Digital Engineering Workflow Development Exercise

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Abstract

A Digital Engineering (DE) workflow was proposed to support pre-acquisition processes and partially modeled within a model-based system engineering (MBSE) tool. Performed in December 2020, this exercise used a weather monitoring example to integrate SE and DE perspectives to refine how DE frameworks can support SE needs. In the SE perspective the workflow takes strategic inputs and elaborates requirements, concept of operations, and performance analysis. When modeled in the DE perspective, those same inputs and elaborations are decomposed into information components. The DE workflow thus becomes a methodology on how information at different stages of abstraction can be decomposed into and composed from the same core elements. This presentation will provide an introduction of the six steps within the DE workflow and how the inputs are used to evaluate multiple solution architectures to select a preferred alternative.

Agenda

Digital Engineering Workflow Development Exercise

- Introduction and Definitions
- The DE Workflow: its inputs and outputs
- Workflow steps applied to a prior Weather Monitoring example
- Observations

Introduction

What does a digitally enabled pre-acquisition process look like?

- A Digital Engineering (DE) workflow was devised to support pre-acquisition SE processes and partially modeled within a model-based systems engineering (MBSE) tool.
  - *Performed in December 2020, this exercise used a Weather Monitoring (WM) example to integrate SE and DE perspectives to refine how DE frameworks can support SE needs.*
- The workflow takes strategic inputs and elaborates requirements, concept of operations, and performance analysis.
  - *When modeled, those same inputs and elaborations are decomposed into core information elements.*
  - *The DE workflow thus becomes a methodology on how information at different stages of abstraction can be decomposed into and elaborated through the core information elements.*
- This presentation will provide an introduction to the six steps within the DE workflow and how the inputs are used to devise and evaluate multiple solution architectures to select a preferred alternative.

Key Terms and Definitions

- A **workflow** is a sequence or pattern of tasks or activities that acts upon or uses work products, typically flowing from one organization or person to another.

- **Digital workflow** means the activity performers are connected digitally.

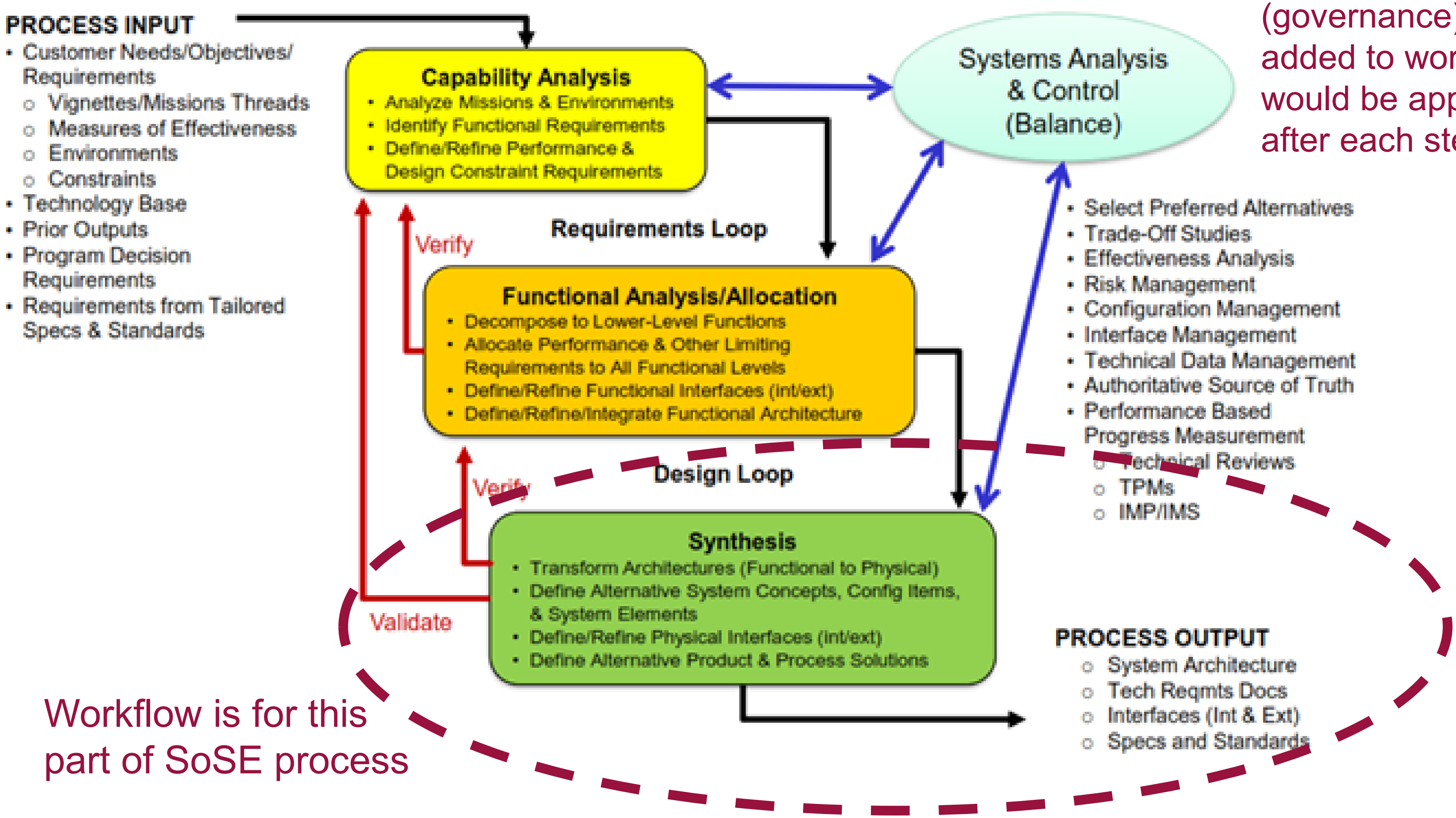
- A **digital engineering ecosystem (DEE)** encompasses the models and data of interest as they interact within a DE Infrastructure (computer hardware, software, servers, storage, networks, encryption, authentication, and other Information Technology elements) and in DE Environments (user-facing application software, visualizations, collaboration systems, and other Information Technology elements).

- **Digital engineering (DE) workflow** implies the digital workflow is performed within a DEE. Digital Engineering is not meant to replace engineering or Systems Engineering (SE), but augments and evolves how they can be performed in a DE ecosystem reflecting an increasingly digital and data-driven world.

Systems of Systems Engineering (SoSE) Process Stages

Pre-Acquisition

Note: Control processes (governance) not added to workflow, but would be appropriate after each step



Workflow is for this part of SoSE process

Output: Technical Requirements for (each) System

Underlying diagram from SMC SYSTEMS ENGINEERING PRIMER AND HANDBOOK, 2005
http://everyspec.com/USAF/USAF-SMC/SMC_SYS_ENG_HDBK_ED-3_14210/

Assumptions & Caveats

- This exercise was performed exclusively in an MBSE tool
- Analysis was not performed to conduct system trades
  - *Analysis was performed in a prior study that integrated analysis tools; this exercise made use of those analyses*
- Example functional and performance requirements not shown in this presentation

SoS Synthesis Workflow Overview

Processes Steps Support Functional-to-Solution Elaboration

Inputs

Use Case
↕
CONOPS
↕
Mission Thread
↕
Portfolio SoS Functional Architecture
↕
SoS Reqmts, CDD Capability Reqmts

Six Process Steps

1) Define Analysis Framework and identify Analysis Methods, Tools, and Scenarios
2) Define Alternate Physical Solution Architectures
3) Analyze CONOPS and Mission Threads to determine Functions and allocate them to Elements of Alternate Architecture
4) Allocate Performance Budget to each element of each Solution Architecture
5) Perform Cost Analysis and Select Preferred Physical Solution Architecture
6) Complete Functional and Performance allocation to Elements of Preferred Architecture

Outputs

Physical Architecture of Programs
↕
System Requirements:

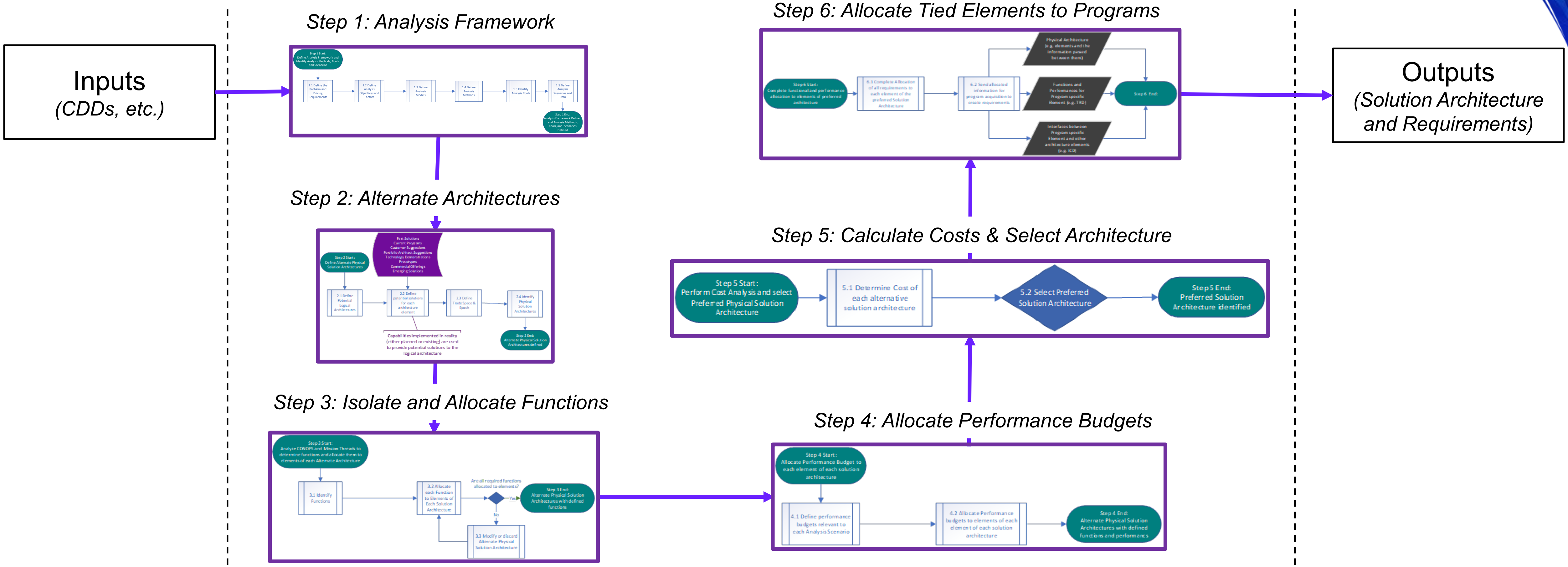
Allocate Functions & Interfaces

Allocated Performance to Programs

The process will generate interface specifications, standards, and requirements per program within a portfolio.

SoS Synthesis DE Workflow Diagrams Overview

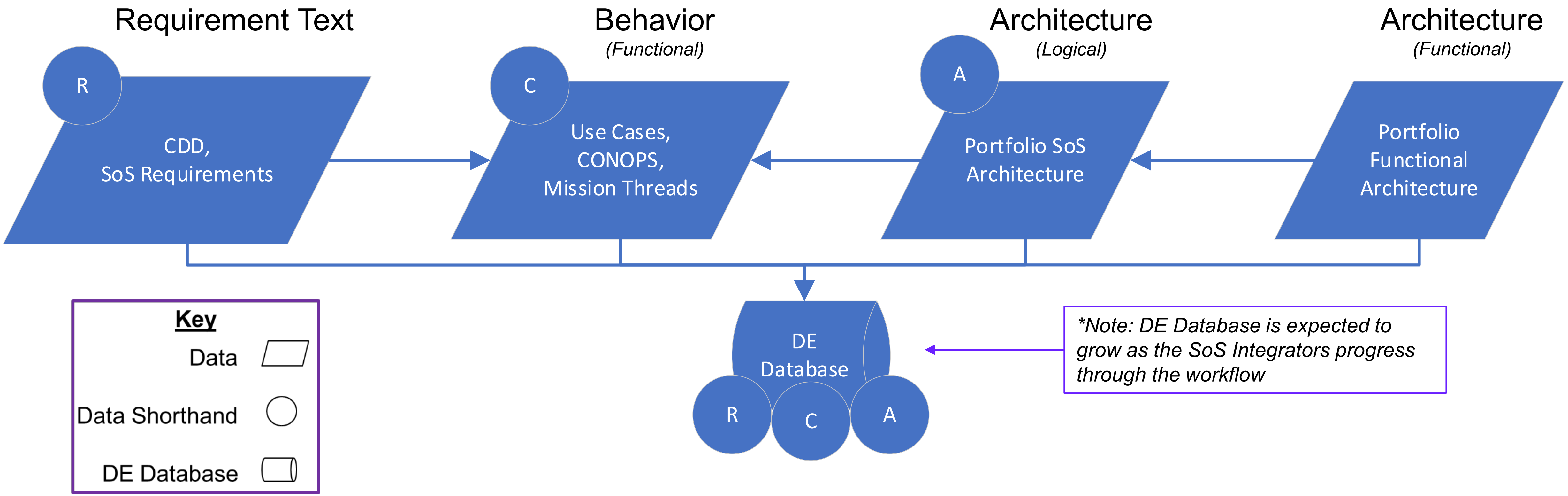
A sequence of 6 steps to move from logical architecture to physical architectures



DE Workflow defines a formal sequence of activities (functions, processes, etc.) and Information Elements being consumed or created within a Digital Engineering Ecosystem.

Workflow Inputs from Capability and Functional Analysis Stages

Contained in DE Database



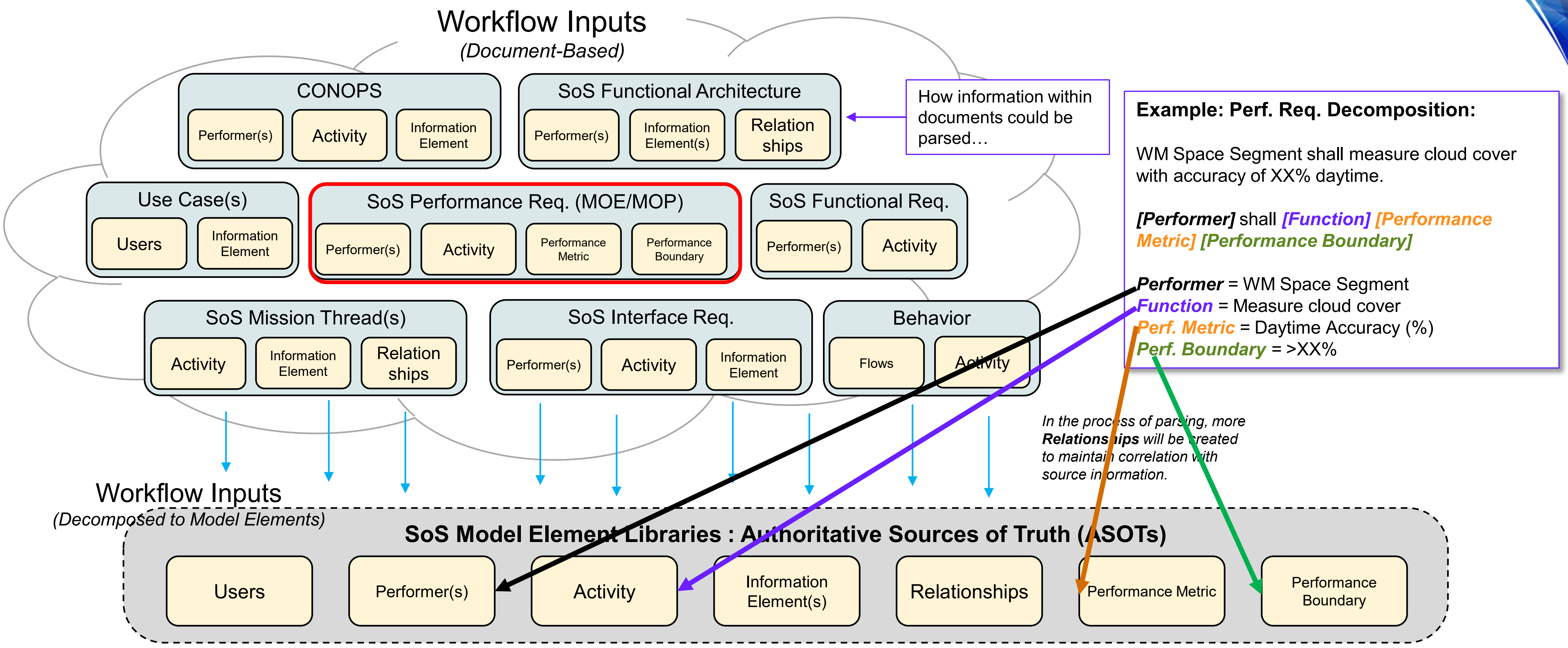
R = Requirements
C = Behavior Context

A = Portfolio SoS Architecture (Logical)

DE Database represents the ASOTs/SoS Data Libraries (e.g. Performers, Activities, etc.)

Workflow Inputs: Digital Engineering ASOT Data Libraries

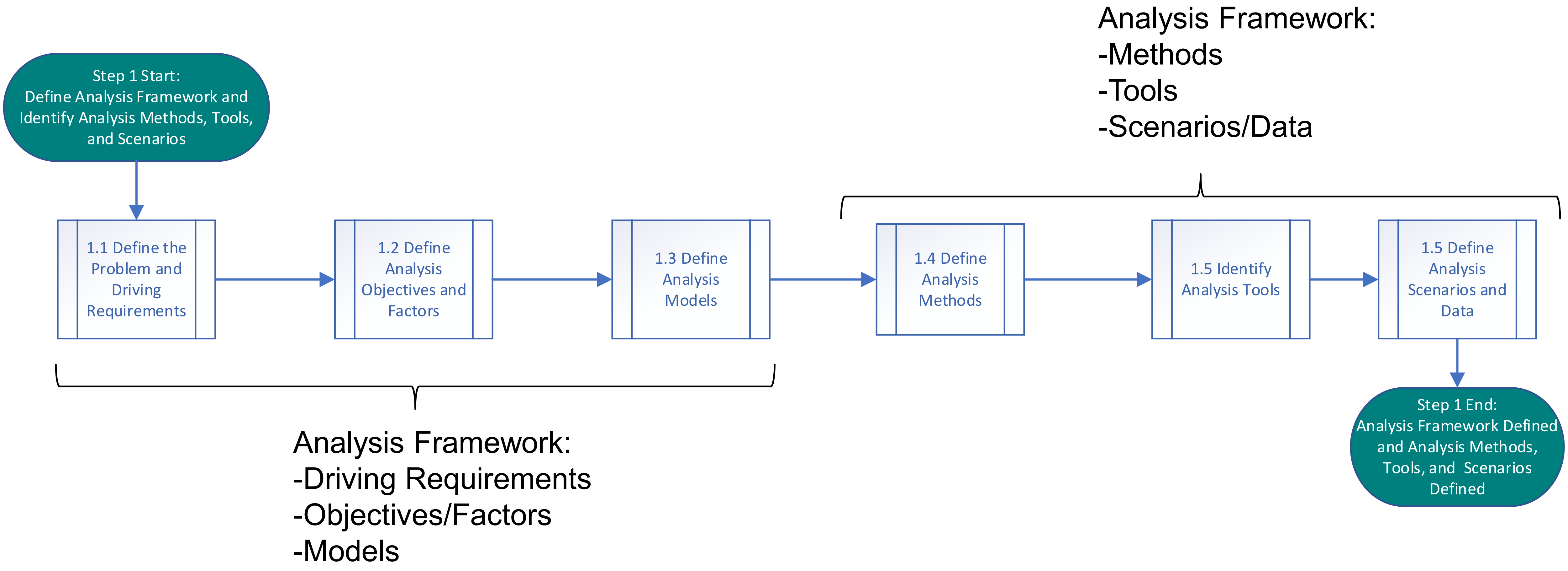
Step 0: Parse all aggregate information into unit pieces (i.e., Document-to-Data transformation)



This exercise of parsing into data types will ensure consistent data usage across the DE workflow.

Workflow Step 1: Define Analysis Framework

Sub-Steps



Know WHY organization is modeling

Analysis Framework for Weather Monitoring (WM) Example

Part 1 of 2

- **Define the problem and driving requirements:**
  - *The problem is to develop a weather monitoring space and ground architecture that utilizes a common bus, ground, and mission data transport services and meets the allocated functional and performance requirements*
  - *Driving requirements are 1) the revisit rate for global collection, and 2) data latency for Centrals to receive collected raw weather data*
  - *Define analysis objectives and factors:*
    - The analysis objectives are to determine the best value architecture in terms of performance and cost
    - Analysis factors (decision metrics) are the revisit rate, raw data latency, and cost
- **Define analysis models:**
  - *Analysis models needed are identical to those used in a prior exercise to determine revisit rate and cost*
  - *An additional analysis model is needed to determine raw data latency*
- **Define analysis methods:**
  - *Analysis methods needed are identical to those used by the prior exercise to determine revisit rate and cost*
  - *An additional analysis method is needed to determine raw data latency*
- **Identify analysis tools:**
  - *Analysis tools needed are identical to those used by the prior exercise to determine revisit rate and cost*
  - *An additional analysis tool is needed to determine the raw data latency*

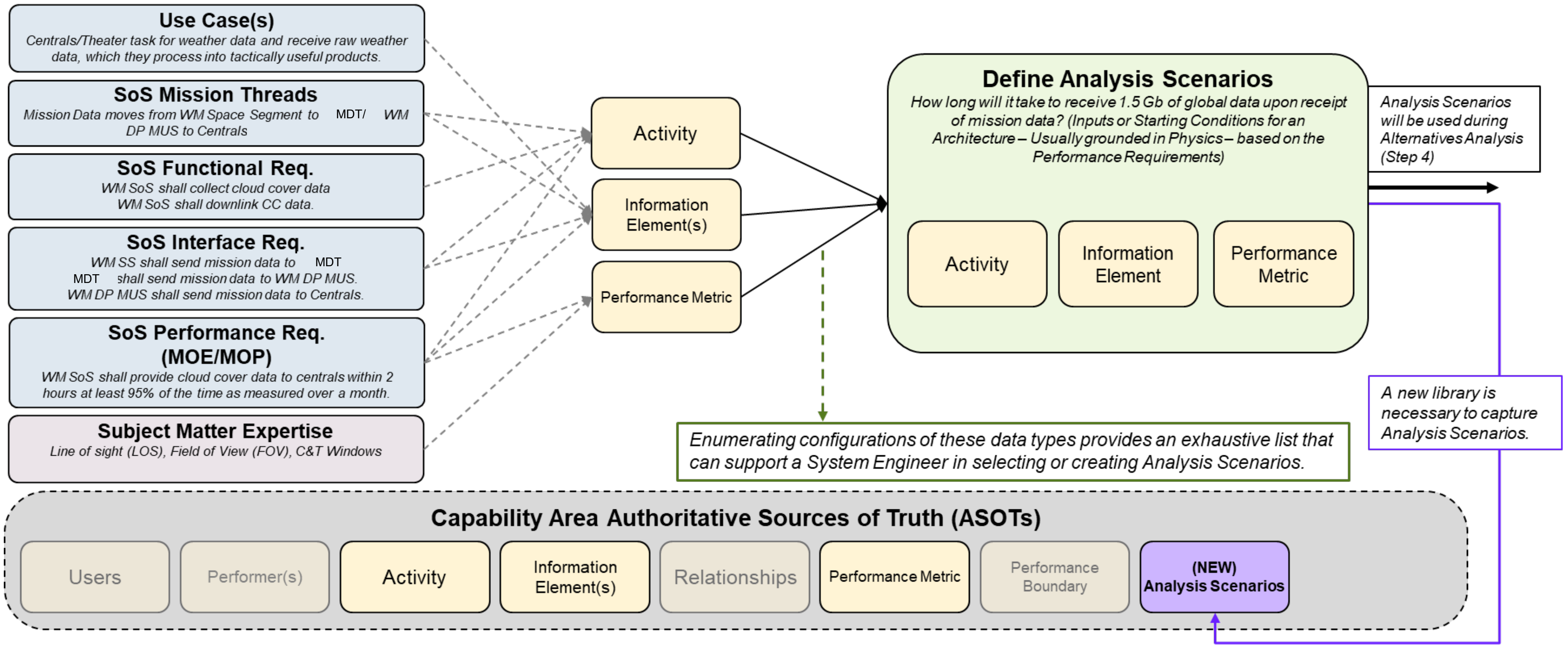
Analysis Framework for Weather Monitoring (WM) Example

Part 2 of 2

- **Define analysis scenarios and data:**
  - *The scenario and data for analyzing the WM mission area to determine revisit rate are identical to those used by the prior exercise.*
  - *The scenario for analyzing the WM SoS architecture to determine raw data latency would include these steps and data parameters:*
    - Select orbit and constellation.
    - Determine Command and Telemetry windows per orbit.
    - Define standing tasking for weather data needs
    - Assumptions on Field Of View of the collection sensor and raw data volumetrics
    - Assumptions on Field Of Regard of sensor
    - Calculate Line Of Sight for sensor over tasked region
    - Determine collection swath each orbit
    - Determine downlink windows for assumed downlink ground stations for each pass/orbit/collection
    - Assume downlink data rate
    - Assume terrestrial communications data rate between ground stations and CONUS
    - Calculate raw data latency

Define an Analysis Framework

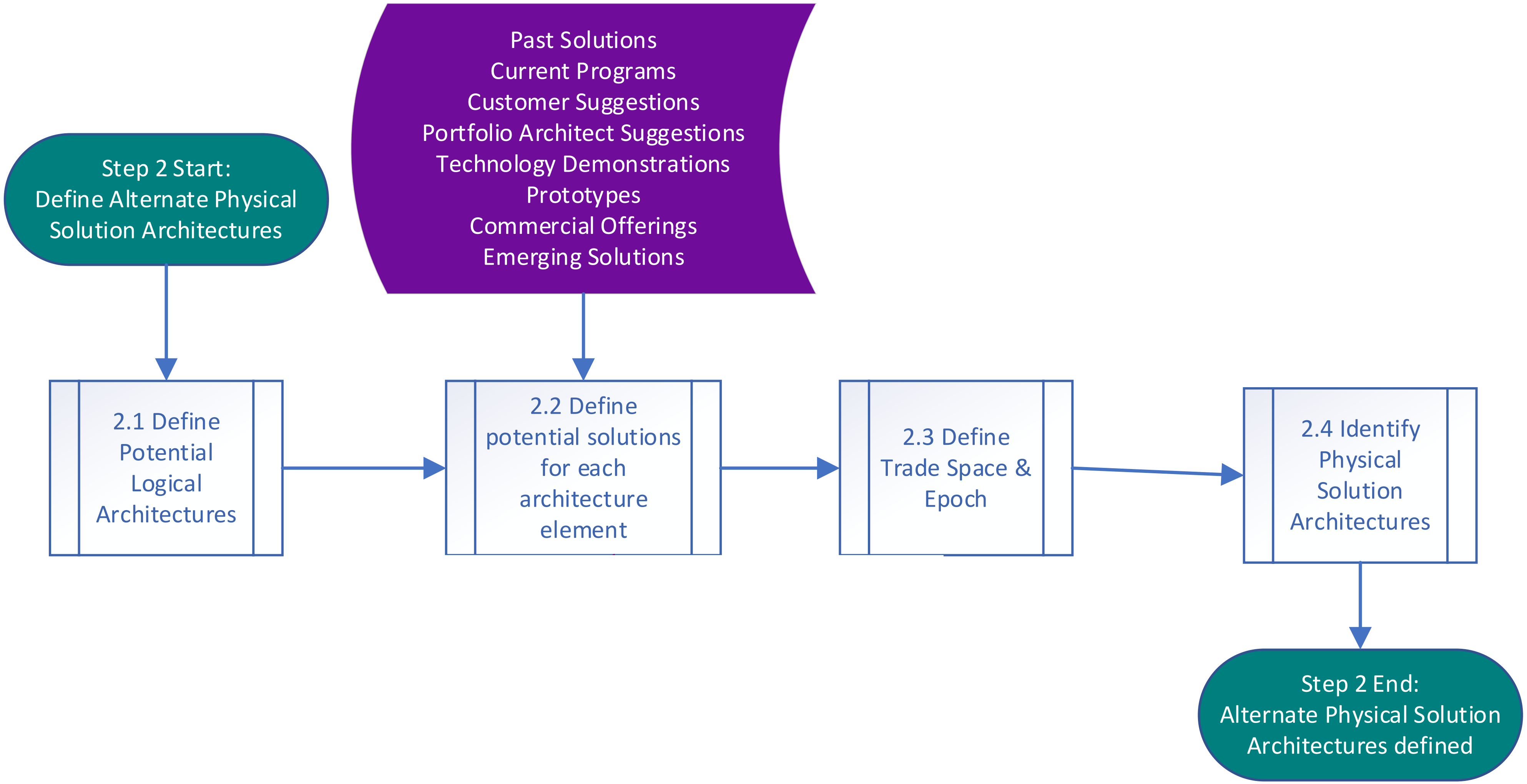
Inputs and Outputs



Example of Analysis Scenarios to assess raw data latency

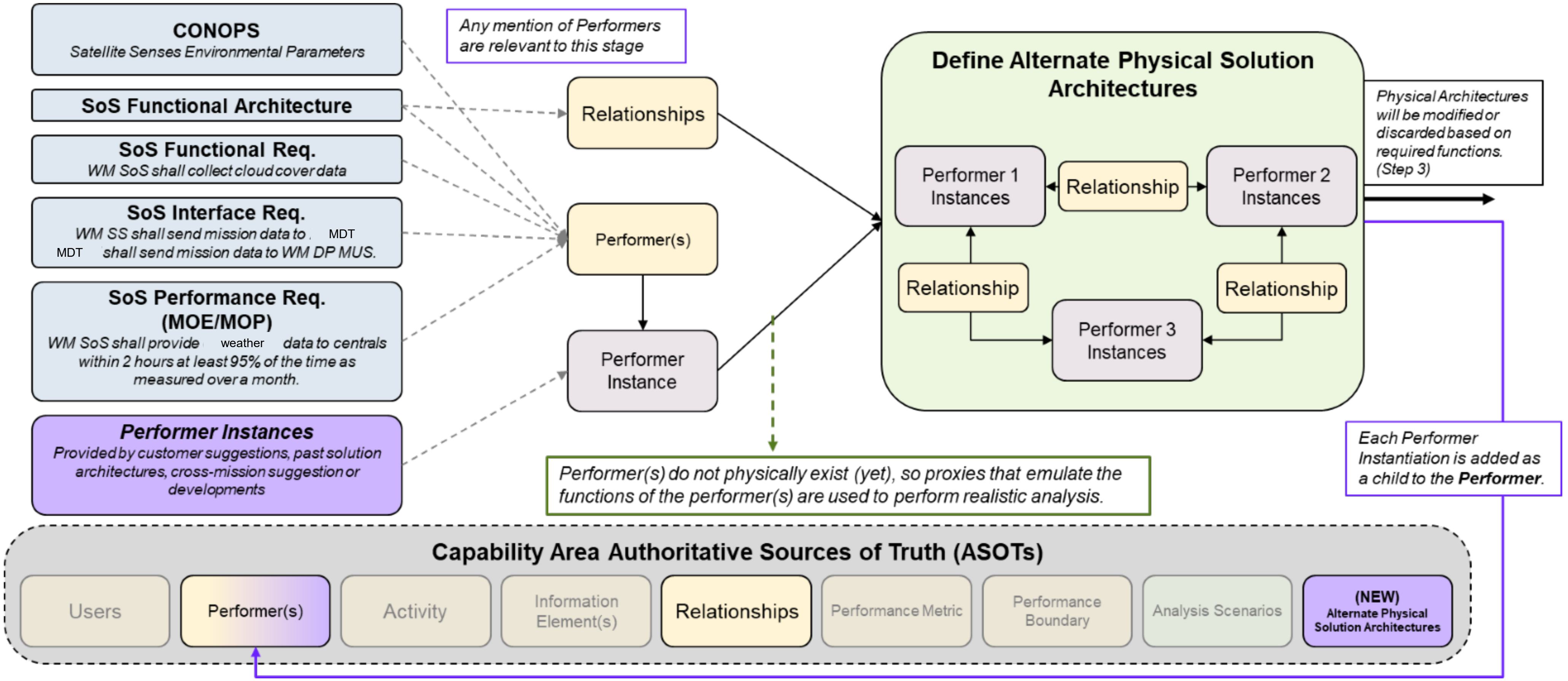
Workflow Step 2 : Define Alternate Physical Solution Architectures

Sub-Steps



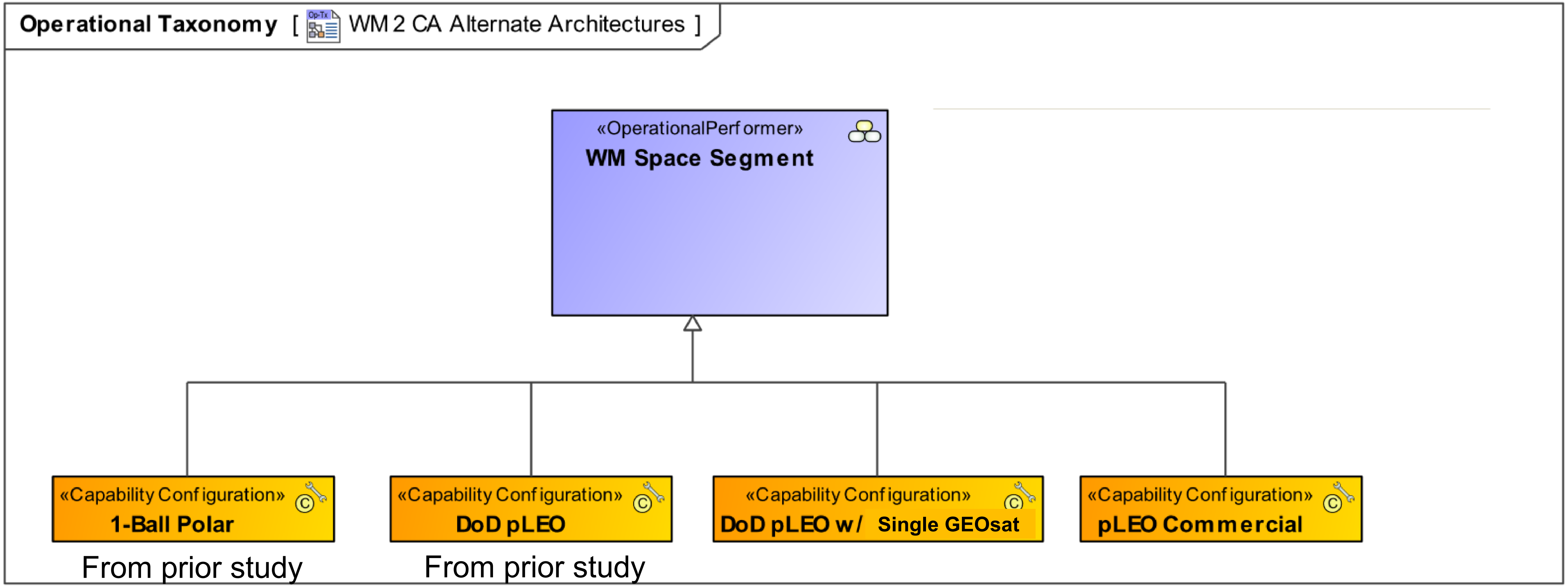
Define Alternate Physical Solution Architectures

Inputs and Outputs



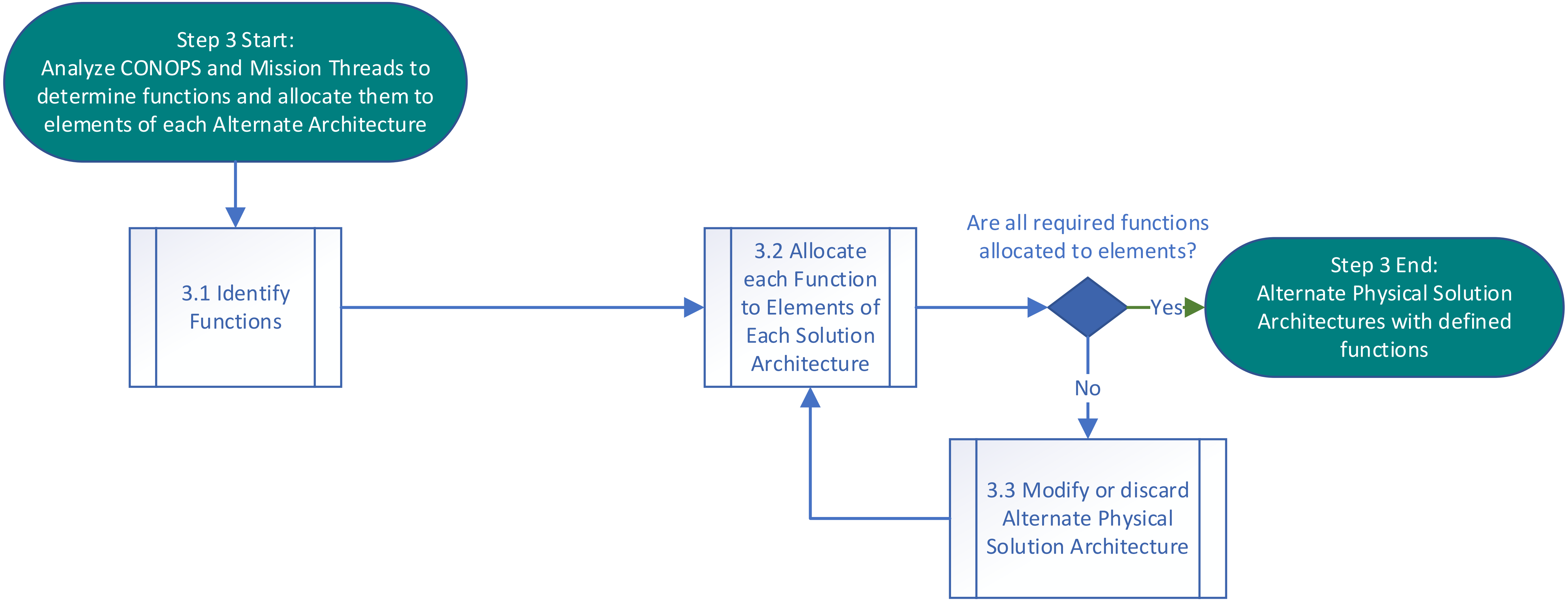
Potential Physical Solution Architectures for the Space Segment

Modeled



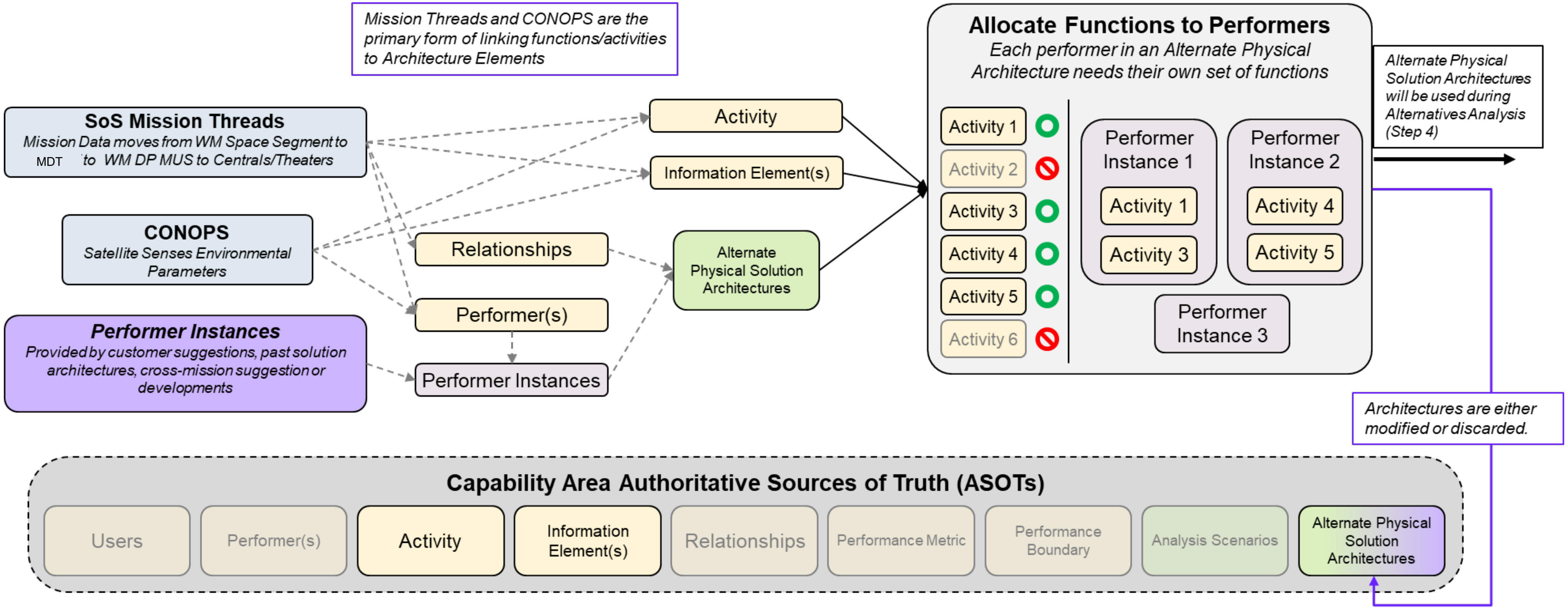
Workflow Step 3: Functions Identified and Allocated to Solutions

Sub-Steps



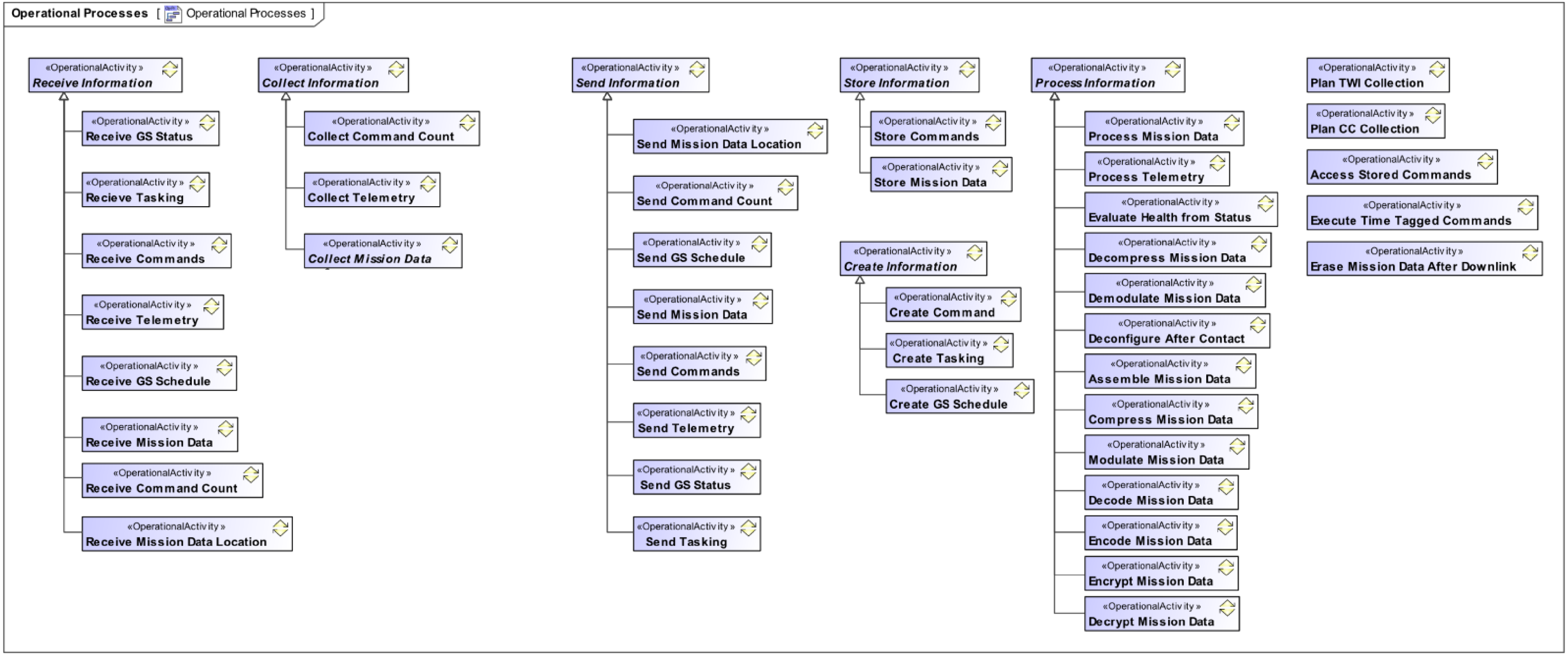
Updating Alternate Physical Solution Architectures with Activities

Updates to Existing Elements

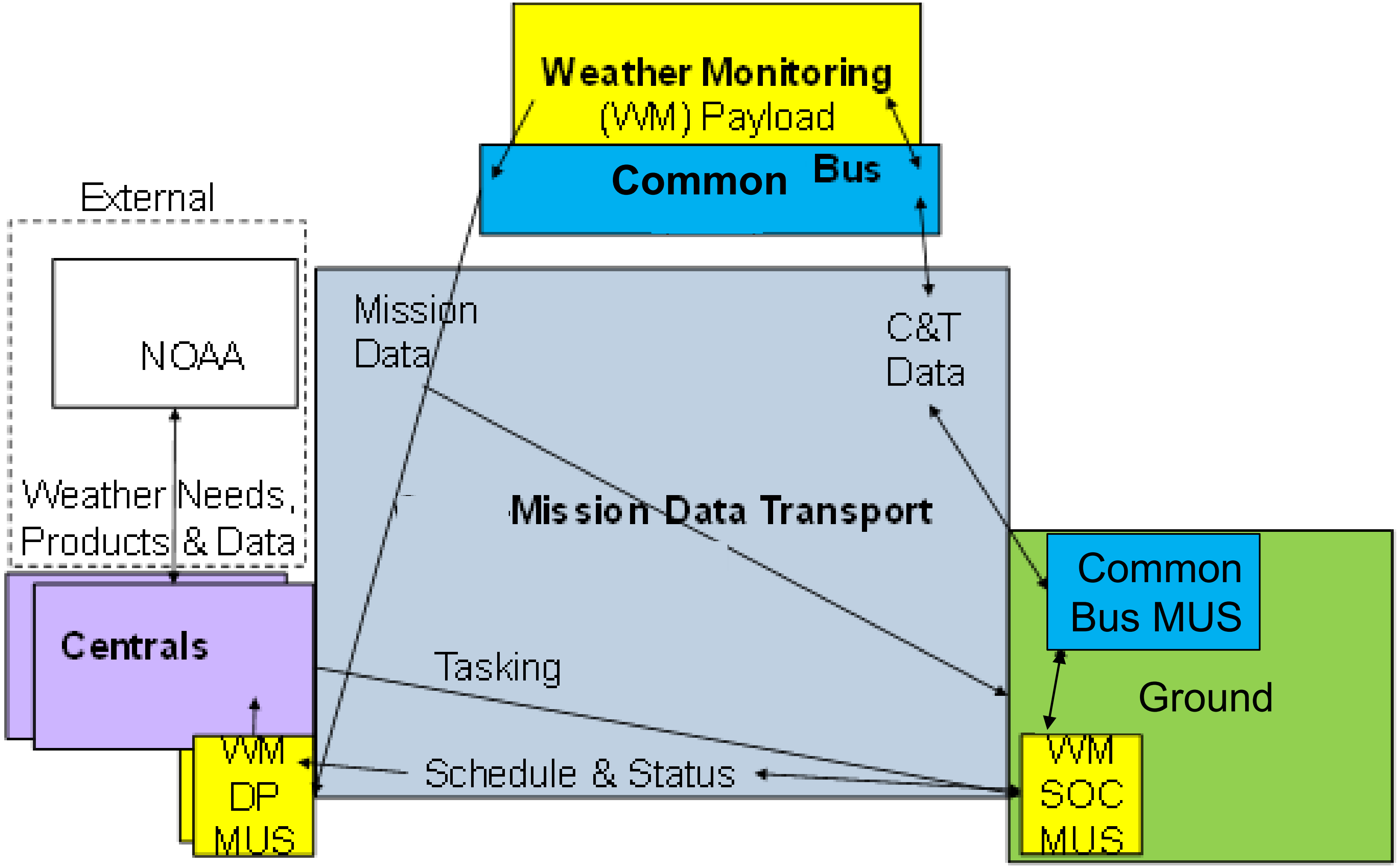


Functions and Activities Identified for Functional Architecture

Modeled

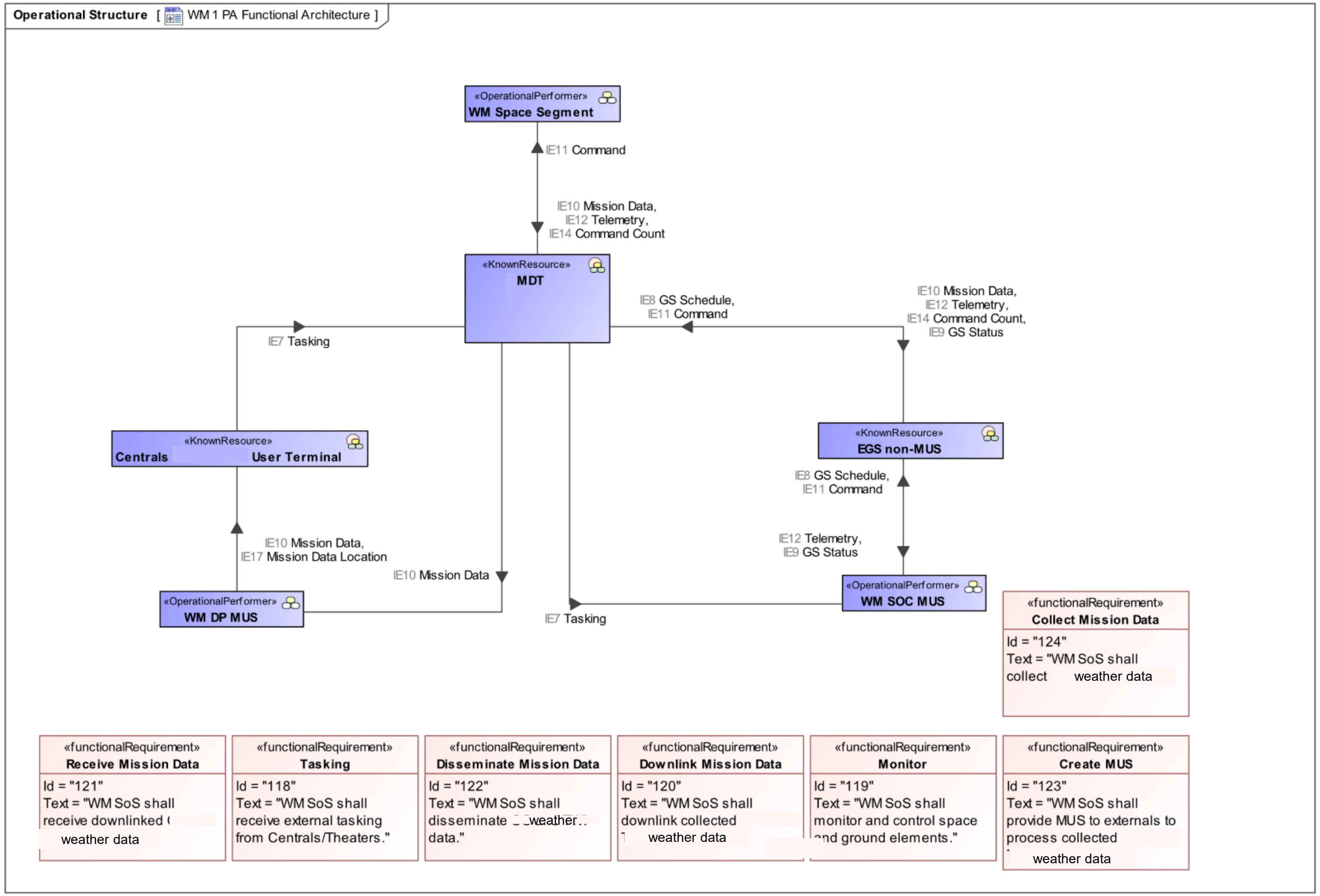


Assumed SoS operational architecture showing information flows

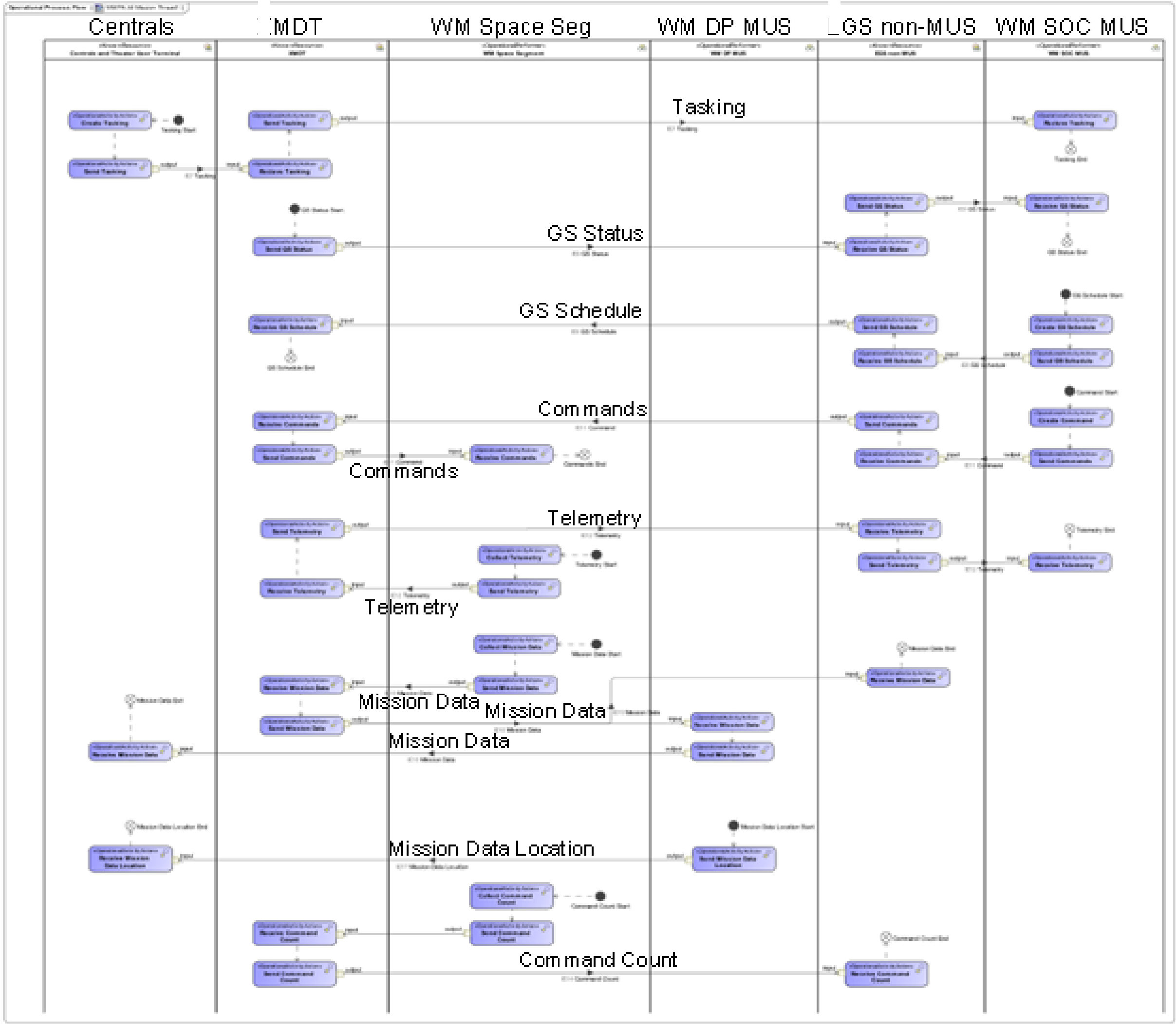


Operational connectivity for Weather Monitoring System of Systems

Showing functional requirements assigned to SoS

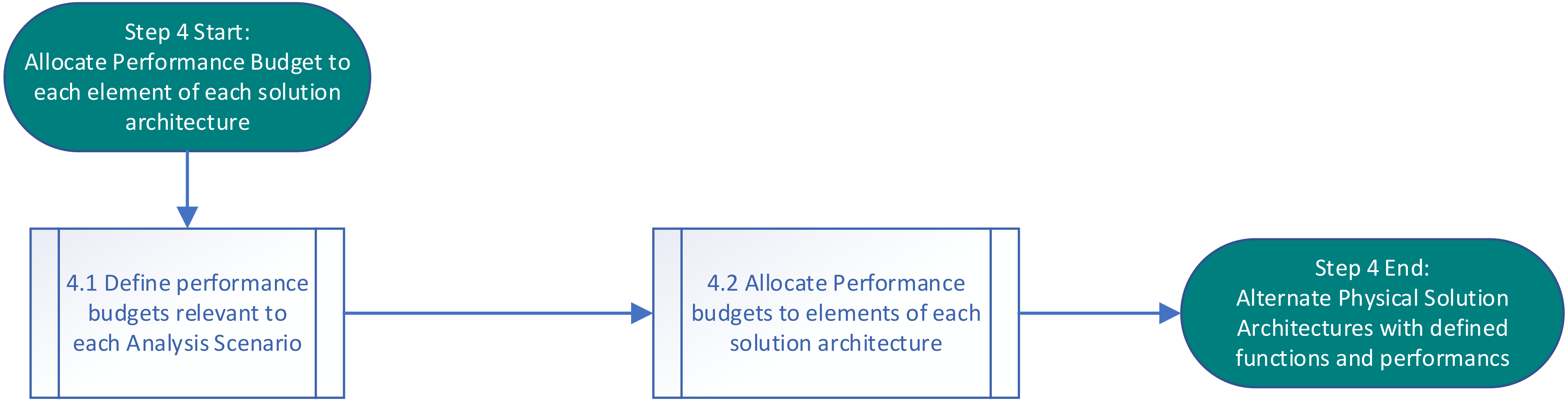


Functions Assigned to Physical Elements with Interface Data Noted



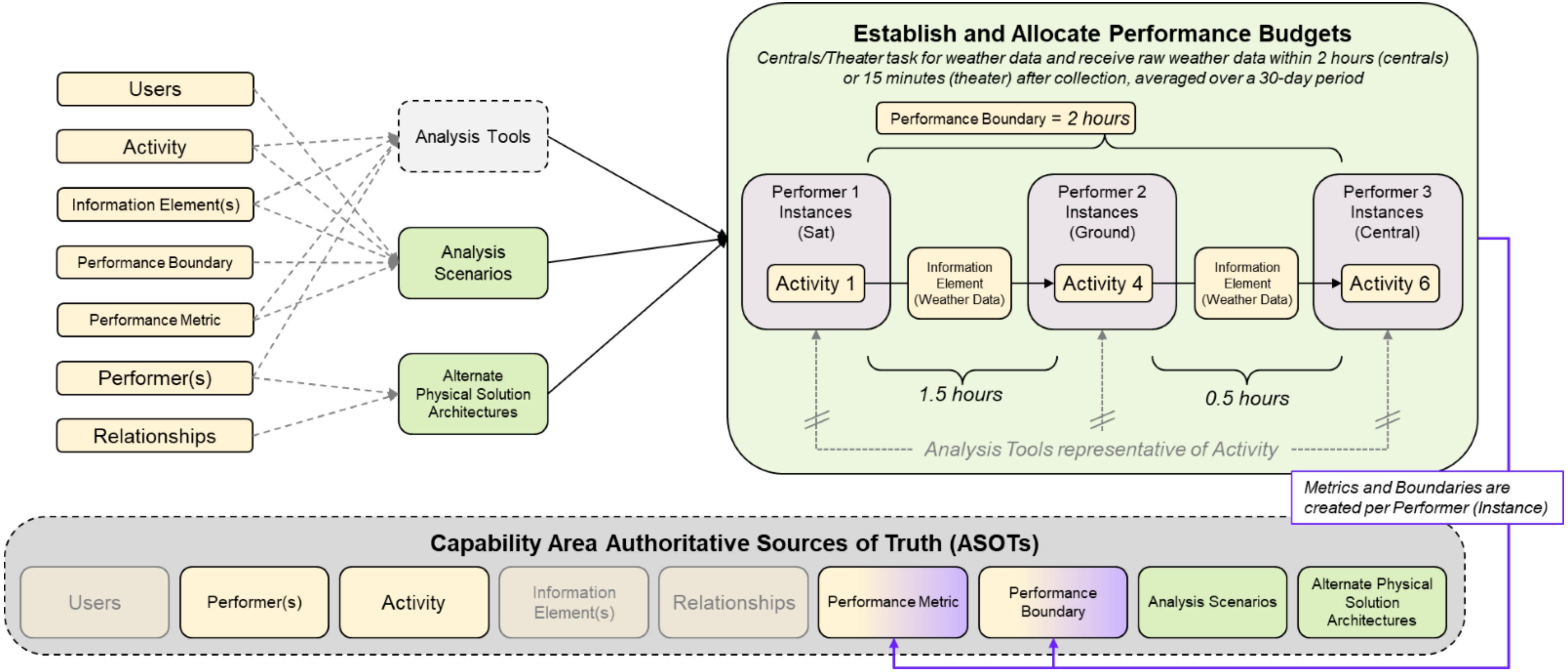
Workflow Step 4: Define and Allocate Performance Budgets

Sub-Steps: Not accomplished in this limited exercise



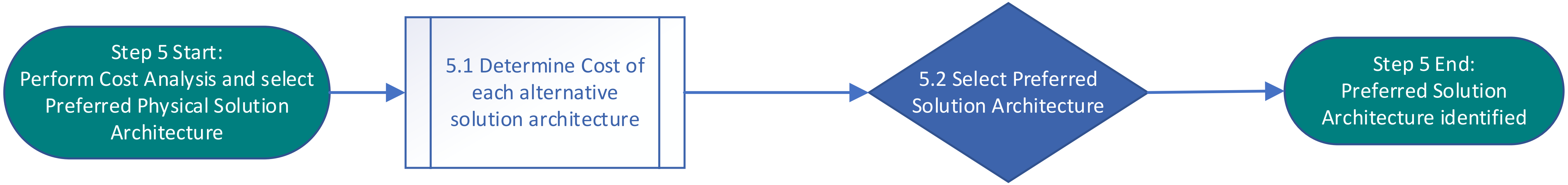
Defining and Allocating Performance Budgets

Inputs and Outputs



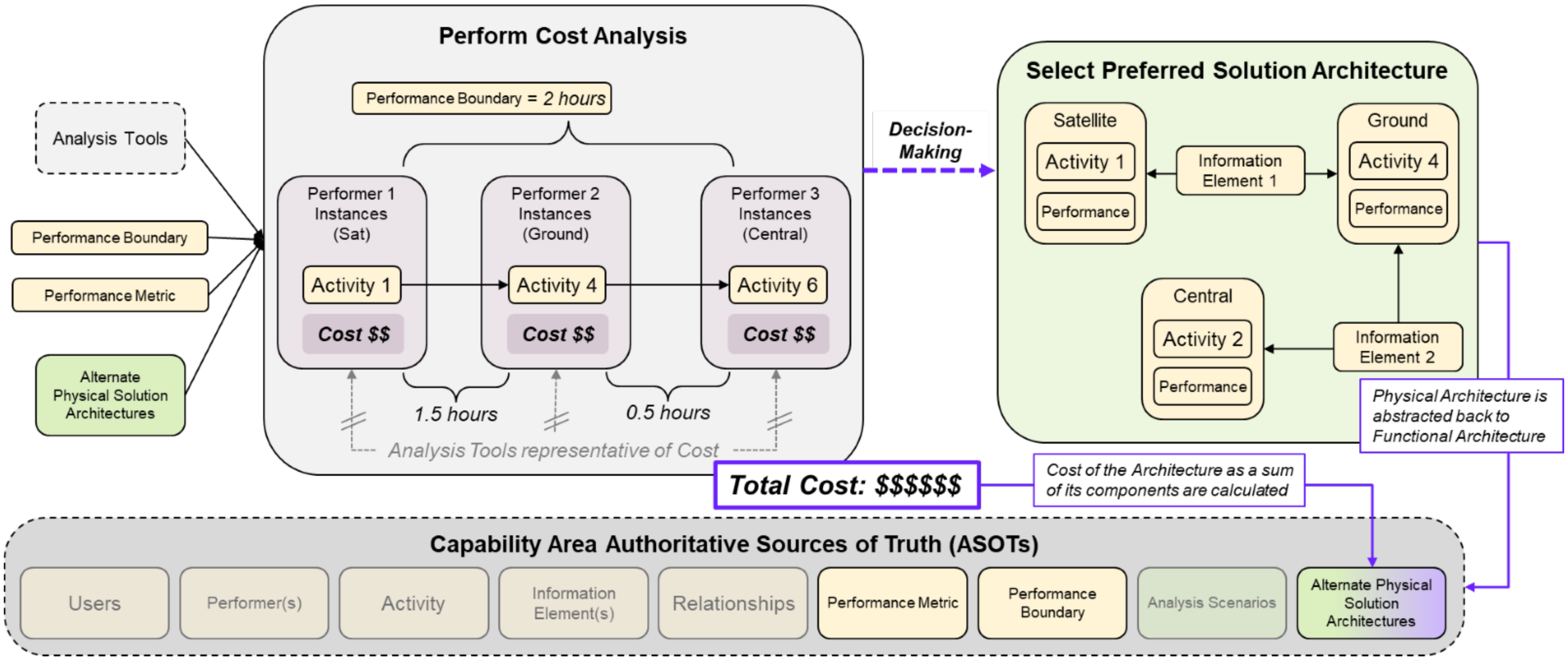
Workflow Step 5: Cost Analysis and Preferred Solution

Sub-Steps: Not accomplished in this limited exercise



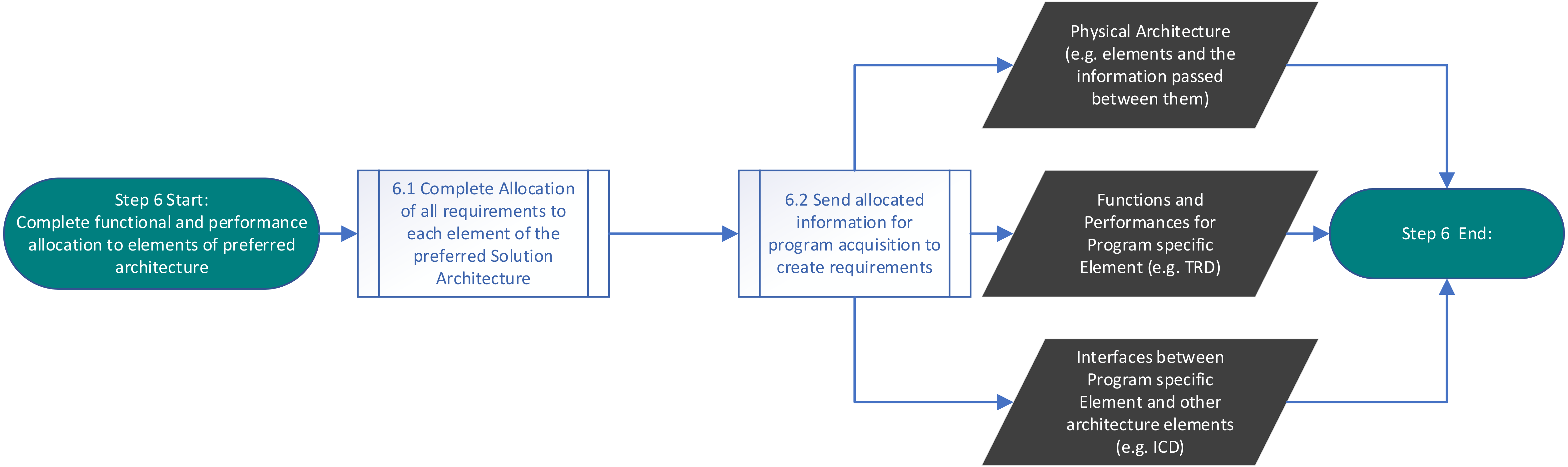
Cost Analysis and Architecture Selection

Inputs and Outputs



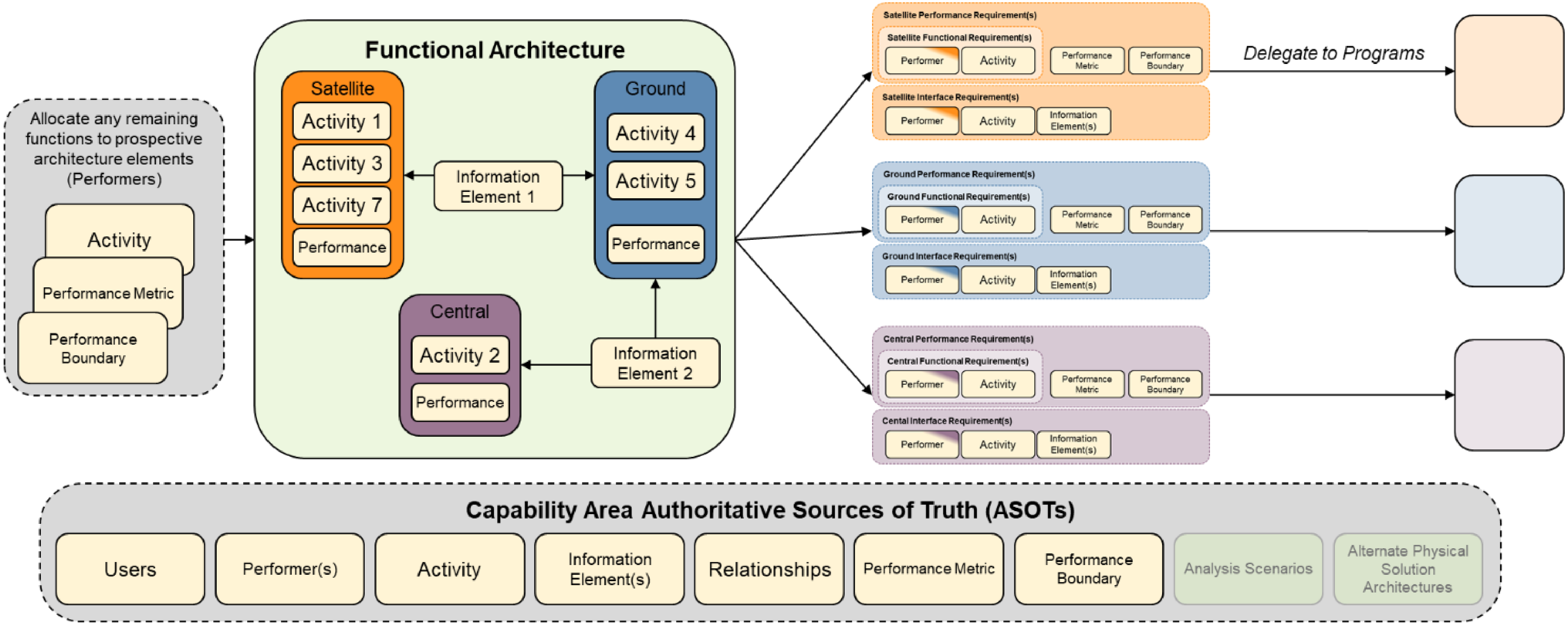
Workflow Step 6: Complete Functional & Performance Allocations

Sub-Steps: Not accomplished in this limited exercise



Program Requirements Allocation

Inputs and Outputs



Exercise Modeling Observations

- As requirements were decomposed and their constituent parts allocated into model element libraries, many products, artifacts, and descriptions consistently reused the same model element types
  - *Common model types devised for common elements*
- As requirements progressed through the workflow steps and as the decompositions became more complex, changes were consistently being made to the product data (requirements, specifications, or diagrams) as each step was iterated, and not as frequently for the common model elements
  - *Governance (review and approval of the product data at each step) has the potential to be complex*

Backup Charts

Definitions of terms

Additional Terms and Definitions

- The **Digital Engineering Environment** encompasses the user-facing application software, visualizations, collaboration systems, and other Information Technology elements with which users interact in order to implement Digital Engineering. Broadly understood as the user-facing elements (tools, GUIs, etc.).

- The **Digital Engineering Infrastructure** encompasses the computer hardware, software, servers, storage, networks, encryption, authentication, and other Information Technology elements that are required to implement Digital Engineering but are not user-facing. Broadly understood as the non-user facing elements (servers, hardware, etc.).

- The **Digital Data, Models, and Analyses** encompasses the information necessary to perform or repeat analyses. Not limited to engineering, but can broadly understood as models, data of interest, processes, workflows, standards, or guides.