Using a Model-Based Systems Engineering Approach For Exploration Medical System Development

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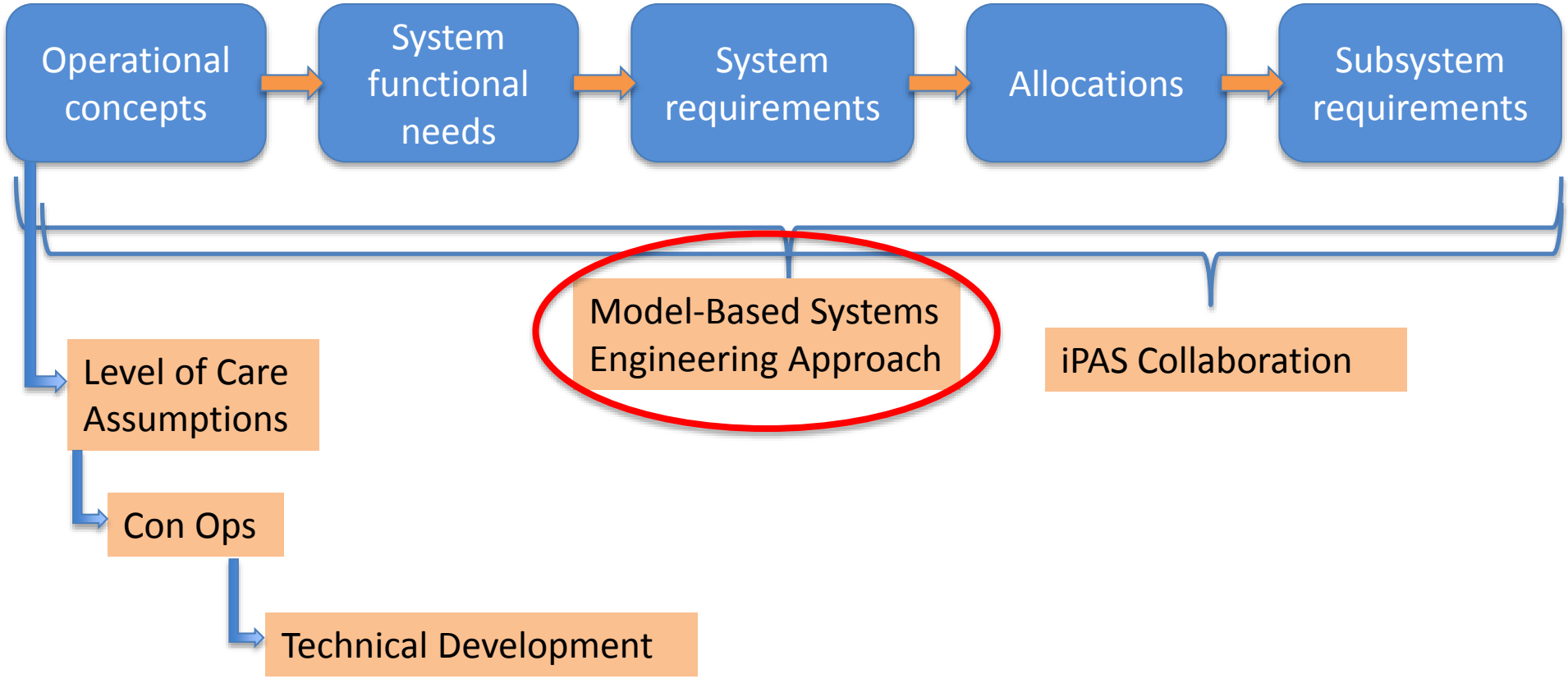
Systems Engineering Session Talks



The needs identified by this work will drive future ExMC research

Systems Engineering Recap

What is Systems Engineering?

- A methodical, disciplined approach for the design, realization, technical management, operations, and retirement of a system.

Systems Engineering Provides:

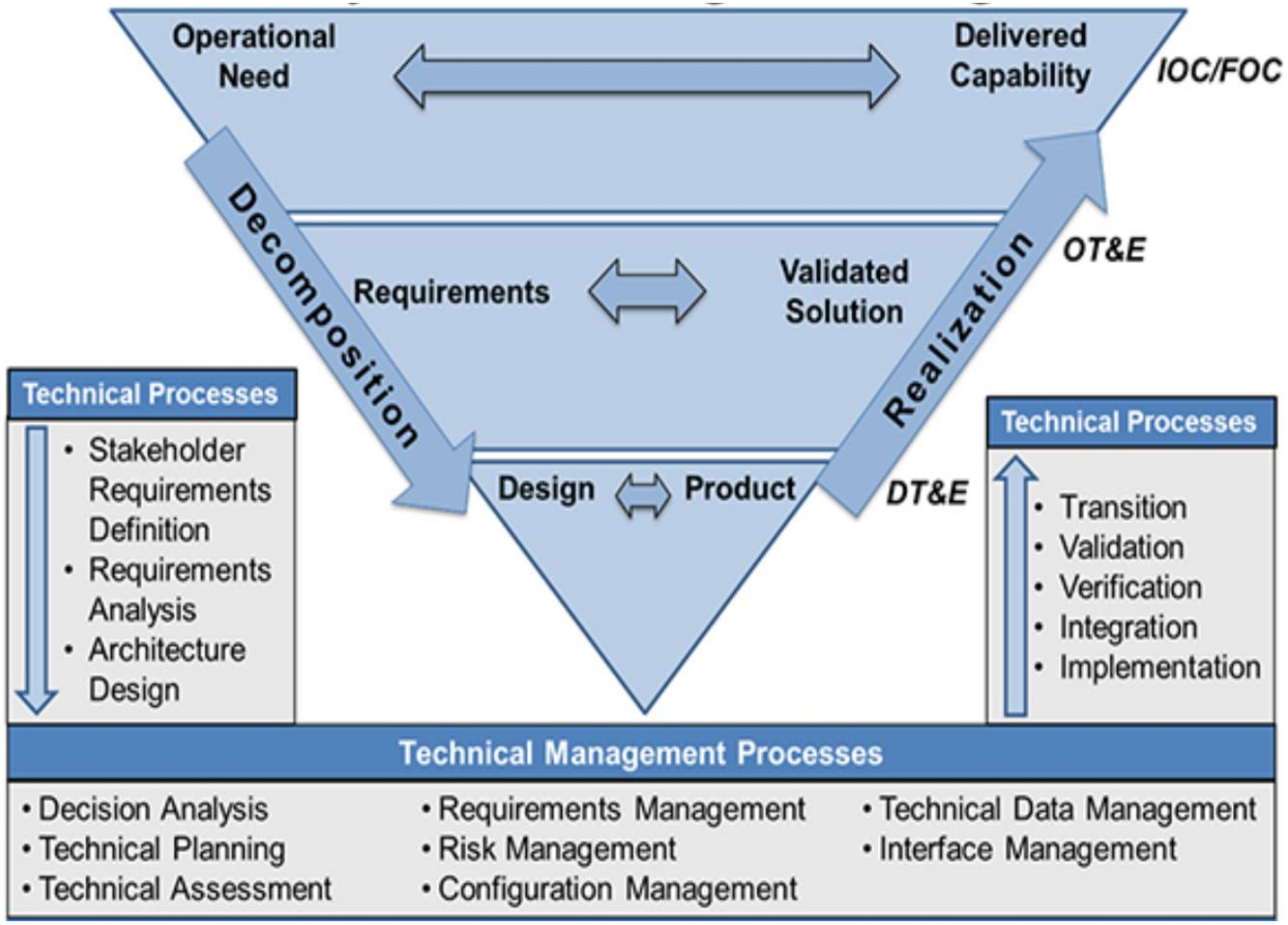
- a way of looking at the “big picture” when making technical decisions.
- a way of achieving stakeholder functional, physical, and operational performance requirements in the intended use environment over the planned life of the systems.
- the art and science of developing an operable system capable of meeting requirements within often opposed constraints.
- a holistic, integrative discipline, wherein the contributions of e.g.,
  - structural engineers
  - electrical engineers
  - mechanism designers
  - power engineers
  - human factors engineers
  - and many more disciplines *(medical!)* are evaluated and balanced…
- To produce a coherent whole that is not dominated by the perspective of a single discipline.[1]

[1]Comments on systems engineering throughout the handbook’s Chapter 2.0 are extracted from the speech “System Engineering and the Two Cultures of Engineering” by Michael D. Griffin, previous NASA Administrator.

Information to Communicate

To communicate with exploration mission development activities, we need to describe:

- **Operational Needs**
- **Requirements**
- **Design Options**
- **Interfaces…**



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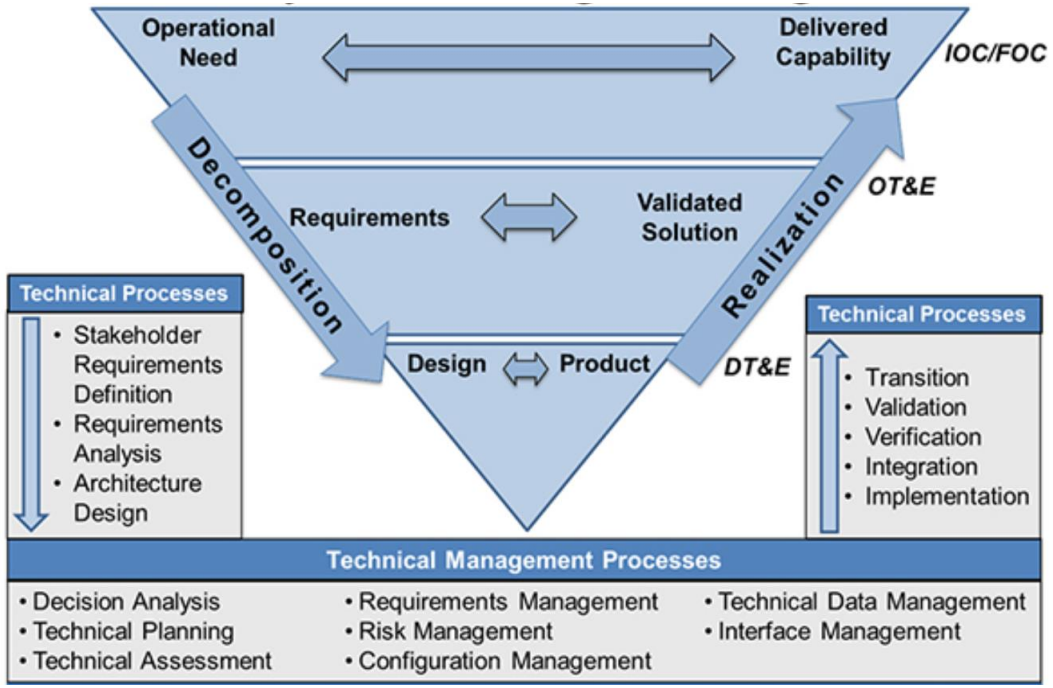
Cover up DT&E, etc on right side

What is Model-Based Systems Engineering?

- The formalized application of modeling to support system requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases.[1]



Emphasis is on controlling the model of the system rather than controlling documentation about the system

1. INCOSE SE Vision 2020 (INCOSE-TP-2004-004-02, Sep 2007)

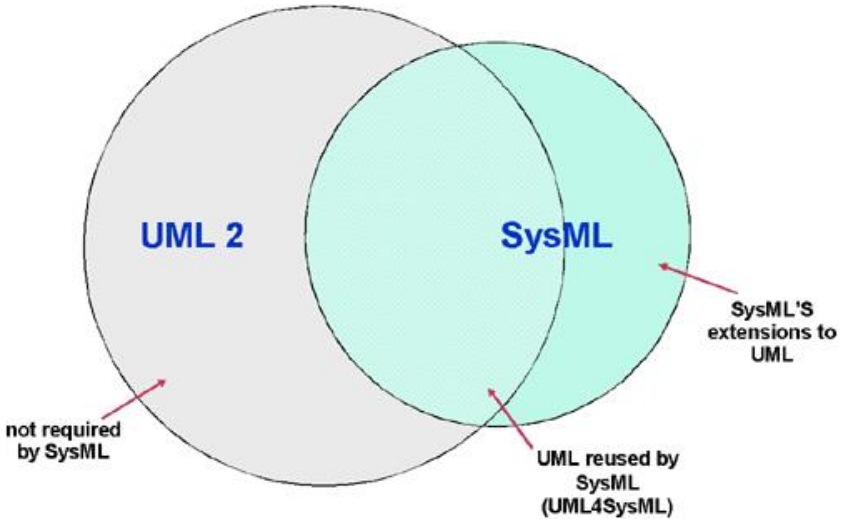
What is a system model in this context?

- A logical model that describes a system's structures, behaviors, interfaces and properties through multiple perspectives to:
  - Facilitate a common understanding of the system
  - Control, measure and report progress of technical solution throughout the project lifecycle including requirements, analysis, design, implementation, verification and operations of the system
  - Abstraction that contains only the details needed to address the intended use of the model
  - Not an analytical model

A system model is like a building blueprint that specifies the system to be implemented

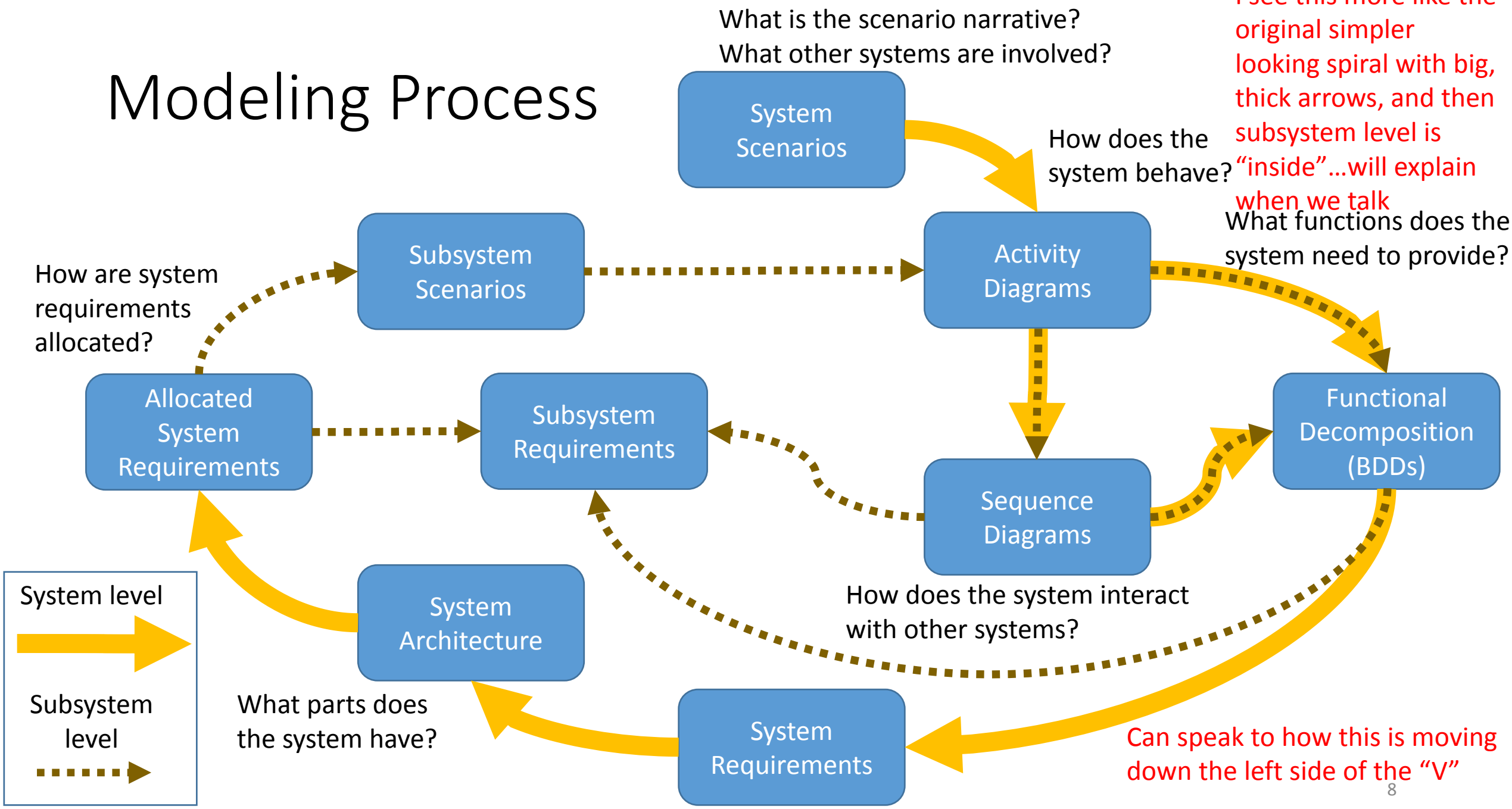
System Modeling Language

- System Modeling Language (SysML) is a graphical modeling language for specifying, analyzing, designing and verifying complex systems that may include hardware, software, information, personnel, procedures and facilities.
- Better than document based
- Used by automobile, aerospace/defense, medical industries



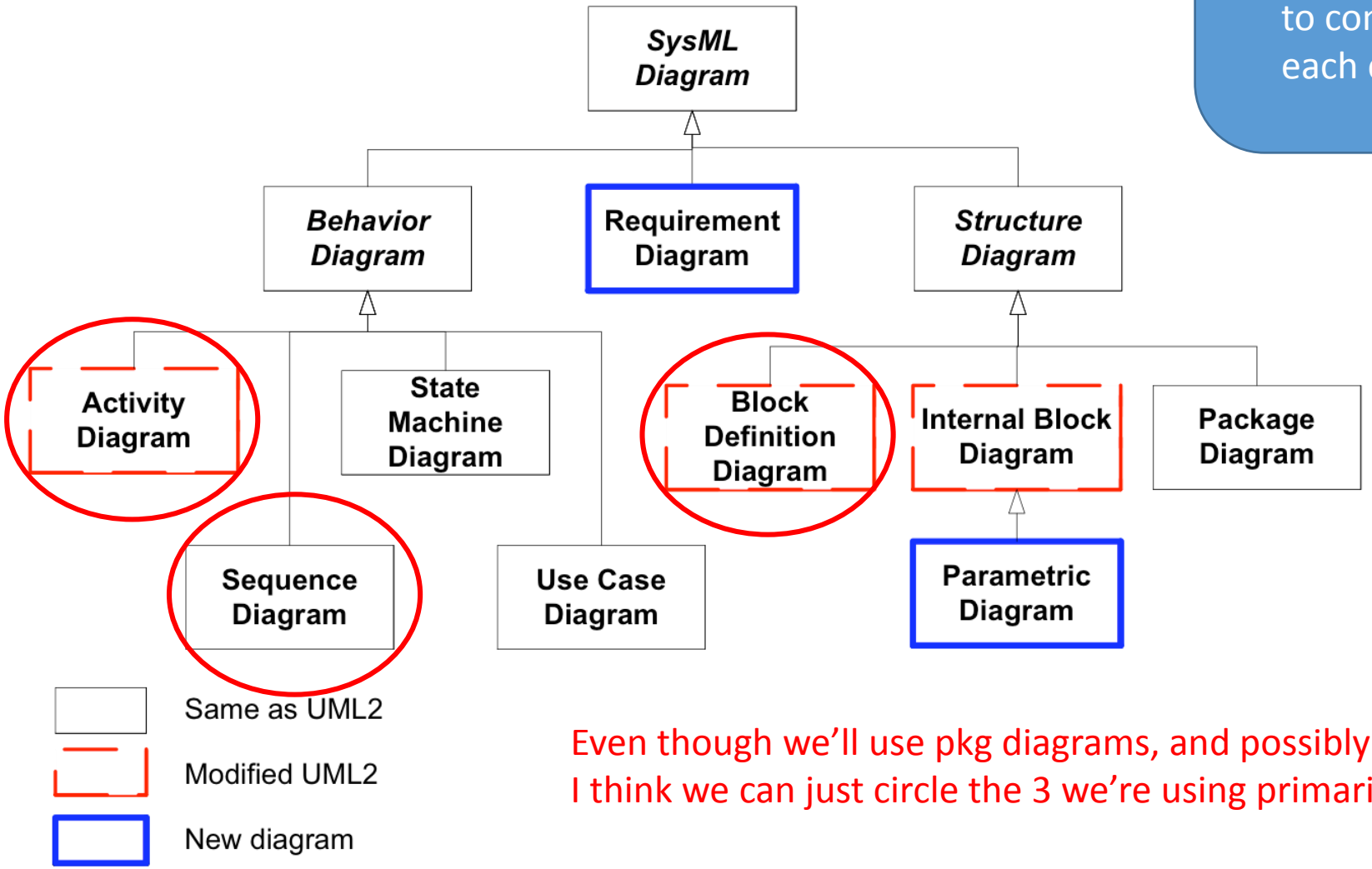
- NASA Agency-wide support for adopting MBSE and SysML
- Enables technical communication with other disciplines regarding interfaces and design in common language

Modeling Process

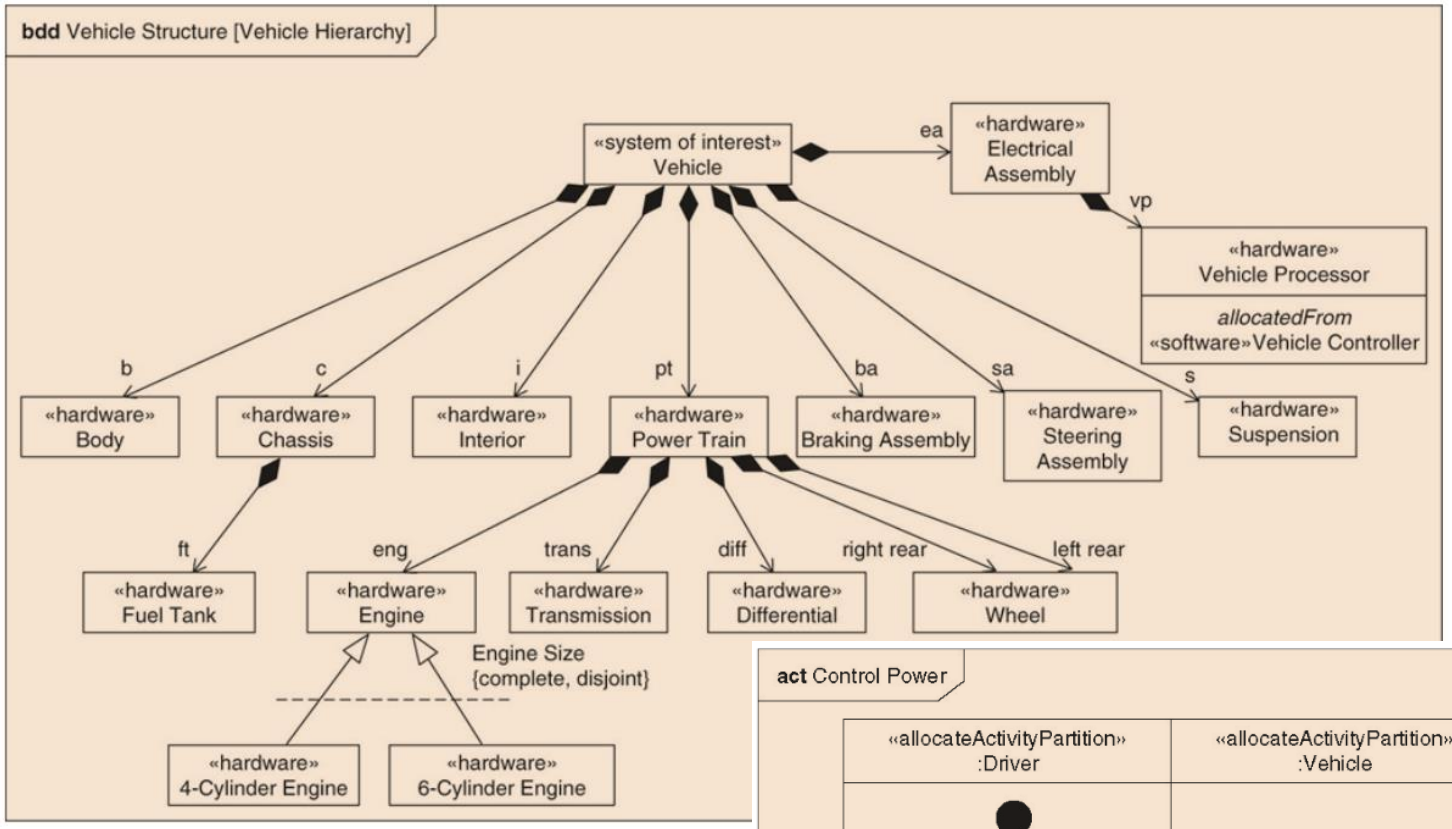


SysML Diagram Types

- Use of all diagram types is not required for a complete SysML model.
- Use as many as it takes to complete a model for each case.



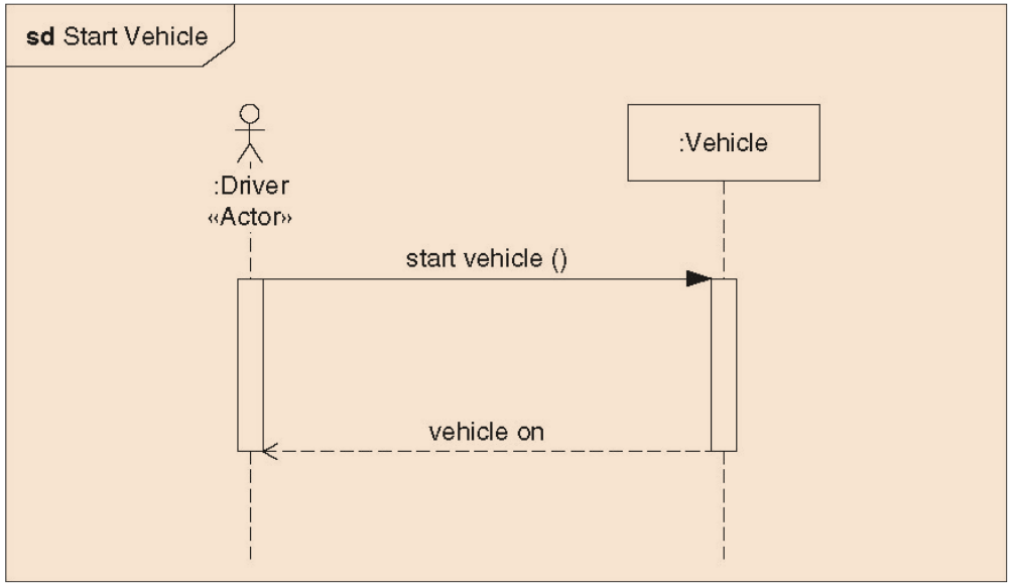
Even though we'll use pkg diagrams, and possibly other diagrams, I think we can just circle the 3 we're using primarily to start.



Block Definition Diagram

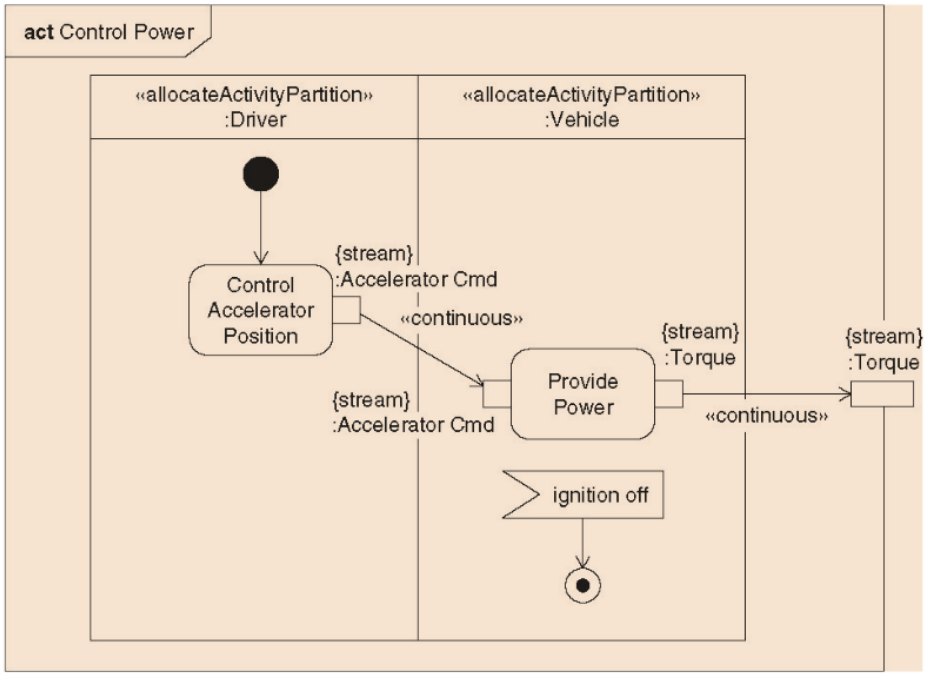
What functions does the system need to provide?

What parts does the system have?



Sequence Diagram

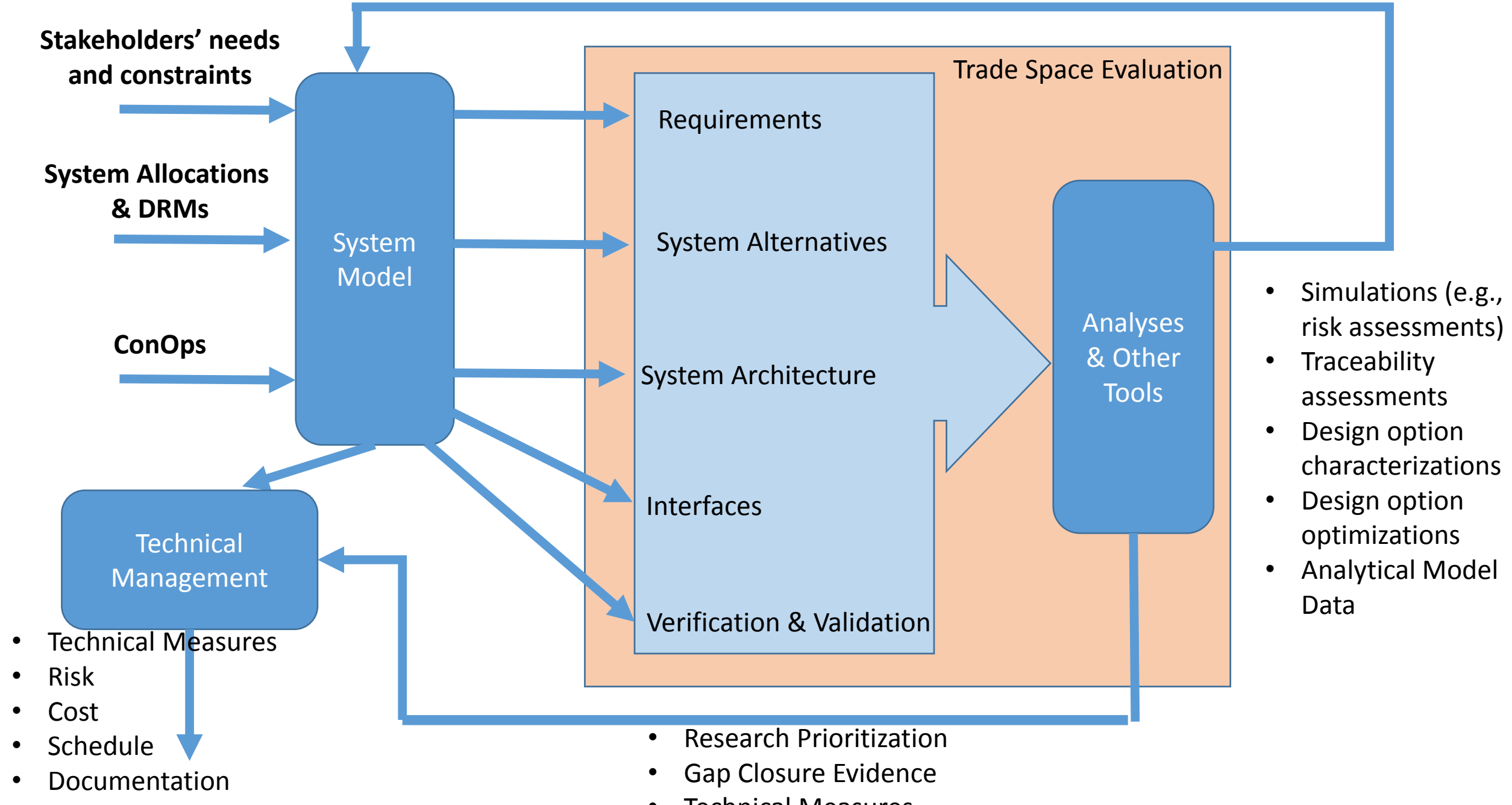
How does the system interact with other systems?



Activity Diagram

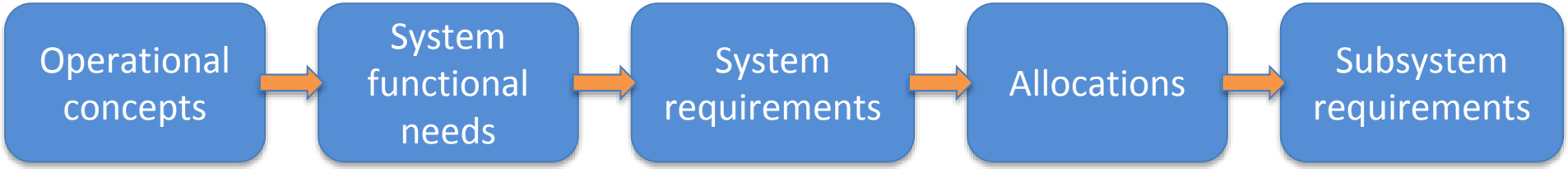
How does the system behave?

The diagram is just a visualization of the model, not the model itself…


Stakeholders' needs and constraints
System Allocations & DRMs
ConOps
System Model
Trade Space Evaluation
Requirements
System Alternatives
System Architecture
Interfaces
Verification & Validation
Analyses & Other Tools
Technical Management
• Simulations (e.g., risk assessments)
• Traceability assessments
• Design option characterizations
• Design option optimizations
• Analytical Model Data
• Technical Measures
• Risk
• Cost
• Schedule
• Documentation
• Research Prioritization
• Gap Closure Evidence

Model Development and Test-bed Integration

- Team from across Centers is building model content (blocks, activities, sequence diagrams)
  - Medical system function identification
  - Medical system architecture and characterization (e.g., mass)



- Will also use to support definition of integrated Habitat test in iPAS environment in Sept. 2017
  - e.g., medical data architecture to collect sensor data and interface with vehicle
  - Hab test team developing Hab SysML models – we will collaborate and share models

Keys to Success

- Commitment from management
- Training
- Tools
- Experienced Modelers

Why this is important:

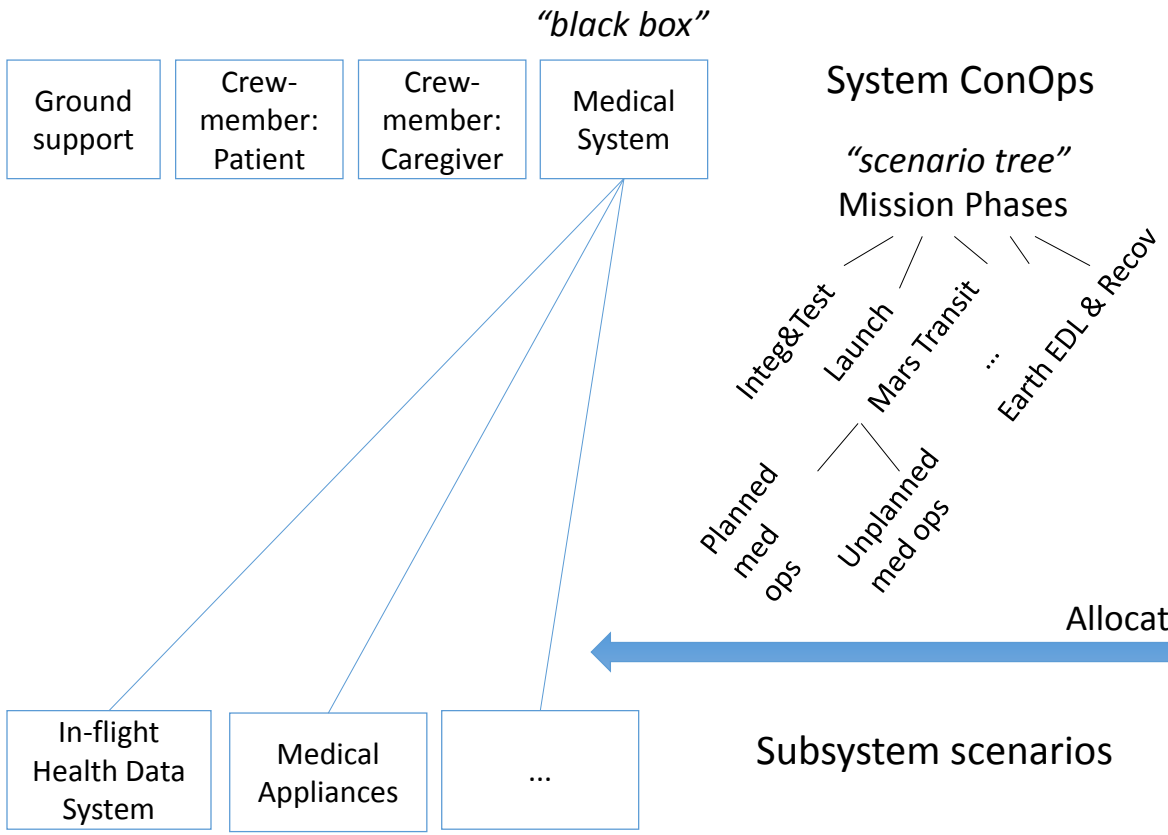
- In-line with our SE approach of providing structured, integrative science and engineering
- Enables increased relevancy to exploration system maturation by communicating in common technical language

Questions?

Backup

ExMC SE Approach Recap

Define what/who is involved in operational activities	Capture activities in scenarios	Capture complementary and reference info	Derive requirements and verification info
Block Definition Diagrams	*Activity Diagrams* *Sequence Diagrams*	*Traditional documents*	*Requirement "shall" statements*



System ConOps

"scenario tree"
Mission Phases

Integ&Test
Launch
Mars Transit
...
Earth EDL & Recov
Planned med ops
Unplanned med ops

Level of Care Definitions

System architecture description

Other Documents…

Medical System requirements

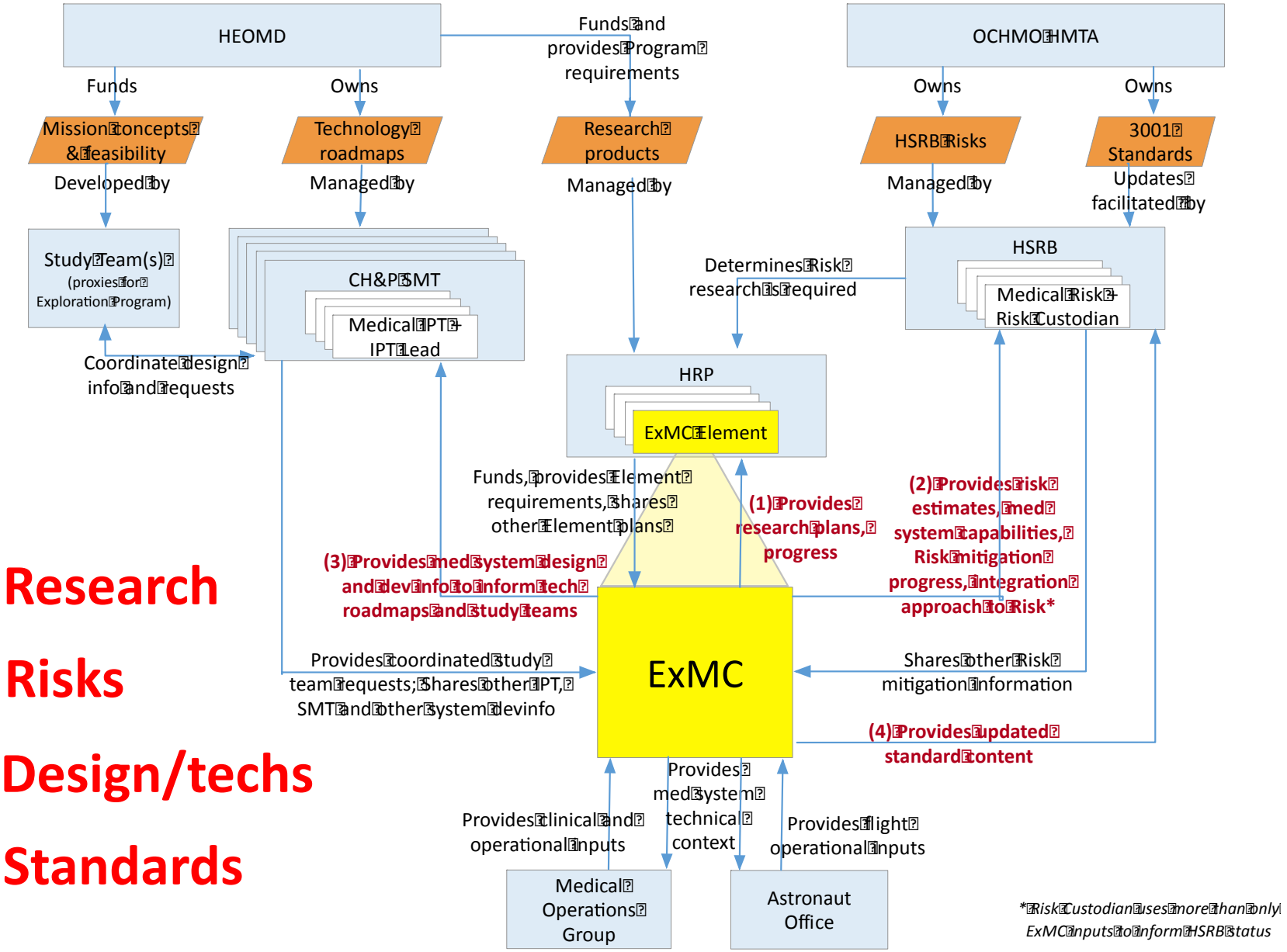
Allocate functions to subsystems

Subsystem scenarios

Docs as needed

Medical Subsystem requirements

Organizational Context



1) Research

2) Risks

3) Design/techs

4) Standards

OMG SysML Specification

- SysML provides graphical representations with a semantic foundation for modeling requirements, behavior, structure and parametrics for knowledge capture and simulation model interoperability.
- INCOSE and Object Management Group (OMG) jointly charted Systems Engineering Domain Special Interest Group (SE DSIG) in 2001
- INCOSE, OMG and ISO AP 233 workgroup developed requirements for the modeling language that went into the UML for Systems Engineering RFP issued in 2003

Why use MBSE?

- Improve quality of the exploration medical system design and specification
- Reuse of system specification and system engineering artifacts
- Improves communication within the element and across engineering disciplines
- Finer control of information stored in the model
  - Information is spread across many documents making relationships unclear resulting in increased costs/errors regarding requirements management, verification and impact assessments
- Promotes rigor across all phases of the project lifecycle
- Change to one element propagates through the entire model
- Evolves over the course of the lifecycle
- Used early in the lifecycle to support evaluation of alternatives
- Later phases it is used for subsystem/component development
- Support system integration and verification activities

Potential Drawbacks to consider:

- Steep learning cure for those new to modeling
- Established culture / organizations entrenched in parochial approach to system design
- Requires commitment from all levels of an organization from management to engineers

Document-Based Systems Engineering

Focus is on developing and maintaining a set of documents to capture various aspects of the system such as requirements, interfaces, design and verification.

Challenges include:

- Information being spread across several documents leading to data inconsistency
- Maintaining and reusing the information for an evolving system design
- Understanding particular aspects of system along with traceability and change impact assessment
- Progress of systems engineering effort is based, in part, on documentation status which does not necessarily reflect quality of requirements or technical solution
- Impacts to cost, schedule and quality often show up integration and testing or after the system is delivered to the customer

Why Use a System Model?

- Characterize and assess an existing system
- Specify and design a new or modified system
  - Represent a system concept
  - Specify and validate system requirements
  - Synthesize system designs
  - Specify component requirements
  - Maintain requirements traceability
- Evaluate the system
  - Conduct system design trade-offs
  - Analyze system performance requirements or other quality attributes
  - Verify that the system design satisfies the requirements
  - Assess the impact of requirements and design changes
- Train users on how to operate or maintain a system
- Support system maintenance and diagnostics

Why this is important:

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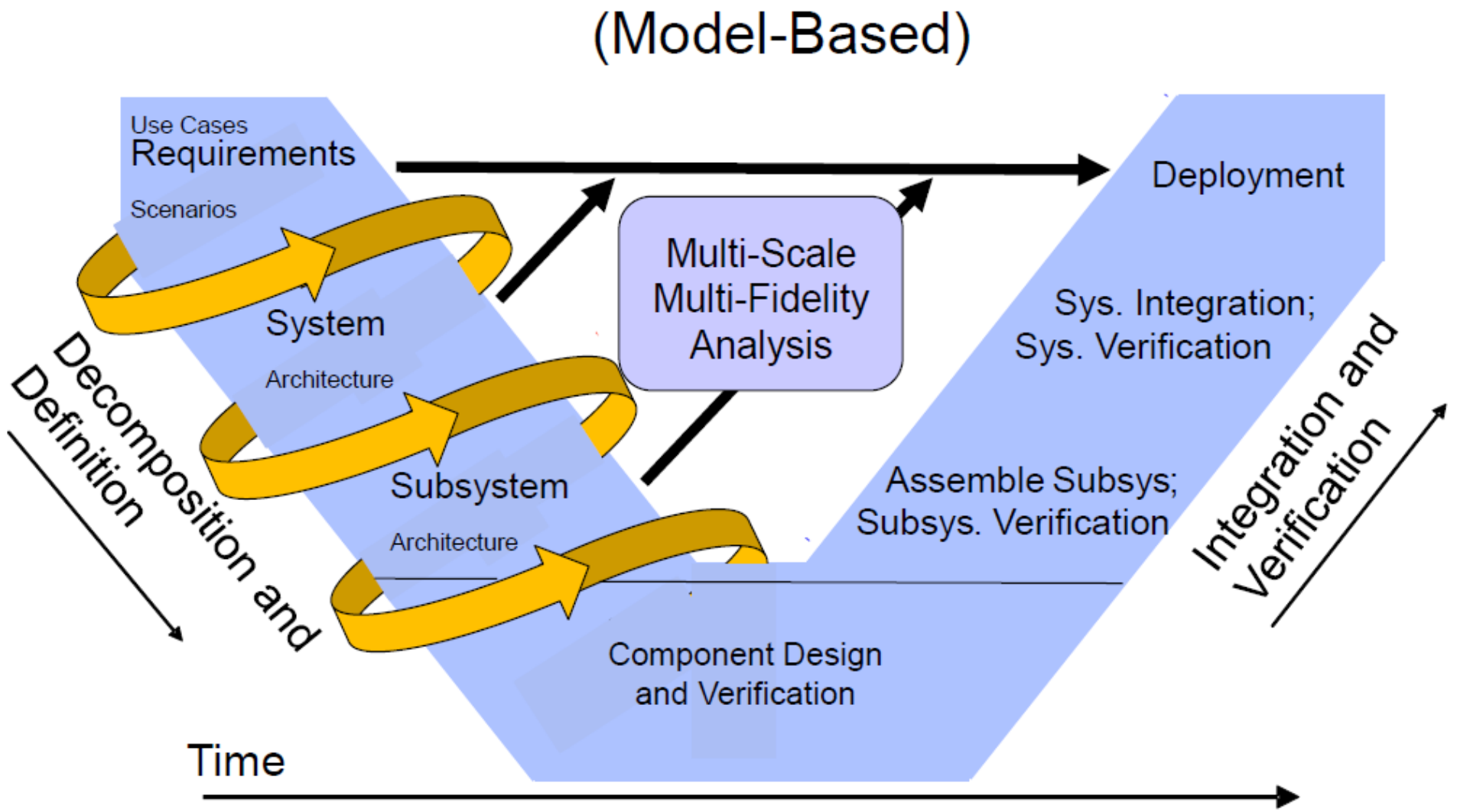
- Enables increased relevancy to exploration system maturation by communicating in common technical language

Model-Based vs. Document-Based

	Model Based	Document Based
Information	• Integrated views from multiple perspectives • Standardized format improves accessibility, analysis and reusability • Improved communication due to shared understanding across HRP and engineering teams	• Spread across multiple documents • Inconsistent format • Duplication of information
Quality	• Improved traceability between requirements, design, analysis and verification • Improved impact analysis and design integrity • Enhanced ability to manage system complexity • Automation	• Poor synchronization between requirements, design, interfaces and sub-system components • Issues likely to be discovered during integration and testing
Effectiveness	• Improved agility • Reduced cost / lower risk • Reuse of system specification and SE artifacts • Quick impact analysis for requirements and design changes • More comprehensive trade space analysis	• Increased costs / risks • Effort to maintain documents impacts design work • Difficult to track progress of technical solution

Systems Engineering Modeling Process



Model Integration

- Understand operational needs and constraints from multiple perspectives (Medical, Crew, Flight Ops, Ground Support, Vehicle/system integration)
- Identify system functions and derive system requirements
- Decompose and allocate requirements to subsystems
- Conduct trade studies and system analysis on design concepts/system components
- Generate documentation
- Identify and track system interfaces
- Determine verification and validation plans
- Collaborate with medical system design team and engineering orgs to facilitate system design and integration
- Track mass properties of medical system
- Manage cost, schedule and risks
- Track and report on technical measures

- Modeling Language - SysML
- Modeling Tool – MagicDraw
- Model Repository - Teamwork Server
- Analysis Tools – IMM, MONSTR, Tableau, Centrifuge
- Requirements Management – TBD
- Project Management – MS Project, Excel and SharePoint
- 7 Modelers located at 4 different NASA Centers (ARC, GRC, JSC and LaRC)

Modeling Process