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RT137 ITAP: SysML Building Blocks for Cost Modeling

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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"

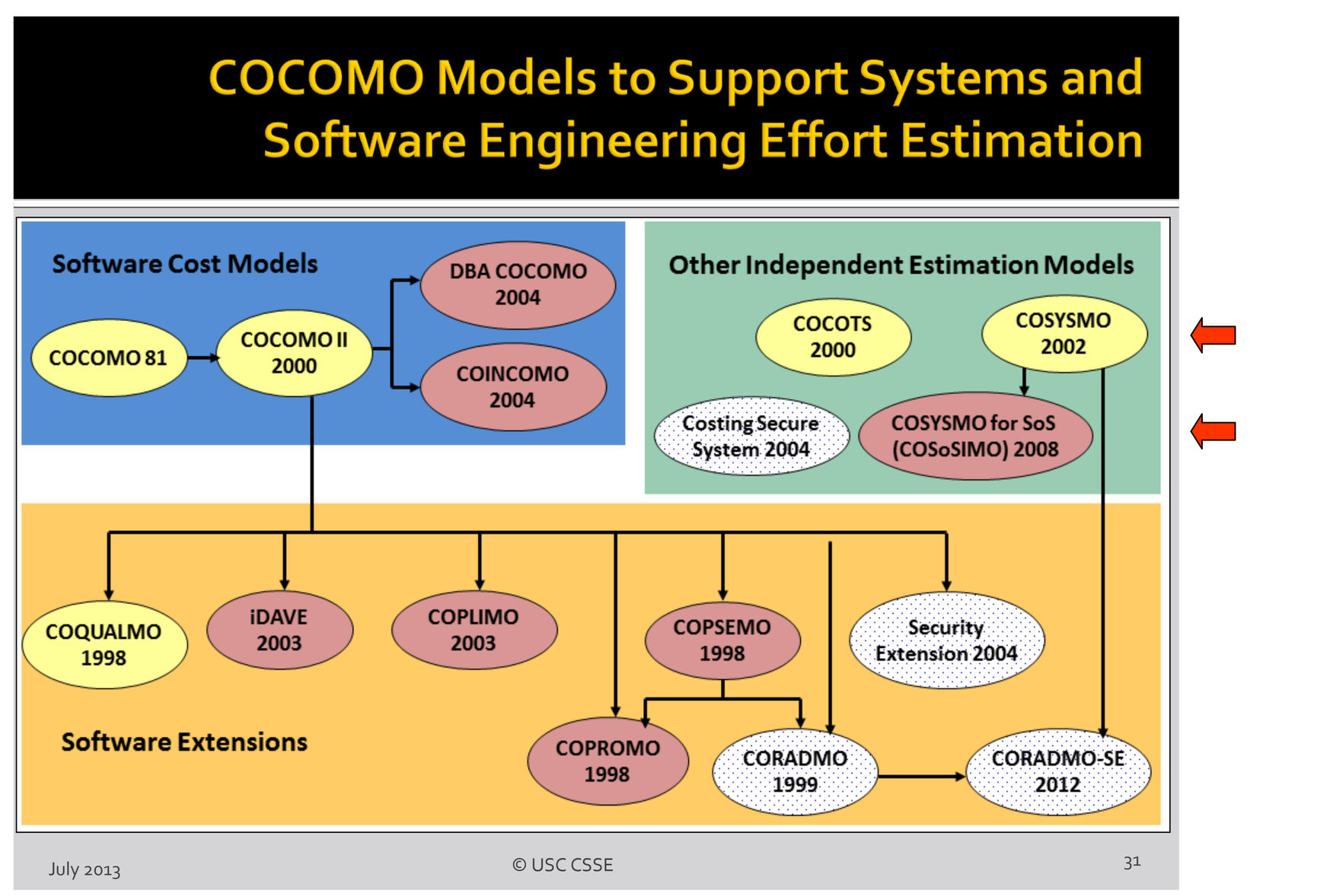
Overall Approach

- 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)

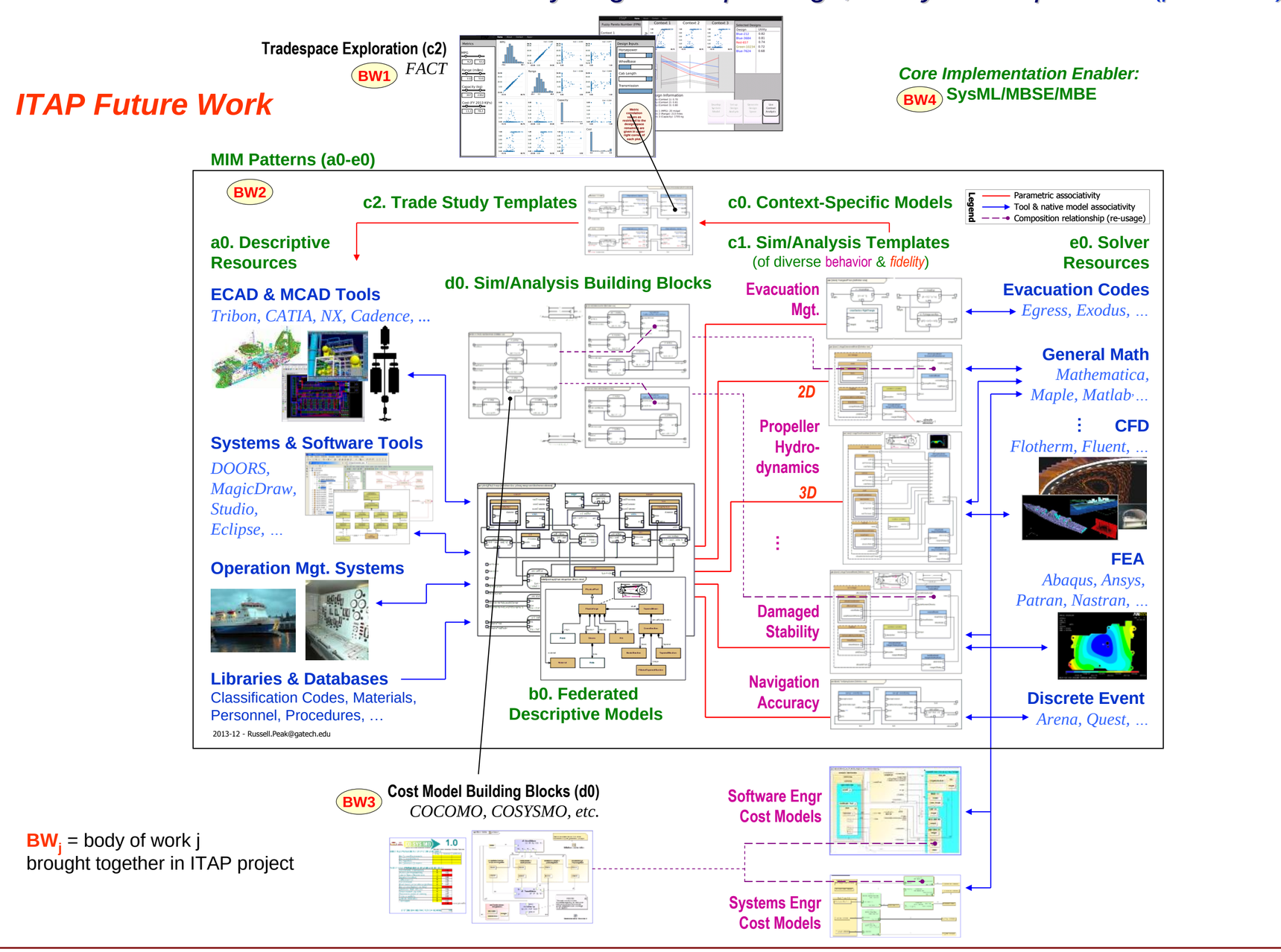
SysML-Based Environment for Advanced Trade Studies

BW3: Cost/Effort Modeling Capabilities



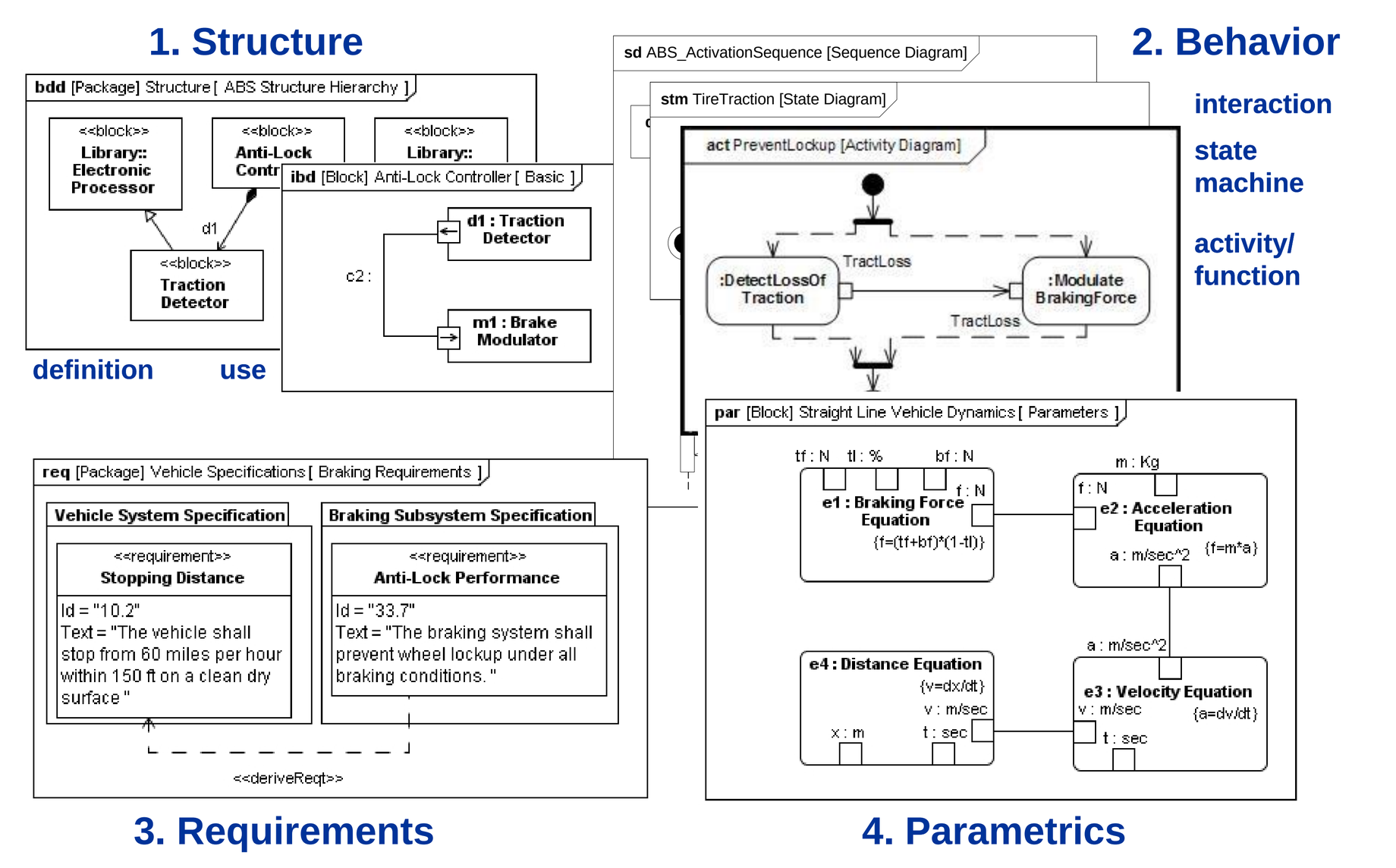
BW2: Patterns for Model Interoperability (MIM)

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

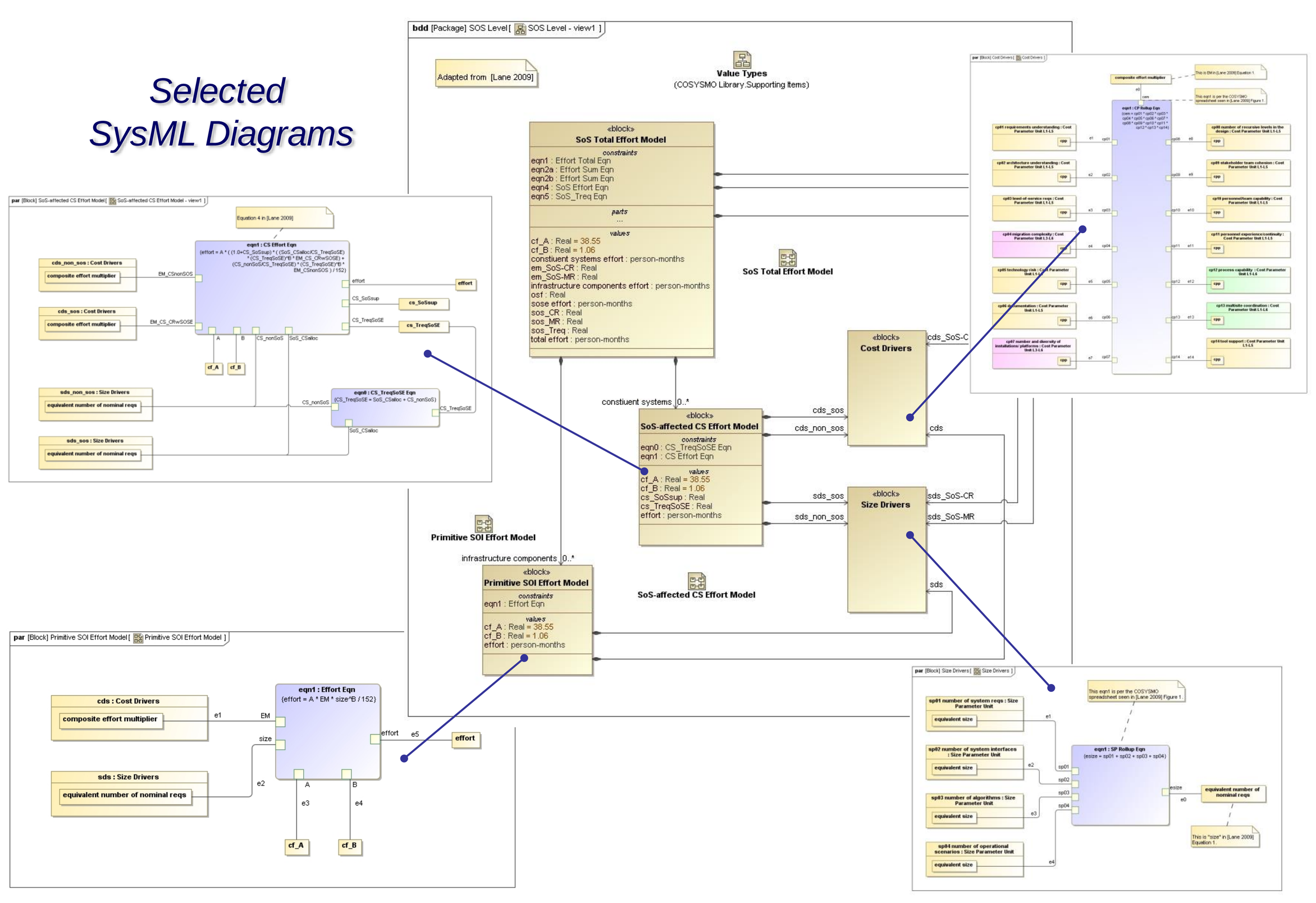


BW4: MBSE/SysML as Implementation Enablers

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



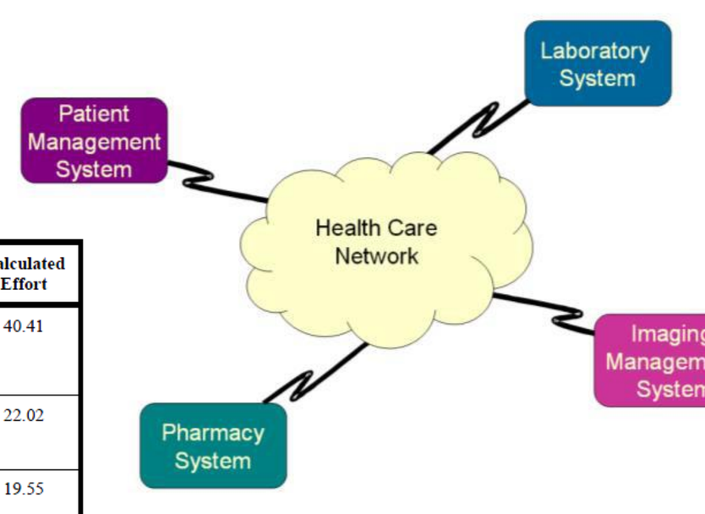
(A) Cost Modeling Concepts Implemented as SysML Building Blocks

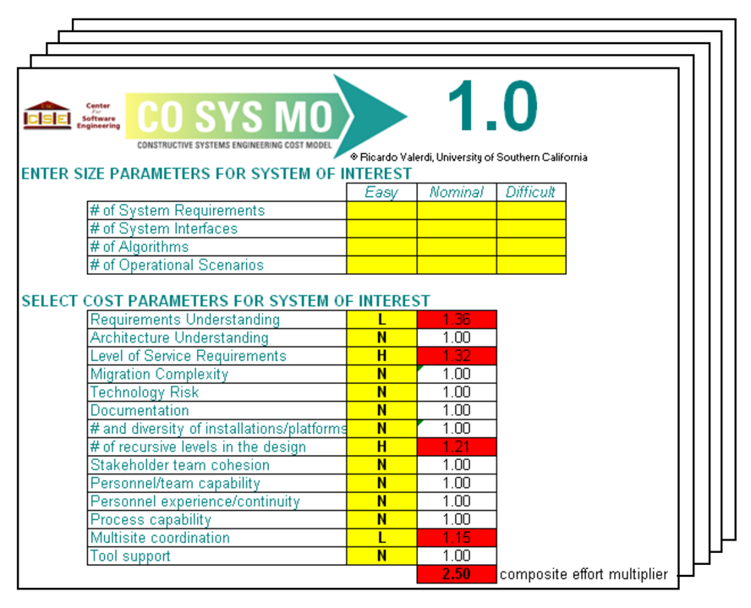


(B1) Healthcare SoS Case Study1 [Lane 2009]

Original Calculations and Results [Lane 2009]

Aspect	Formula	Calculated Effort
SoSE effort (Equation 5)	Effort = 38.55*[((SoS_CR / SoS_Treq)* (SoS_Treq)^1.06 * EM_SOS-CR) + ((SoS_MR / SoS_Treq)* (SoS_Treq)^1.06 * EM_SOS-MR*OSF)] /152 = 38.55*[((50 / 52) * (52)^1.06 * 2.50) + (20/52)*(52)^1.06 * 0.47 * 10%)] / 152	40.41
Pharmacy System effort (Equation 4)	Effort = 38.55*[(1.0+CS_SoSsup) * ((SoS_CSalloc/CS_TreqSoSE)* (CS_TreqSoSE)^1.06 * EM_CS-CRwSOSE) + (CS_nonSoS/CS_TreqSoSE) * (CS_TreqSoSE)^1.06 * EM_CSnonSOS] /152 = 38.55 *[(1.15) * ((50/70)*(70)^1.06 * 1.06 + (20/70) *(70)^1.06 * 0.72] / 152	22.02
Laboratory System effort (Equation 4)	Effort = 38.55*[(1.0+CS_SoSsup) * ((SoS_CSalloc/CS_TreqSoSE)* (CS_TreqSoSE)^1.06 * EM_CS-CRwSOSE) + (CS_nonSoS/CS_TreqSoSE) * (CS_TreqSoSE)^1.06 * EM_CSnonSOS] /152 = 38.55 *[(1.15) * ((50/50)*(50)^1.06 * 1.06 + 0] / 152	19.55
Imaging System effort (Equation 4)	Effort = 38.55*[(1.0+CS_SoSsup) * ((SoS_CSalloc/CS_TreqSoSE)* (CS_TreqSoSE)^1.06 * EM_CS-CRwSOSE) + (CS_nonSoS/CS_TreqSoSE) * (CS_TreqSoSE)^1.06 * EM_CSnonSOS] /152 = 38.55 *[(1.15) * ((50/50)*(50)^1.06 * 1.06 + 0] / 152	19.55
New infrastructure component effort (Equation 1)	Effort = 38.55*EM*(size)^1.06/152 = 38.55 * 1.0 * (100)^1.06 / 152	33.43
	Total Effort:	134.96

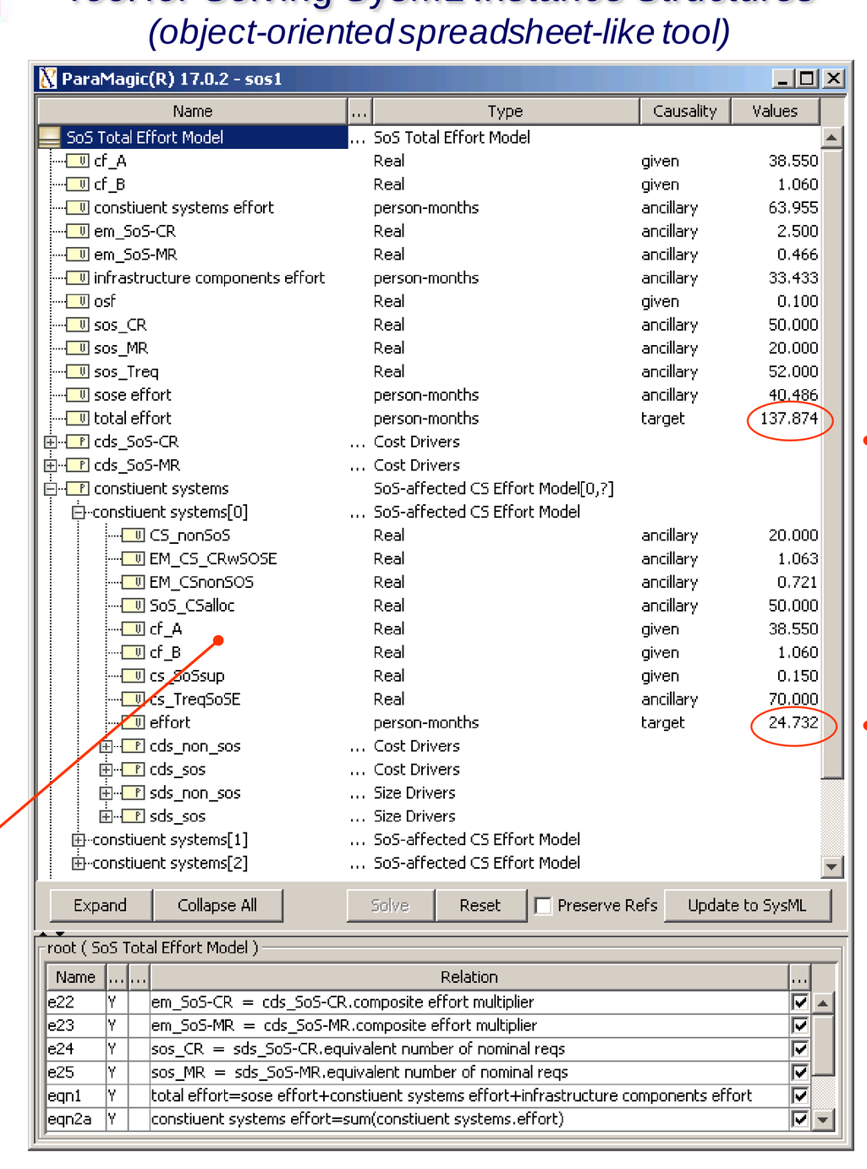




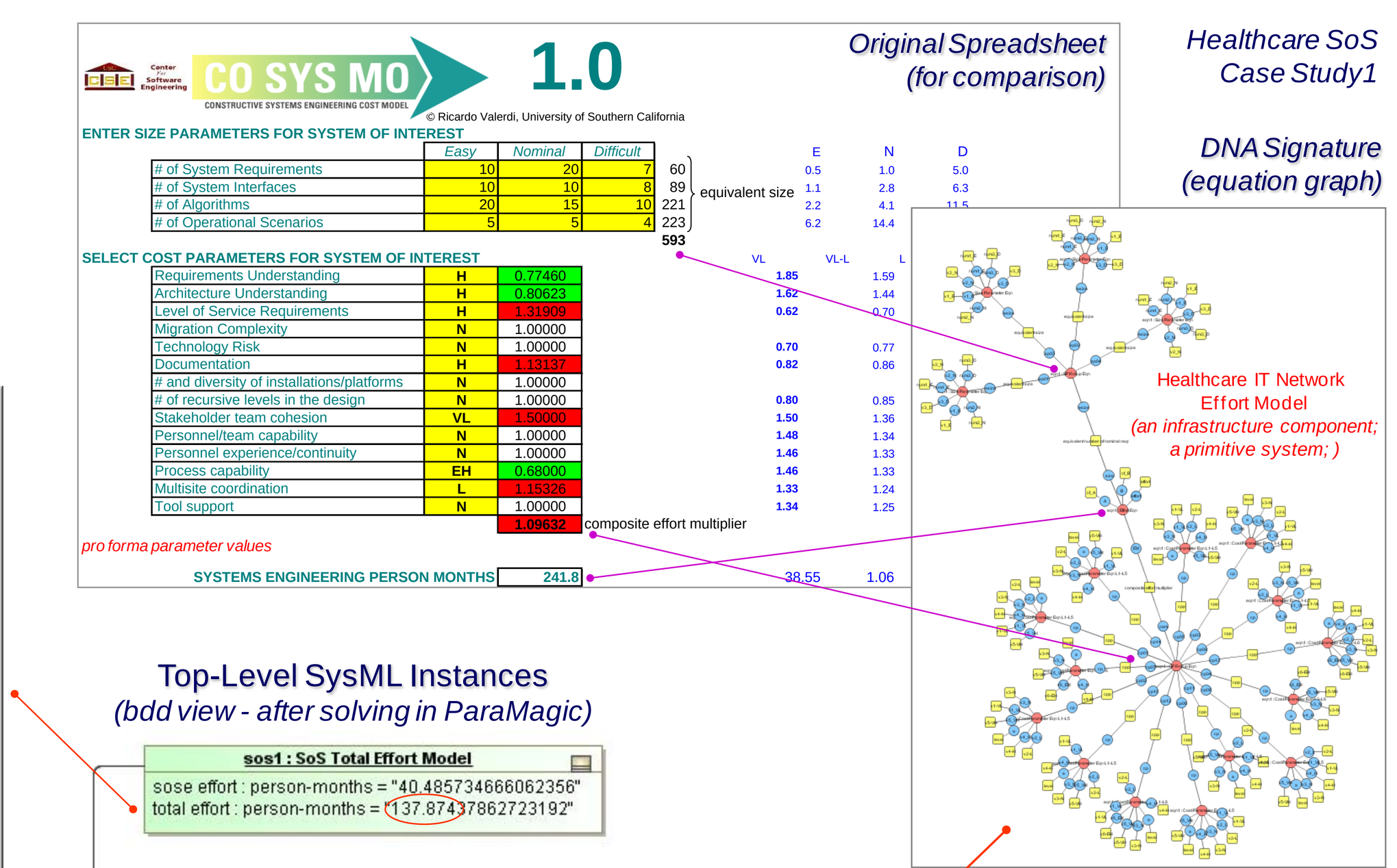
Recursive application of COSYSMO concepts for each constituent system in SoS, plus considerations specific to SoS top-level.

Case Study 1: Model Execution

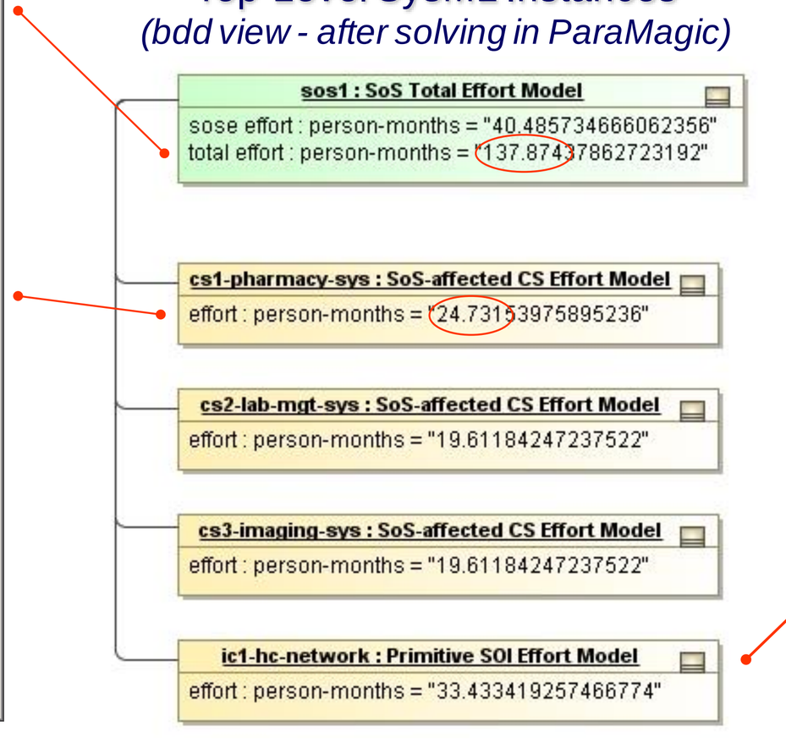
Tool for Solving SysML Instance Structures
(object-oriented spreadsheet-like tool)



Subset of SysML Model - DNA Signature View

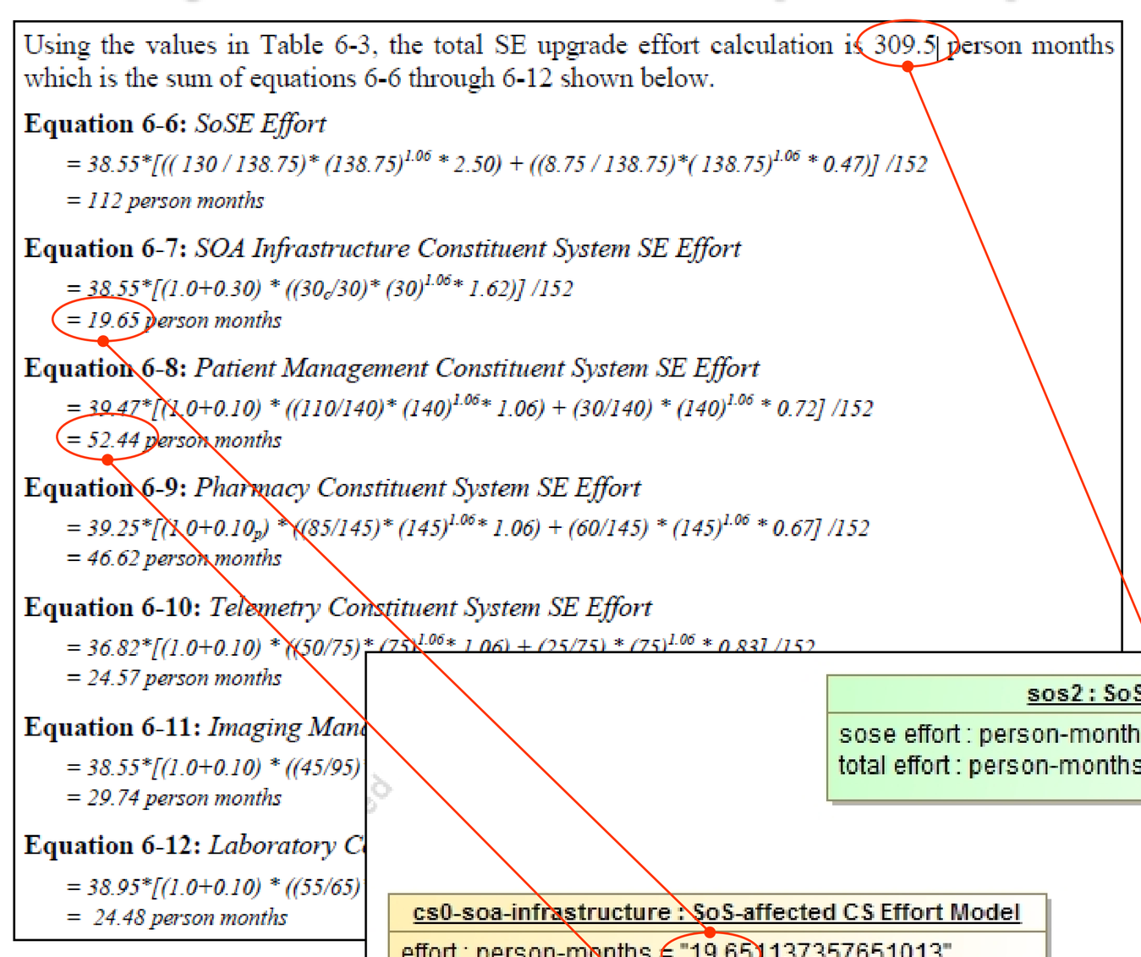


Top-Level SysML Instances
(bdd view - after solving in ParaMagic)



(B2) Healthcare SoS Case Study2: Results Verification

Original Calculations & Results [Lane et al.]



Using the values in Table 6-3, the total SE upgrade effort calculation is 309.5 person months which is the sum of equations 6-6 through 6-12 shown below.

Equation 6-6: *SoSE Effort*
= 38.55*[((130 / 138.75)* (138.75)^1.06 * 2.50) + ((8.75 / 138.75)*(138.75)^1.06 * 0.47)] /152
= 112 person months

Equation 6-7: *SOA Infrastructure Constituent System SE Effort*
= 38.55*[(1.0+0.30) * ((30/30)* (30)^1.06* 1.62)] /152
= 19.65 person months

Equation 6-8: *Patient Management Constituent System SE Effort*
= 39.47*[(1.0+0.10) * ((110/140)* (140)^1.06* 1.06) + (30/140) * (140)^1.06 * 0.72] /152
= 52.44 person months

Equation 6-9: *Pharmacy Constituent System SE Effort*
= 39.25*[(1.0+0.10) * ((85/145)* (145)^1.06* 1.06) + (60/145) * (145)^1.06 * 0.67] /152
= 46.62 person months

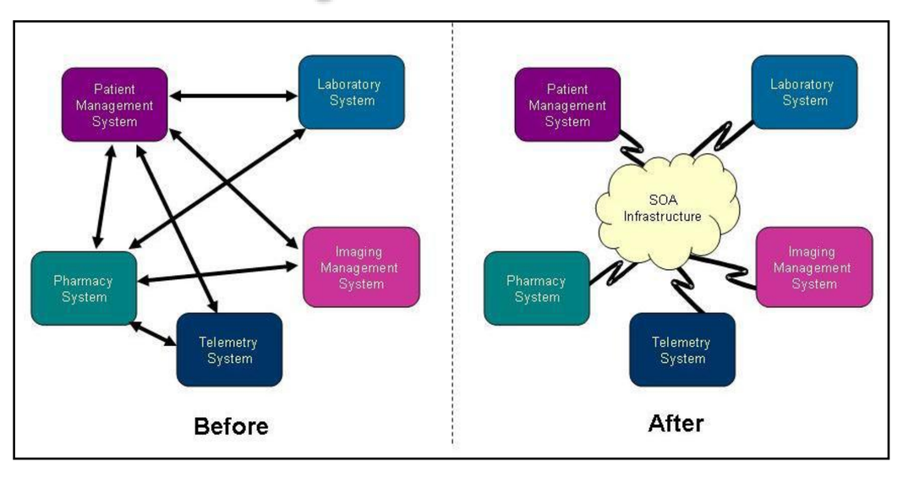
Equation 6-10: *Telemetry Constituent System SE Effort*
= 36.82*[(1.0+0.10) * ((50/75)* (75)^1.06* 1.06) + (25/75) * (75)^1.06 * 0.83] /152
= 24.57 person months

Equation 6-11: *Imaging Mana*
= 38.55*[(1.0+0.10) * ((45/95)
= 29.74 person months

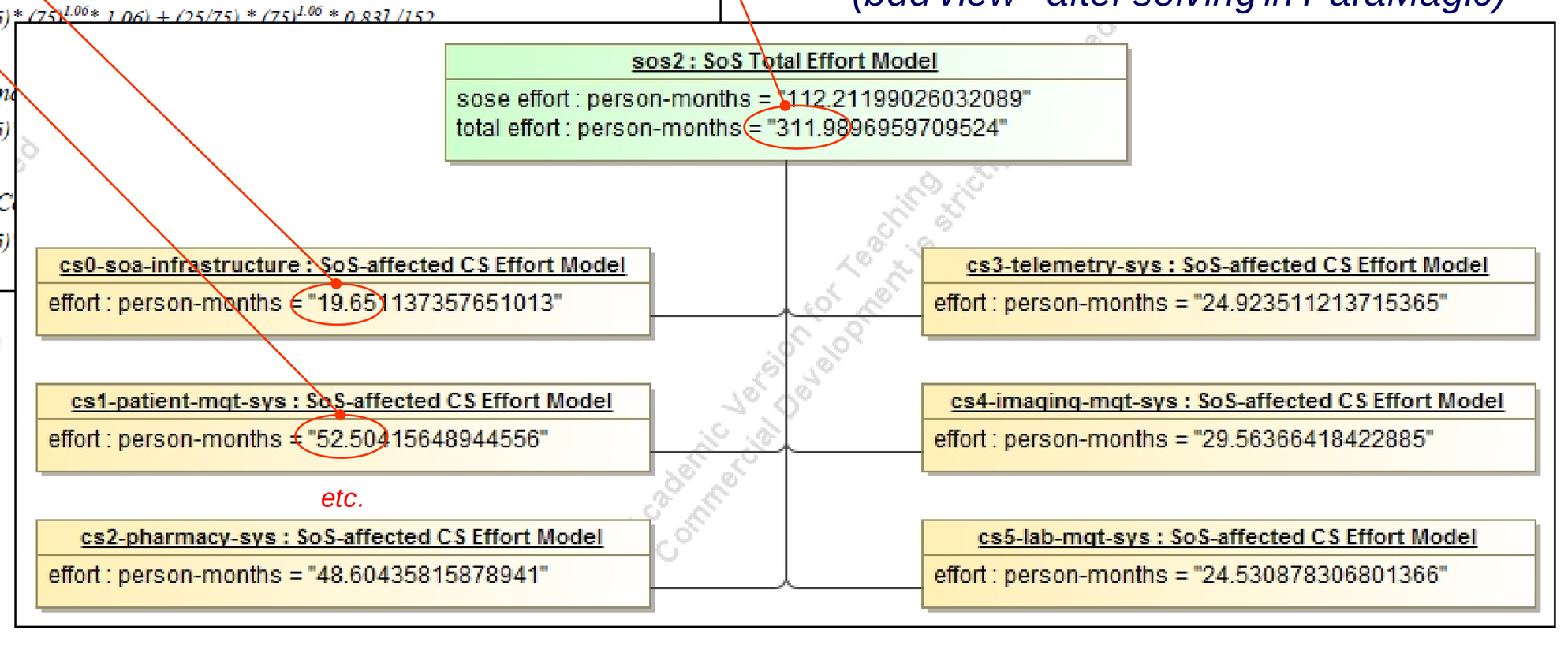
Equation 6-12: *Laboratory C*
= 38.95*[(1.0+0.10) * ((55/65)
= 24.48 person months

Good comparison (subject to errors in round-off)

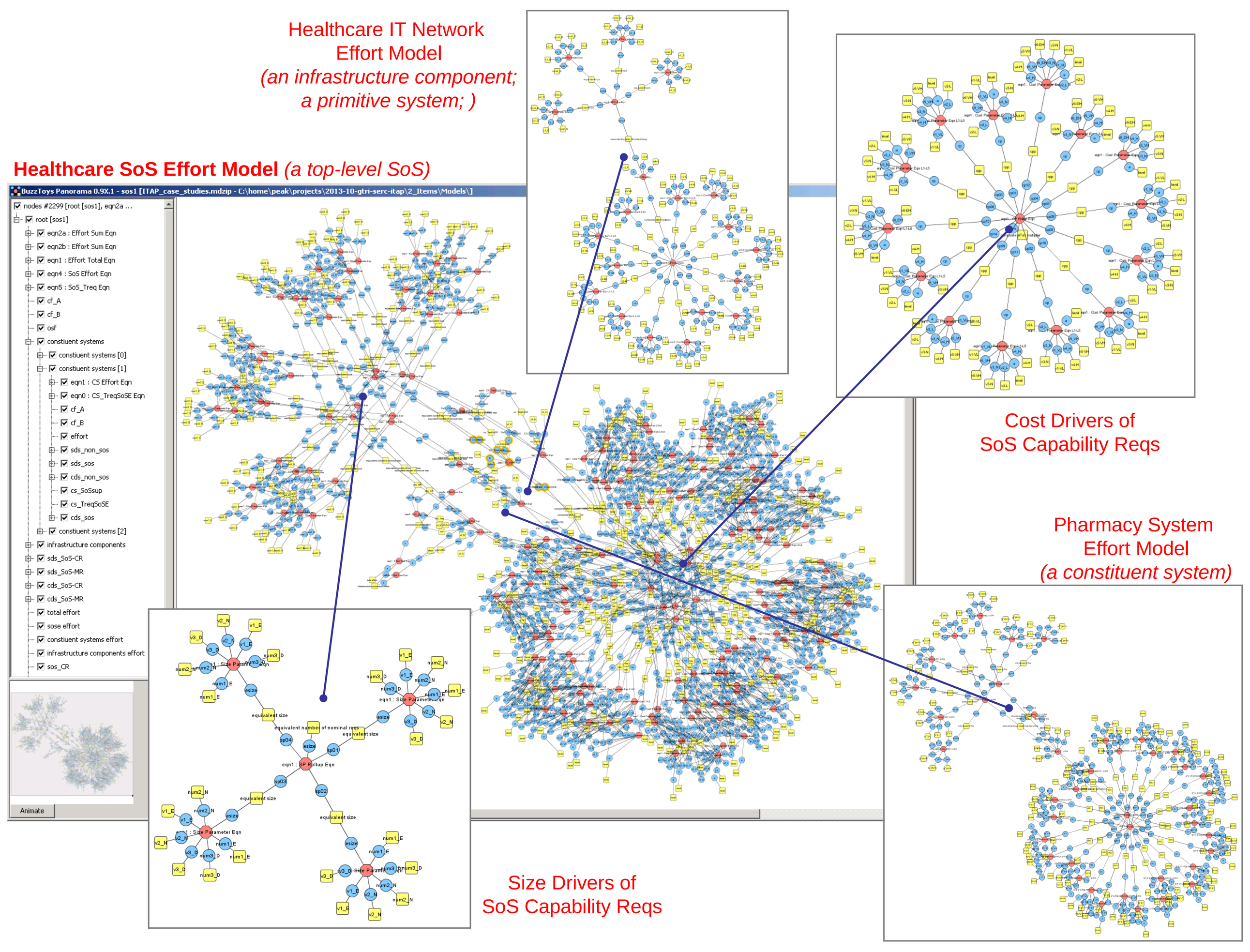
Original Schematic



Top-Level SysML Instances
(bdd view - after solving in ParaMagic)



Case Study1: Full SysML Model - DNA Signature View

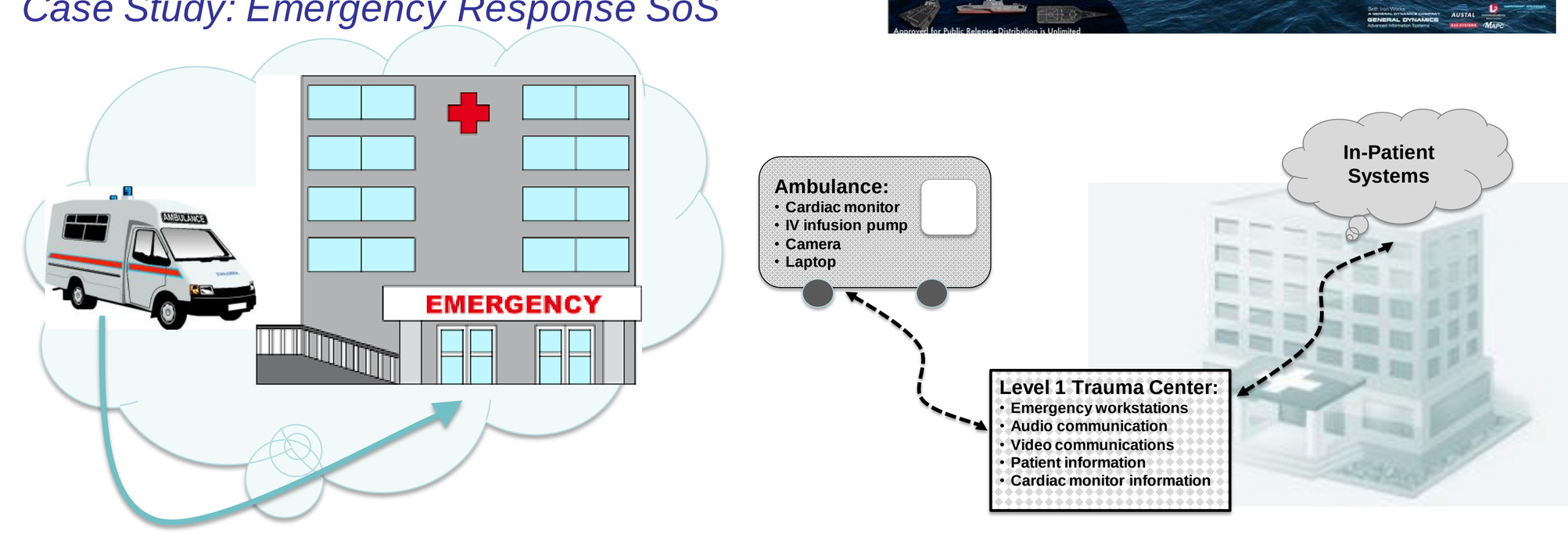


(C) Applications and Candidate Future Case Studies

- 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"*