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RT137 ITAP: SysML Building Blocks for Cost Modeling

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Systems Engineering Research Center (SERC)

RT137 ITAP: SysML
Building Blocks for Cost Modeling

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Objectives

- Contribute key capability towards goals of ITAP, which is the *"-ilities" Tradespace and Affordability Program* (RT46/113/137)
- Provide model-based affordability analysis for tradespaces that include diverse complex "-ilities"

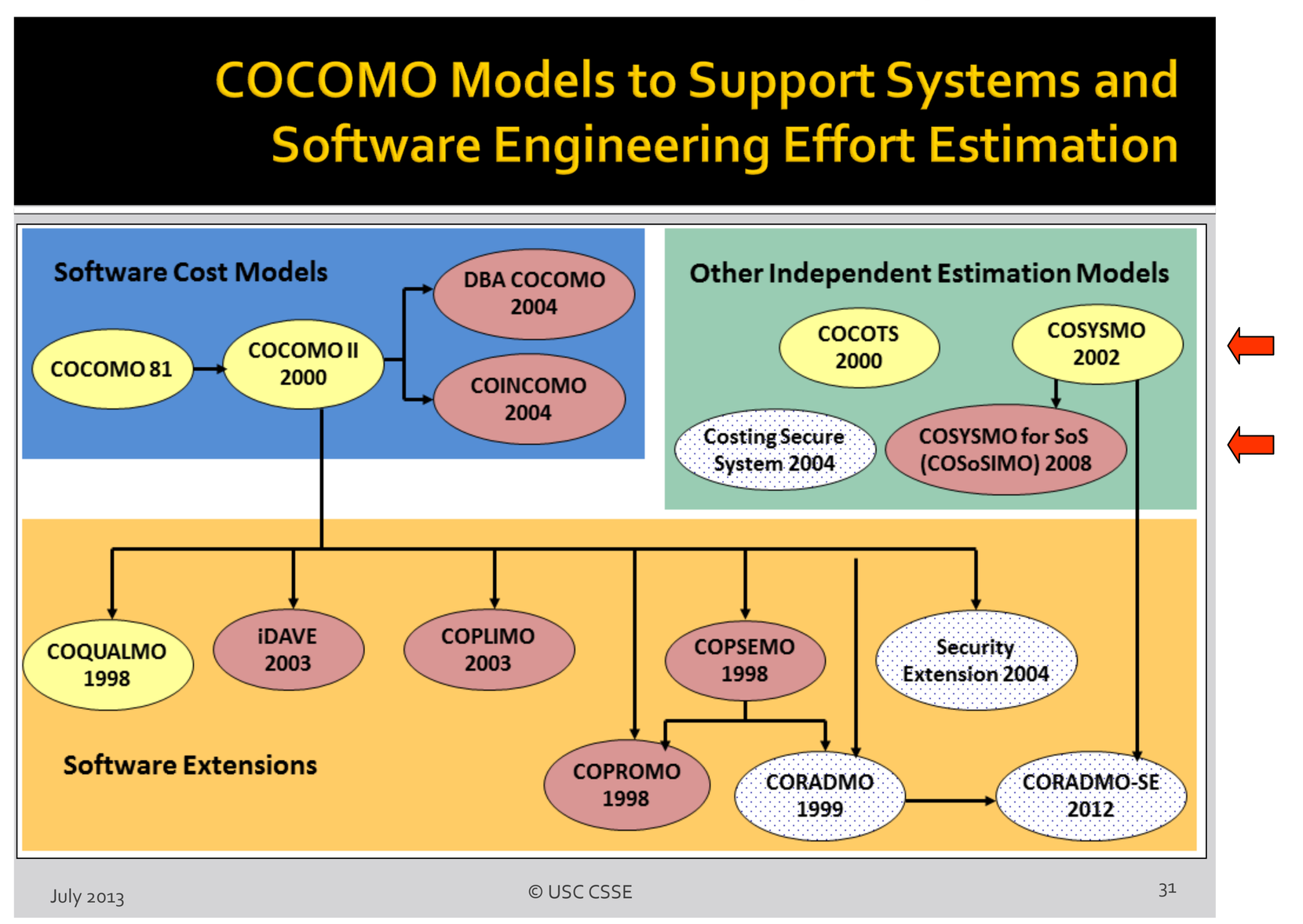
Overall Approach

- Leverage and extend several current bodies of work (BWi):
  - — BW1: Trade study capabilities (FACT/ERS/Cortex)
  - — BW2: Patterns for model interoperability (MIM)
  - — BW3: Cost modeling capabilities (COSYSMO ...)
  - — BW4: Implementation enablers (MBSE/SysML ...)
- Incorporate other "ilities" via BW3-like modeling in future phases

BW1: Trade Study Capabilities (FACT)

SysML-Based Environment for Advanced Trade Studies

BW3: Cost/Effort Modeling Capabilities


COCOMO Models to Support Systems and Software Engineering Effort Estimation
Software Cost Models
COCOMO 81
COCOMO II 2000
DBA COCOMO 2004
COINCOMO 2004
Other Independent Estimation Models
COCOTS 2000
COSYSMO 2002
Costing Secure System 2004
COSYSMO for SoS (COSoSIMO) 2008
COQUALMO 1998
iDAVE 2003
COPLIMO 2003
COPSEMO 1998
Security Extension 2004
Software Extensions
COPROMO 1998
CORADMO 1999
CORADMO-SE 2012
July 2013
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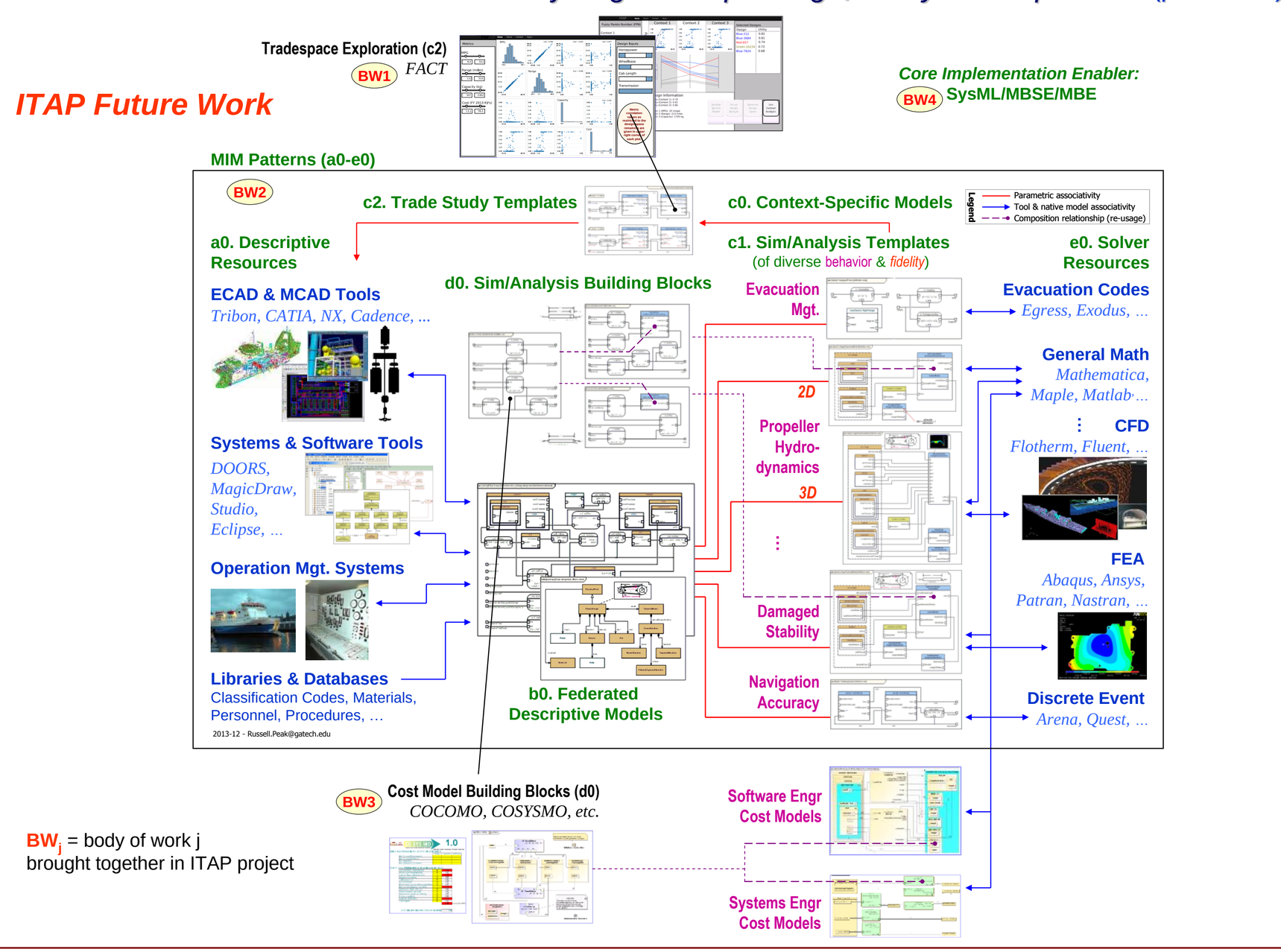
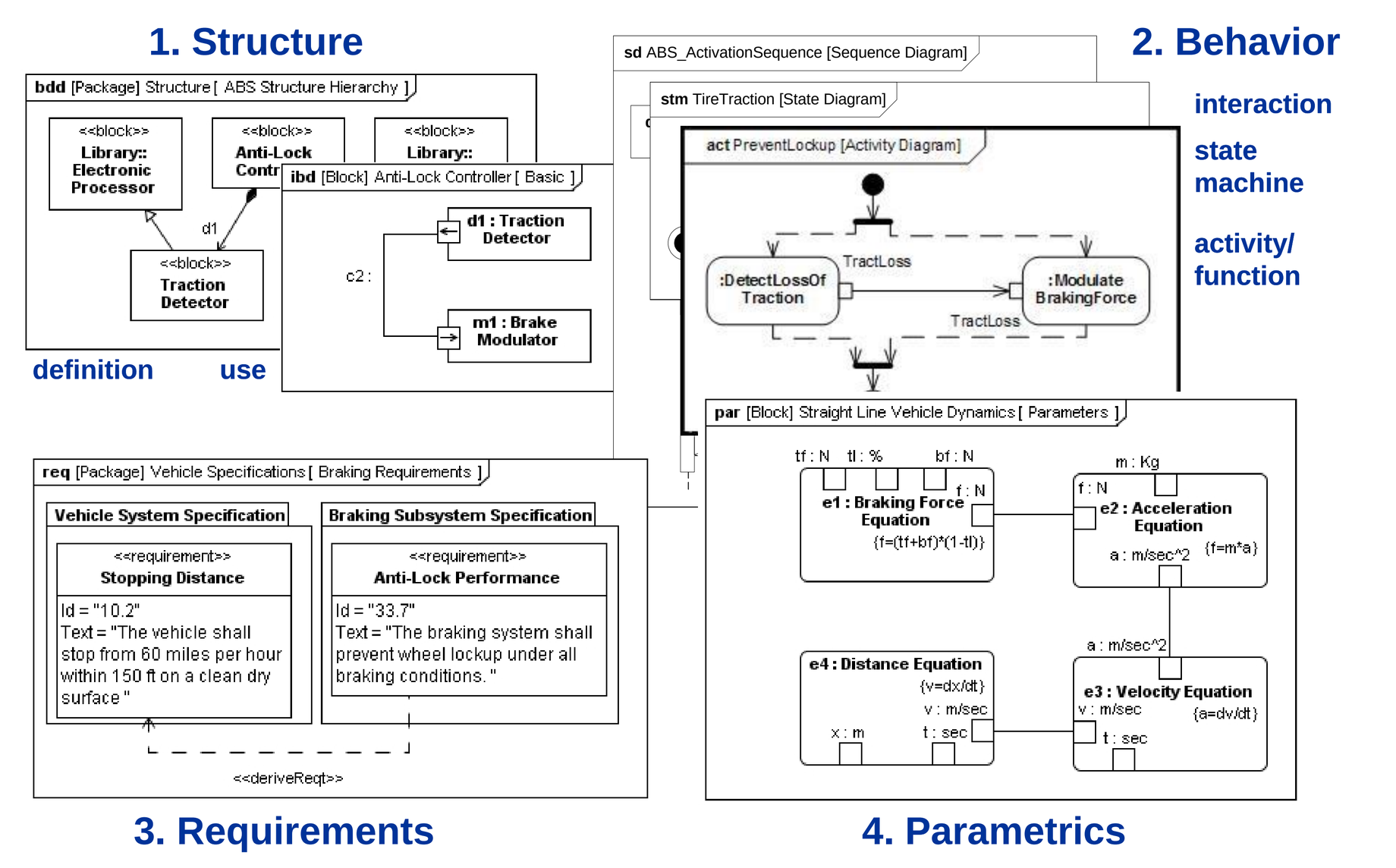
BW2: Patterns for Model Interoperability (MIM)

MIM Panorama with Envisioned ITAP Synergies: *Ship Design, Analysis & Operation (pro-forma)*

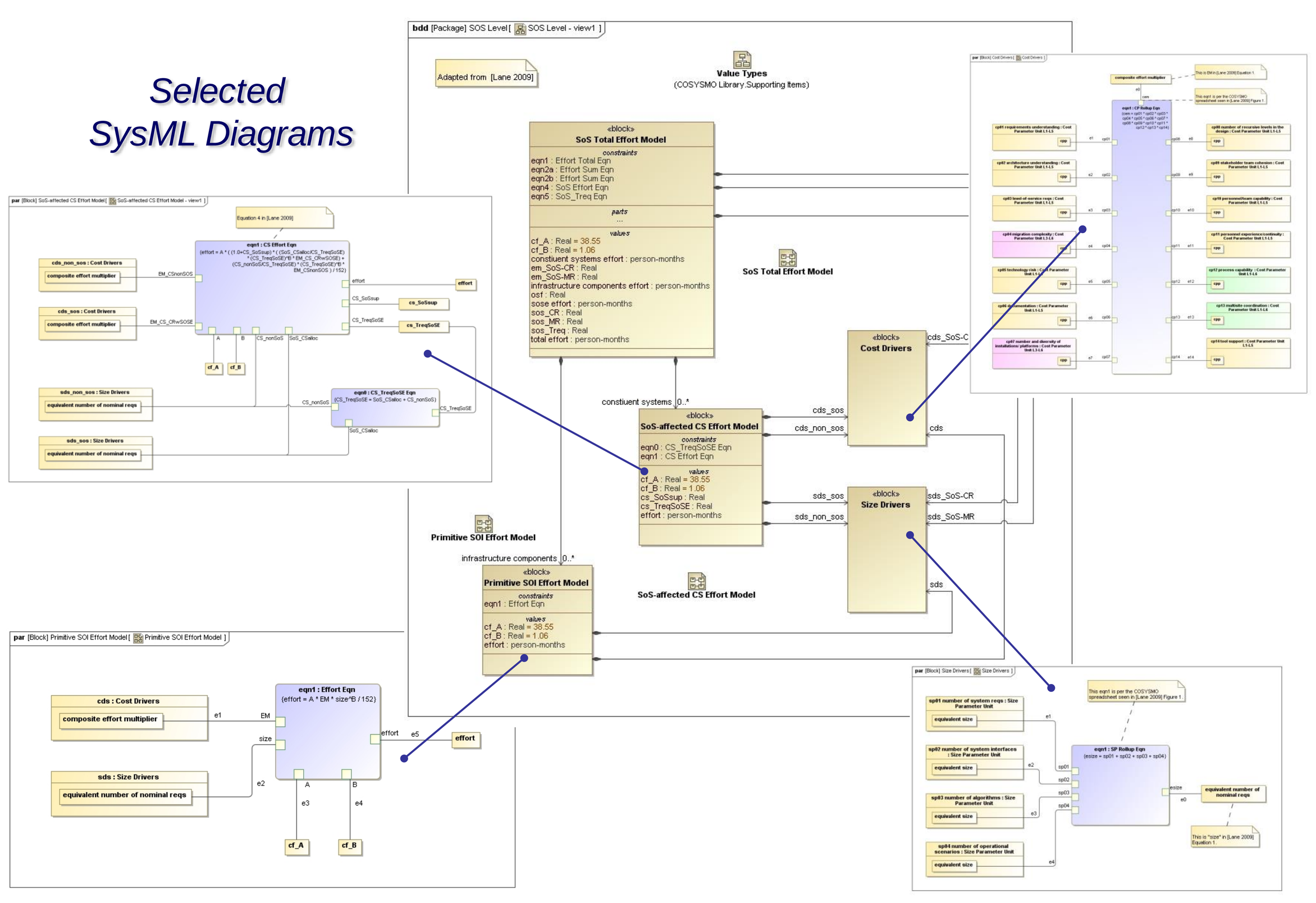

ITAP Future Work
Tradespace Exploration (c2)
FACT
Core Implementation Enabler:
SysML/MBSE/MBE
MIM Patterns (a0-e0)
c2. Trade Study Templates
c0. Context-Specific Models
a0. Descriptive Resources
c1. Sim/Analysis Templates
e0. Solver Resources
ECAD & MCAD Tools
d0. Sim/Analysis Building Blocks
Evacuation Codes
General Math
CFD
FEA
Systems & Software Tools
Operation Mgt. Systems
Libraries & Databases
b0. Federated Descriptive Models
Discrete Event
Cost Model Building Blocks (d0)
COCOMO, COSYSMO, etc.
Software Engr Cost Models
Systems Engr Cost Models
BWj = body of work j brought together in ITAP project

BW4: MBSE/SysML as Implementation Enablers

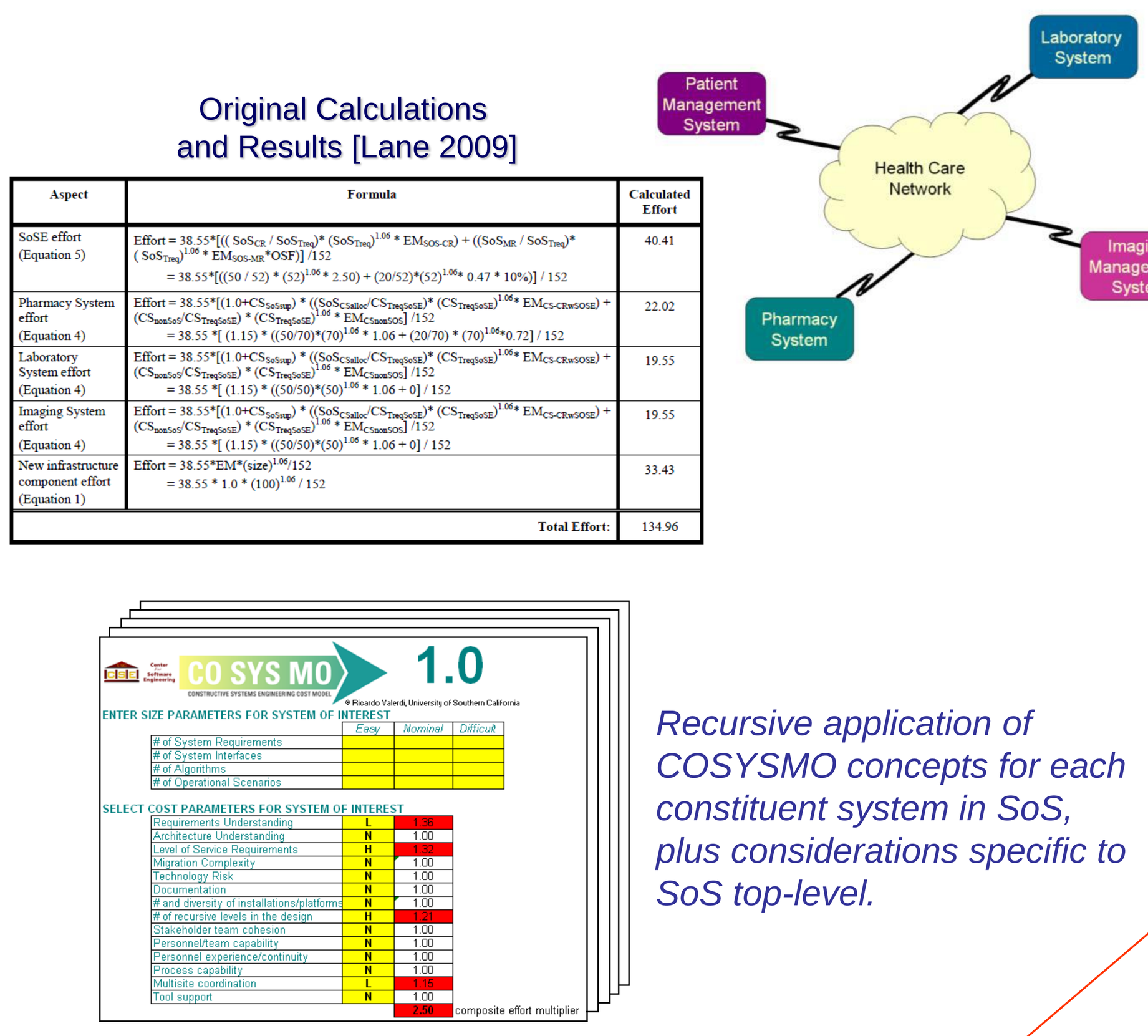
Automotive Anti-Lock Braking System Example – www.omgsysml.org



(A) Cost Modeling Concepts Implemented as SysML Building Blocks

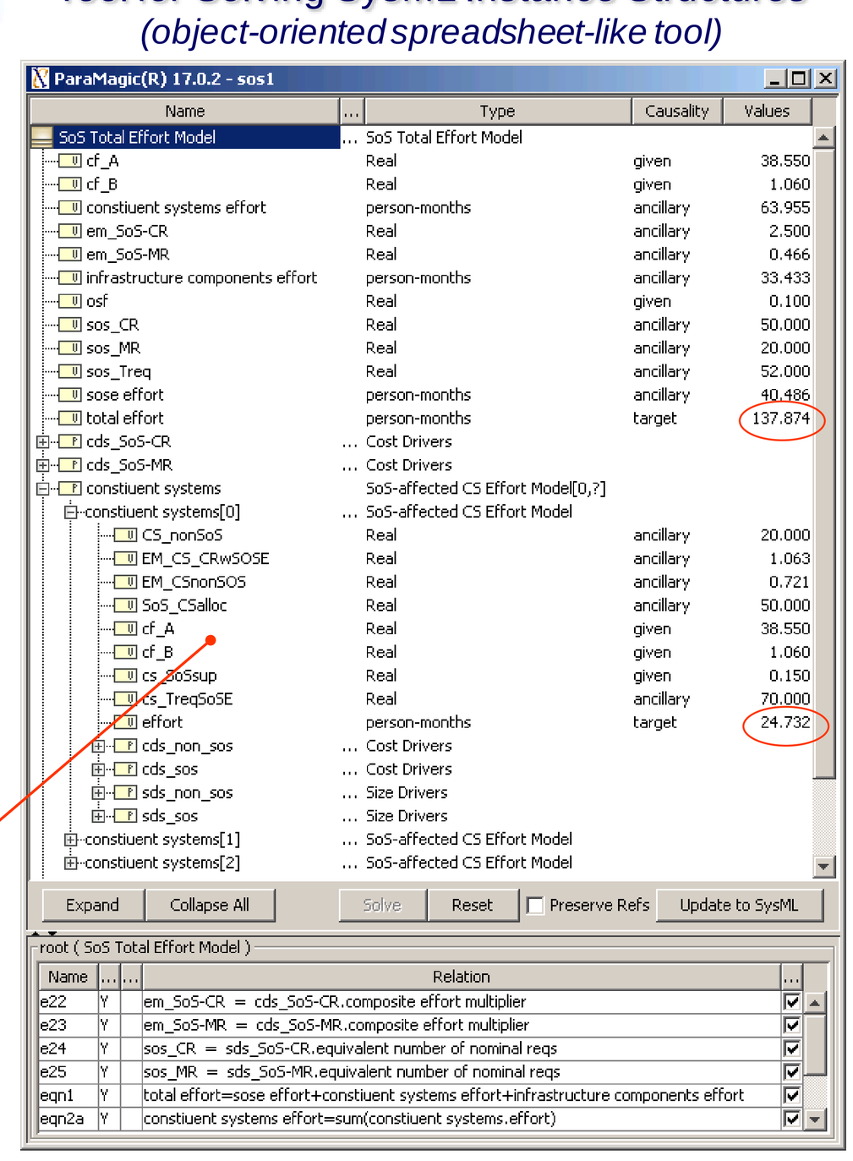


(B1) Healthcare SoS Case Study1 [Lane 2009]

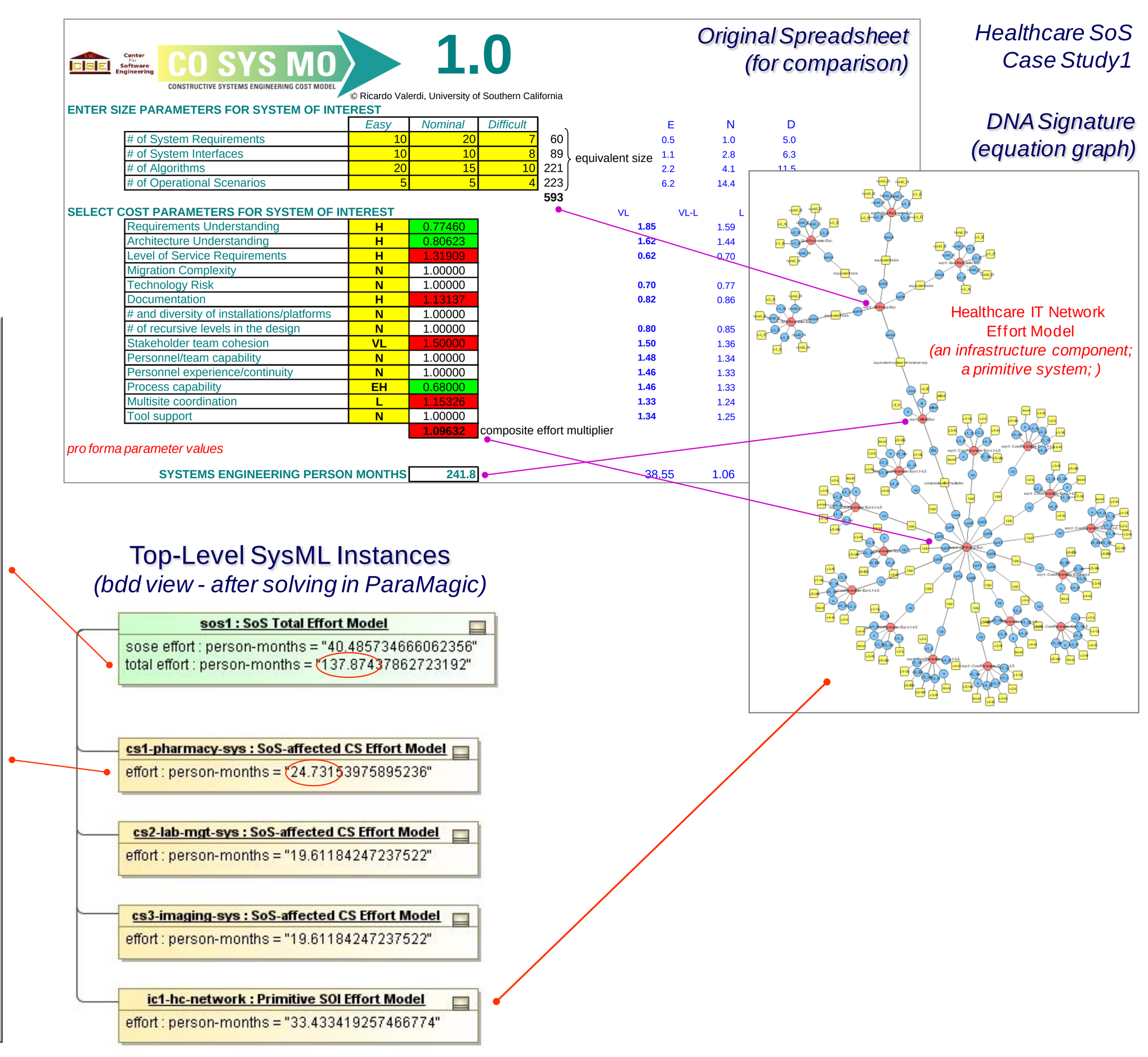

Original Calculations and Results [Lane 2009]
Patient Management System
Laboratory System
Health Care Network
Imaging Management System
Pharmacy System
Recursive application of COSYSMO concepts for each constituent system in SoS, plus considerations specific to SoS top-level.

Case Study 1: Model Execution

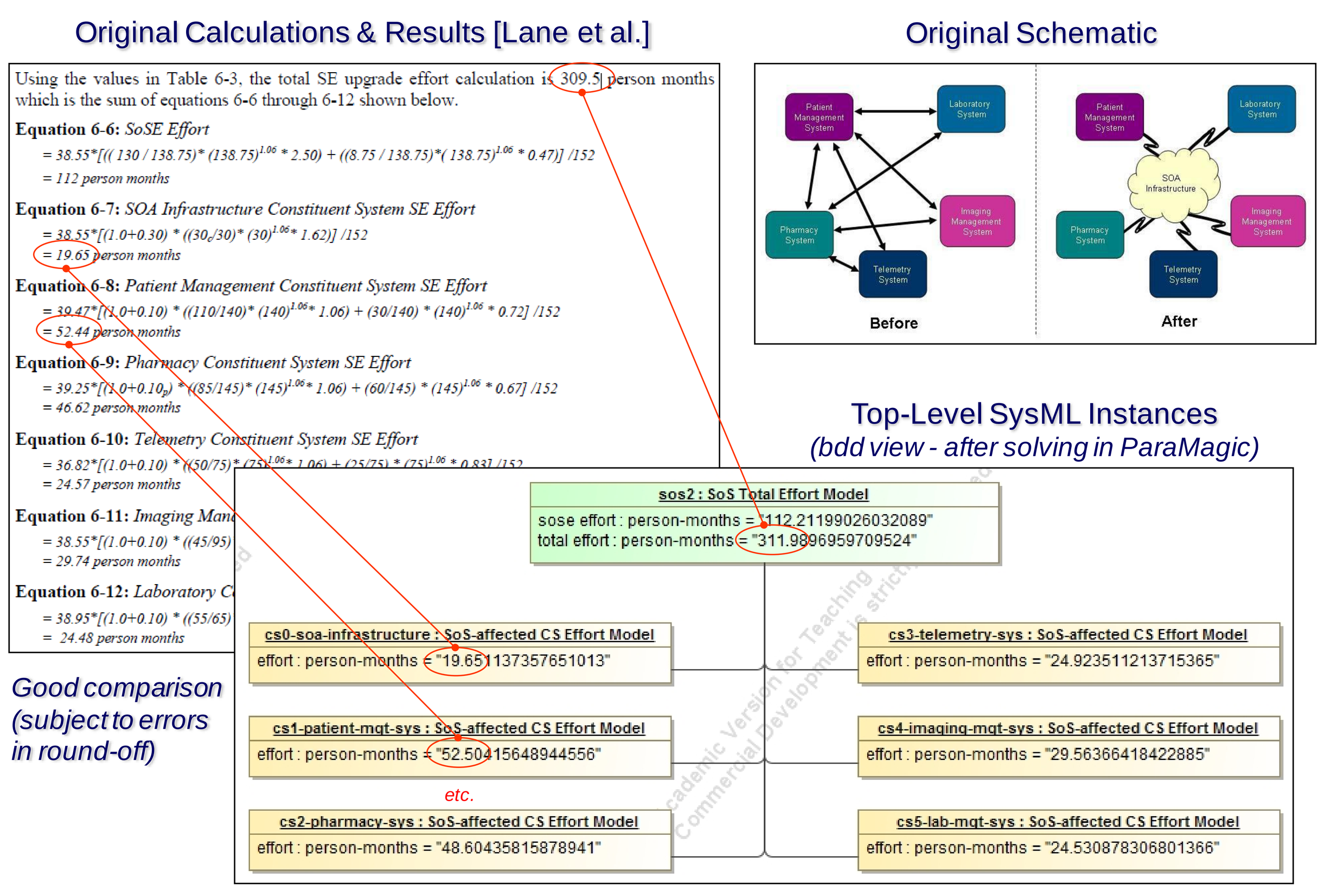
Tool for Solving SysML Instance Structures
(object-oriented spreadsheet-like tool)



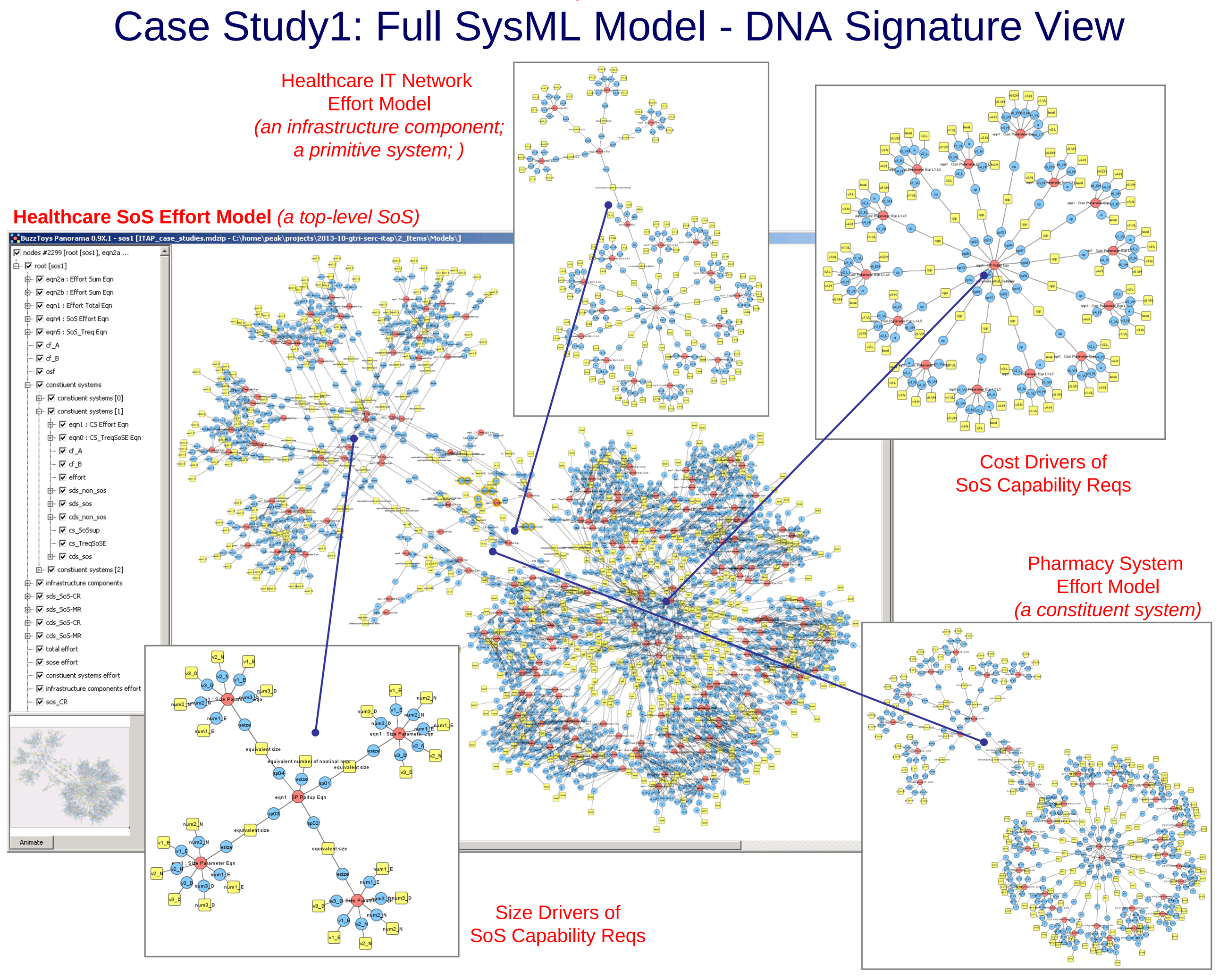
Subset of SysML Model - DNA Signature View


Original Spreadsheet (for comparison)
Healthcare SoS Case Study1
DNA Signature (equation graph)
Healthcare IT Network Effort Model
(an infrastructure component; a primitive system;)
Top-Level SysML Instances
(bdd view - after solving in ParaMagic)
sos1 : SoS Total Effort Model
sose effort : person-months = "40.4857346660623 56"
total effort : person-months = "137.874378627231 92"
cs1-pharmacy-sys : SoS-affected CS Effort Model
effort : person-months = "24.7315 3975895236"
cs2-lab-mgt-sys : SoS-affected CS Effort Model
effort : person-months = "19.61184247237522"
cs3-imaging-sys : SoS-affected CS Effort Model
effort : person-months = "19.61184247237522"
ic1-hc-network : Primitive SOI Effort Model
effort : person-months = "33.433419257466774"

(B2) Healthcare SoS Case Study2: Results Verification


Original Calculations & Results [Lane et al.]
Original Schematic
Before
After
Top-Level SysML Instances
(bdd view - after solving in ParaMagic)
sos2 : SoS Total Effort Model
sose effort : person-months = "112.21199026032089"
total effort : person-months = "311.9896959709524"
cs0-soa-infrastructure : SoS-affected CS Effort Model
effort : person-months = "19.651137357651013"
cs1-patient-mgt-sys : SoS-affected CS Effort Model
effort : person-months = "52.50415648944556"
cs2-pharmacy-sys : SoS-affected CS Effort Model
effort : person-months = "48.60435815878941"
cs3-telemetry-sys : SoS-affected CS Effort Model
effort : person-months = "24.923511213715365"
cs4-imaging-mgt-sys : SoS-affected CS Effort Model
effort : person-months = "29.56366418422885"
cs5-lab-mgt-sys : SoS-affected CS Effort Model
effort : person-months = "24.530878306801366"
etc.
Good comparison (subject to errors in round-off)

Case Study1: Full SysML Model - DNA Signature View

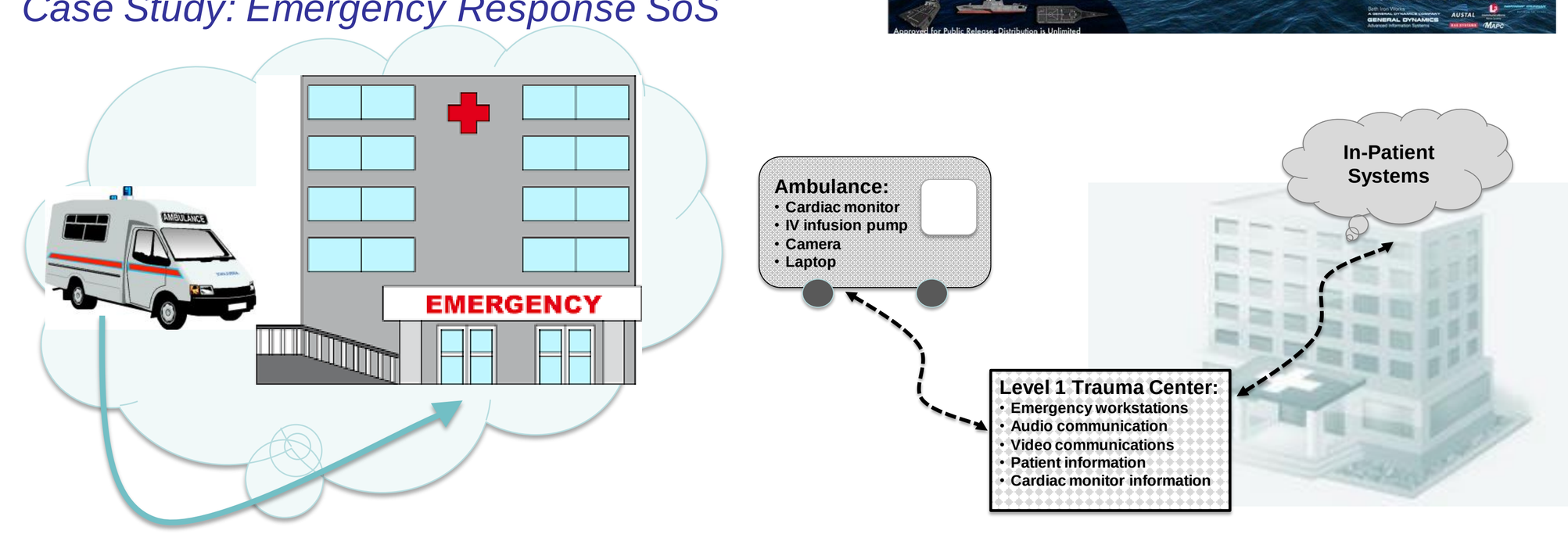

Healthcare IT Network Effort Model
(an infrastructure component; a primitive system;)
Healthcare SoS Effort Model (a top-level SoS)
Cost Drivers of SoS Capability Reqs
Pharmacy System Effort Model
(a constituent system)
Size Drivers of SoS Capability Reqs

(C) Applications and Candidate Future Case Studies

- Analysis of alternatives (AoA)
  - – Subsystem/component upgrades
  - – Levels of capability option performance within SoS
  - – Interoperability assessments for alternatives
- System/component retirement (or replacement) assessments
- Capabilities vs. costs

Case Study: Military Operations SoS

Case Study: Emergency Response SoS



Approach (Oct 2013 - Dec 2015)

- Implement cost modeling concepts as SysML building blocks
  - — Based on SoS/COSYSMO systems engineering cost (effort) modeling work by Lane, Valerdi, Boehm, et al.
  - — Provides generic, reusable knowledge capture
- Apply SysML building blocks to system-of-systems (SoS) case studies
- Characterize broader applications for affordability trade studies

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Accomplishments & Observations

- Created cost modeling building blocks in SysML
- Successfully validated via two healthcare SoS case studies:
  - — Base complexity (Case 1) and increased complexity (Case 2)
- Characterized integration approach and application usages:
  - — *By other tools:* FACT/ERS/Cortex, ...
  - — *With other capabilities:* risk analysis, schedule analysis, …
  - — *In normal system models:* idealization algorithms for sizing/costing factors
  - — *Via user-friendly interfaces:* OpenMBEE for model-based wikis
- Benefits:
  - — Enables better knowledge capture (e.g., includes units):
    - — More modular, reusable, precise, maintainable, complete, ...
    - — Acausal; better verification & validation vs. spreadsheets; ...
  - — Enables swapping in/out alternative subsystem designs
  - — Provides patterns that are easy-to-apply with many systems/SoS
- *Provides key step for affordability trade studies with diverse "-ilities"*