JCOSE
Japan Council on Systems Engineering

Introduction to ARCADIA/CAPELLA and NASA Systems Engineering handbook: Modeling overview with the HUBBLE Space Telescope

DROUIN Remy

Capella
Open Source MBSE Solution

ARCADIA

Speaker introduction

Speaker: DROUIN Remy

- ***Avionic systems engineer in the French Air Force***
- ***Team Leader (Systems Engineering) in automotive industry***
- ***Program Manager in elevator industry***
- ***Head of system department in defense industry***
- ***Lecturer for French Engineering School introducing Systems Engineering and Model-Based Systems Engineering***
- ***SE/MBSE in defense industry***

"The NASA System Engineering (SE) handbook aims to provide general guidance and information on systems engineering, as it should be applied throughout NASA. The handbook introduces 3 common technical processes. One of these, is the System Design Process, describing the stakeholders expectations, requirements definition, logical decomposition and design solution definition. The 4 activities can be supported by a Model-Based Systems Engineering (MBSE) approach. To do so, an appropriate method and tool is necessary as the one provided by the ARChitecture Analysis & Design Integrated Approach. ARCADIA, with its modeler CAPELLA, is a MBSE solution supporting system modeling activities. Based on 4 architectural layers, which are Operational Analysis, System Analysis, Logical and Physical Architecture, it is a structured architecture engineering method for defining and validating multi-domain systems. This talk will present an educational overview of the ARCADIA methodology and System Design Process from the NASA SE, by introducing MBSE artefacts for space system.
The HUBBLE Space Telescope (HST) is a Cassegrain reflector telescope. Orbiting above the earth, HST elaborates a clear view of the universe free from the blurring and absorbing effects of the atmosphere. In order to illustrate the journey throughout CAPELLA, the HST will be introduced, as example, based on public information available. The goal is not to model the entire system as well as not apply all ARCADIA concepts, but just to introduce few diagrams of ARCADIA/CAPELLA
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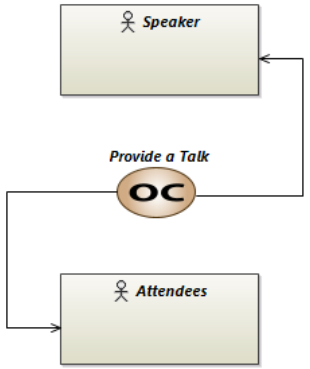
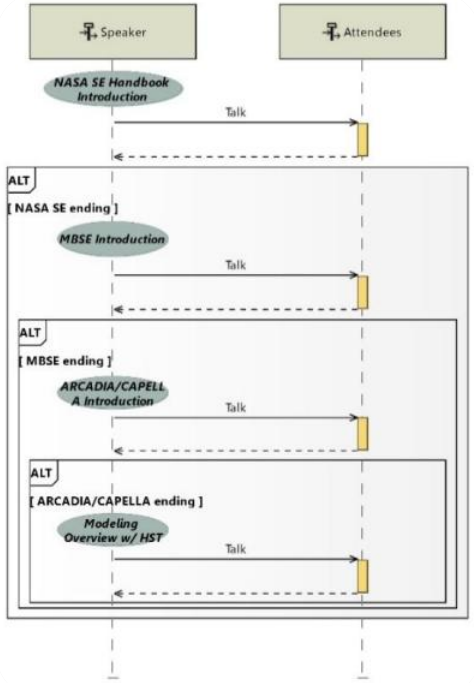
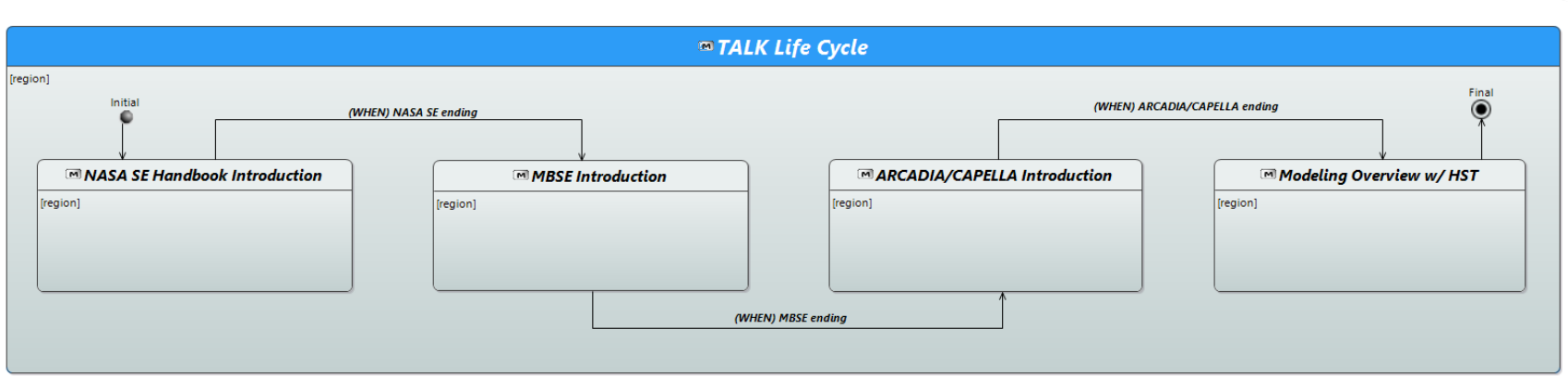
TALK Life Cycle

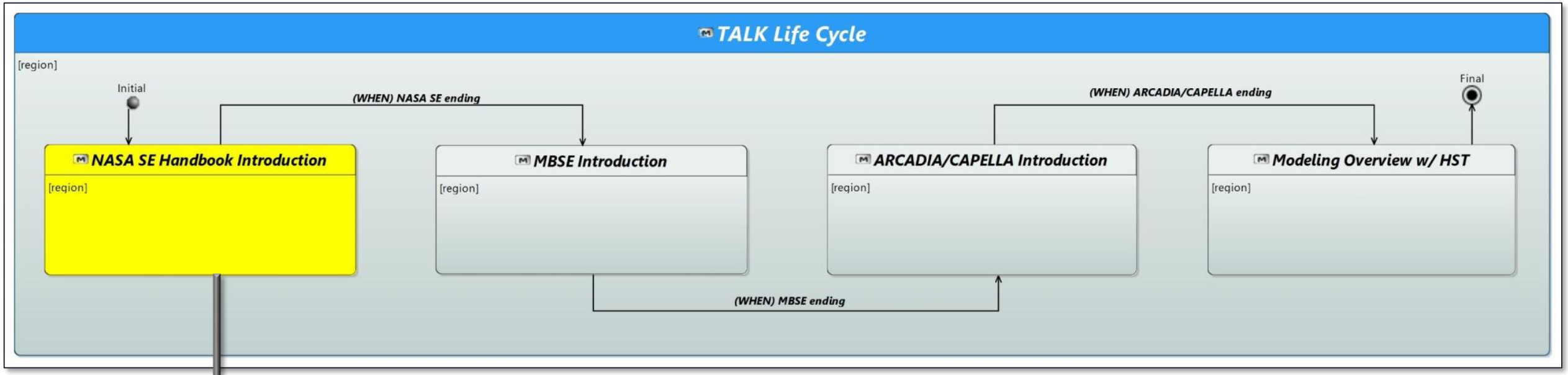
- NASA Systems Engineering Handbook
- MBSE
- ARCADIA/CAPELLA
- Modeling overview with HUBBLE Space Telescope

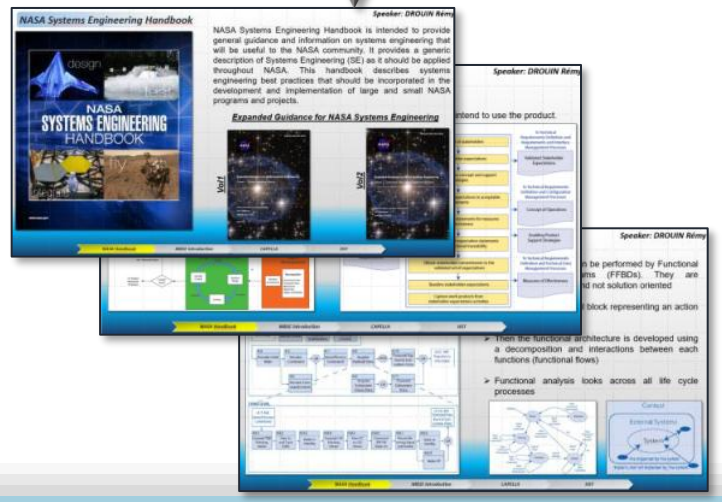




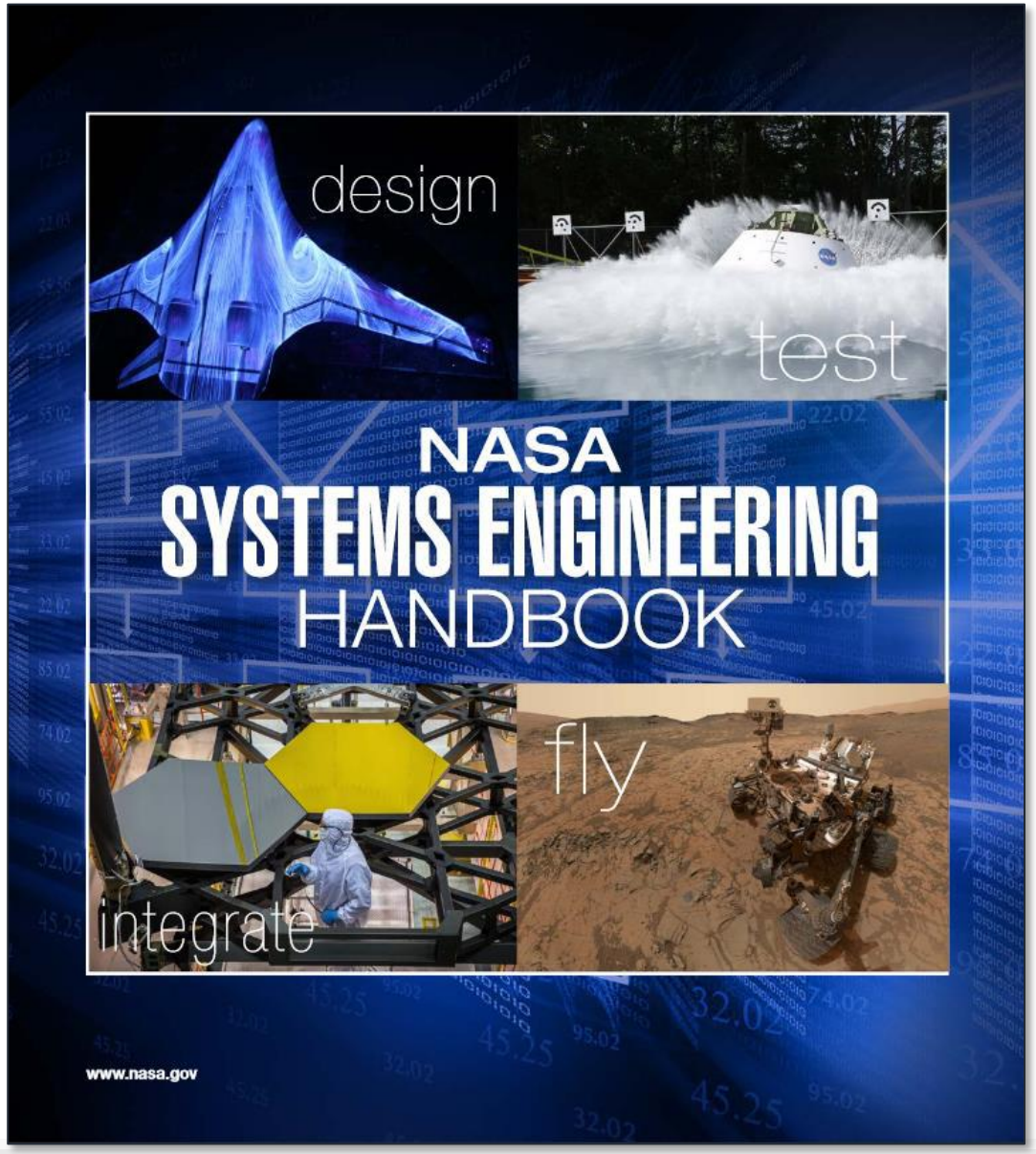


TALK Life Cycle





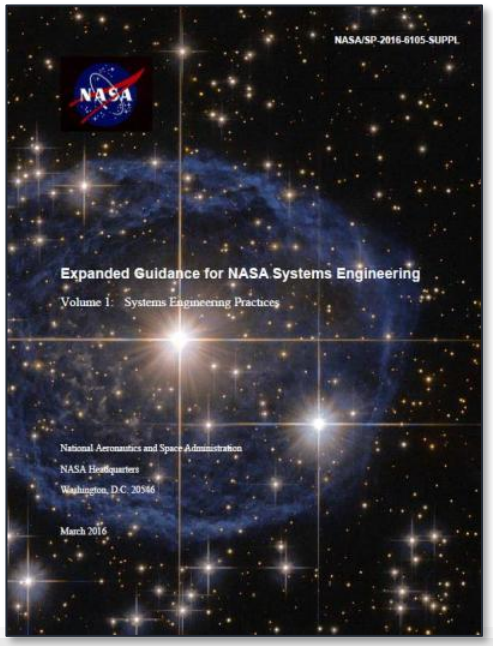
NASA Systems Engineering Handbook



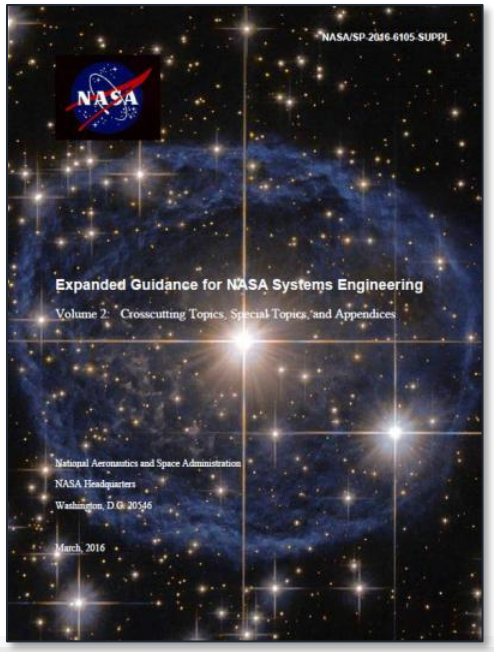
NASA Systems Engineering Handbook is intended to provide general guidance and information on systems engineering that will be useful to the NASA community. It provides a generic description of Systems Engineering (SE) as it should be applied throughout NASA. This handbook describes systems engineering best practices that should be incorporated in the development and implementation of large and small NASA programs and projects.

Expanded Guidance for NASA Systems Engineering

Vol1

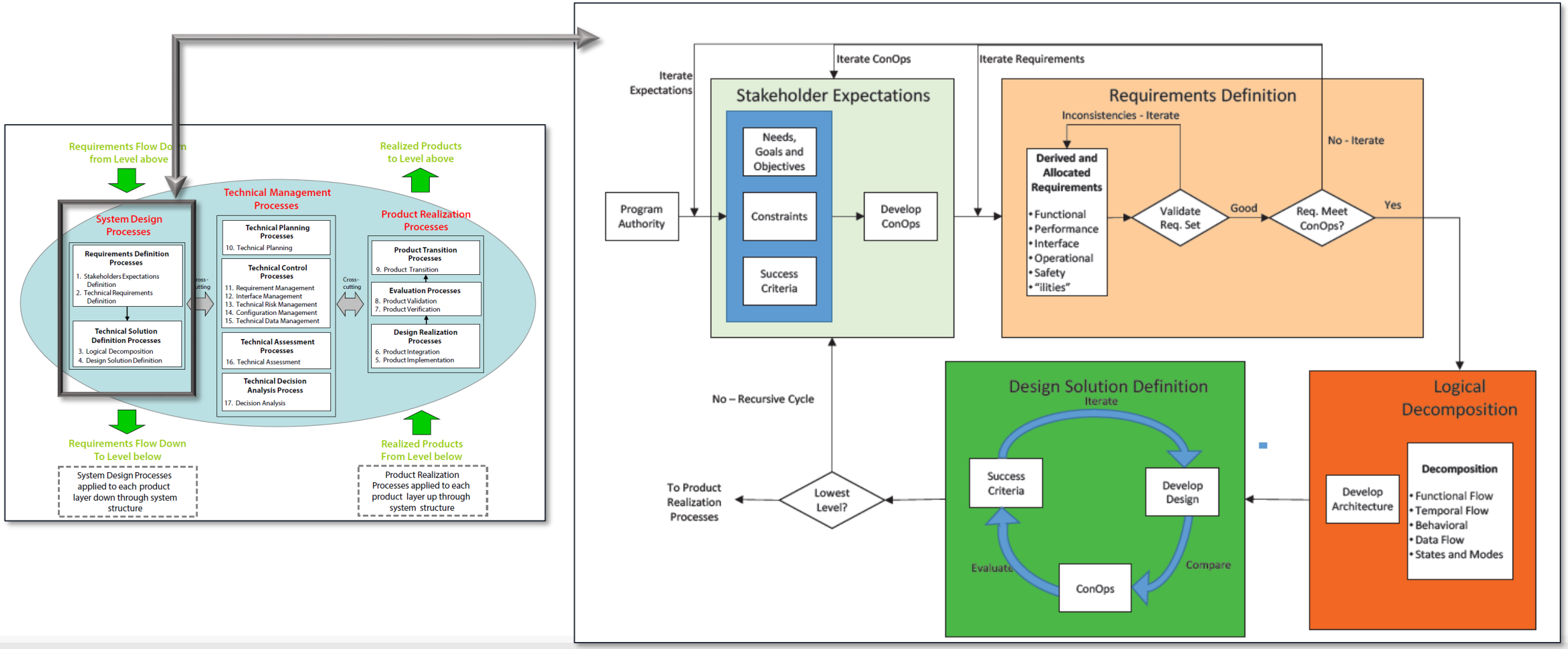


Vol2

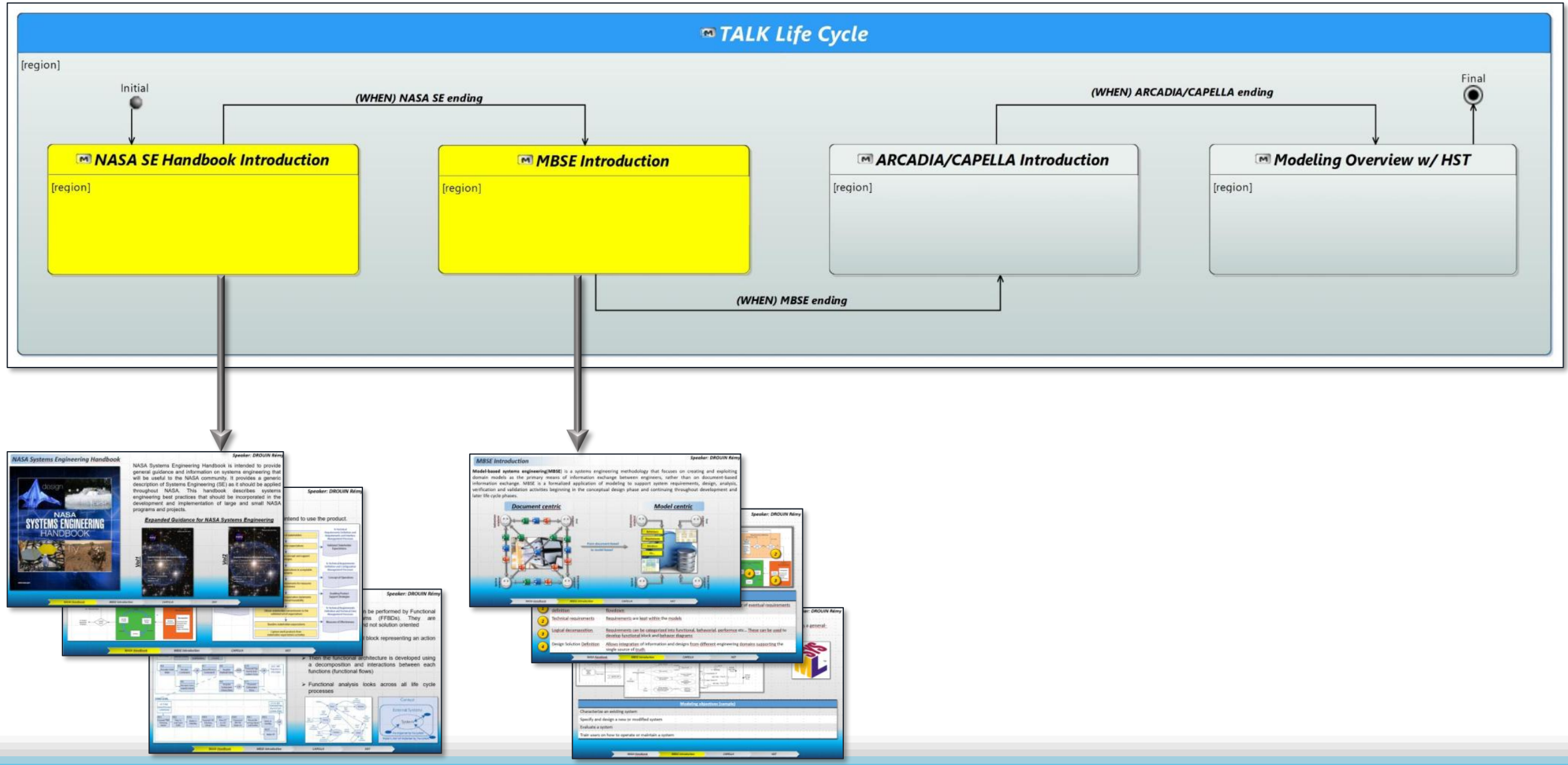


NASA SE Handbook – System Design Process

The four system design processes are used to define and baseline stakeholder expectations, generate and baseline technical requirements, decompose the requirements into logical and behavioral models, and convert the technical requirements into a design solution that will satisfy the baselined stakeholder expectations.

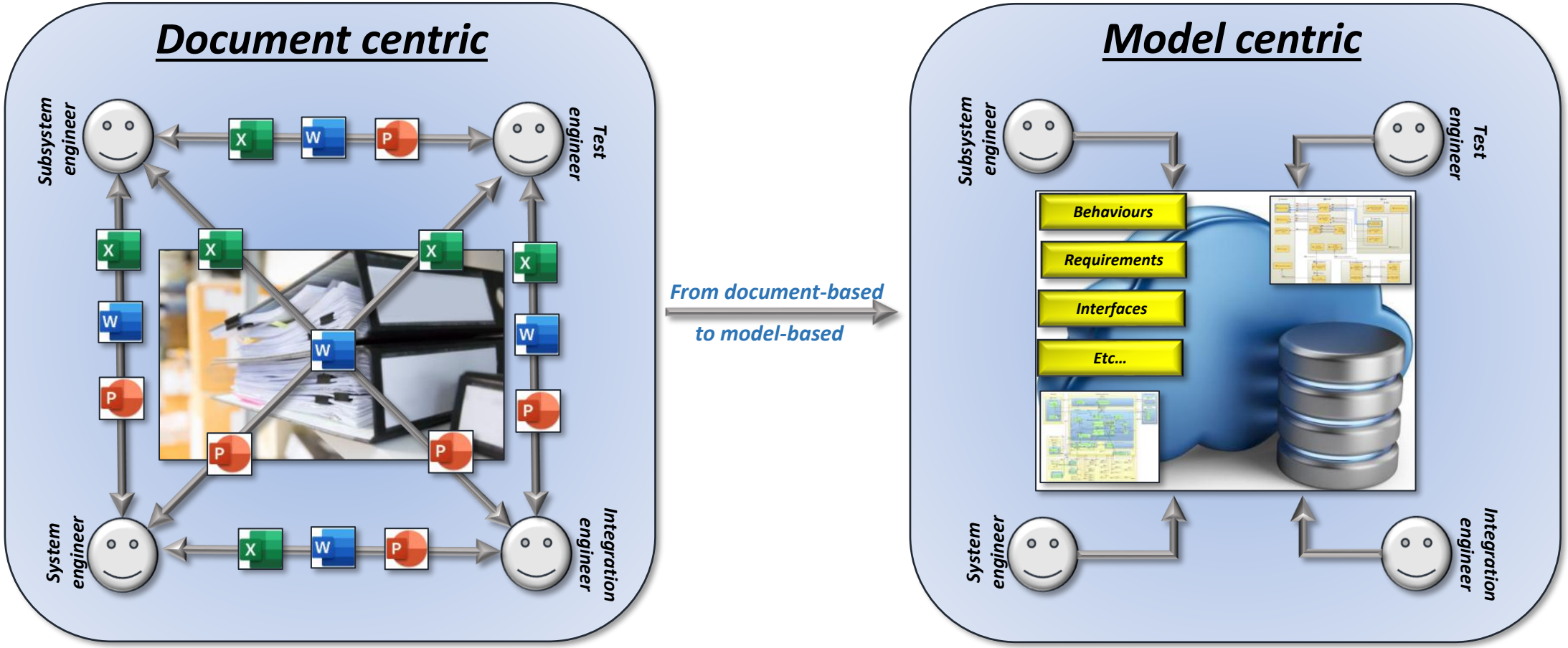


TALK Life Cycle



MBSE Introduction

Model-based systems engineering(**MBSE**) is a systems engineering methodology that focuses on creating and exploiting domain models as the primary means of information exchange between engineers, rather than on document-based information exchange. MBSE is a 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.

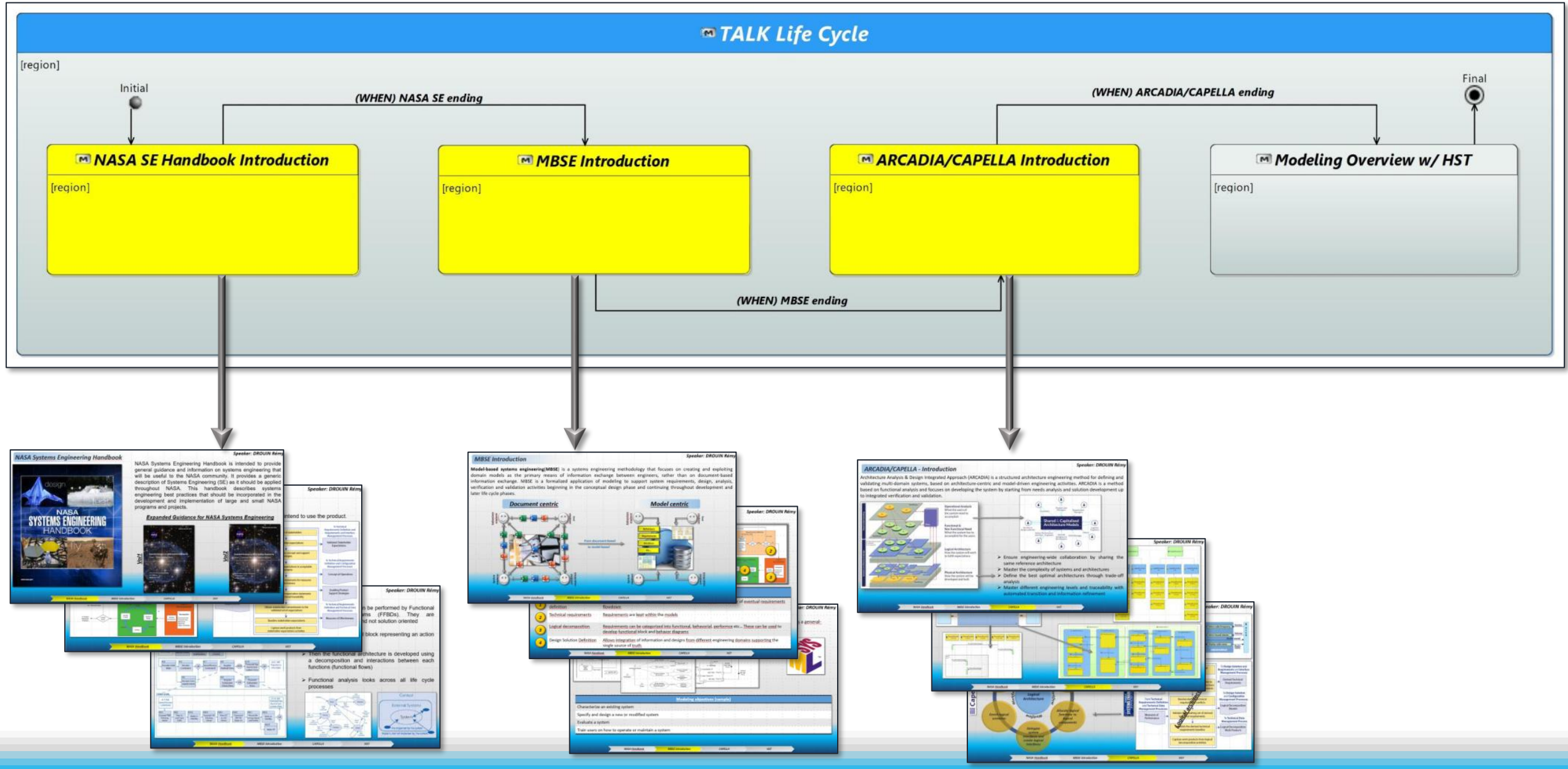


MBSE Benefits

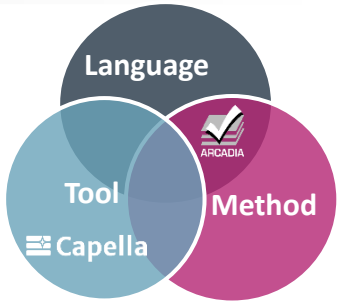
Model-based systems engineering does not affect process but will enable the opportunity for overall better quality, lower cost, and lower risk.

Overall MBSE benefits (sample):	NASA MBSE benefits (sample)
Enhance communication	Greater consistency of all products because any single piece of design information can be expressed authoritatively in a single place that can later be referred to by others for decisions, derivations, or formation of artifacts
Reduce development risk	Better visibility into the salient characteristics of a system because multiple views can be created that succinctly address specific stakeholder concerns
Encourage collaboration	Model-based artifacts can be generated automatically, lowering the effort to keep them up to date with the result that artifacts can always match the best available information
Manage complexity	Navigation, traceability, and interrogation of information are facilitated in the model-based approach
Automatic document generation	Can be less investment lost in erroneous design because sometimes the model reveals a flaw as soon as it is created, enabling correction before downstream work is done, work that would be invalid if the upstream mistake were not corrected immediately
Reuse of existing models in several projects	
Better requirements traceability	
More stakeholder involvement	
Digitalization	
Single source of truth	

TALK Life Cycle



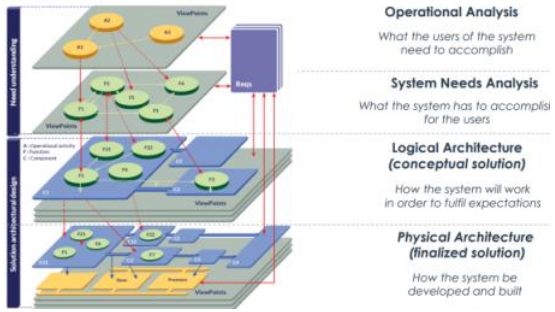
ARCADIA/CAPELLA - Introduction



ARCADIA/CAPELLA

Method

ARCADIA



Operational Analysis
What the users of the system need to accomplish

System Needs Analysis
What the system has to accomplish for the users

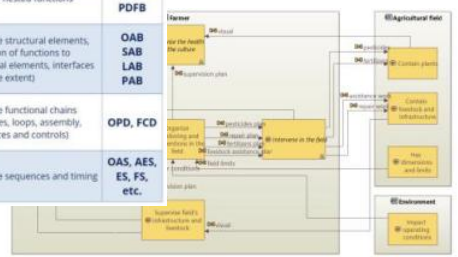
Logical Architecture (conceptual solution)
How the system will work in order to fulfil expectations

Physical Architecture (finalized solution)
How the system be developed and built

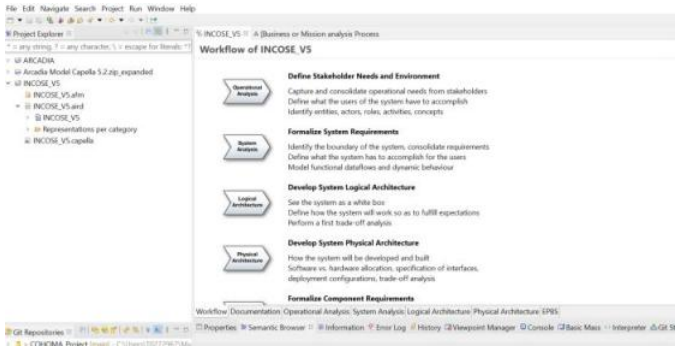
Language

ARCADIA

Concepts	Diagrams	Purpose	Tags
	Capabilities diagrams	Describe capabilities and involvement of actors, entities, system constituents	OCB MCB CR
	Dataflow diagrams	Describe functions and their dependencies, describe several levels of nested functions	OAIB SDFB LDFB PDFB
	Architecture diagrams	Describe structural elements, allocation of functions to structural elements, interfaces (to some extent)	OAB SAB LAB PAB
	Functional Chains description	Describe functional chains (branches, loops, assembly, sequences and controls)	OPD, FCD
	Scenarios	Describe sequences and timing	OAS, AES, ES, FS, etc.

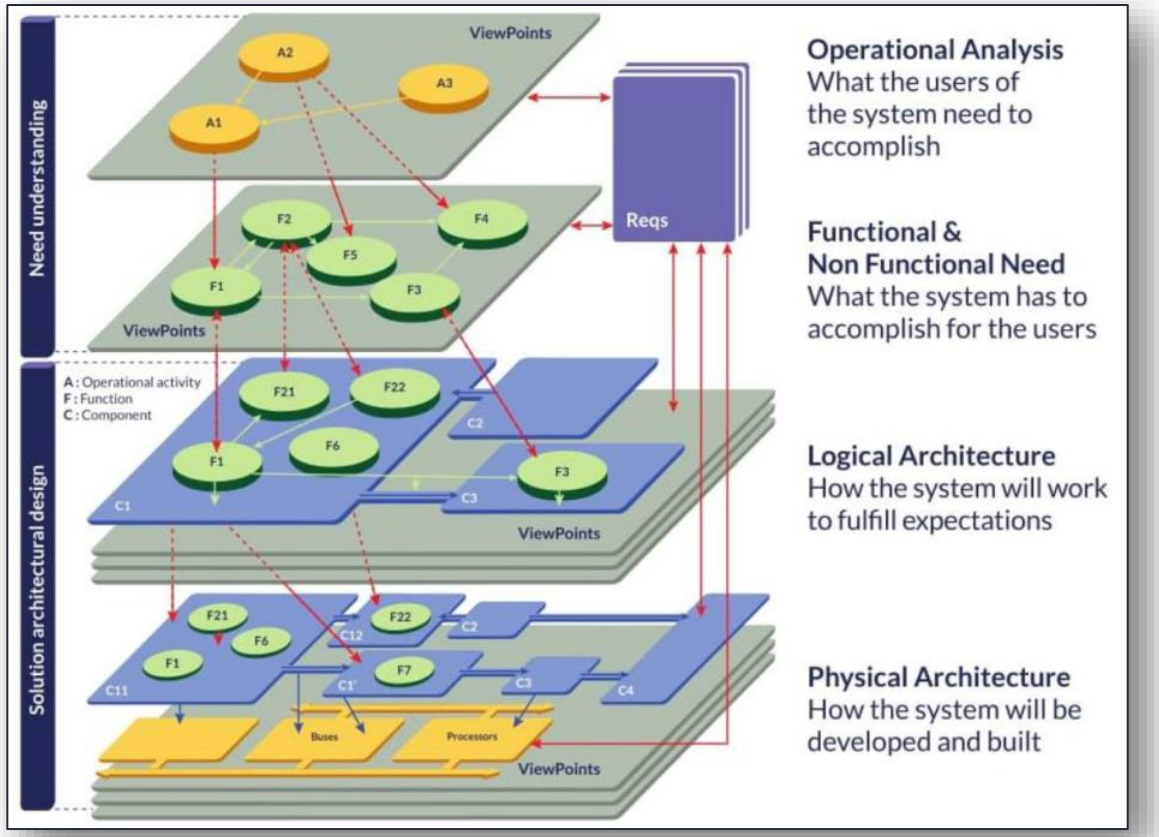


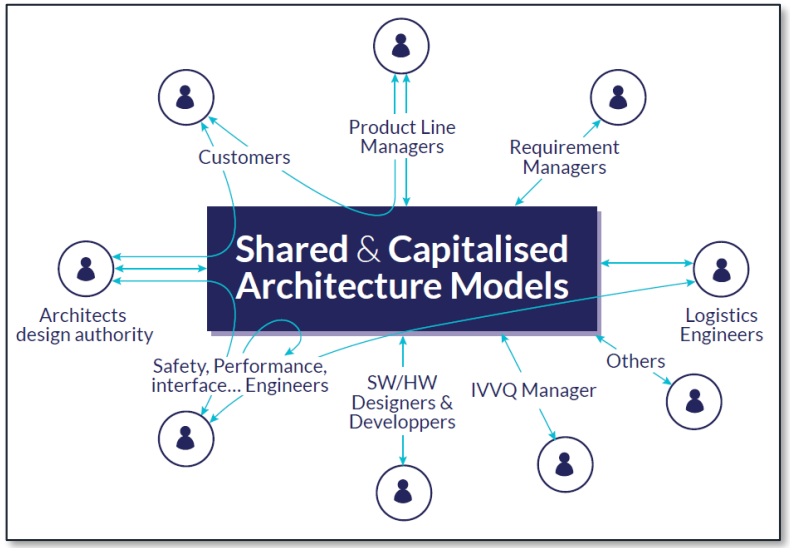
Tool



ARCADIA/CAPELLA - Introduction

ARChitecture **A**nalysis & **D**esign **I**ntegrated **A**pproach (**ARCADIA**) is a structured architecture engineering method for defining and validating multi-domain systems, based on architecture-centric and model-driven engineering activities. ARCADIA is a method based on functional analysis and focuses on developing the system by starting from needs analysis and solution development up to integrated verification and validation.





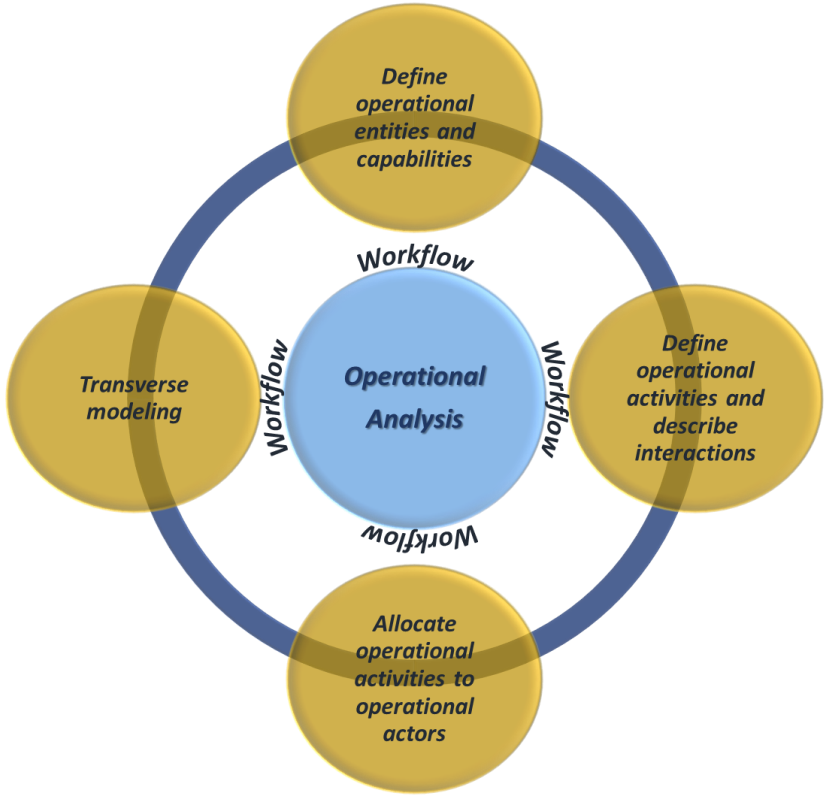
- Understand the real needs and context
- Define and share the solution among stakeholders
- Secure Sub-System/SW/HW engineering, prepare subcontracting
- Early evaluate and justify architectural design
- Prepare and master Verification & Validation

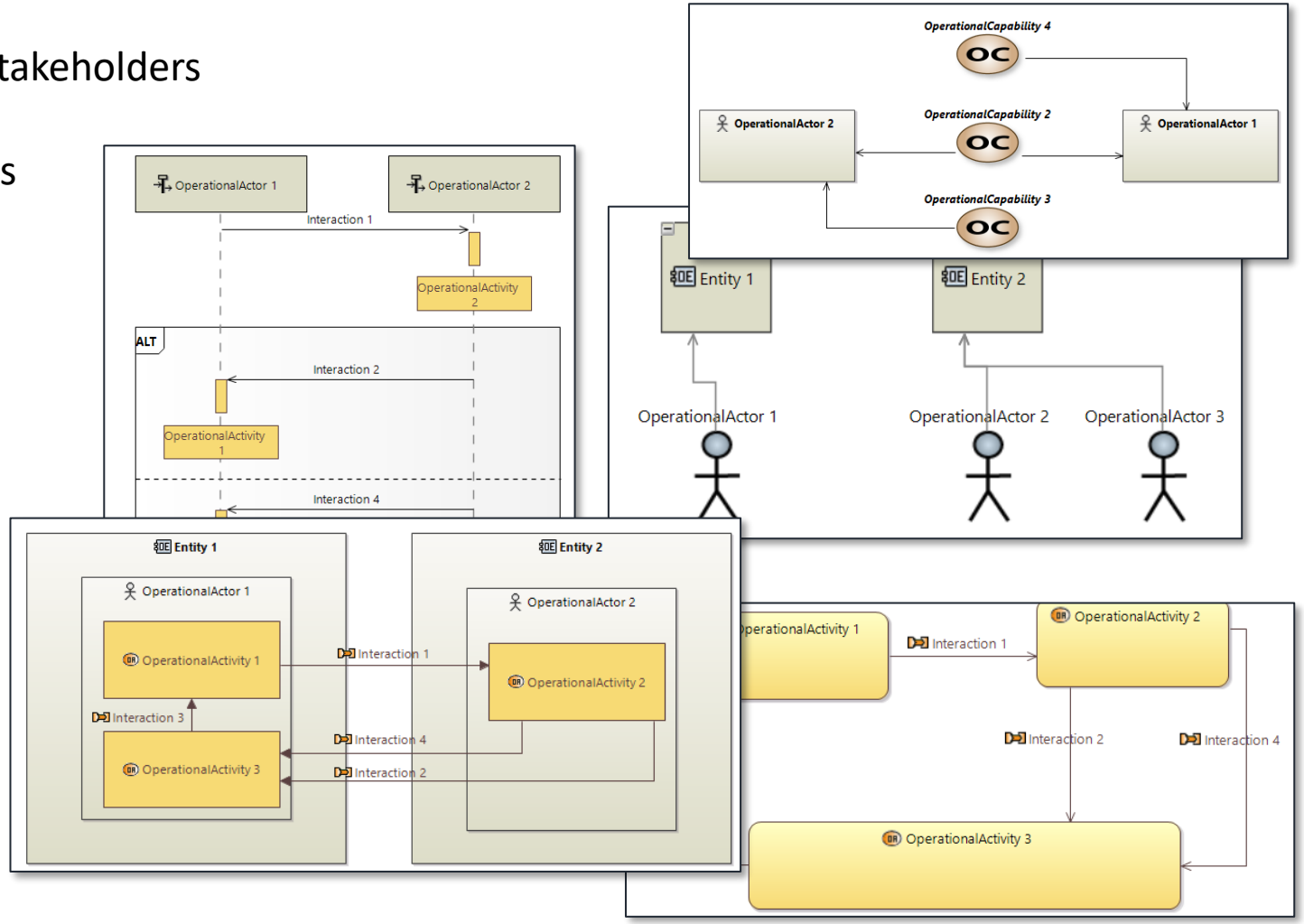
ARCADIA/CAPELLA - Operational Analysis

The OA perspective focuses on analyzing the customer needs and goals, expected missions and activities, far beyond system requirement

Define Stakeholder needs and environment

- Capture and consolidate operational needs from stakeholders
- Define what the users have to accomplish
- Identify entity, actors, roles, activities and concepts



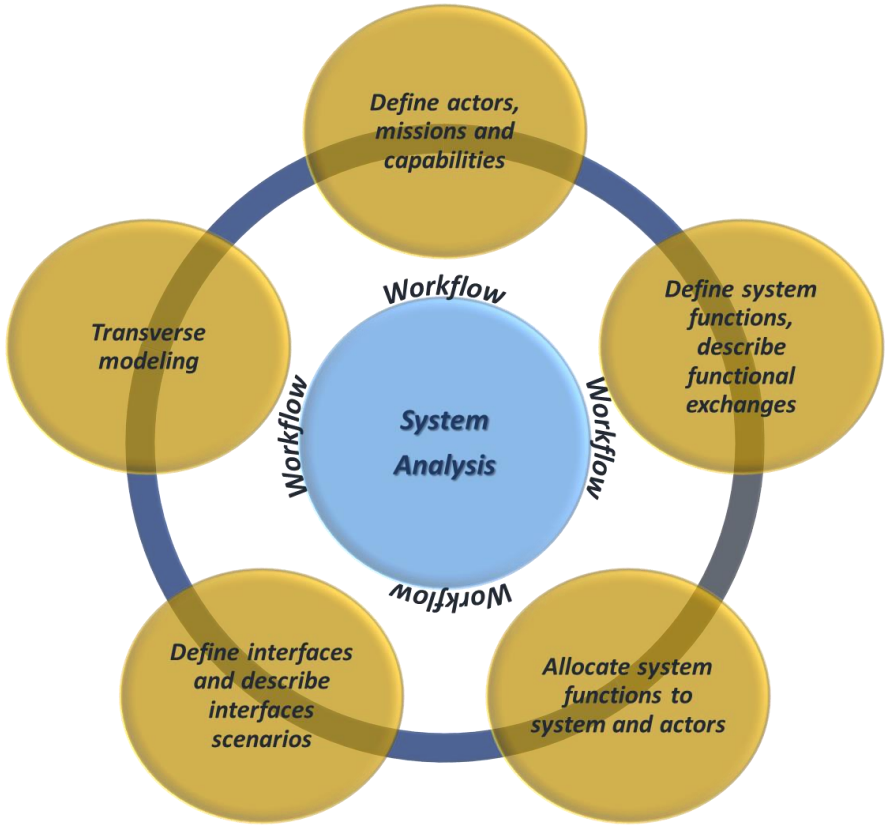


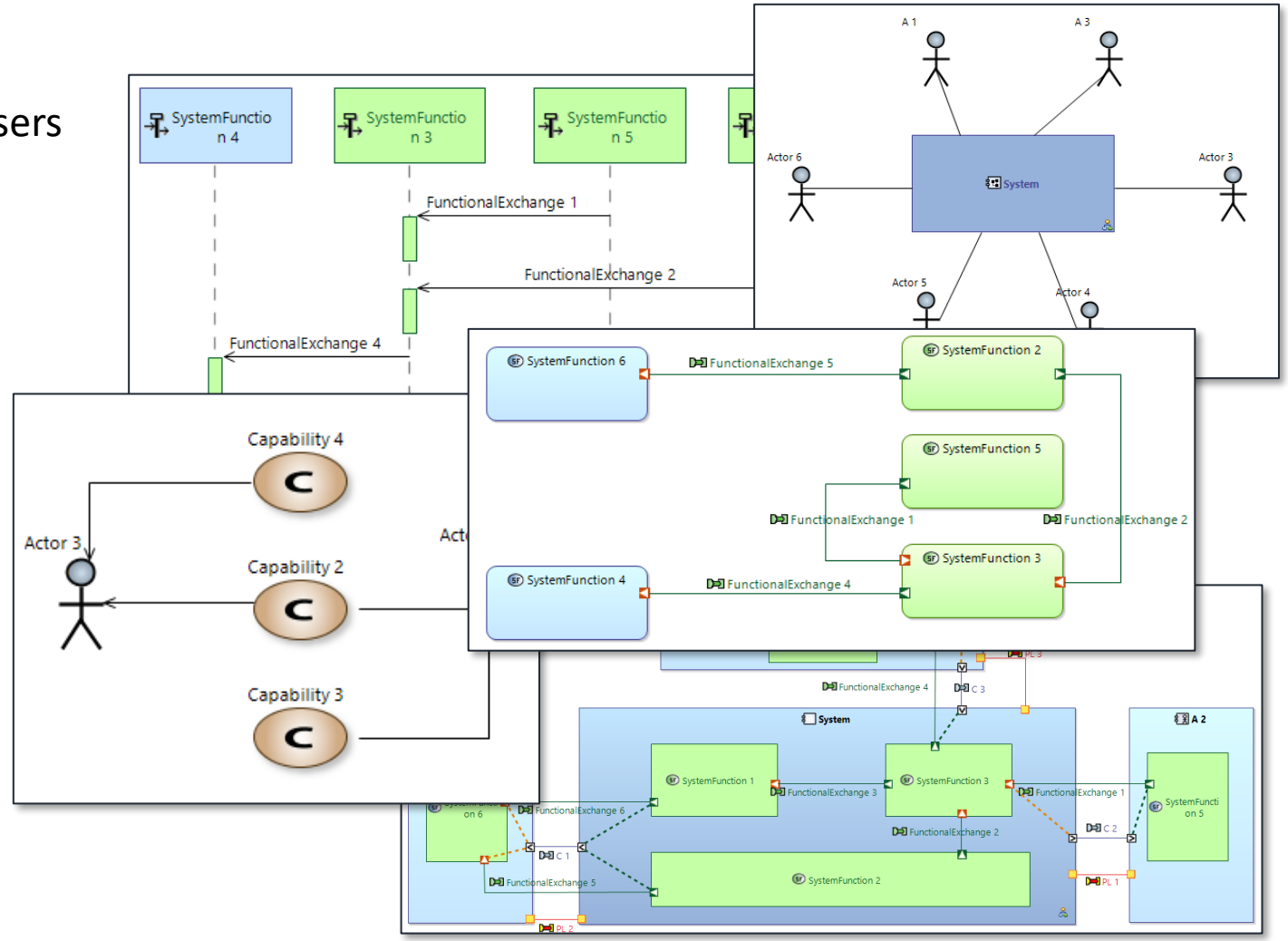
ARCADIA/CAPELLA - System Analysis

The SA perspective focuses on the **system itself**, in order to define **how it can satisfy the former operational need**

Formalize system requirements

- Identify the boundary of the system
- Define what the system has to accomplish for the users
- Model functional dataflows and dynamic behaviour



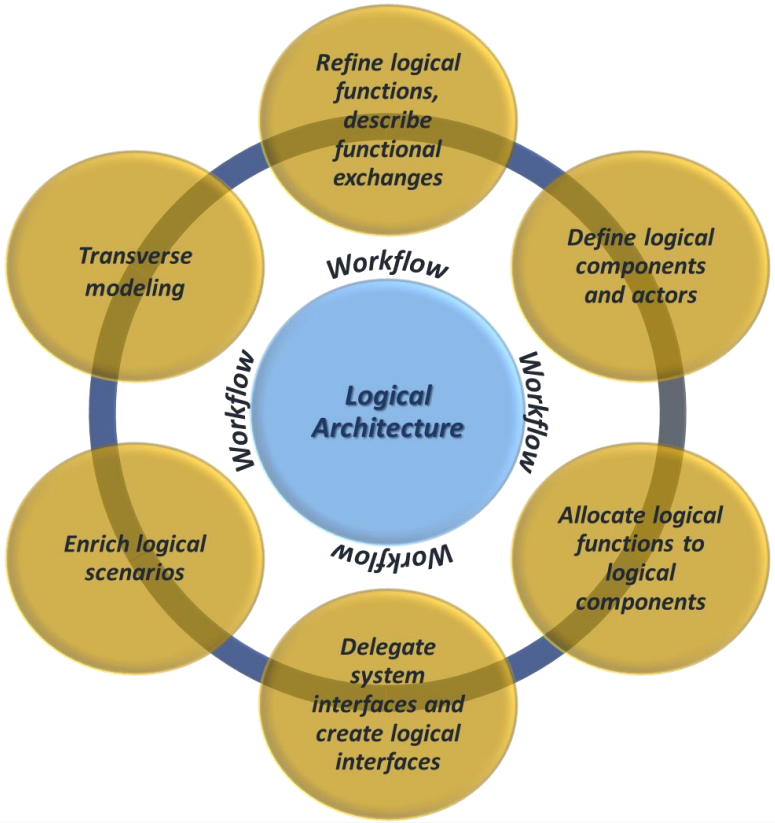


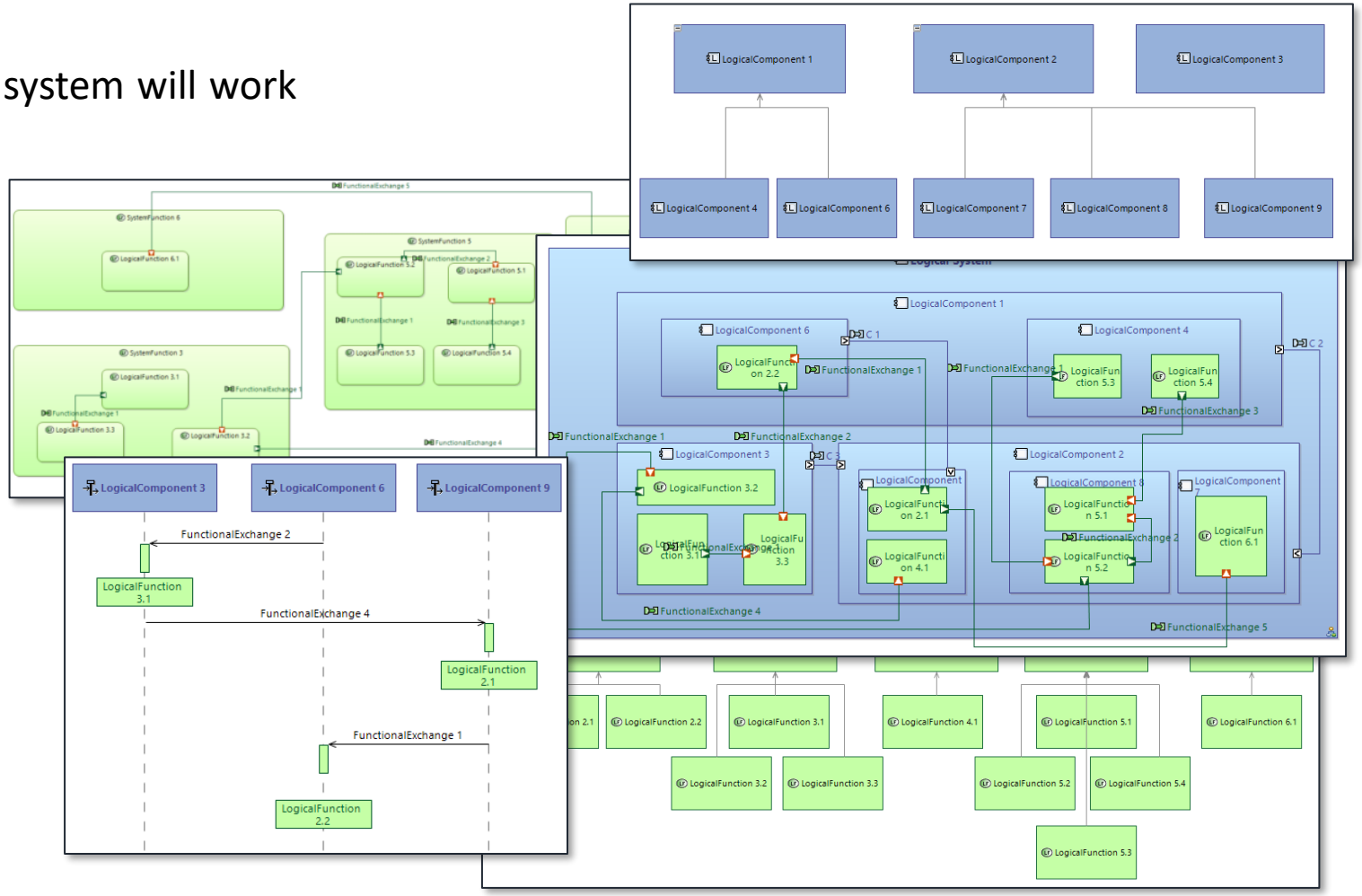
ARCADIA/CAPELLA - Logical Architecture

This LA perspective aims at building a **coarse-grained component breakdown of the system** carrying most important engineering decisions

Develop Logical architecture

- See the system as a white box define how the system will work so as to fulfill expectations
- Perform a trade-off analysis



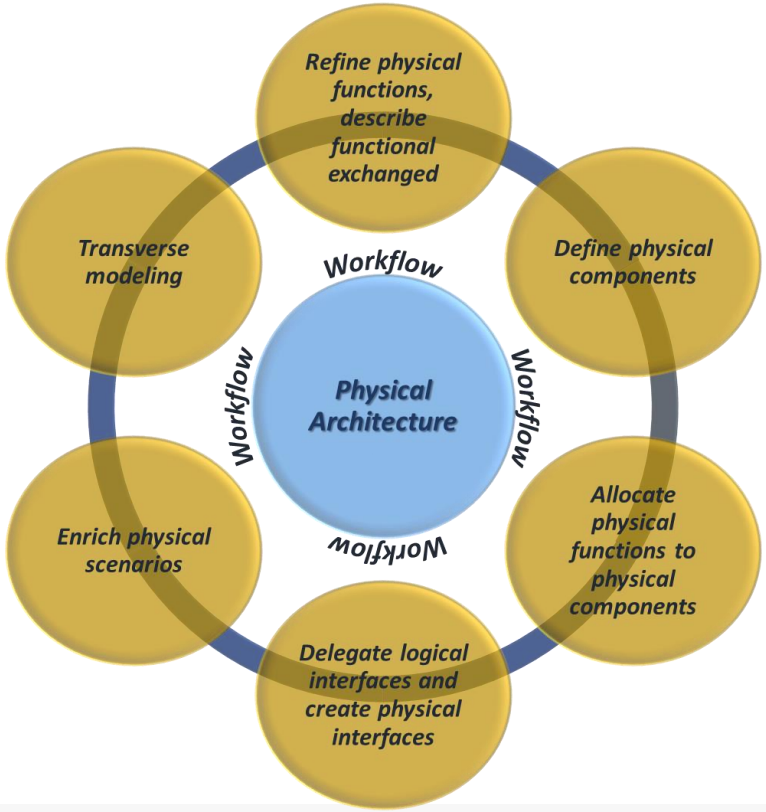


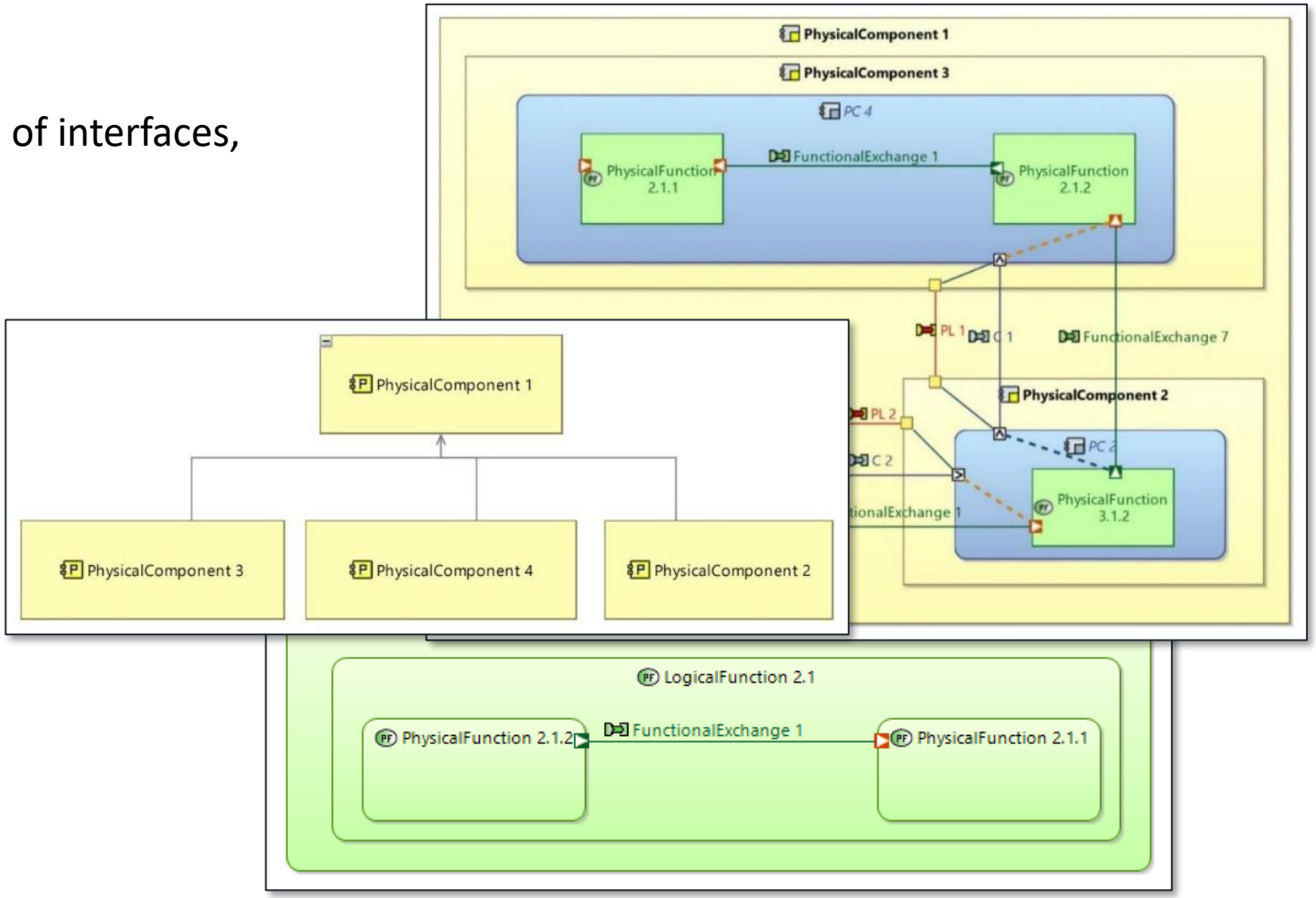
ARCADIA/CAPELLA - Physical Architecture

The PA perspective has the same intent as the logical architecture building, except that it defines the “final” architecture of the system at this level of engineering.

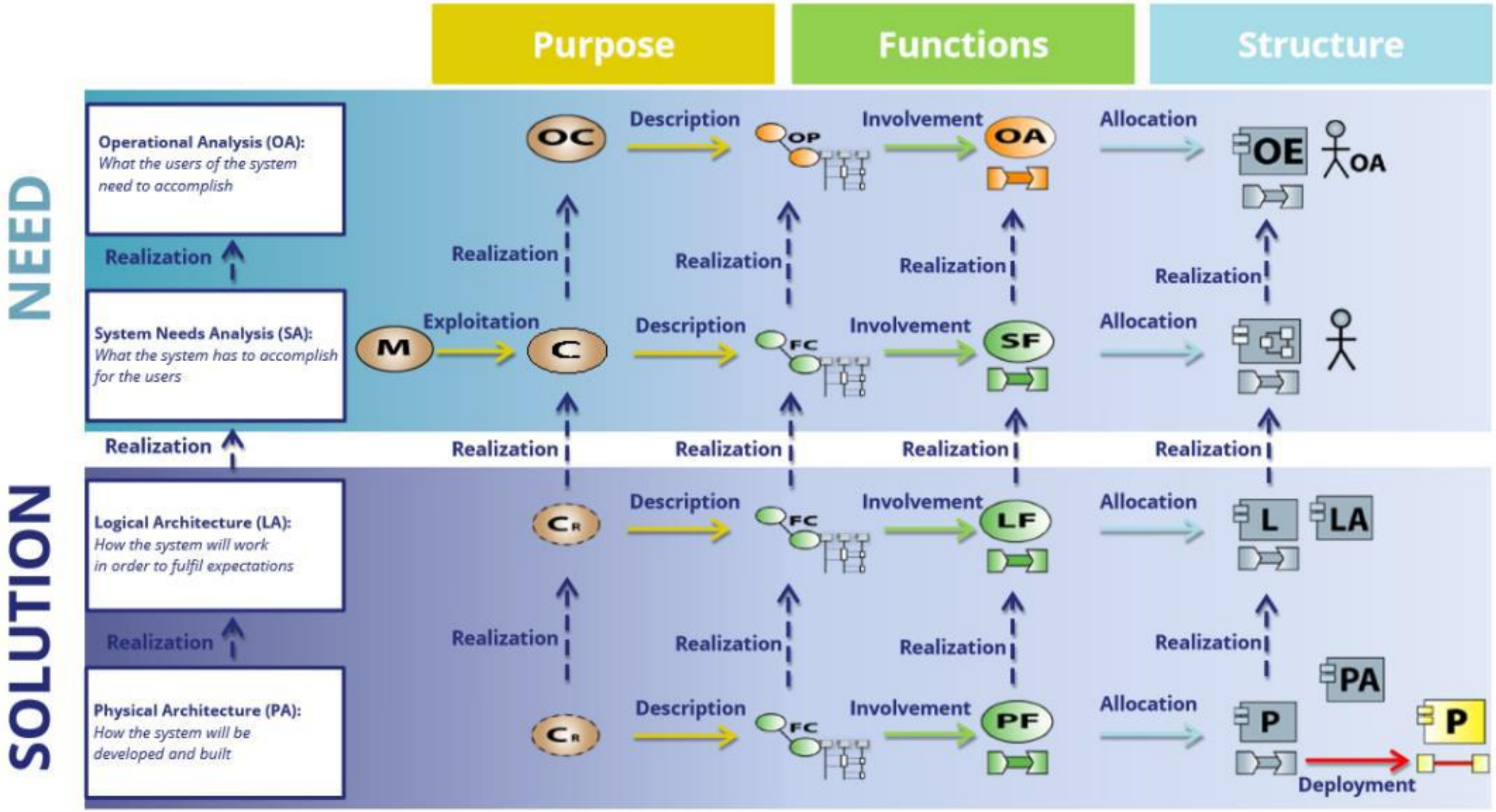
Develop Physical architecture

- How the system will be developed and built
- Software vs. hardware allocation, specification of interfaces,
- deployment configurations, trade-off analysis



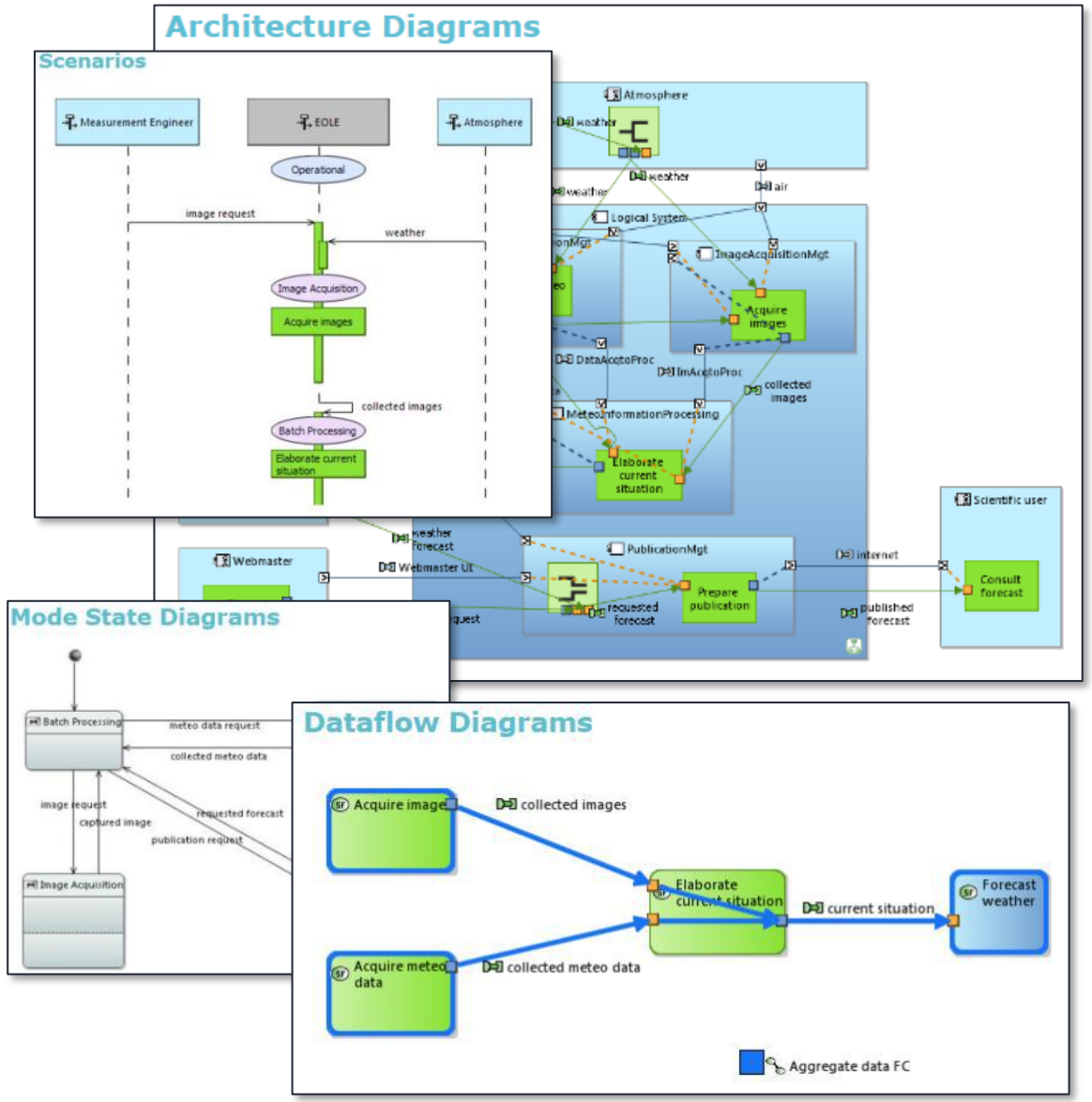


ARCADIA/CAPELLA - Concepts

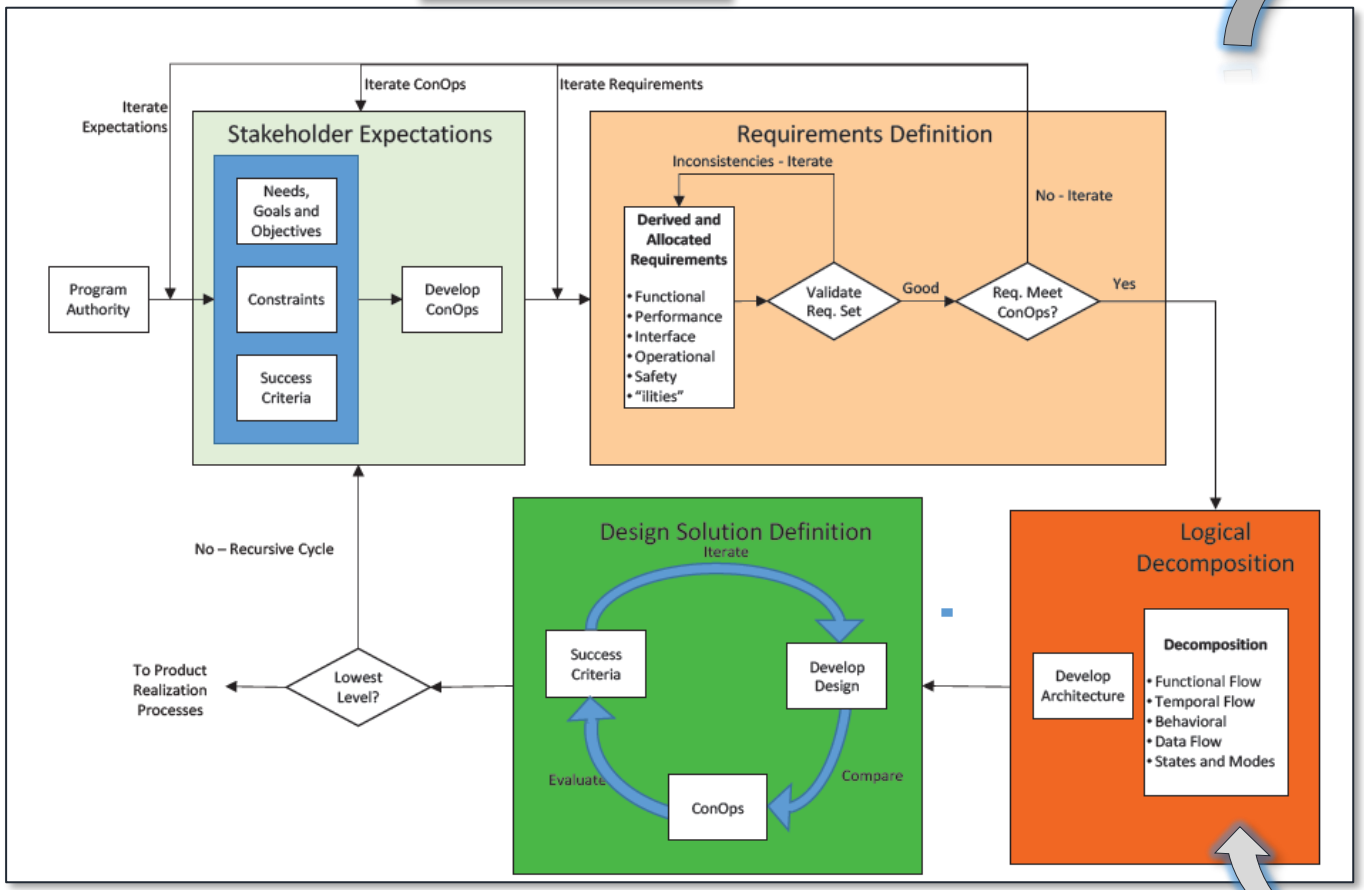


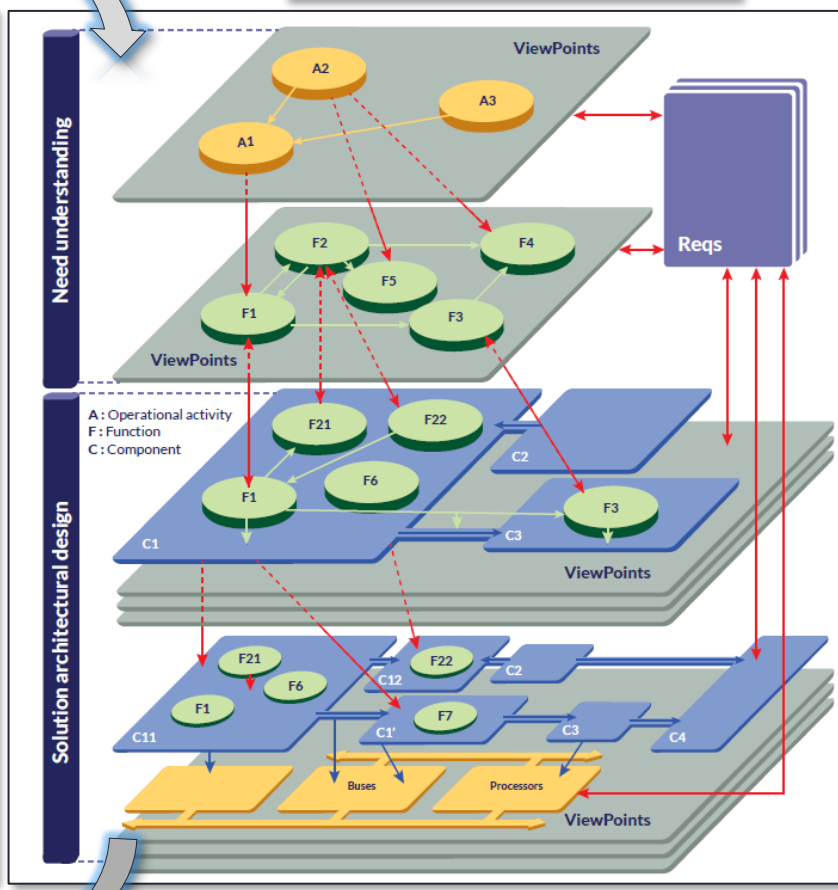
ARCADIA/CAPELLA - Diagram description

Diagram	Description
Breakdown diagram	Stakeholders/Functions/Components decomposition through graphical tree
Capability diagram	Equivalent to a use-case diagram, used to organize the functional analysis
Dataflow diagram	Provide informations exchanged between functions
Architecture diagram	Described the assembly of components or functions and interfaces
Scenario	Provdes dynamic behavior between functions
Mode&State	Provide the working type of function or actor or system.
Class diagram	Often, data-class diagram compress of exchange items or data parameters utilized in a system



ARCADIA Versus NASA System Engineering Handbook





Operational Analysis
What the users of the system need to accomplish

Functional & Non Functional Need
What the system has to accomplish for the users

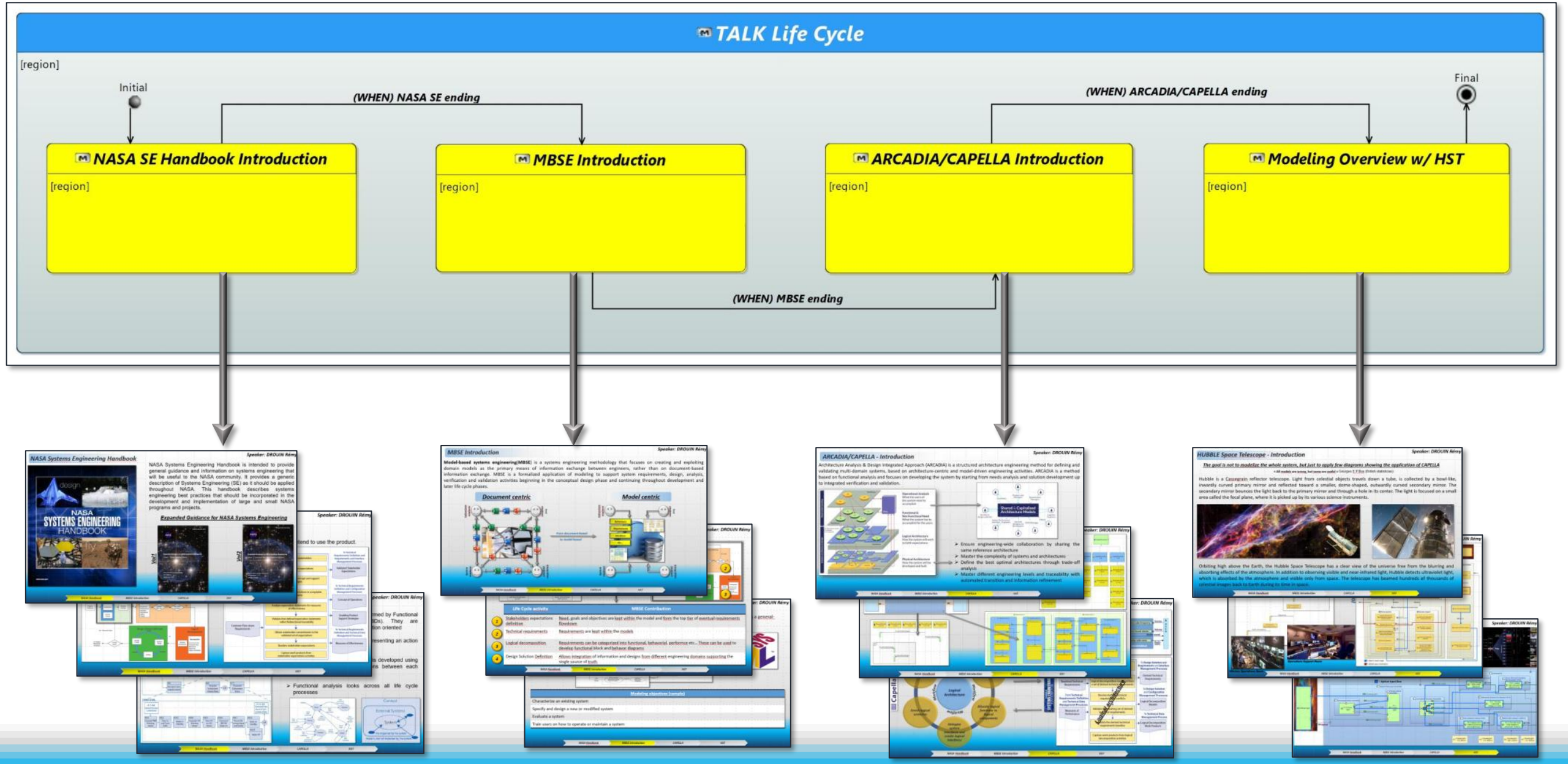
Logical Architecture
How the system will work to fulfill expectations

Physical Architecture
How the system will be developed and built

Requirements definition process
Technical solution definition process

Need understanding
Solution architectural design

TALK Life Cycle

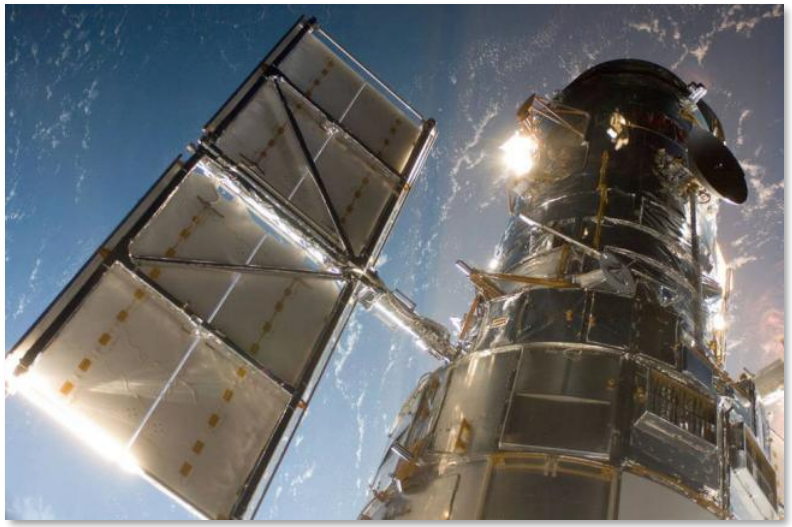


HUBBLE Space Telescope - Introduction

The goal is not to model to the entire system as well as not apply all ARCADIA concepts, but just to introduce few diagrams of ARCADIA/CAPELLA

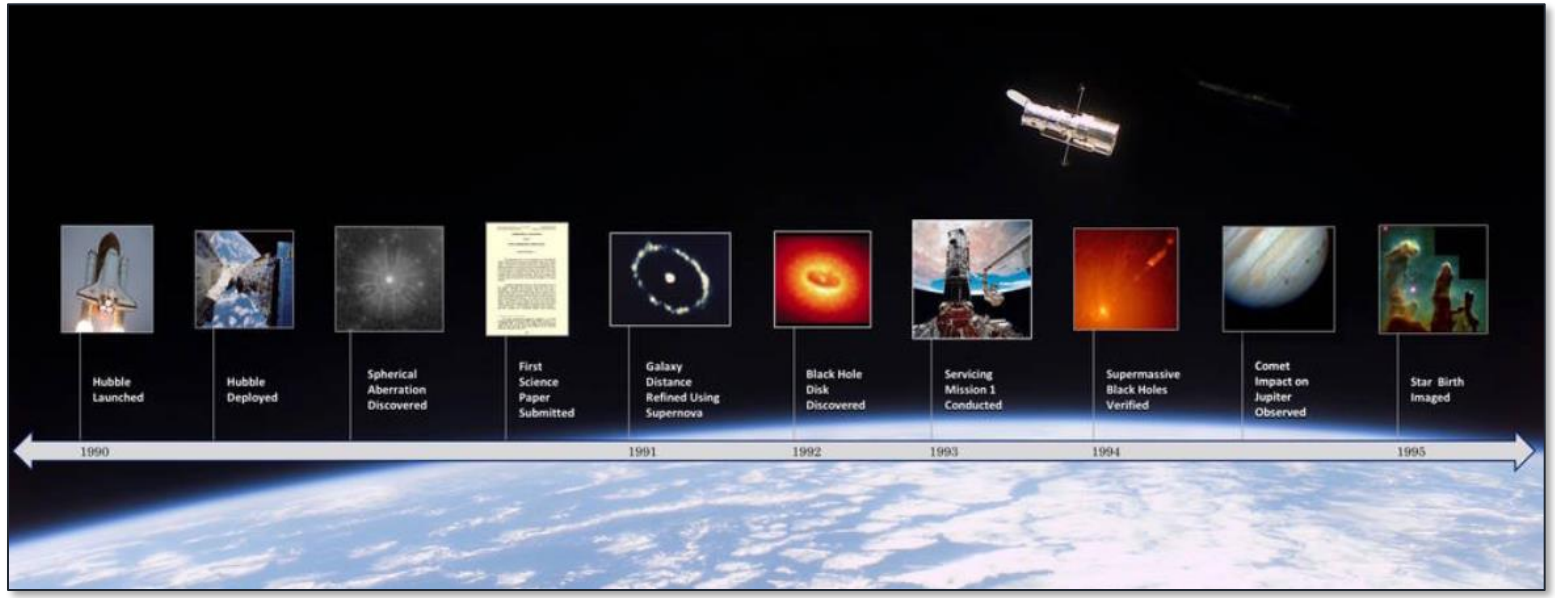
« All models are wrong, but some are useful » George E.P.Box (British statistician)

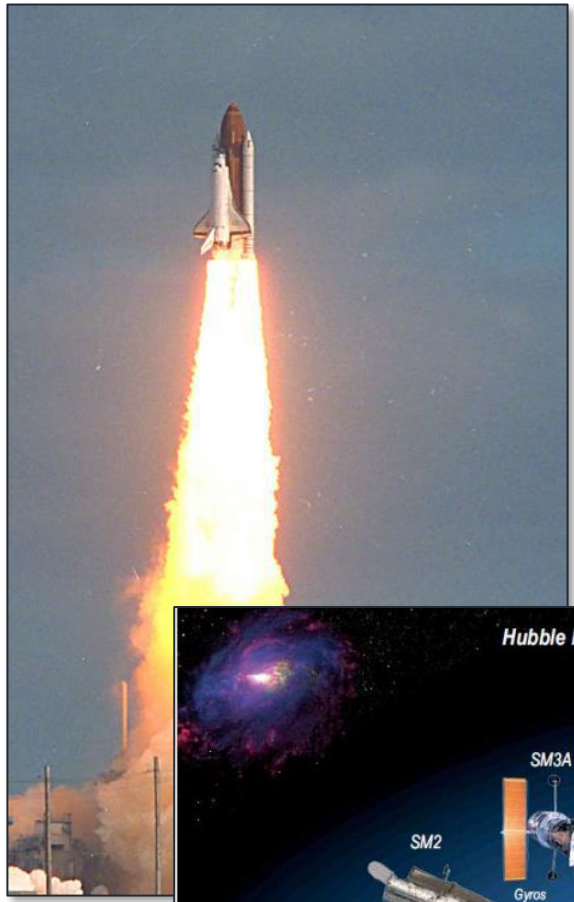
Hubble is a Cassegrain reflector telescope. Light from celestial objects travels down a tube, is collected by a bowl-like, inwardly curved primary mirror and reflected toward a smaller, dome-shaped, outwardly curved secondary mirror. The secondary mirror bounces the light back to the primary mirror and through a hole in its center. The light is focused on a small area called the focal plane, where it is picked up by its various science instruments.

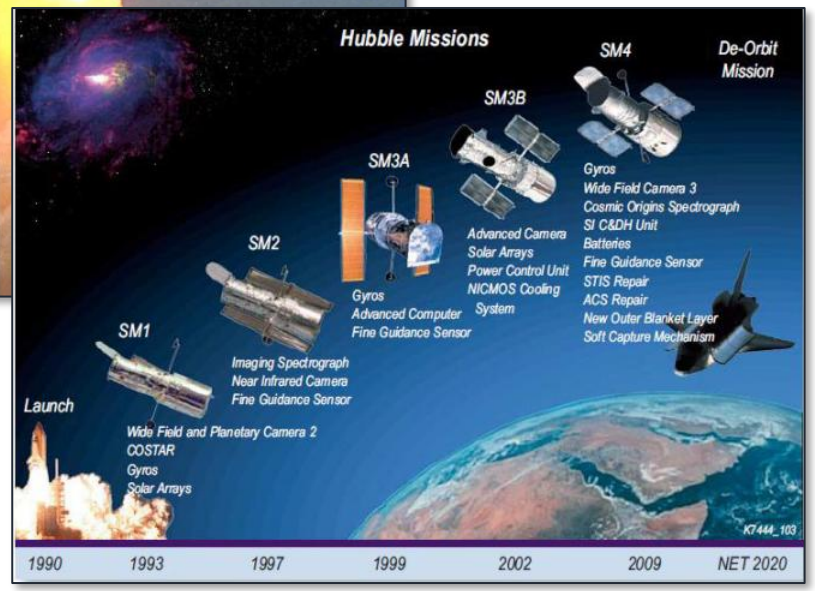


Orbiting high above the Earth, the Hubble Space Telescope has a clear view of the universe free from the blurring and absorbing effects of the atmosphere. In addition to observing visible and near-infrared light, Hubble detects ultraviolet light, which is absorbed by the atmosphere and visible only from space. The telescope has beamed hundreds of thousands of celestial images back to Earth during its time in space.

HUBBLE Space Telescope facts





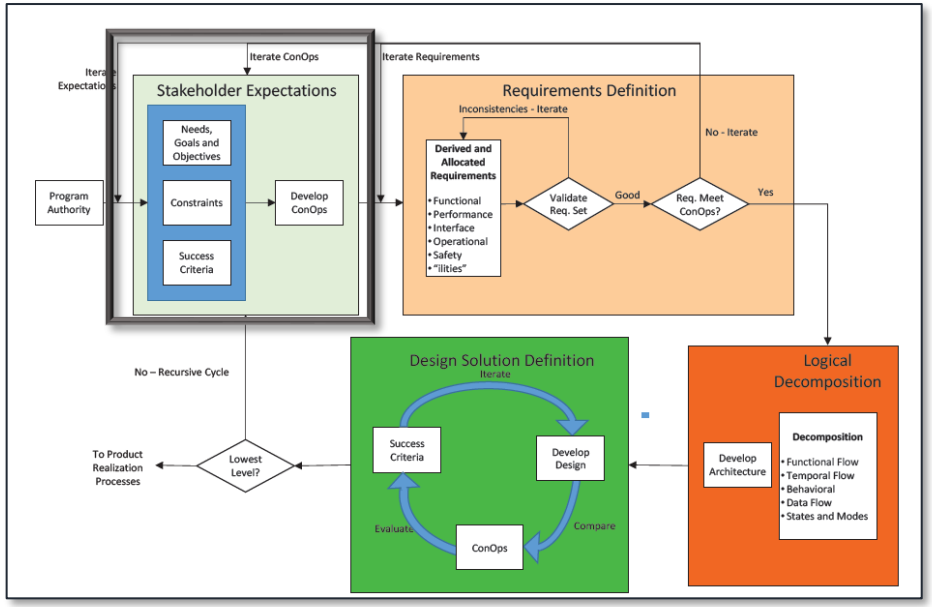


- ***Launched:*** April 24, 1990
- ***Deployed:*** April 25, 1990. First Image – May 20, 1990
- ***Servicing missions:*** 4 (SM1 – SM4)
- ***Launch vehicle:*** Space Shuttle Discovery (STS-31)
- ***Launch site:*** Kennedy Space Center, Florida
- ***Location:*** Orbiting 340 miles (540 kilometers) above the Earth
- ***Orbital Period:*** Approximately 95 minutes to complete one orbit around Earth
- ***Speed:*** About 17,000 mph (27,300 kph)
- ***Wavelength coverage:*** Sensitivity to light: Ultraviolet through Infrared (115-1700nm)

Operational Analysis

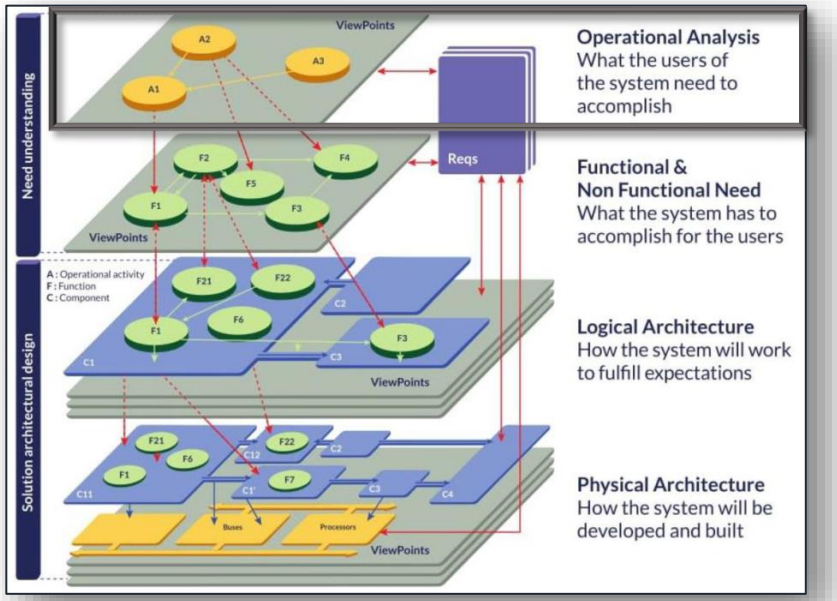
Requirements definition process

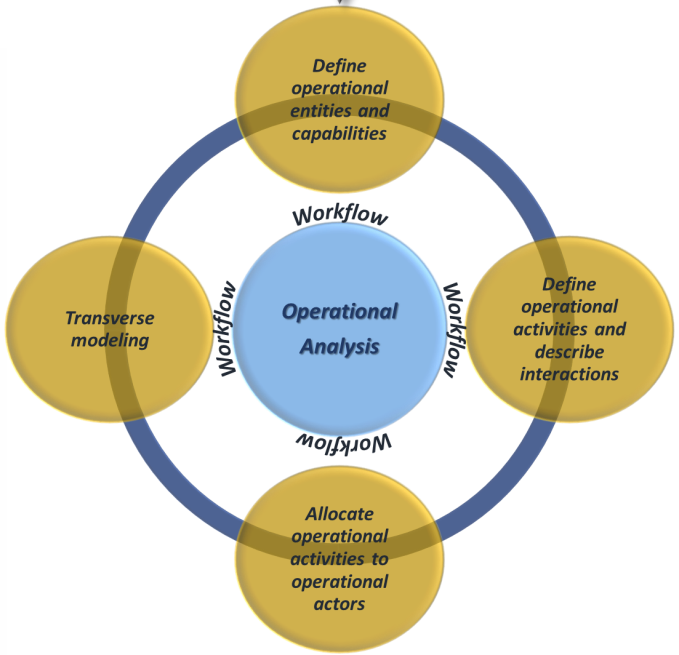
Technical solution definition process



Need understanding

Solution architectural design





Operational Analysis

Purpose

Run peer review science program selection

OC

Advance the state-of-the-art astronomical research, archives and tools for scientific discovery

OC

Helps turn great science ideas into great science

OC

Help hummanity to explore the universe

OC

Manage daily operation support

OC

Manage daily mission operation

OC

Behind Hubble's captivating images and groundbreaking science is a team of people who control the telescope, ensure its health and safety, and innovate ways to keep it at top performance more than three decades after its launch. This group of engineers, scientists, and operators at NASA's Goddard Space Flight Center work together to monitor Hubble as it travels around Earth, point the telescope at cosmic targets, and solve any problems that arise. They perform their work in specialized facilities that provide the tools and equipment needed to operate this great observatory and continue its legacy of success.

NASA GODDARD SPACE FLIGHT CENTER

HUBBLE SPACE TELESCOPE (HST)

LAUNCHED APRIL 24, 1990

We are the science operations center for the Hubble Space Telescope. Our
the lifecycle of a scientific proposal for Hubble observations, which we hav
since its launch in 1990. We help turn great science ideas into great science, highlight the results, and distribute the data acquired for others to use. Our work includes running the peer-reviewed science program selection, planning and scheduling of the telescope, characterizing the performance of the instruments, maintaining and enhancing the archive of data, and making the data freely available to the world.

STScI SPACE TELESCOPE SCIENCE INSTITUTE

Help hummanity to explore the universe

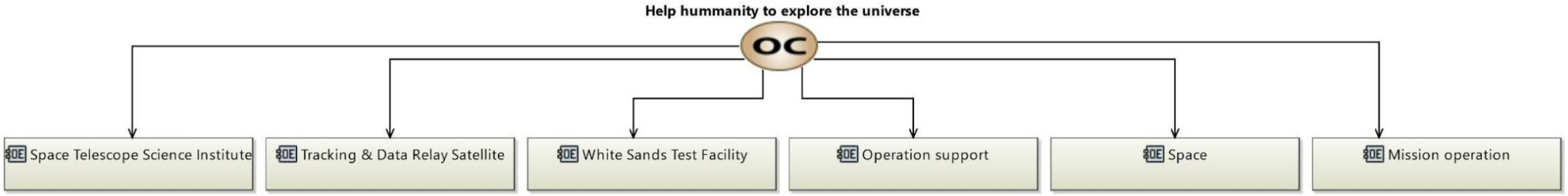
OC

- Space Telescope Science Institute
- Tracking & Data Relay Satellite
- White Sands Test Facility
- Operation support
- Space
- Mission operation

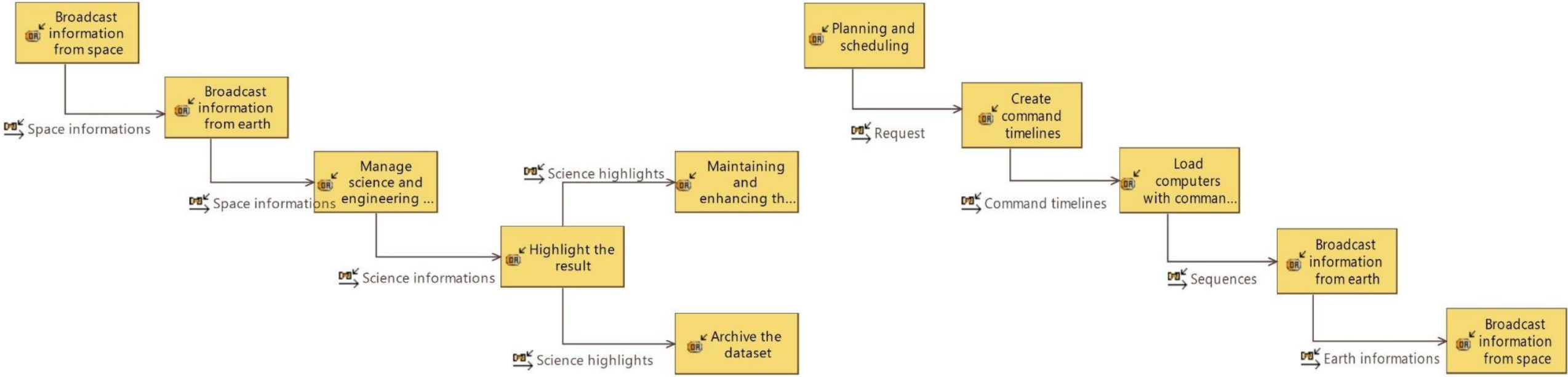
The goal is not to model the entire system as well as not apply all ARCADIA concepts, but just to introduce few diagrams of ARCADIA/CAPELLA

Operational Analysis

Purpose



Functions



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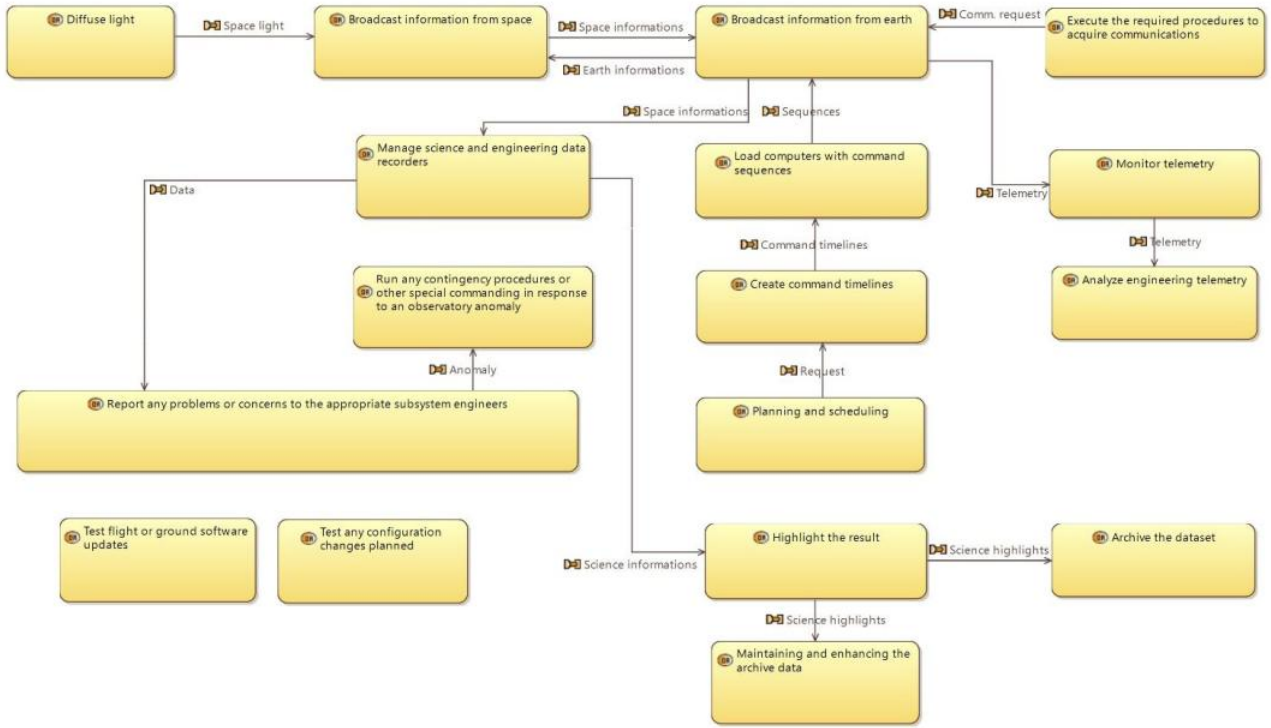
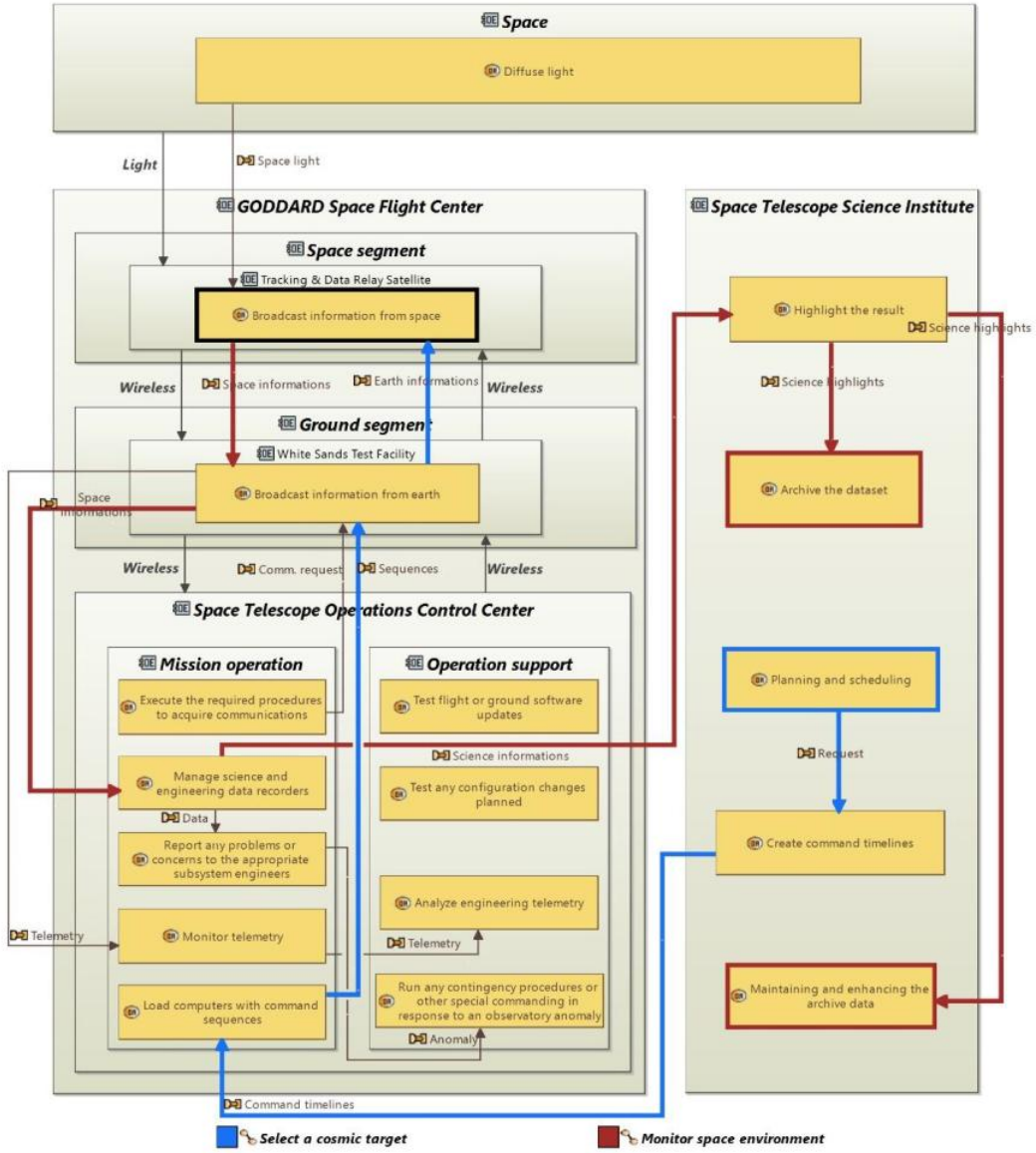
Operational Analysis

Functions

Structure





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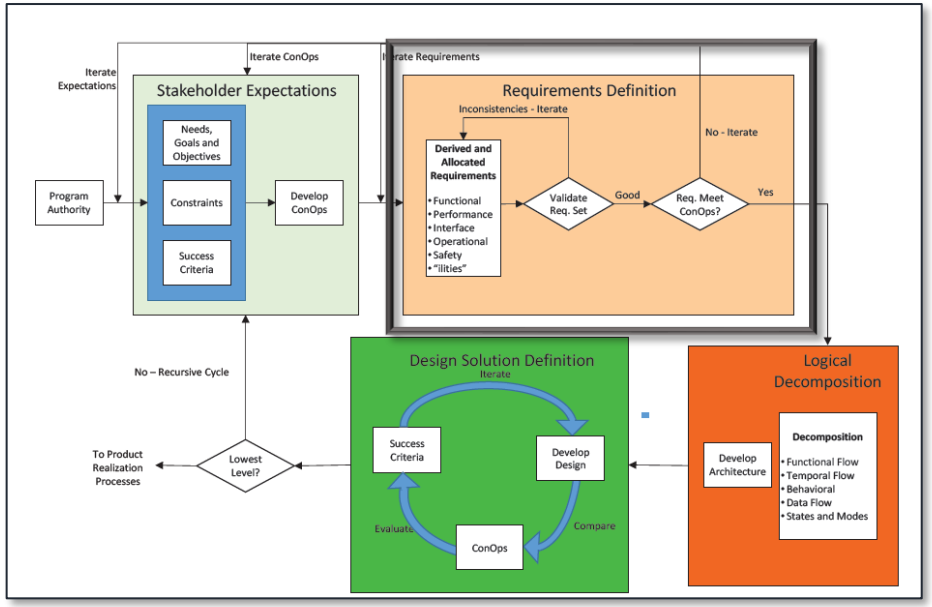
System Analysis

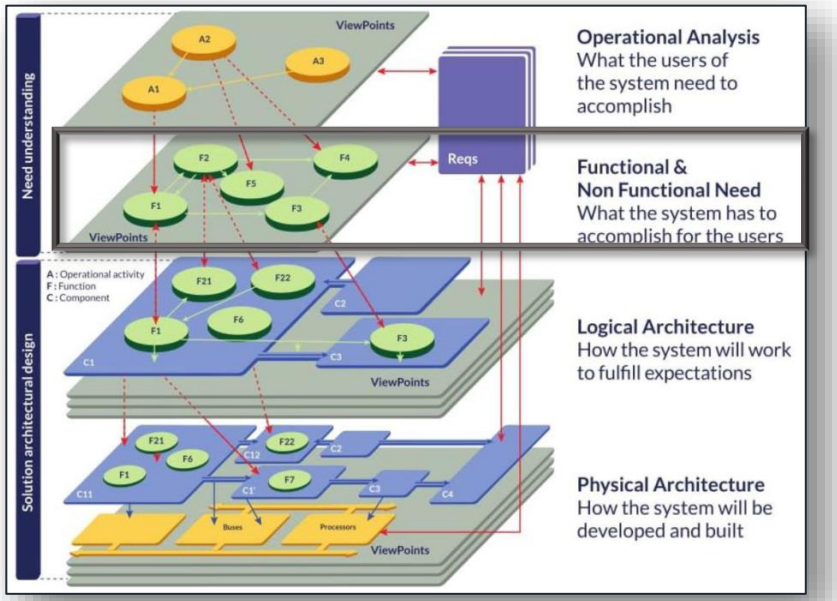
Requirements definition process

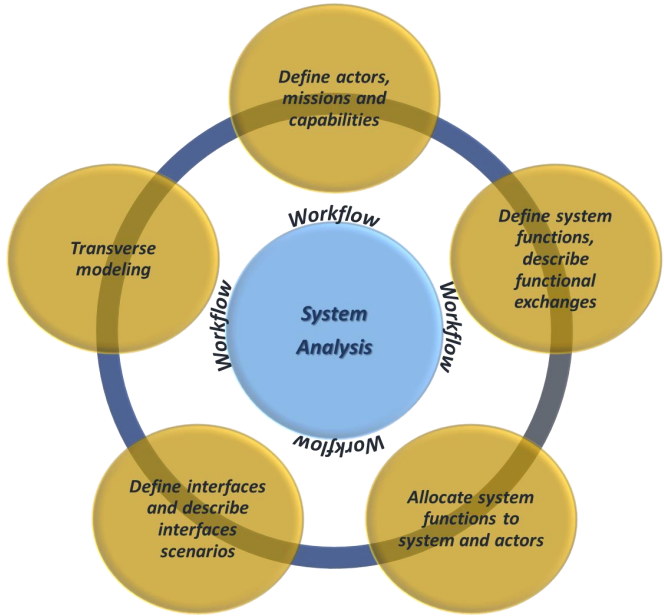
Technical solution definition process



Need understanding

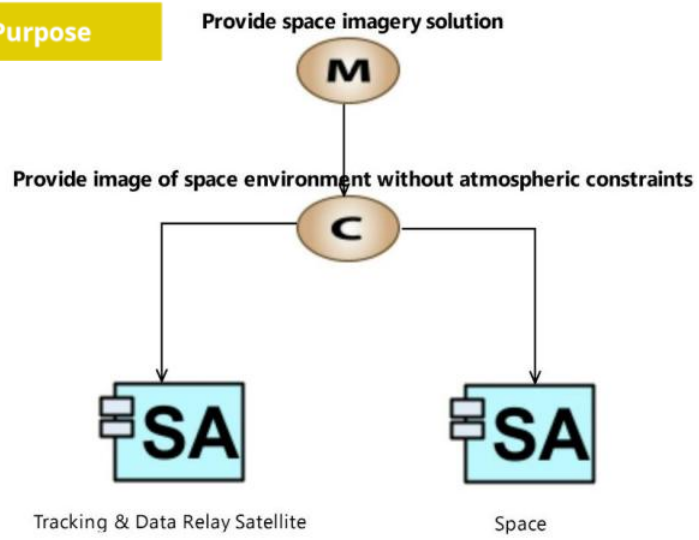
Solution architectural design



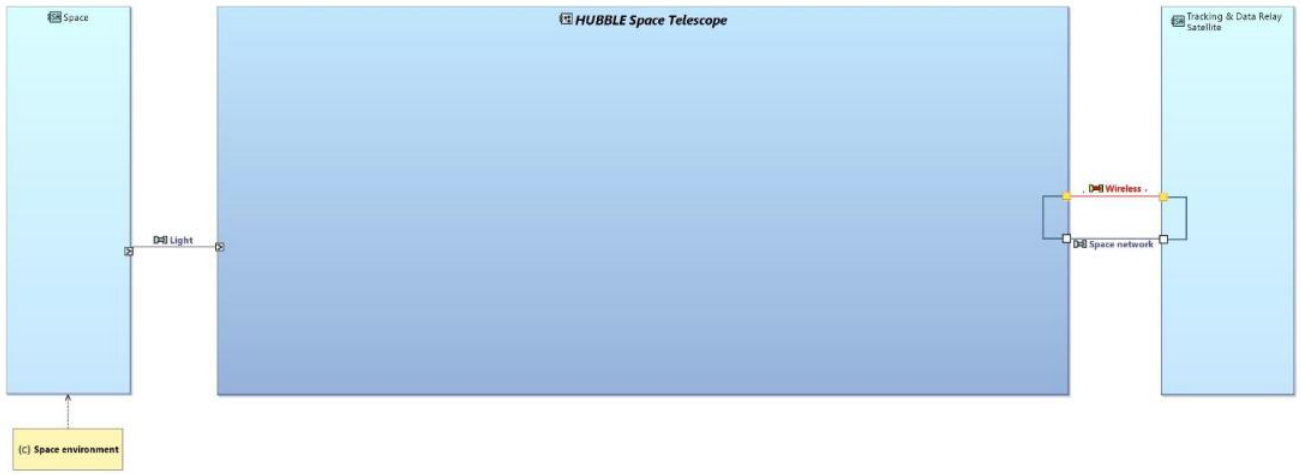


System Analysis

Purpose



Structure



(Capability) Provide image of space environment without atmospheric constraints

Referencing Elements	Current Element	Referenced Elements
Exploiting Missions	Provide image of space environment without atmospheric constraints	**Active In Modes**
Provide space imagery solution	**Owned Functional Chains**	Mission Operation
Realizing Capability Realizations	Images Sharing	**Involved Components**
Provide image of space environment without atmospheric constraints	Star Pointing	HUBBLE Space Telescope
	Scenarios	Space
	[ES] [FS] Images Sharing (ES)	Tracking & Data Relay Satellite
	[FS] Images Sharing	**Involved Functional Chains**
	[FS] Star Pointing	Images Sharing
	All Related Diagrams	Star Pointing
	[MCB] Capabilities	**Involved System Functions**
	[SDFB] Provide image of space environment without atmospheric constraints	Broadcast information from space
		Capture cosmic light
		Control pointing
		Diffuse light
		Manage communication with earth
		Manage data science and engineering
		Root System Function
		Translate light into data
		Realized Operational Capabilities
		Help hummanity to explore the universe

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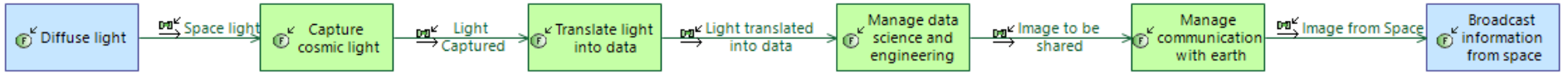
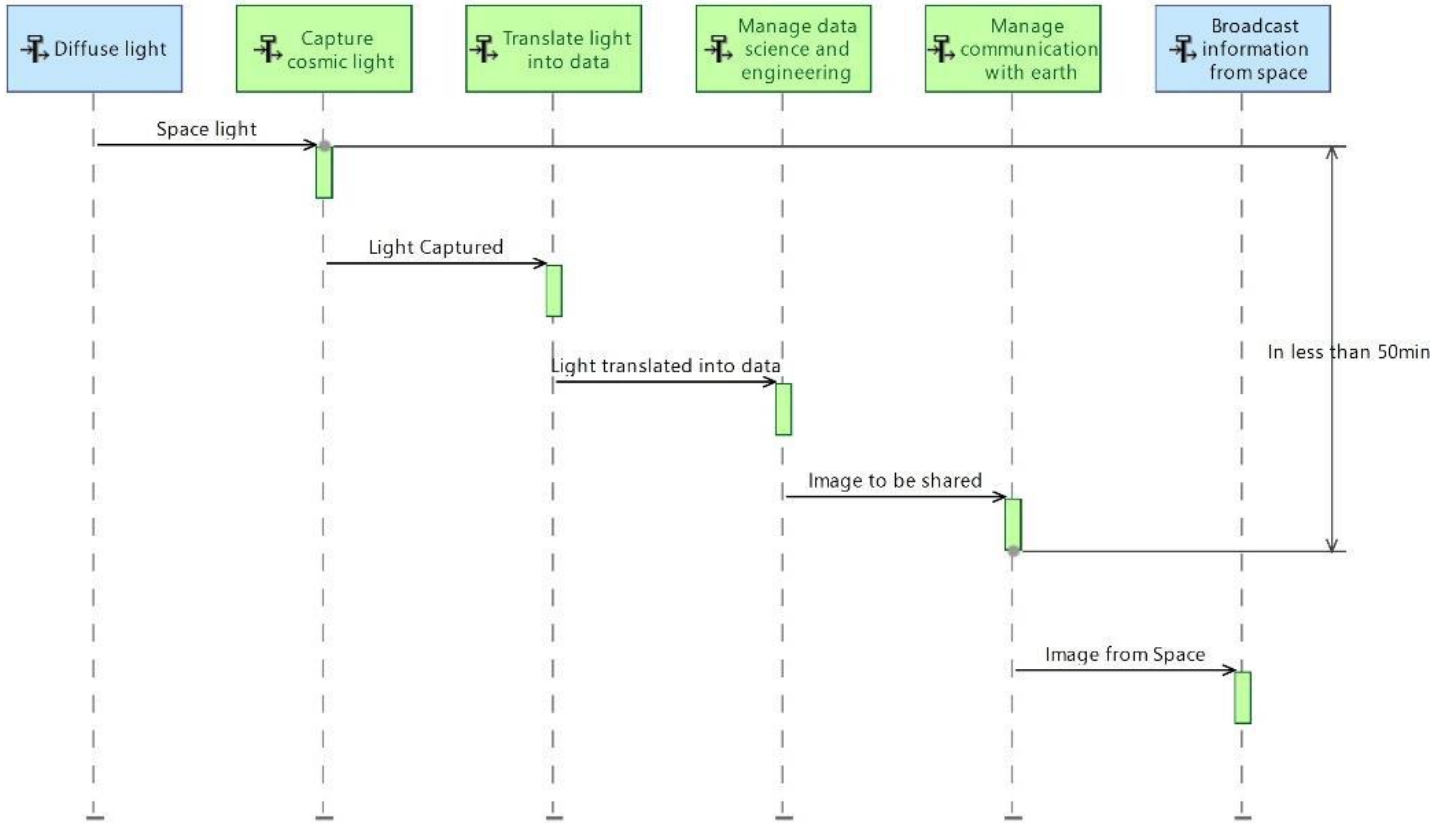
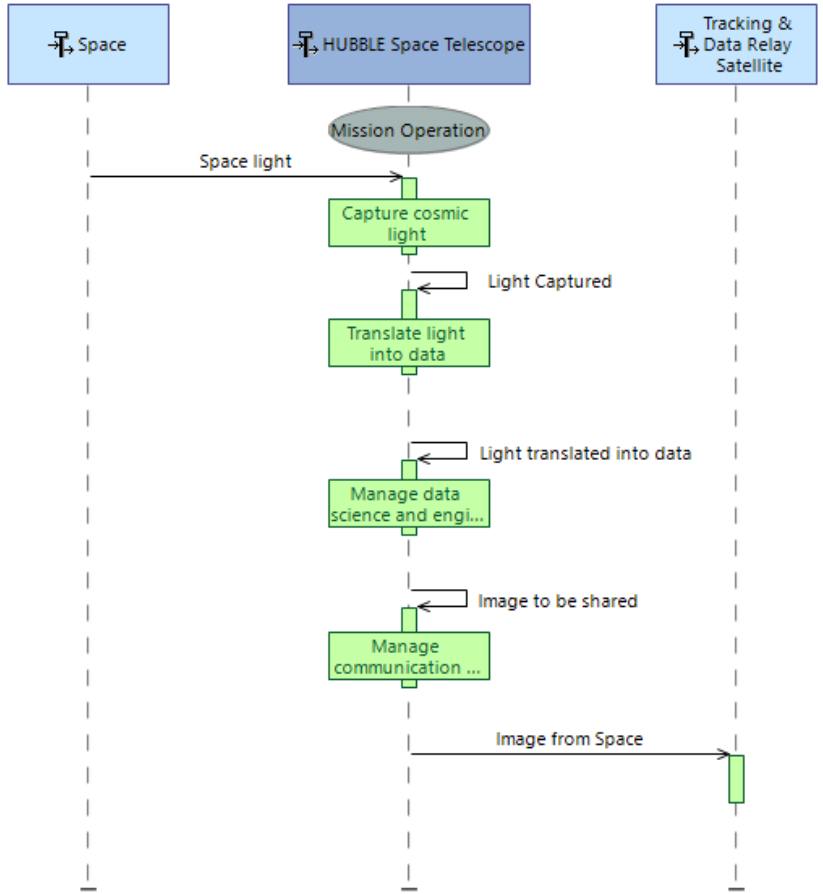
System Analysis

Purpose

Functions







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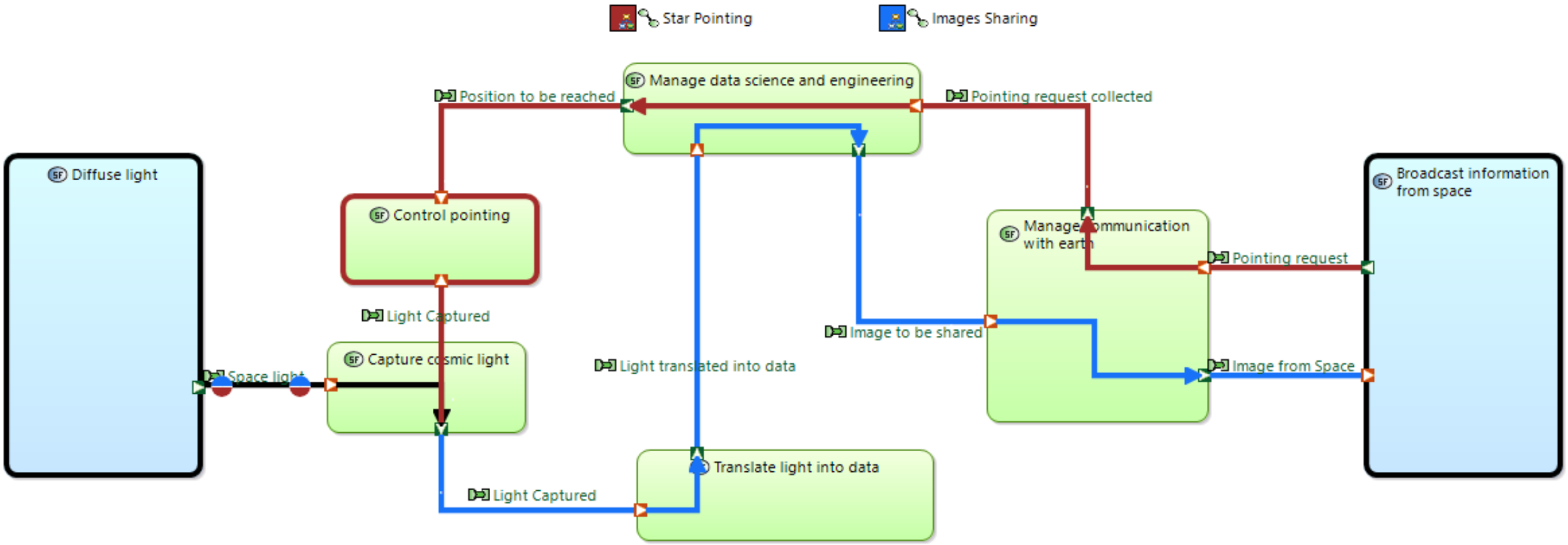
System Analysis

Functions



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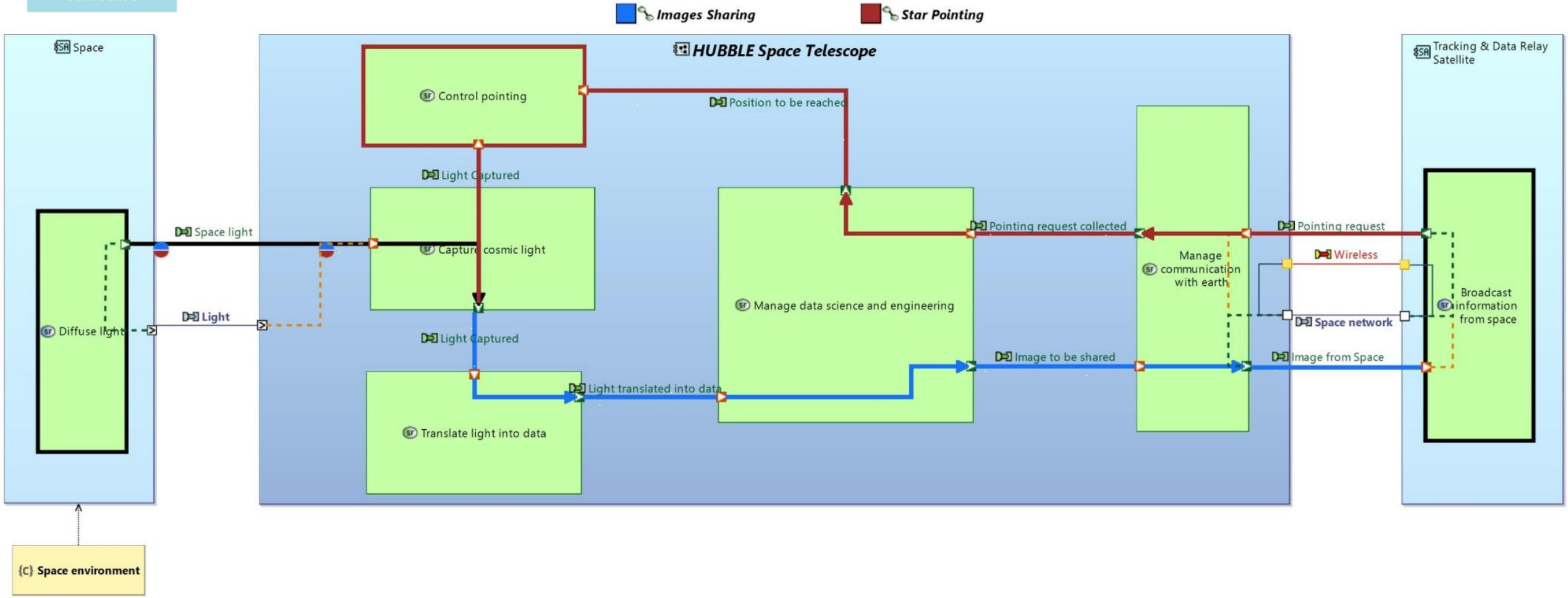
System Analysis

Functions

Structure



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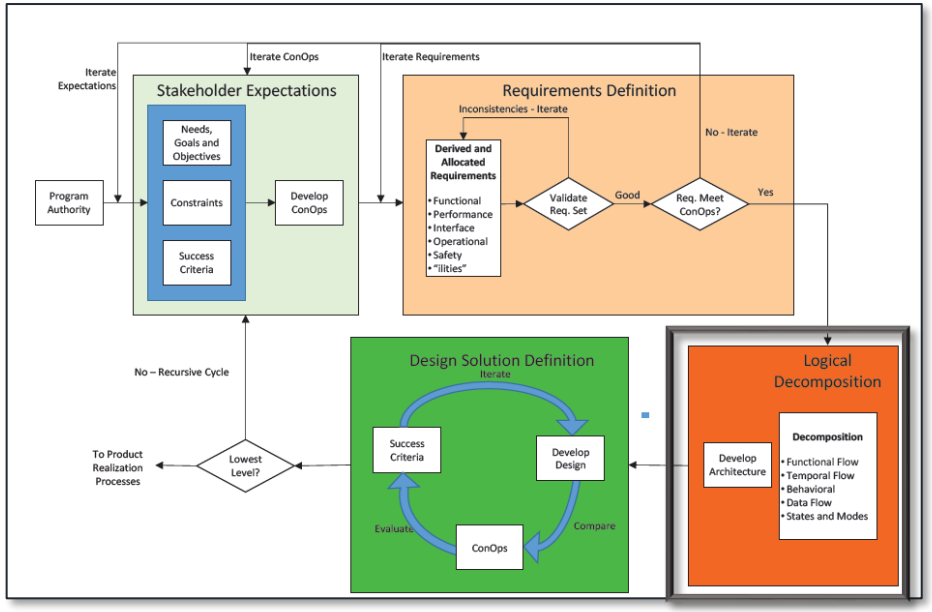
Logical Architecture

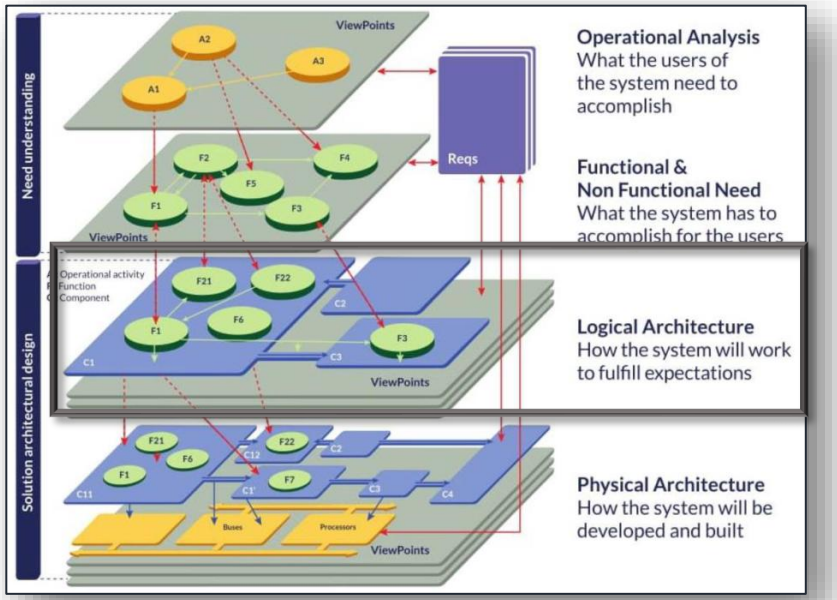
Requirements definition process

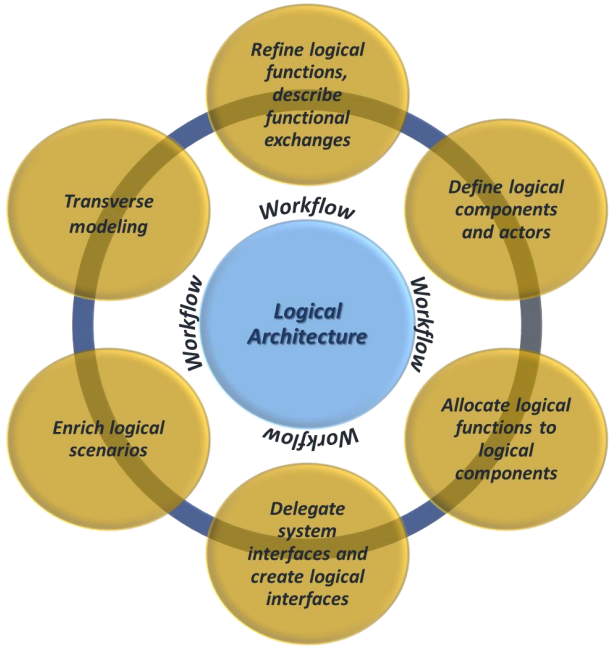
Technical solution definition process



Need understanding

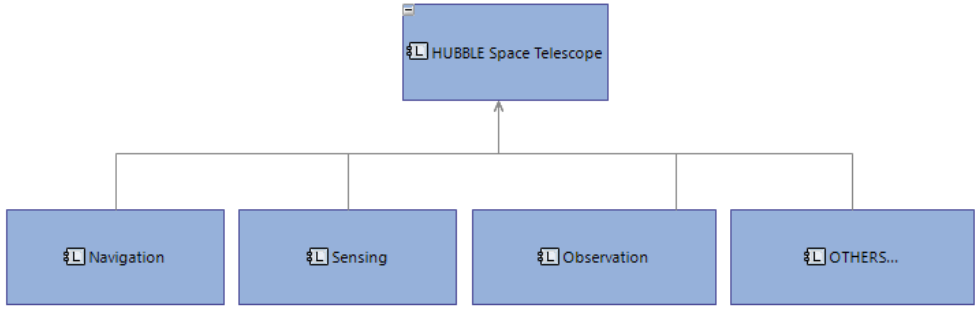
Solution architectural design

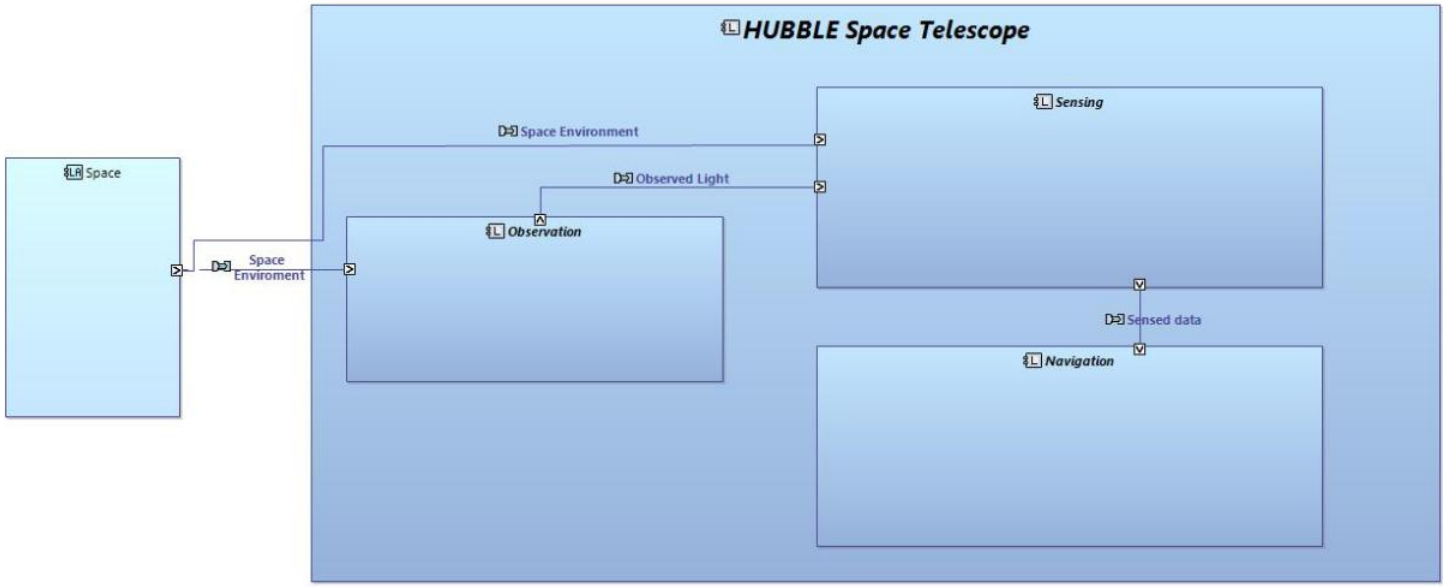




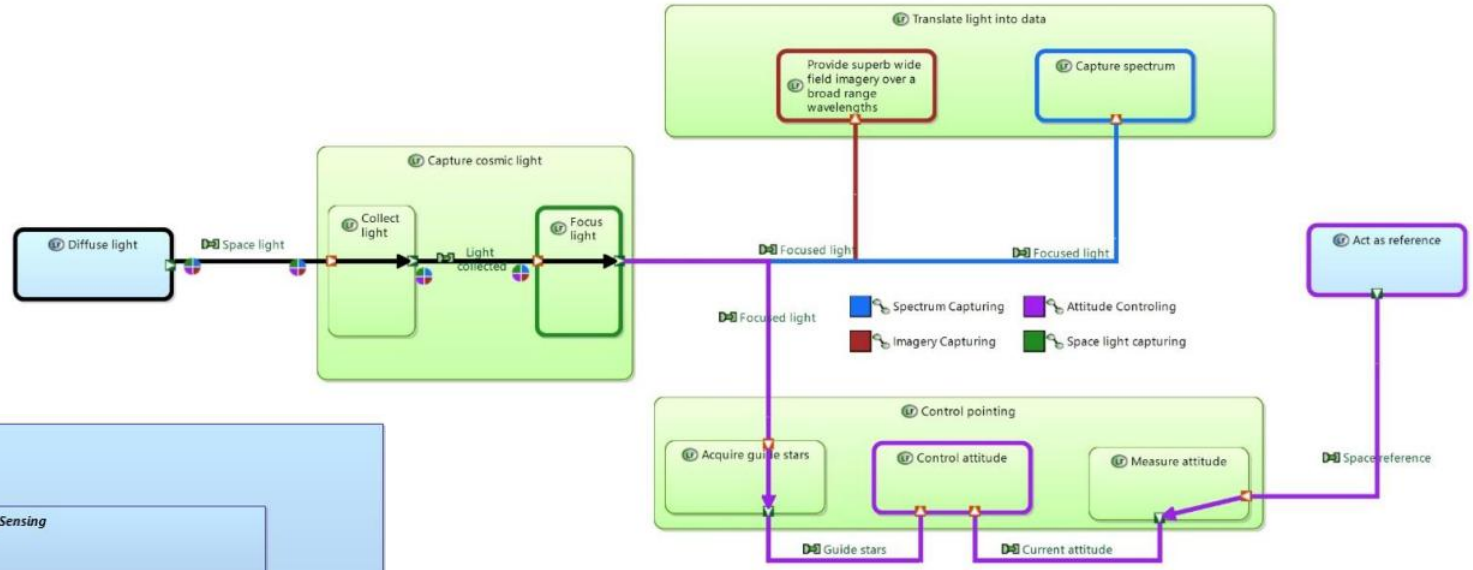
Logical Architecture

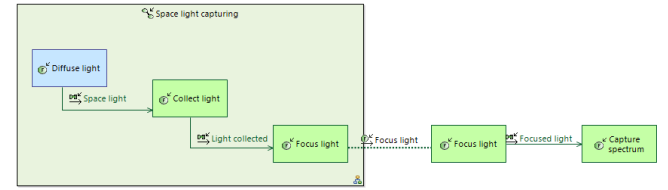
Structure

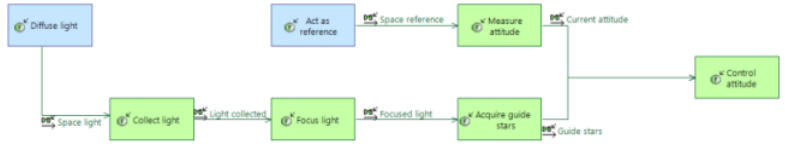




Functions







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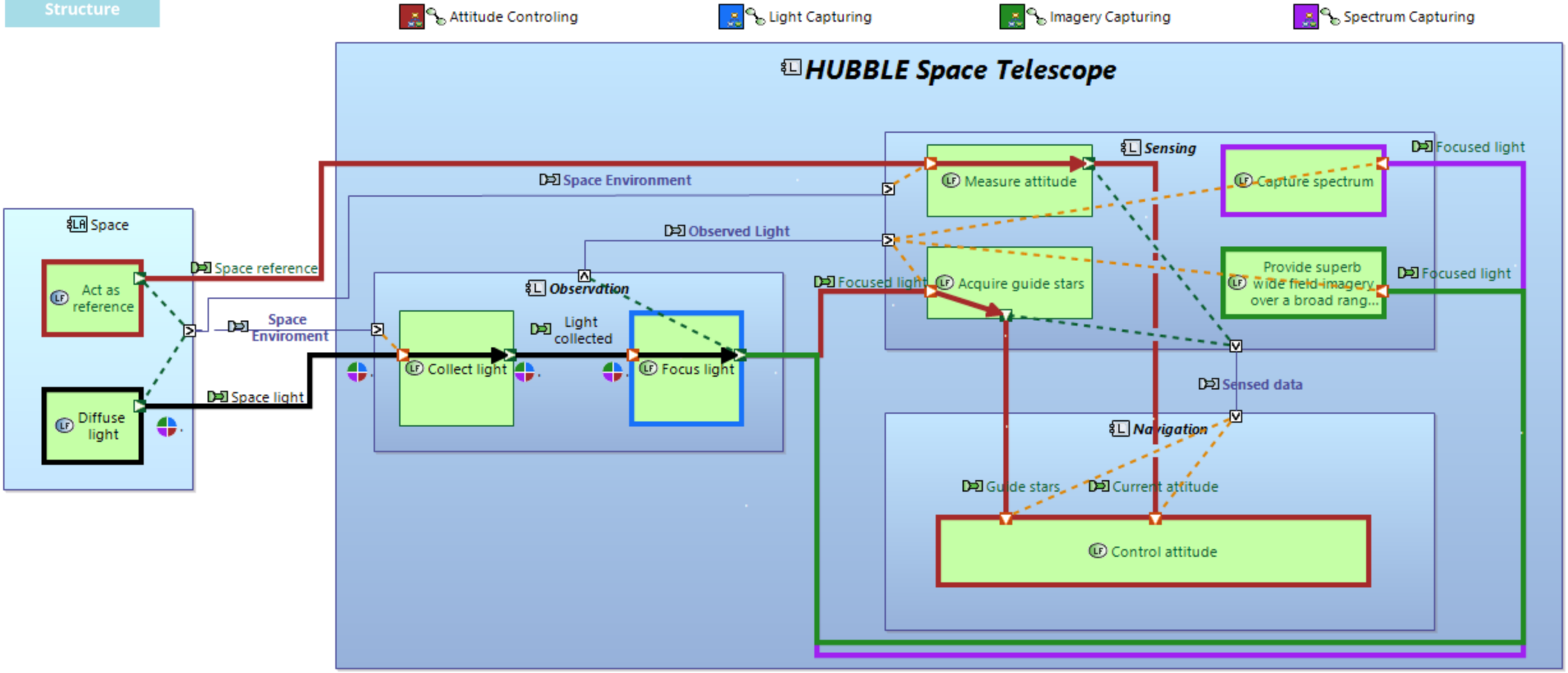
Logical Architecture

Functions

Structure



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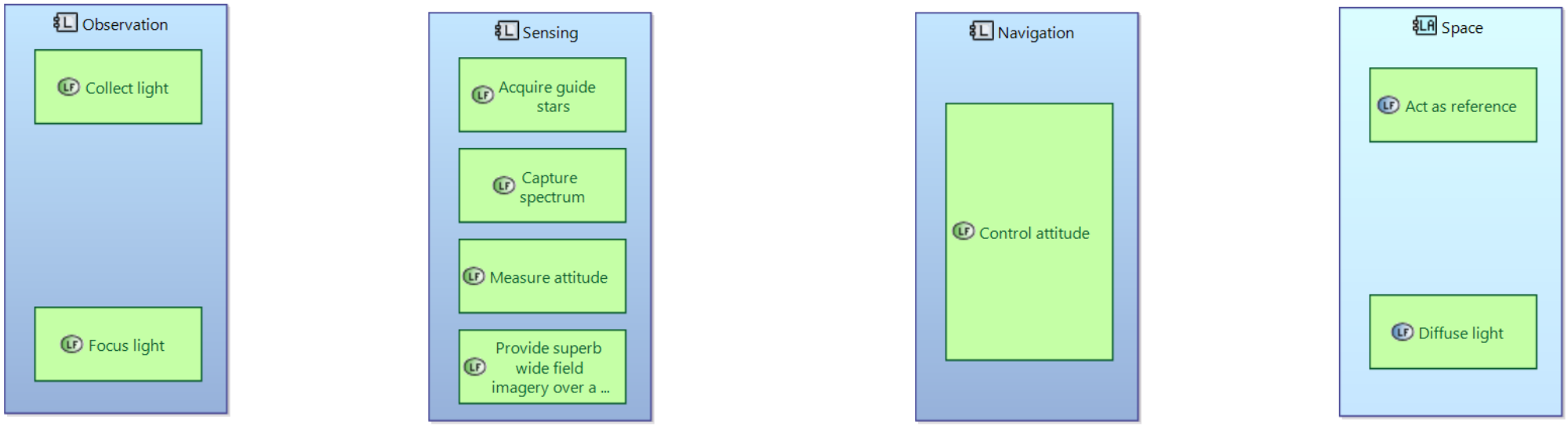
Logical Architecture

Functions

Structure



	Diffuse light	Act as reference	Collect light	Focus light	Provide s...	Capture spectrum	Acquire guide stars	Control attitude	Measure attitude
HUBBLE Space Telescope									
Observation			X	X					
OTHERS...									
Navigation								X	
Sensing					X	X	X		X
Space	X	X							

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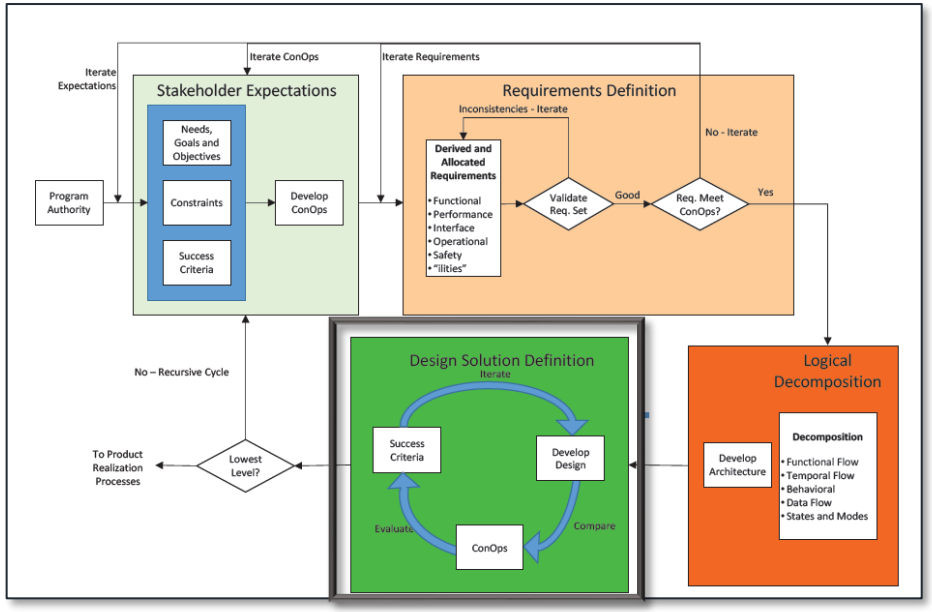
Physical Architecture

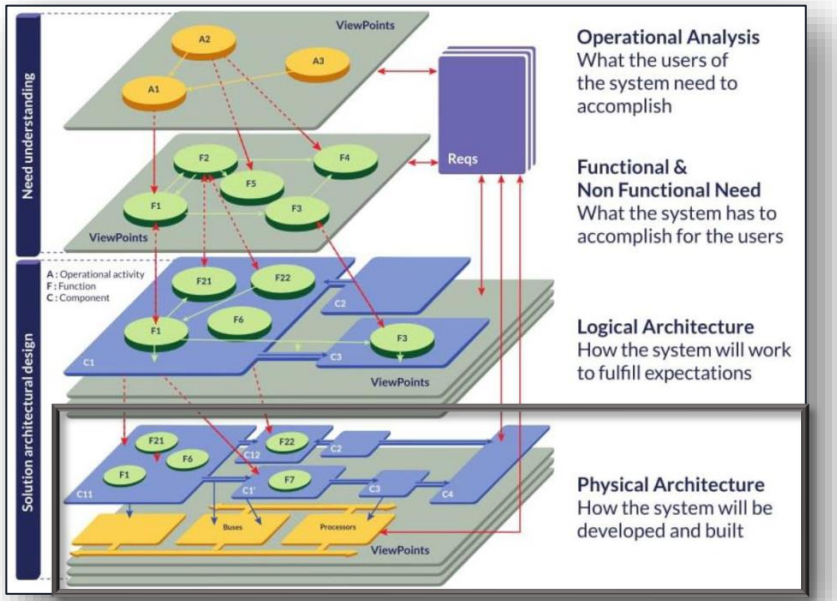
Requirements definition process

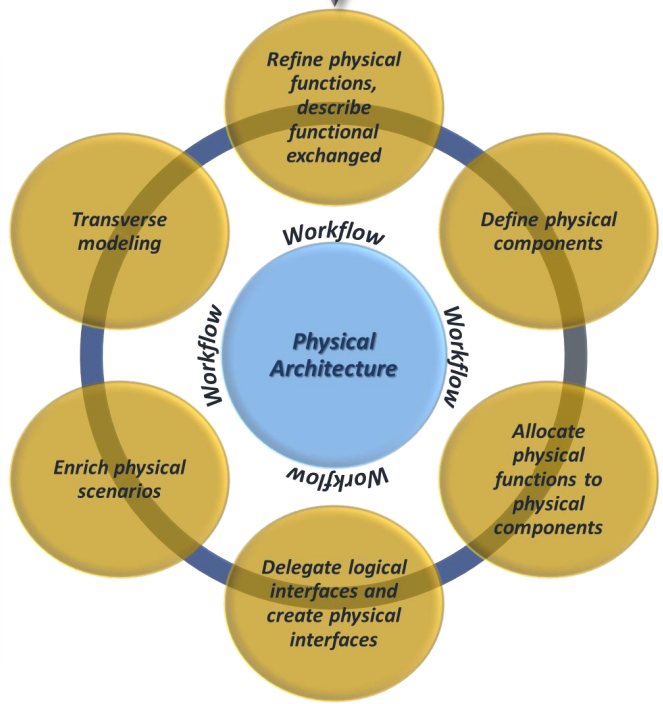
Technical solution definition process



Need understanding

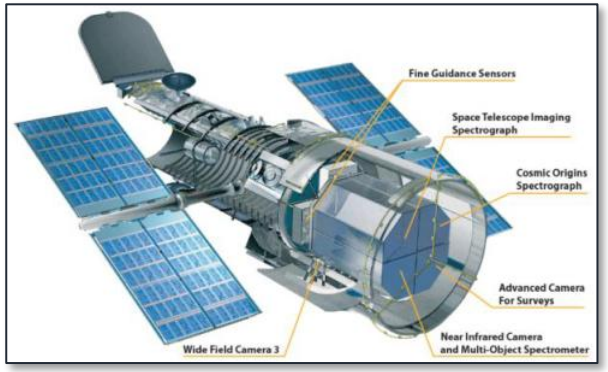
Solution architectural design



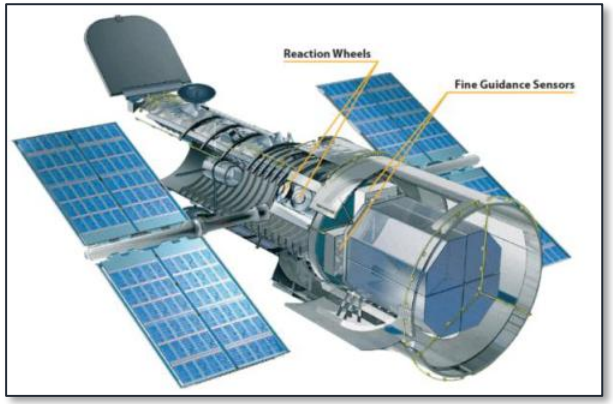


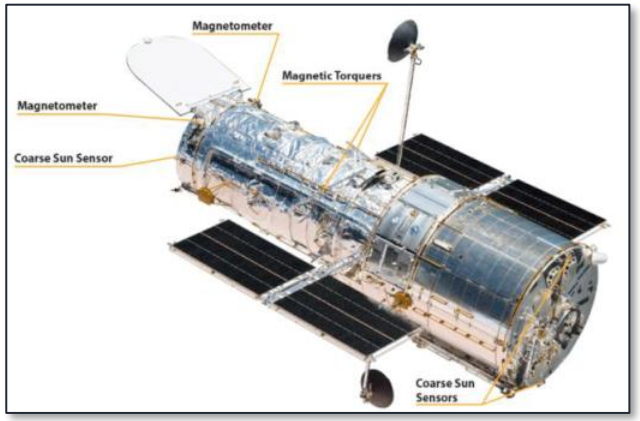
Physical Architecture

Structure



- HUBBLE Space Telescope
  - Optical Telescope Assembly (OTA)
    - Primary Mirror Assembly (PMA)
      - Main Ring (MR)
      - Reaction Plate Assembly (RPA)
      - Primary Mirror Assembly Baffles
      - Main Baffles Assembly (MBA)
      - Central Baffles Assembly (CBA)
      - Primary Mirror (PM)
    - Secondary Mirror Assembly (SMA)
      - Secondary Mirror Subassembly (SMSA)
      - Secondary Baffles Assembly (SBA)
    - Focal Plane Structure Assembly (FPSA)
      - Focal Plane Deck Assembly (FPDA)
      - Scientific Instrument Support Structure (SISS)
      - SSM-Equipment Shelf (SSM-ES)
  - Scientific Instruments (SIs)
    - Advanced Camera for Survey (ACS)
    - Wide Field Planetary Camera (WFC3)
    - Space Telescope Imaging Spectrograph (STIS)
    - Cosmic Origins Spectrograph (COS)
  - OTHERS...





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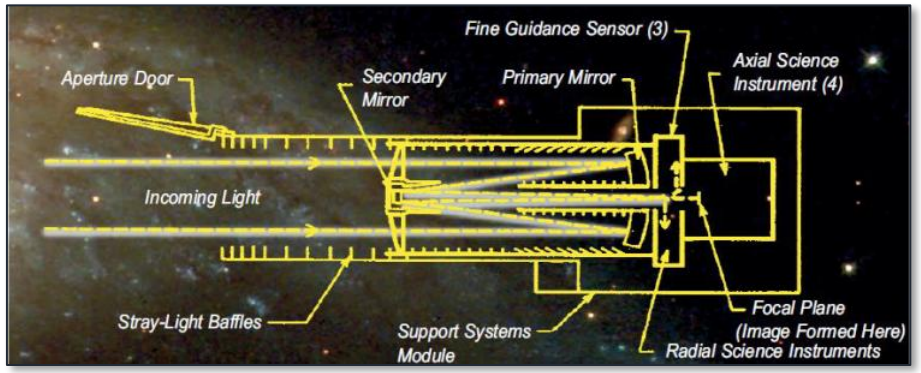
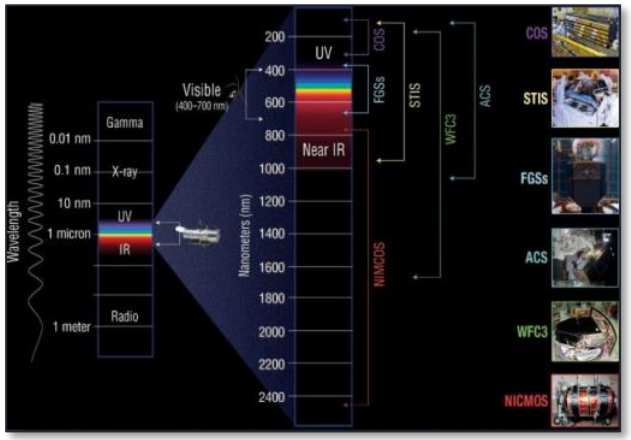
Physical Architecture

Speaker: DROUIN Remy

Functions

Structure





Secondary Mirror Assembly (SMA)
- Light concentrator
  - PF Focus light

Primary Mirror Assembly (PMA)
- Light collector
  - PF Collect light

Focal Plane Structure Assembly (FPSA)
- Focal plane

P Cosmic Origins Spectrograph (COS)
- P Ultra Violet sensor
  - PF Provide ultra violet spectrum

P Advanced Camera for Survey (ACS)
- P Wide Field Imagery sensor#1
  - PF Provide wide field imagery in visible wavelengths

P Space Telescope Imaging Spectrograph (STIS)
- P Spectrograph Imagery sensor
  - PF Obtain high resolution spectra of resolved objetcs

P Wide Field Planetary Camera (WFC3)
- P Wide Field Imagery sensor#2
  - PF Provide a wide field imagery in ultra violet, visible and infrared light

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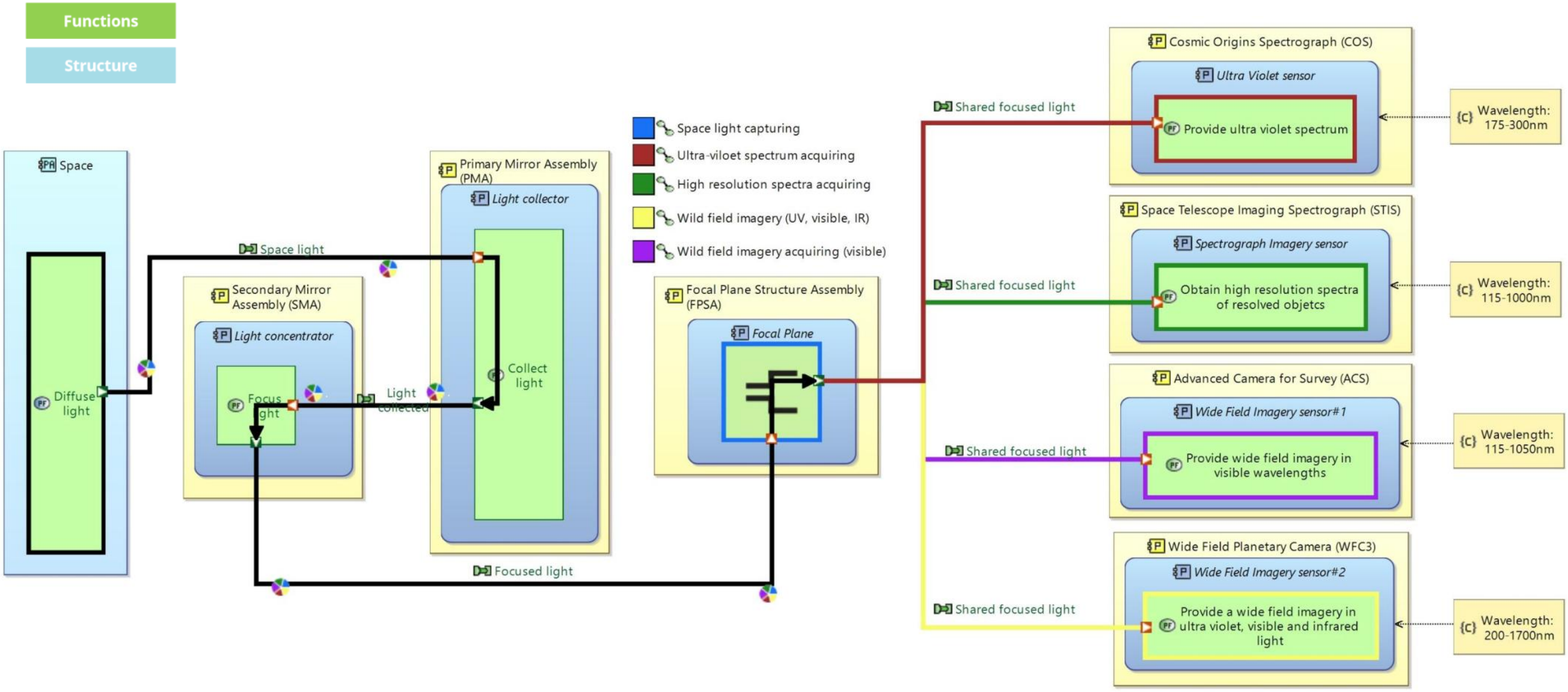
Physical Architecture



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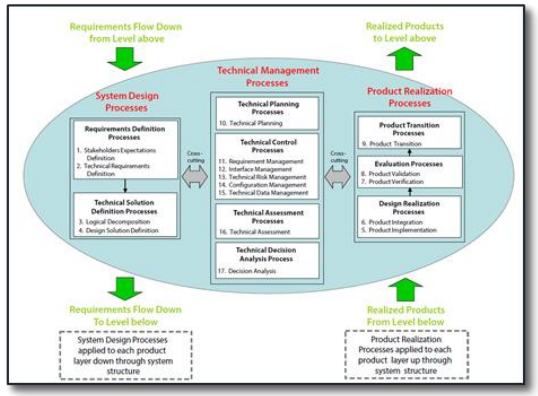
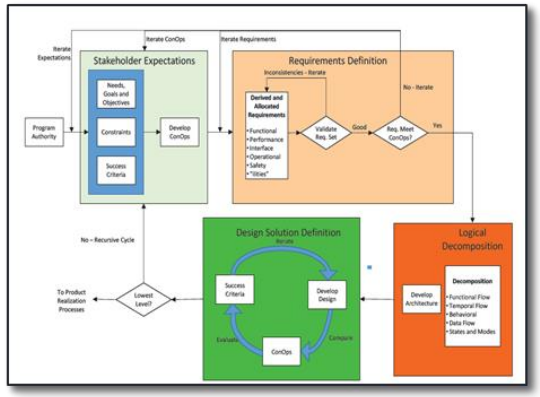
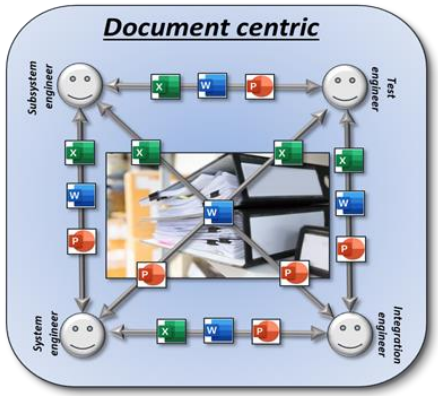
HIGHLIGHTS

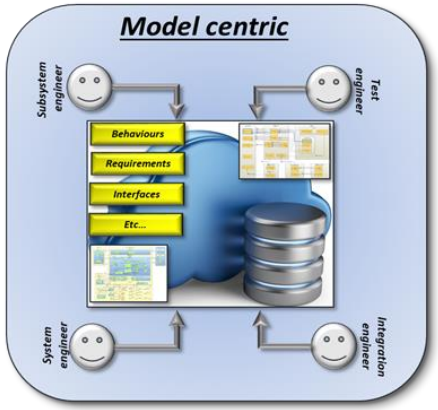
NASA Handbook
Systems Engineering



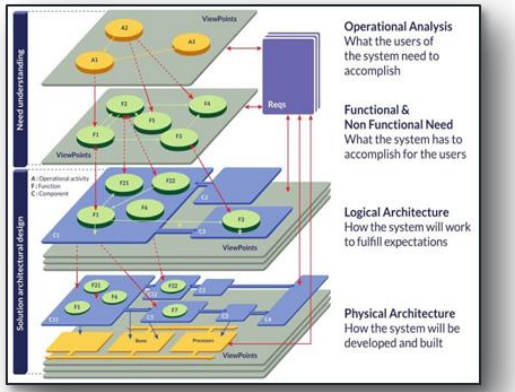


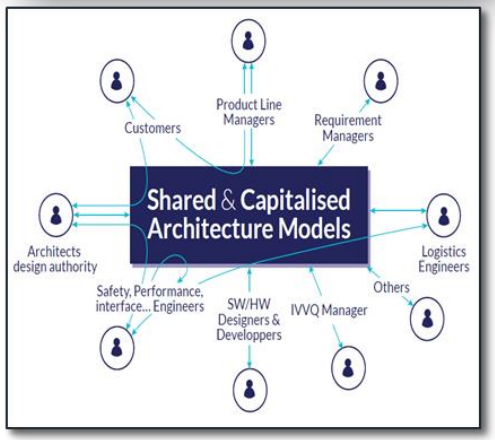
MBSE introduction
Mode-Based Systems Engineering



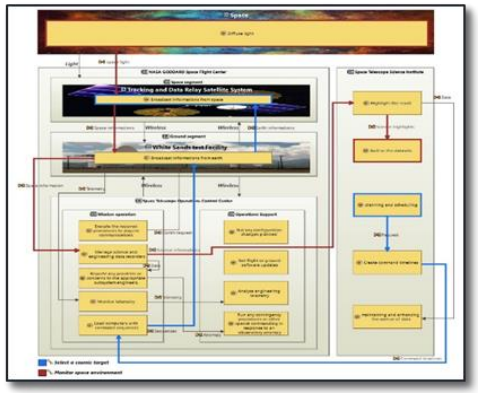


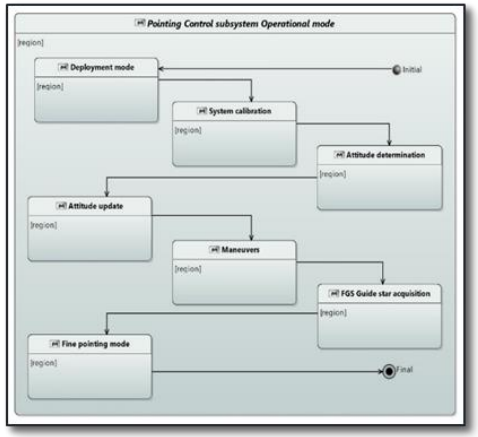
CAPELLA/ARCADIA
MBSE solution





HST
Application





Thank you