives
- Exploring tradeoffs
- Adjusting requirements & objectives based on capability information

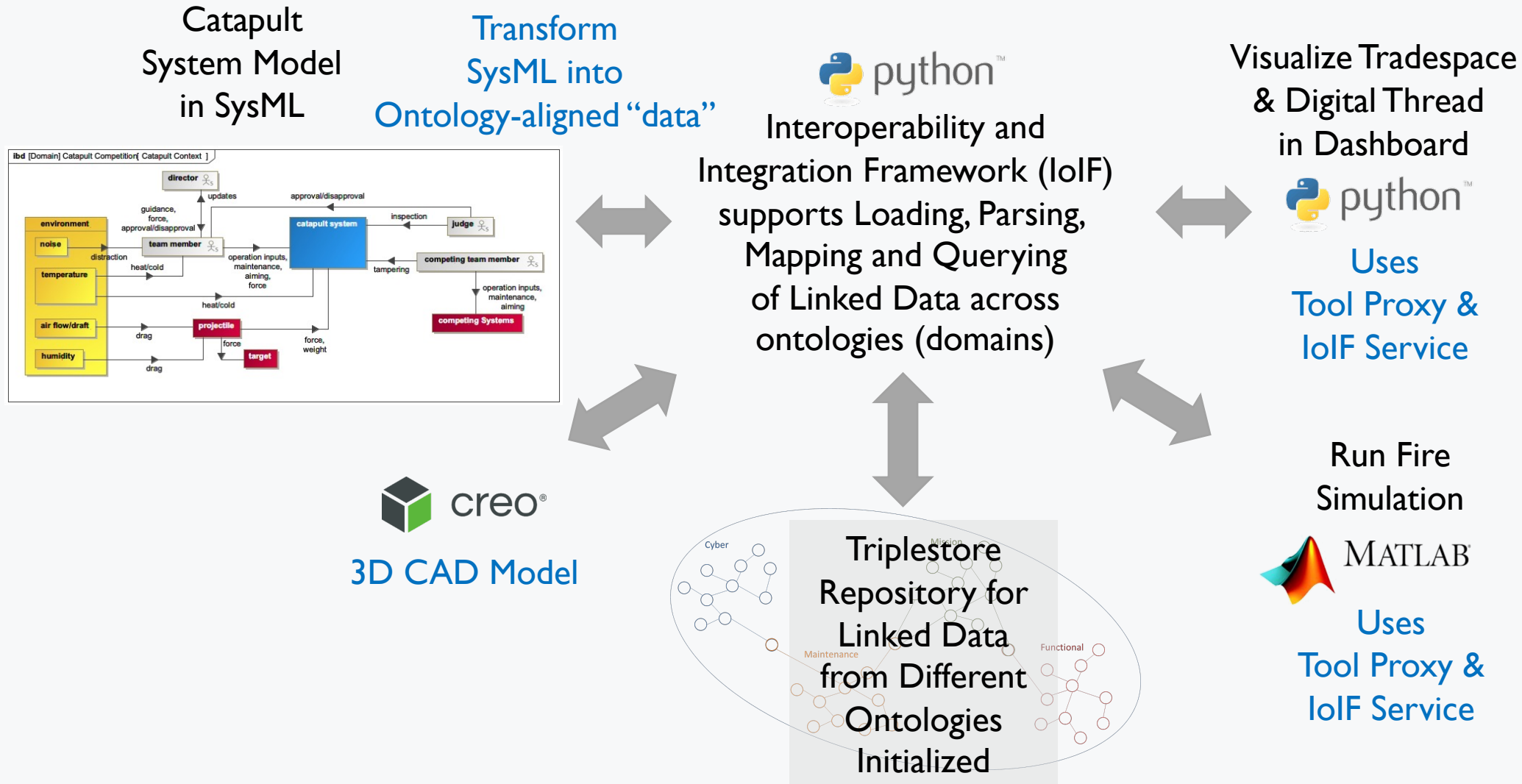


Example Reference Architecture for "Full Stack" with Tools

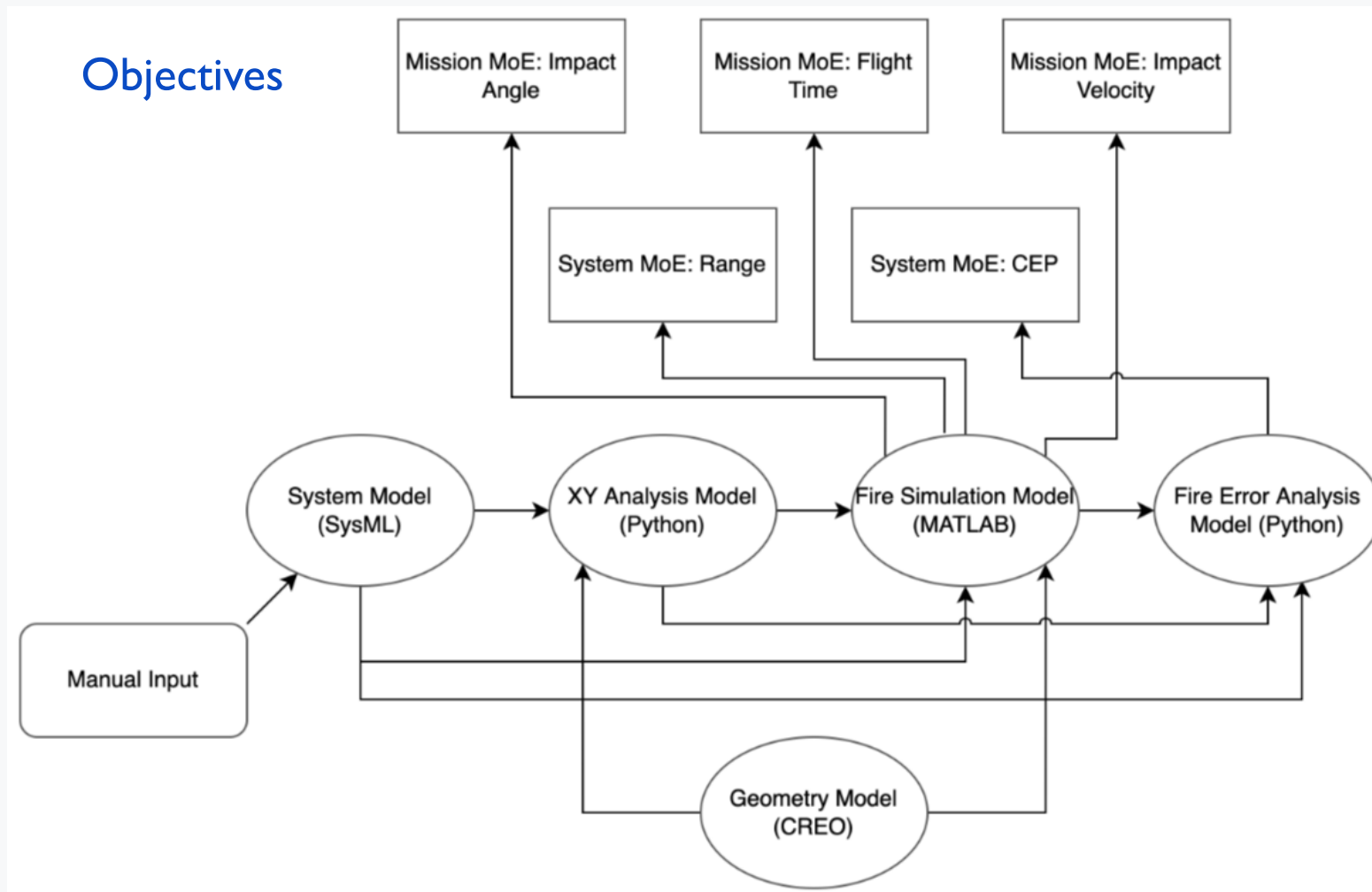


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IoIF Catapult Ontology-Based Use Case used in Course and Exercise



Abstract Digital Thread Showing Interconnections between Models & MoEs & Workflow Executed in Python-based Jupyter Notebook

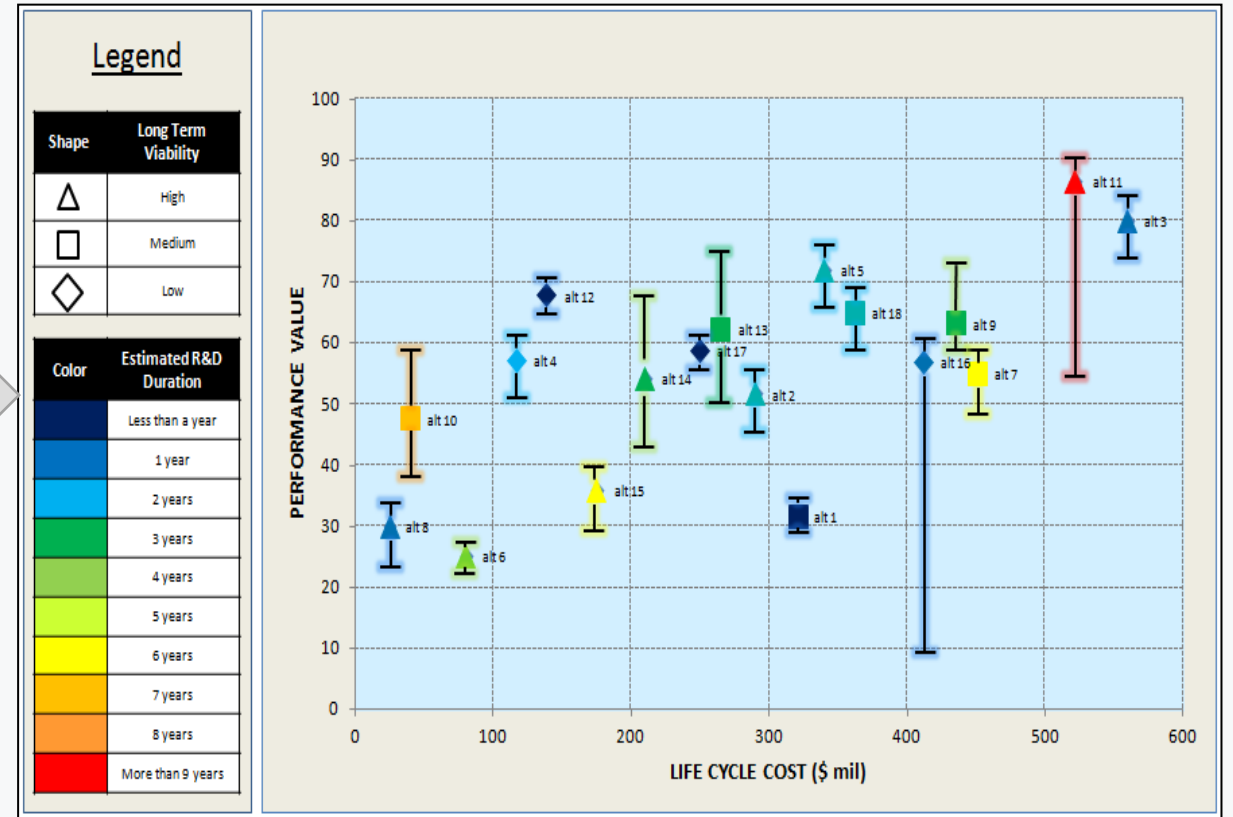
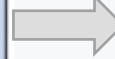
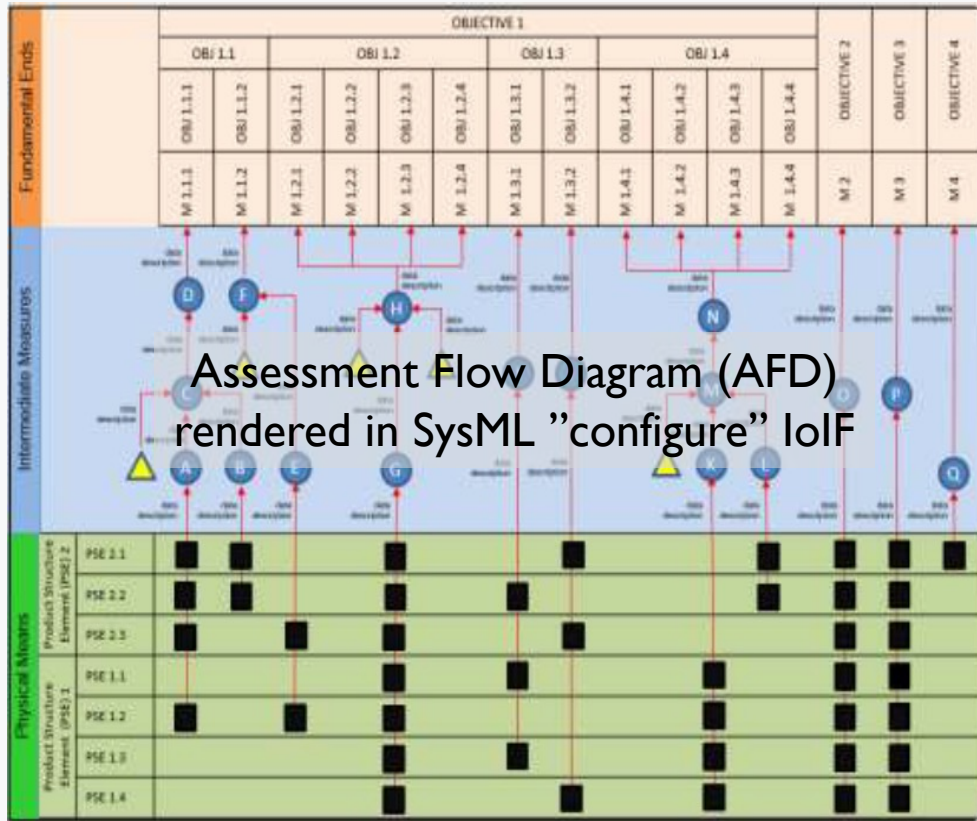


HOW: System of Analysis Methodology derived from ISEDM* formalized using IoF and SysML

Objective (Key Performance Parameters/Indicators) and/or Mission Measures

Scatter Plot Dashboard for Decision Making related to Objectives

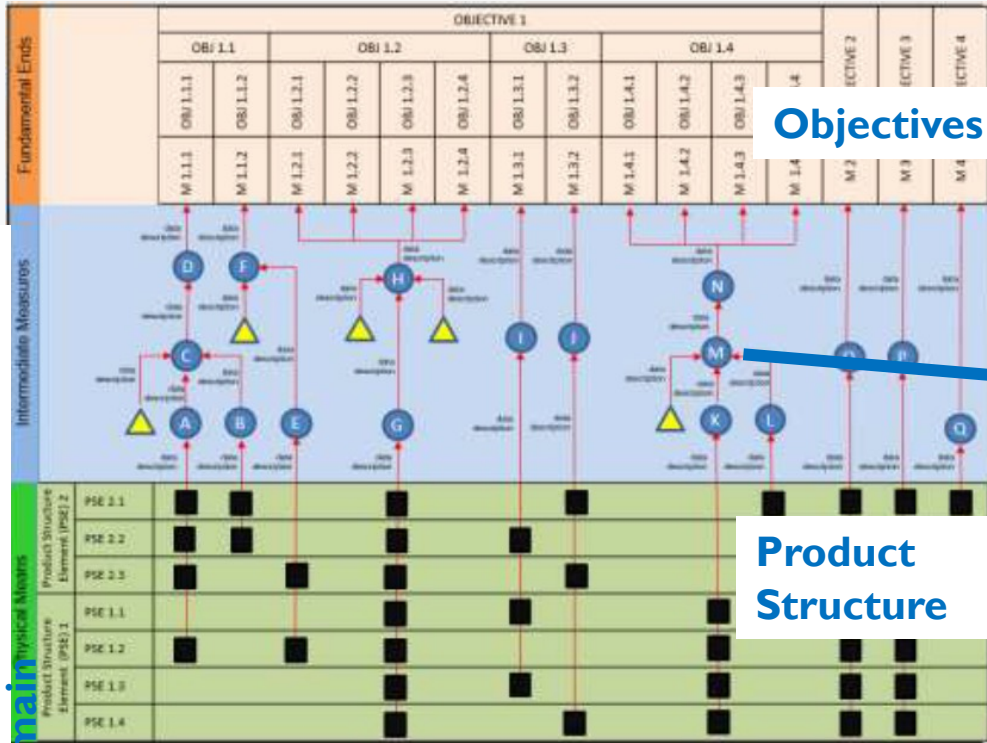
Parameters from the Domain



*Integrated Systems Engineering Decision Method (Cilli 2015): additional details in backup.

AFD Formalized Representation of IoIF Data Exchanges between Analysis Tools using SysML

Domain Parameters from the



Objectives

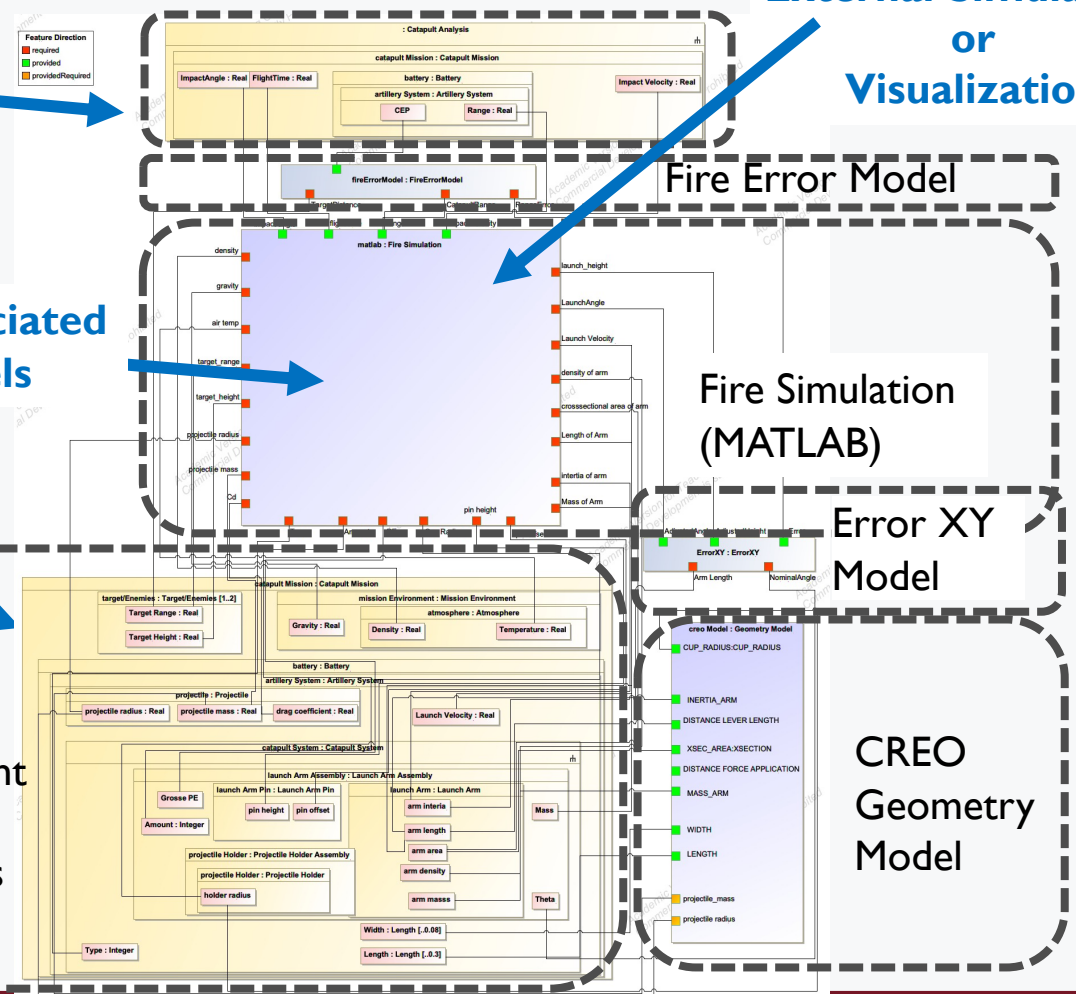
Product Structure

Yellow blocks are SysML elements and value properties

Blue blocks are External Simulations or Visualization

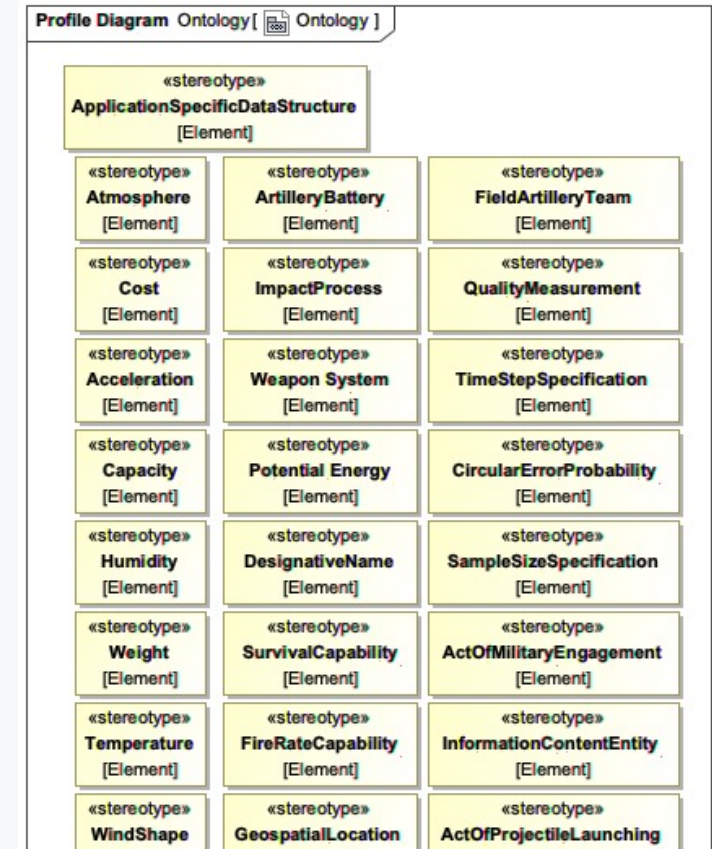
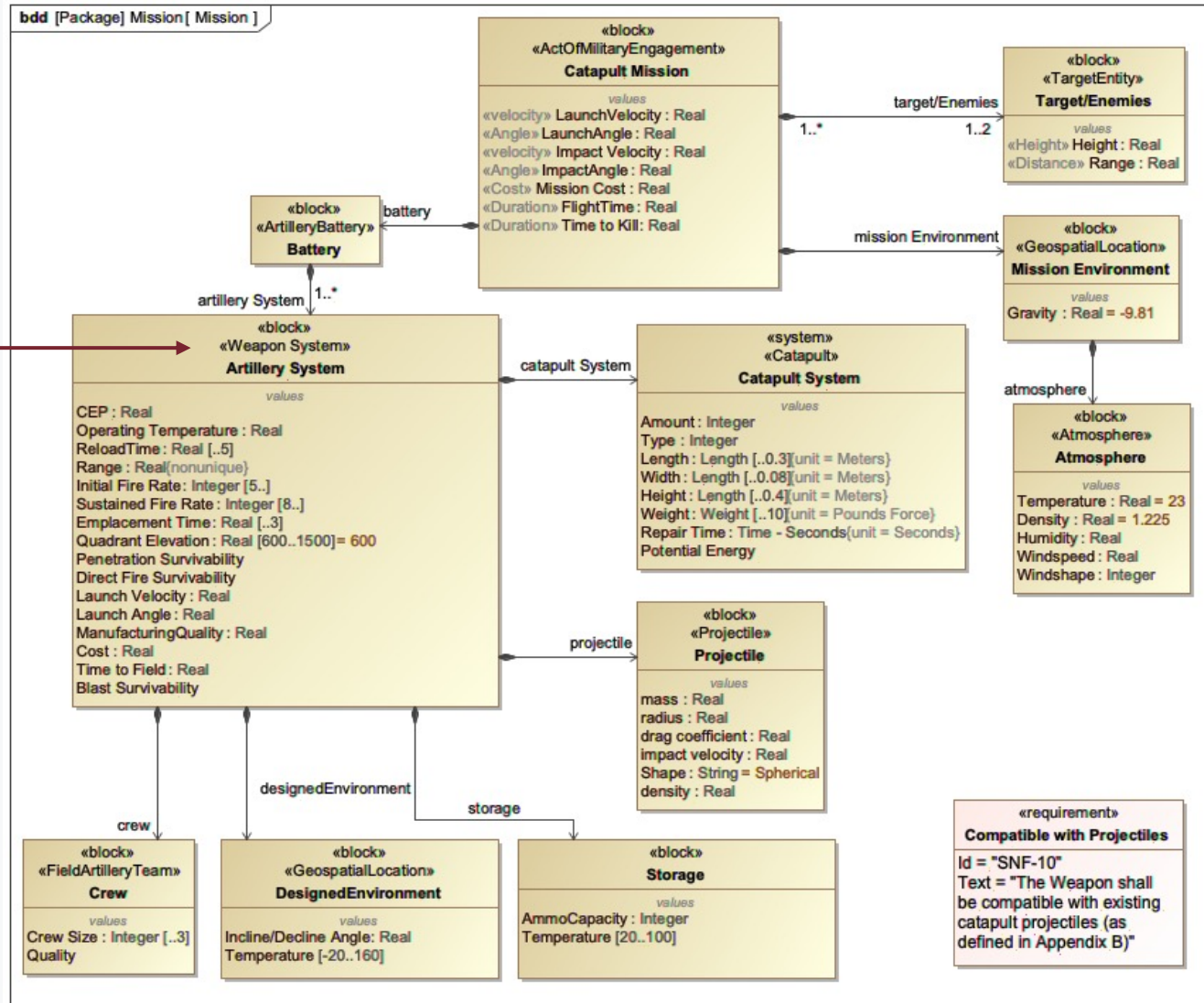
Associated Models

Mission, System & environment related parameters



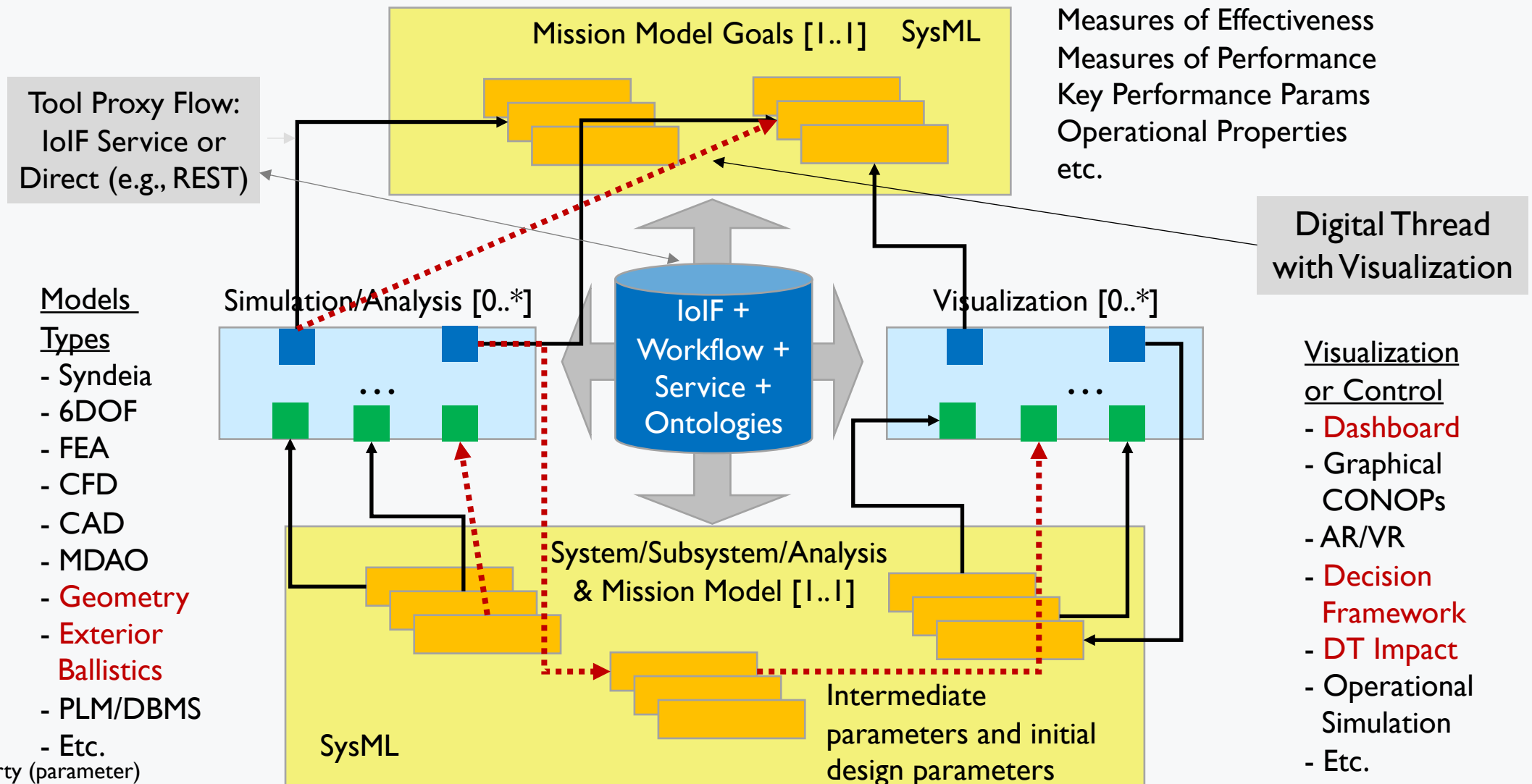
Catapult Mission/System Model Tagged with Stereotypes that Map to Ontology Classes

Stereotype "Tag" maps to Ontology Class

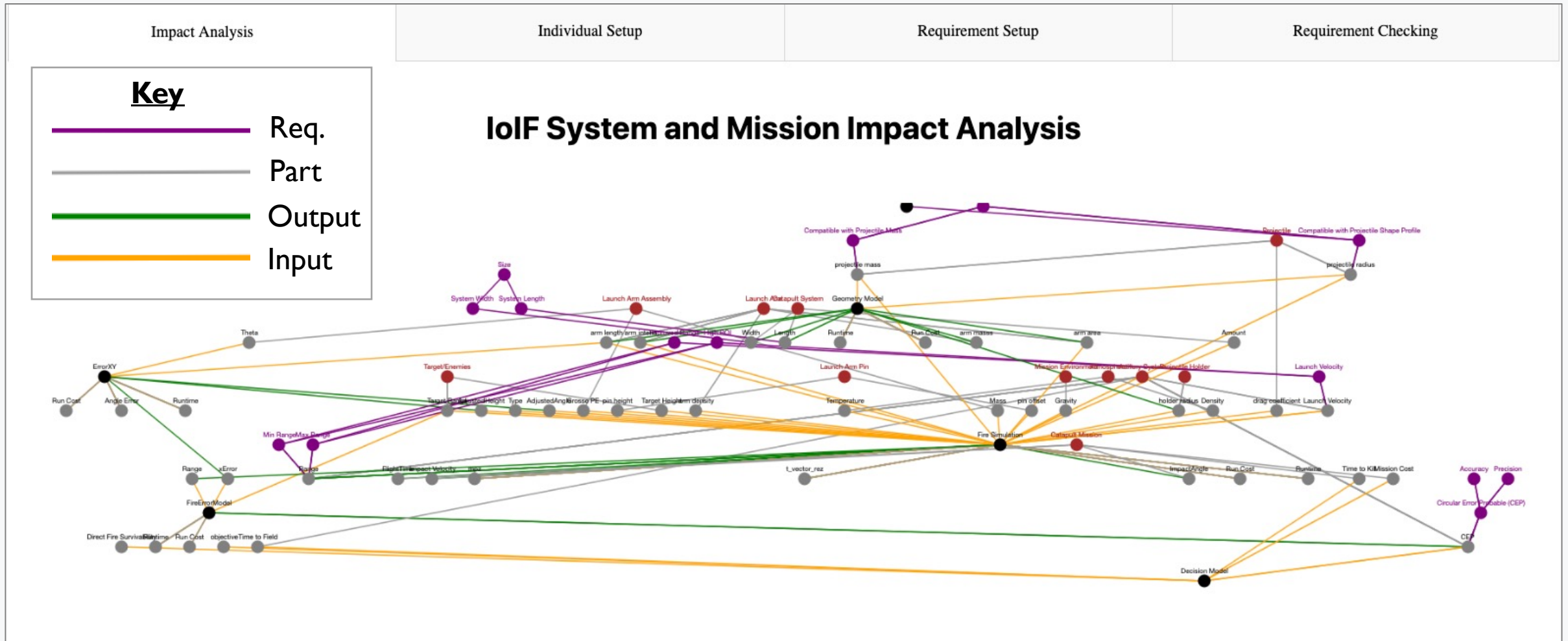


Stereotypes provide straightforward means to provide the required metadata for tagging system and mission models

AFD Generalization that can be Configured for Various Types of Analyses with Digital Thread

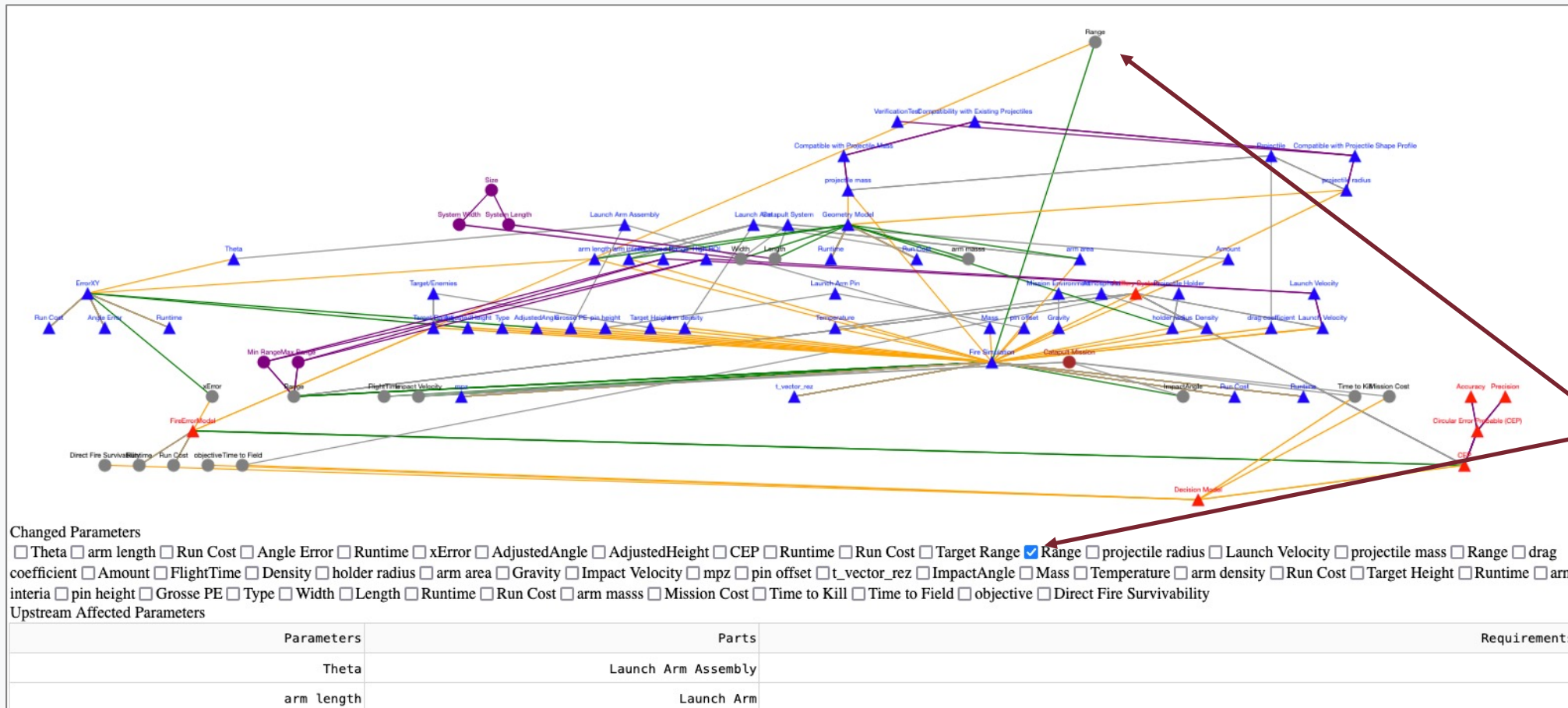


Digital Thread Impact Analysis Visualization runs in Web-browser and data rendered in Dashboard is live data coming from IoIF



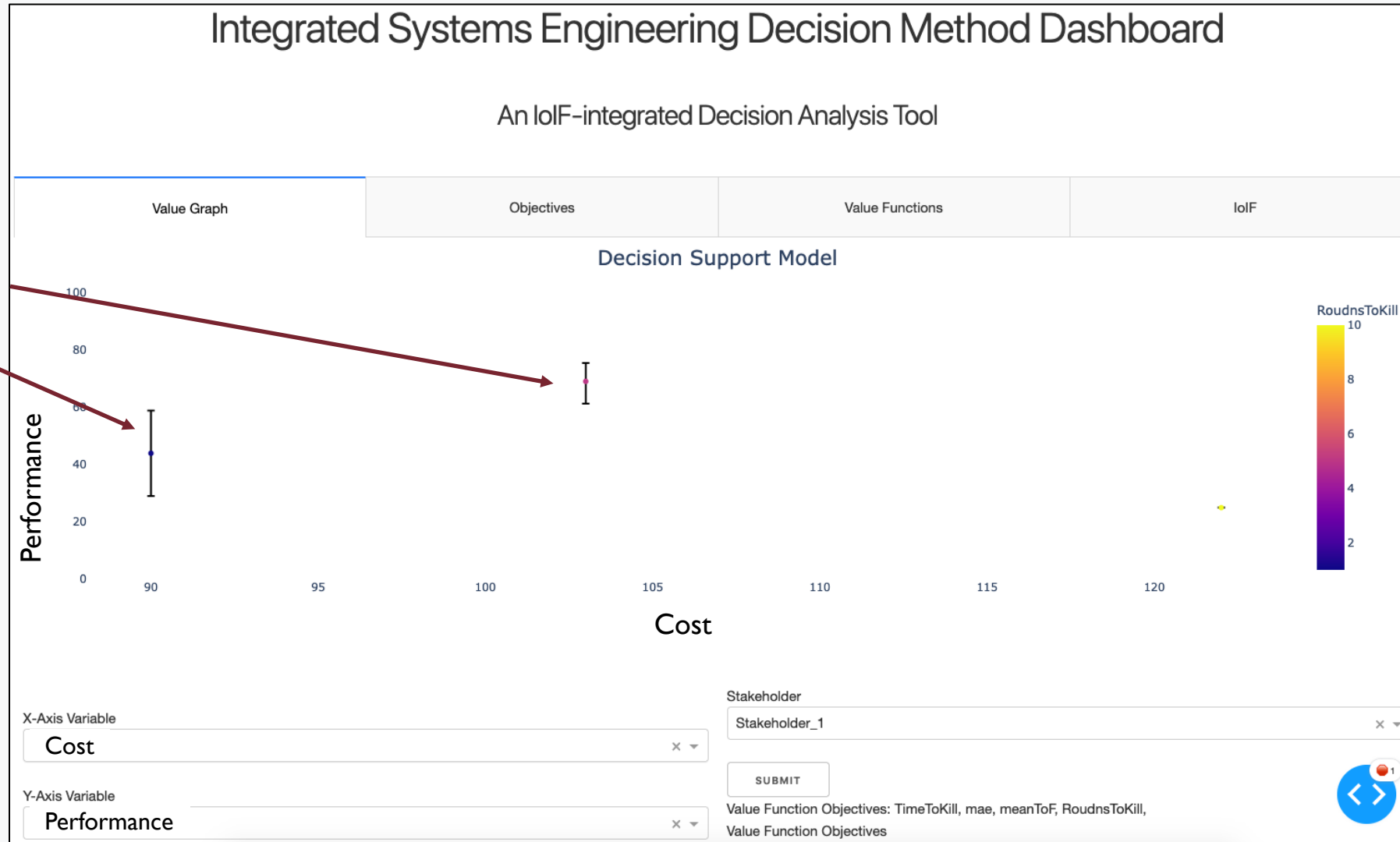
Visualization show Upstream & Downstream Connections to Modified Parameter

- Blue indicates entities upstream of a changed parameter;
- Red indicates entities downstream that may be affected

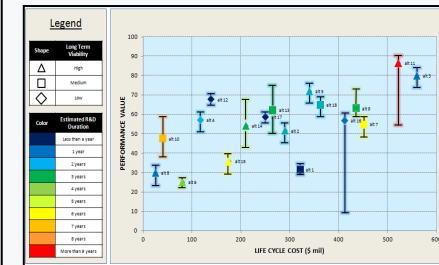


Range is modified parameter

IoIF Decision Dashboard



Dashboard Implementation is Python-based Notional Rendering of Scatter Plot



Conclusions – How Well

- Developed five case studies with different ontologies using an evolving IoIF Methodology
 - Methodology formalizes mission and system objectives and system parameters using an Assessment Flow Diagram (AFD) based on Integrated System Engineering Decision Method (ISEDMD)
 - Mission and System models are tagged with stereotypes that are aligned with the Ontologies used by IoIF
 - IoIF use AFD to represent interconnection of models and simulations used in the analyses
 - IoIF coordinates workflow of the simulations and visualization of Digital Thread
- Delivering second training course to transition research (Fall 2022)
- Have two PhD projects investigating the use of IoIF

Research Tasks and Collaborator Network

RT-48 (2013) Mark Blackburn (PI), Stevens Rob Cloutier (Co-PI) - Stevens Eirik Hole - Stevens Gary Witus – Wayne State	RT-168 – Phase I & II (2016) Mark Blackburn (PI), Stevens Dinesh Verma (Co-PI) – Stevens Ralph Giffin Roger Blake - Stevens Mary Bone – Stevens Andrew Dawson – Stevens (Phase I) Rick Dove John Dzielski, Stevens Paul Grogan - Stevens Deva Henry – Stevens (Phase I) Bob Hathaway - Stevens Steven Hoffenson - Stevens Eirik Hole - Stevens Roger Jones – Stevens Benjamin Kruse - Stevens Jeff McDonald – Stevens (Phase I) Kishore Pochiraju – Stevens Chris Snyder - Stevens Gregg Vesonder – Stevens (Phase I) Lu Xiao – Stevens (Phase I) Brian Chell (Grad) – Stevens Luigi Ballarinni (Grad) – Stevens Harsh Kevadia (Grad) – Stevens Kunal Batra (Grad) – Stevens Khushali Dave (Grad) – Stevens Rob Cloutier – Visiting Professor Robin Dillon-Merrill – Georgetown Ian Grosse – UMass Tom Hagedorn – UMass Todd Richmond – USC Edgar Evangelista – USC	RT-195 (2018) Mark Blackburn (PI), Stevens Mary Bone - Stevens Ralph Giffin - Stevens Benjamin Kruse - Stevens Russell Peak – Georgia Tech. Stephen Edwards – Georgia Tech. Adam Baker (Grad) – Georgia Tech. Marlin Ballard (Grad) – Georgia Tech. Donna Rhodes - MIT Mark Austin – Univ. Maryland Maria Coelho (Grad) – Univ. Maryland	ART-002 (2018) – ART-022 (2021/22) Mark Blackburn (PI), Stevens Dinesh Verma (Co-PI) – Stevens Kunal Batra – Stevens Mary Bone - Stevens John Dzielski, Stevens Steven Hoffenson - Stevens Steve Hespelt – Stevens Tom Hagedorn – Stevens Roger Jones – Stevens Philip Odonkor – Stevens Benjamin Kruse – Stevens/VT Chris Snyder - Stevens Brian Chell – Stevens Daniel Dunbar (PhD) – Stevens Maximillian Vierlboeck (PhD) - Stevens Andrew Underwood (Ungrad) – Stevens Benjamin Steinwurtzel (Ungrad) Cory Phillipe (Grad) - Stevens Ian Grosse – Univ. of Massachusetts Doug Eddy – Univ. of Massachusetts Joe Gabbard – Virginia Tech Kyle Tanous– Virginia Tech Jared Van Dam (PhD) – Virginia Tech Kelsey Quinn (PhD) – Virginia Tech	WRT-1036 (2020) Mark Blackburn (PI), Stevens John Dzielski- Stevens Russell Peak – Georgia Tech. Selcuk Cimtalay – Georgia Tech. Taylor Fields – Georgia Tech. William Stock (Grad) – Georgia Tech. Sahil Panchal – Georgia Tech Jake Sisavath – Georgia Tech Gabriel Rizzo – Georgia Tech WRT-1054 (2022) Mark Blackburn (PI), Stevens John Dzielski- Stevens Tom Hagedorn – Stevens Steve Hespelt – Stevens Daniel Dunbar (PhD) – Stevens Russell Peak – Georgia Tech. Selcuk Cimtalay – Georgia Tech. Taylor Fields – Georgia Tech.
RT-118 (2014) Mark Blackburn (PI), Stevens Rob Cloutier - Stevens Eirik Hole - Stevens Gary Witus – Wayne State		WRT-1008 (2019) Mark Blackburn (PI), Stevens Mary Bone - Stevens John Dzielski- Stevens Benjamin Kruse - Stevens Bill Rouse – Stevens/Georgetown Russell Peak – Georgia Tech. Selcuk Cimtalay – Georgia Tech. Adam Baker (Grad) – Georgia Tech. Marlin Ballard (Grad) – Georgia Tech. Alanna Carnevale (Grad) – Georgia Tech. William Stock (Grad) – Georgia Tech. Michael Szostak (Grad) – Georgia Tech. Donna Rhodes - MIT Mark Austin – Univ. Maryland Maria Coelho (Grad) – Univ. Maryland		
RT-141 (2015) Mark Blackburn (PI), Stevens Mary Bone - Stevens Gary Witus – Wayne State				
RT-157 (2016) Mark Blackburn (PI), Stevens Mary Bone - Stevens Roger Blake - Stevens Mark Austin – Univ. Maryland Leonard Petnga – Univ. of Maryland				
RT-170 (2016) Mark Blackburn (PI), Stevens Mary Bone - Stevens Deva Henry - Stevens Paul Grogan - Stevens Steven Hoffenson - Stevens Mark Austin – Univ. of Maryland Leonard Petnga – Univ. of Maryland Maria Coelho (Grad) – UMD Russell Peak – Georgia Tech. Stephen Edwards – Georgia Tech. Adam Baker (Grad) – Georgia Tech. Marlin Ballard (Grad) – Georgia Tech.				

THANK YOU

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