Recent Experience with Applied MBSE

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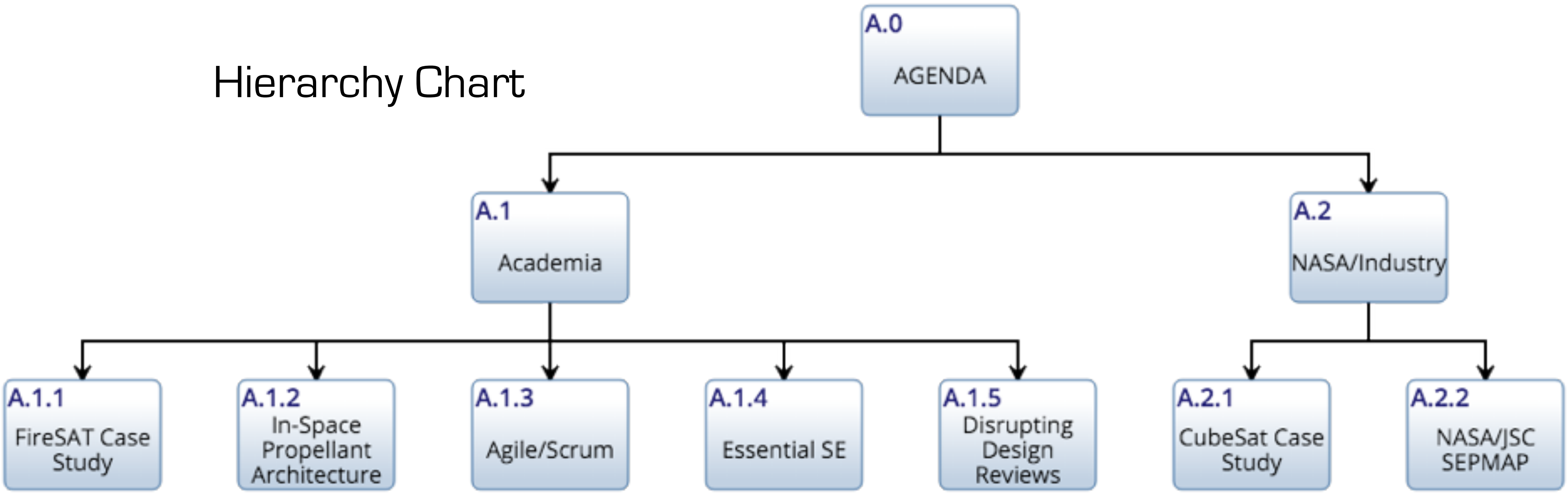
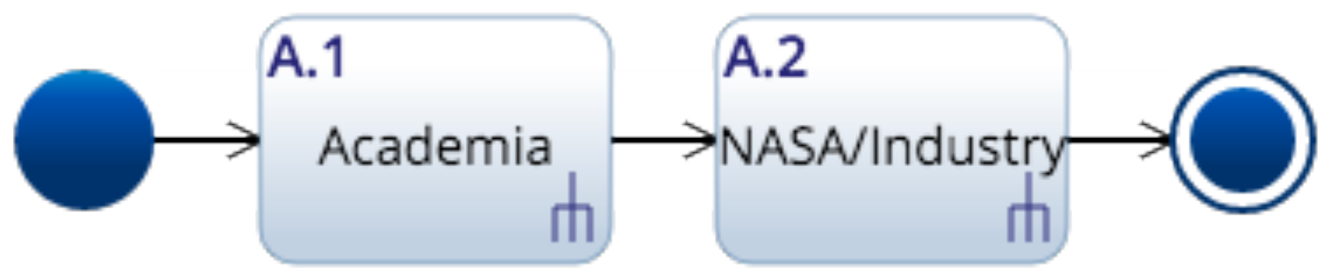
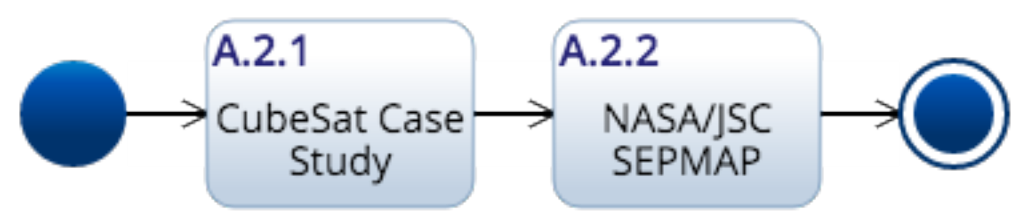
Presentation Model

Hierarchy Chart



Activity Diagrams





All models built using

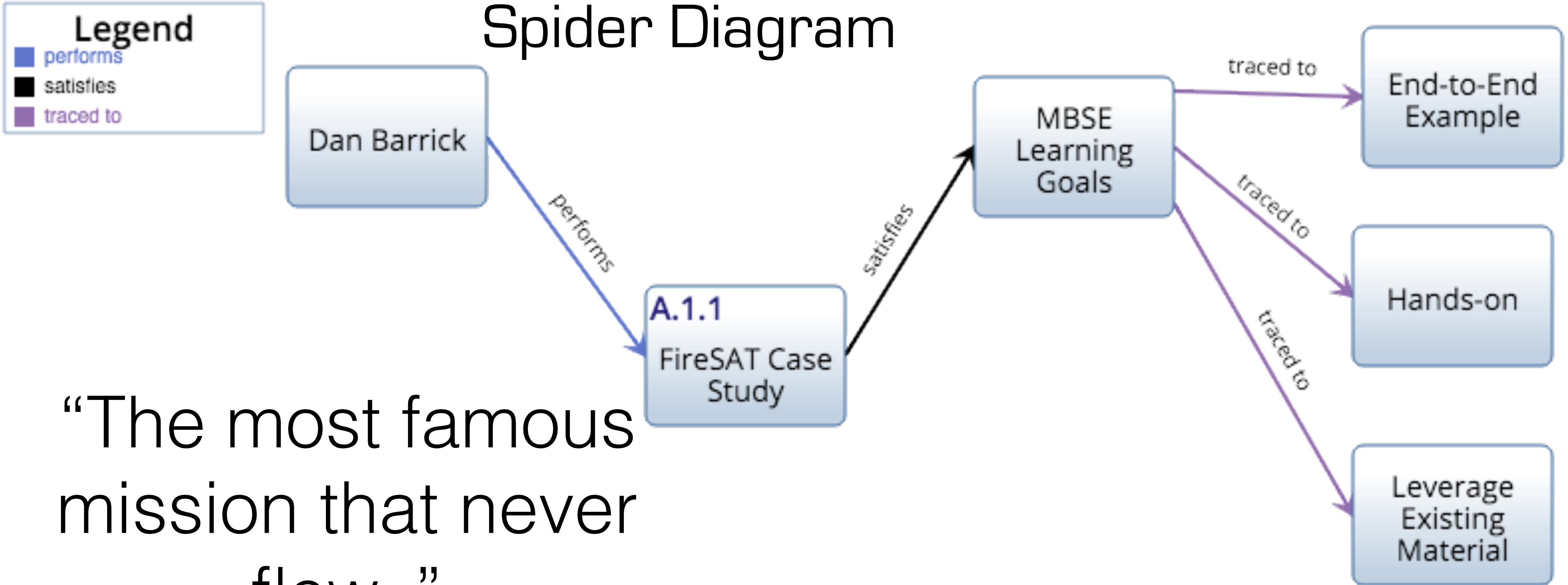
Innoslate

Master of Engineering - Space Systems Engineering

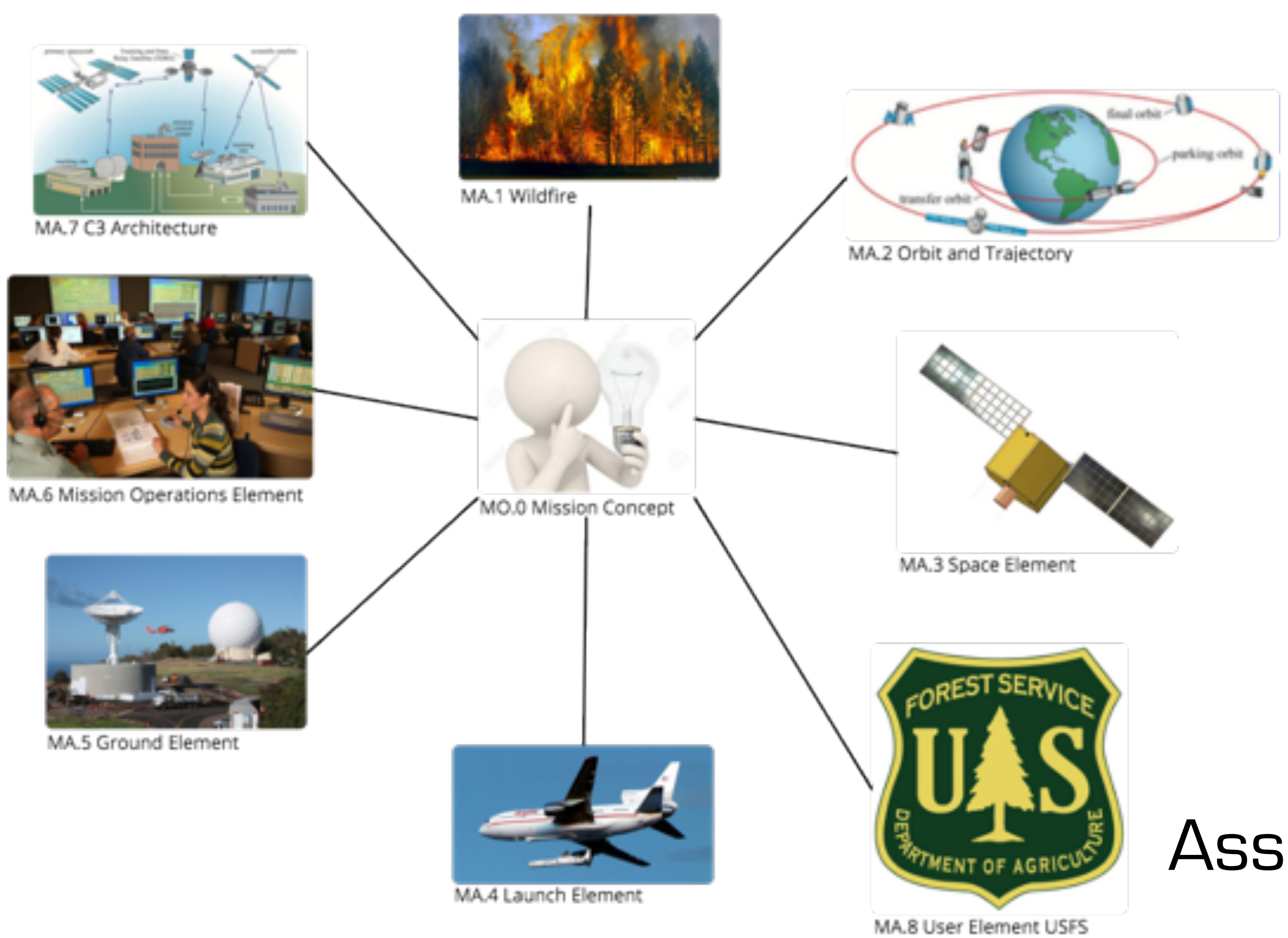
- Stevens Institute of Technology (SIT) is a private, coeducational research university located in Hoboken, New Jersey, United States.
- It is one of the oldest technological universities in the United States, and was the first college in America solely dedicated to mechanical engineering.
- Founded from an 1868 bequest from Inventor and Innovator Edwin Augustus Stevens
- Enrollment at Stevens includes more than 5,000 undergraduate and graduate students representing 47 states and 60 countries throughout Asia, Europe and Latin America.
- The university is home to three national Centers of Excellence as designated by the U.S. Departments of Defense and Homeland Security including the Systems Engineering Research Center, a DoD UARC.

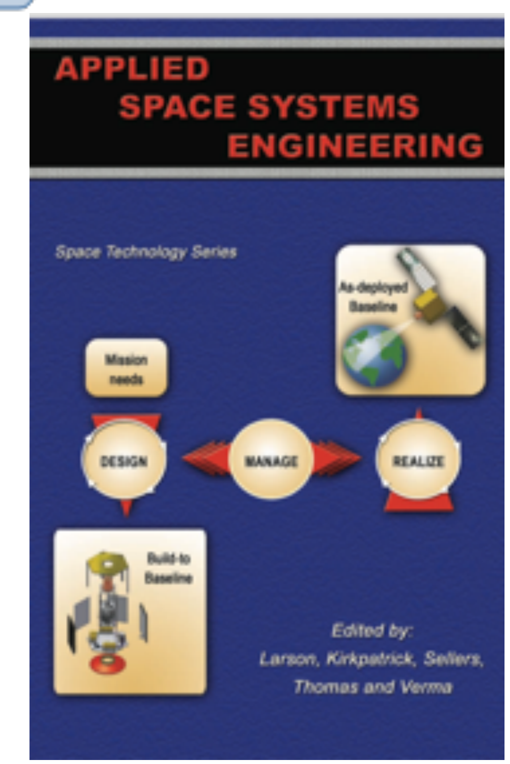
- As part of their Masters program, students have to do a 1-semester independent research project - SYS800, research summarized here was done with these students

Spider Diagram



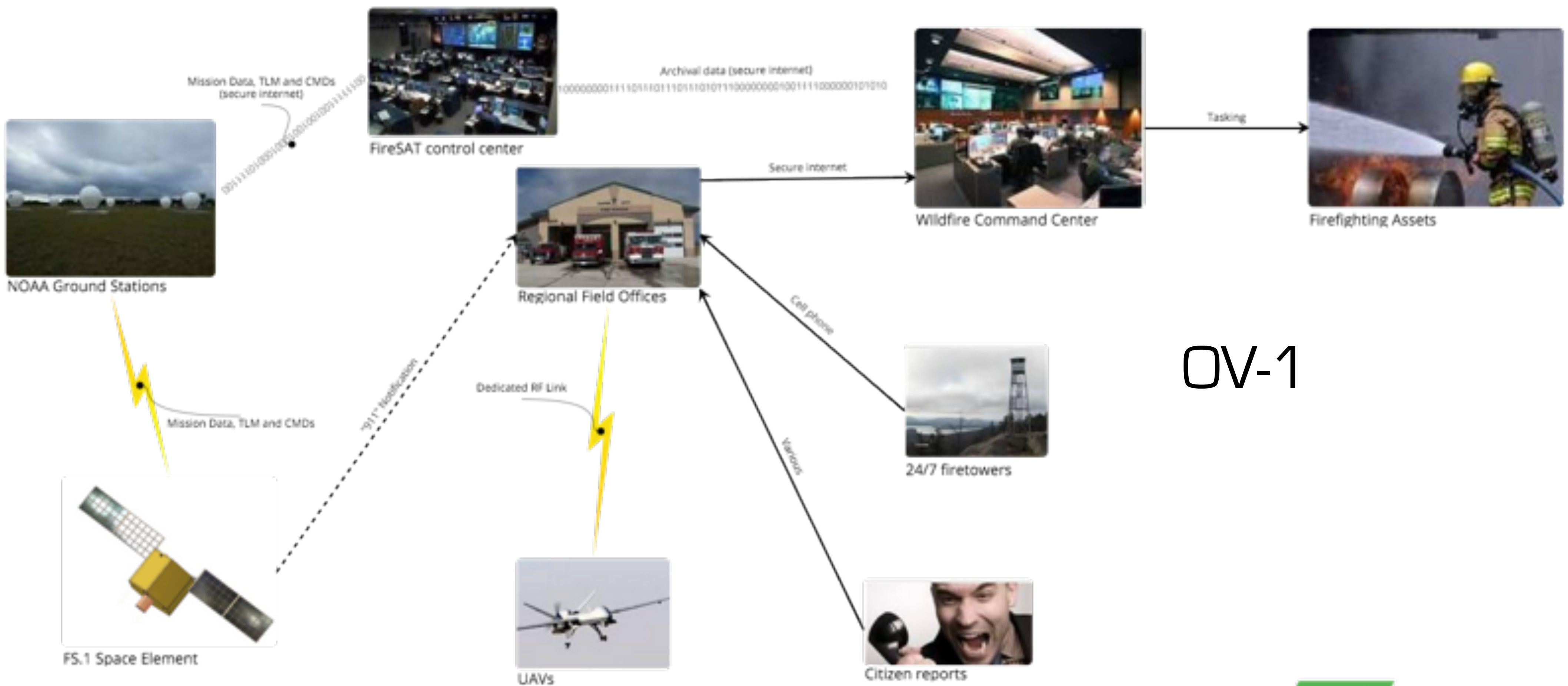
"The most famous mission that never flew.."





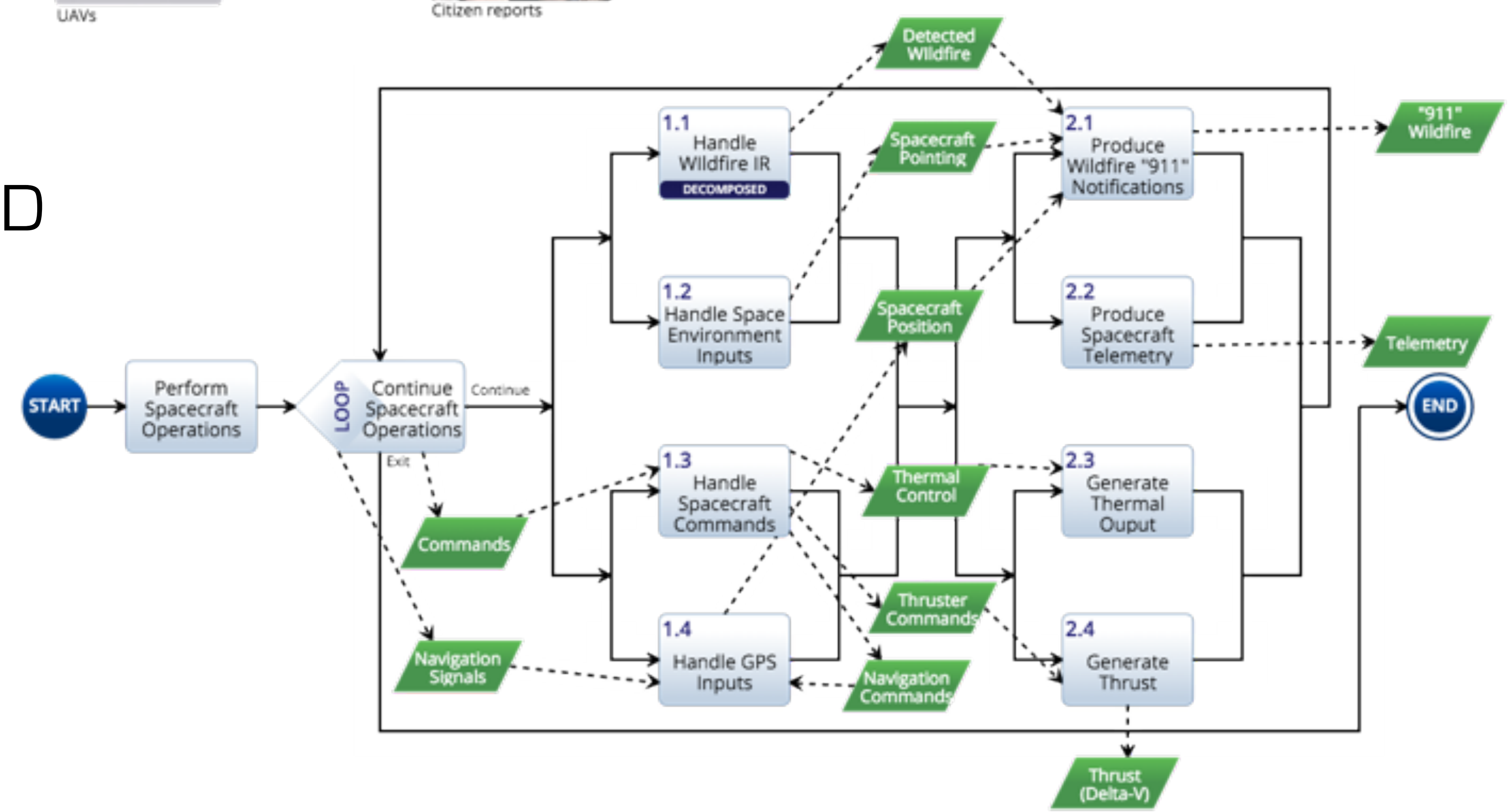
Asset Diagram

OV-1



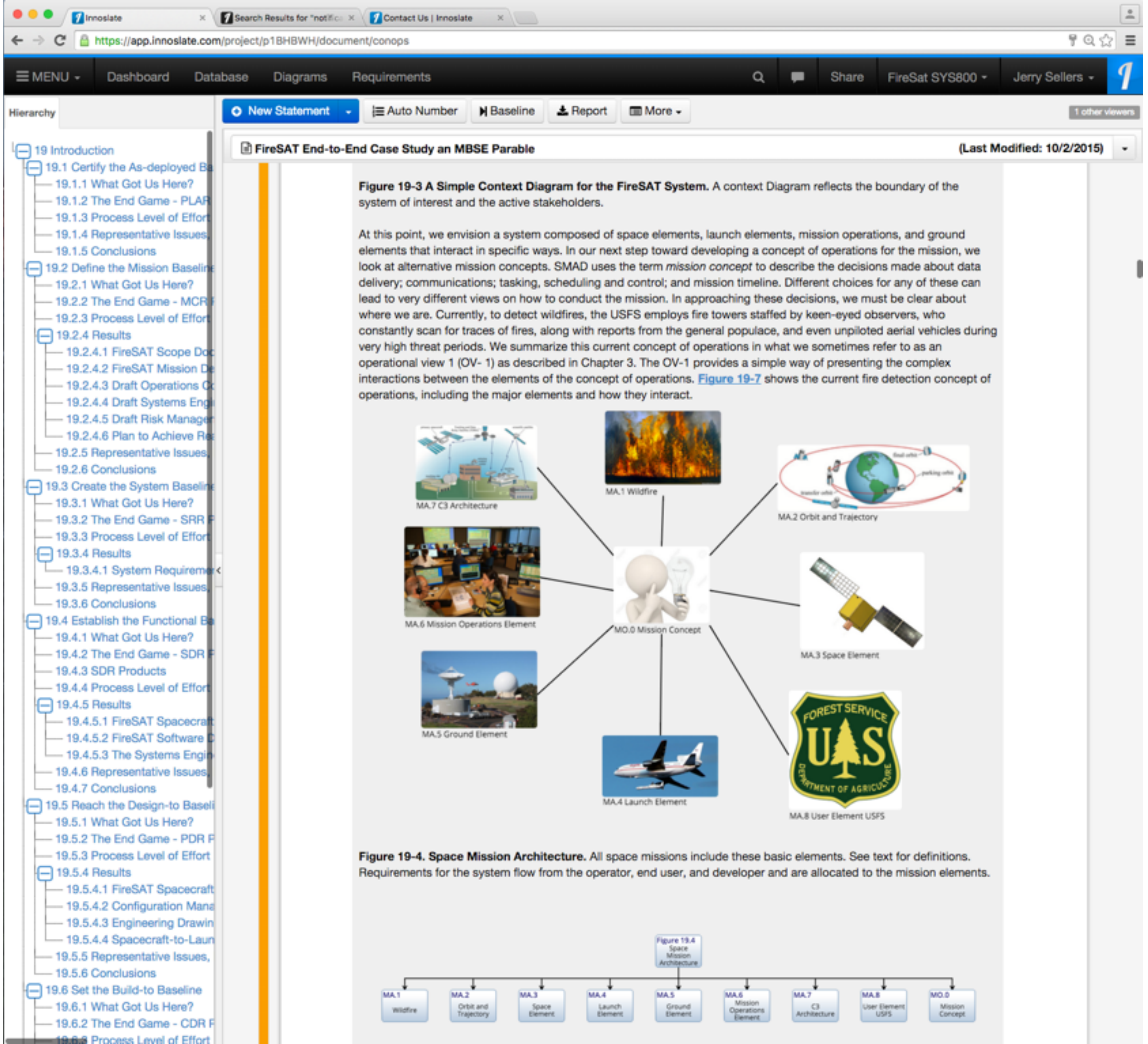
Mission Data, TLM and CMDs (secure internet)
FireSAT control center
Archival data (secure internet)
Wildfire Command Center
Tasking
Firefighting Assets
NOAA Ground Stations
Secure internet
Regional Field Offices
Cell phone
24/7 firetowers
Mission Data, TLM and CMDs
"911" Notification
Dedicated RF Link
Various
FS.1 Space Element
UAVs
Citizen reports

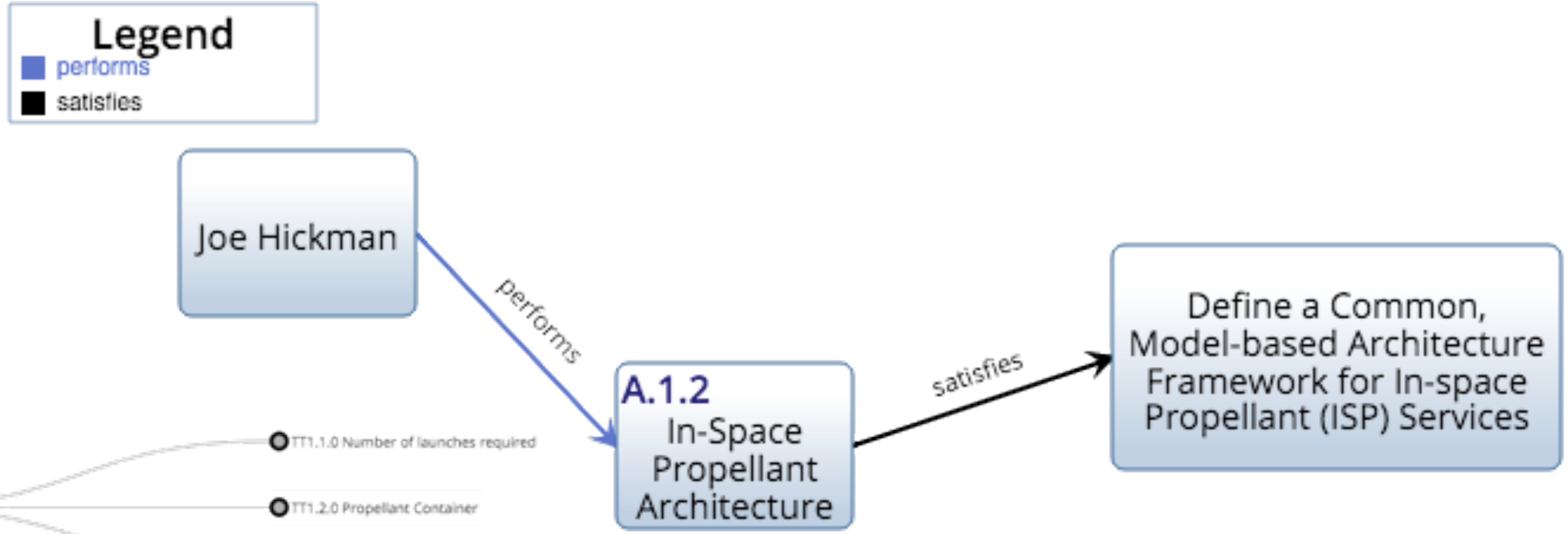
EFFBD

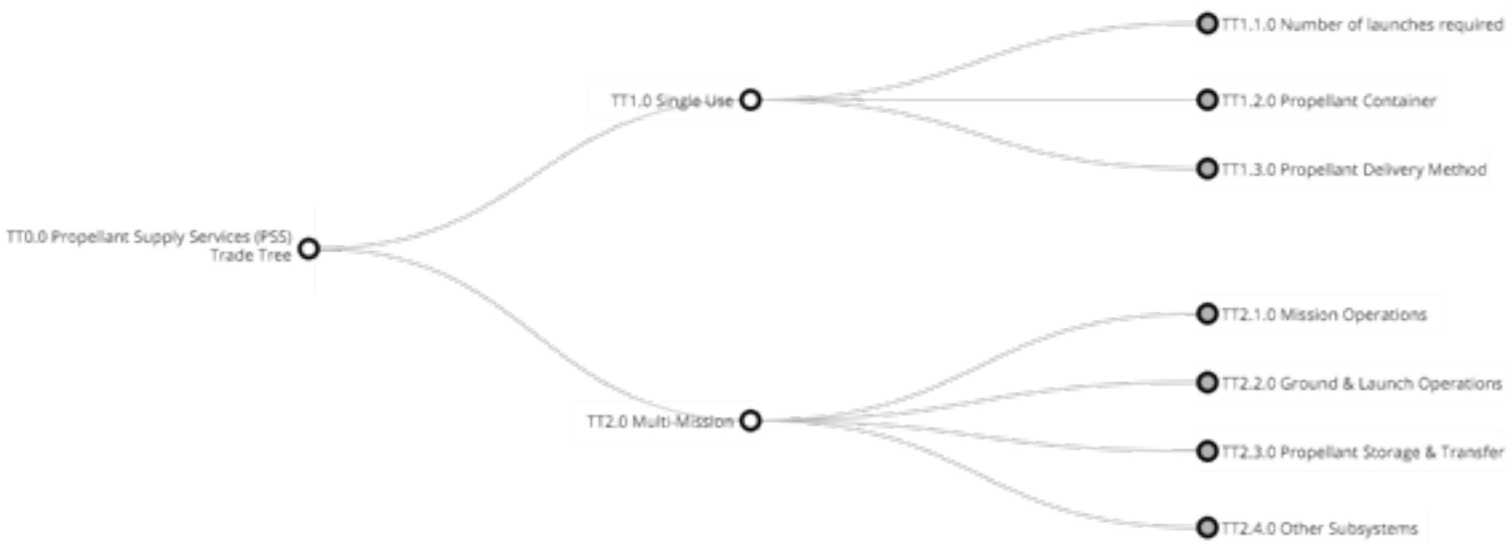


START
Perform Spacecraft Operations
LOOP
Continue Spacecraft Operations
Continue
Exit
1.1 Handle Wildfire IR
DECOMPOSED
1.2 Handle Space Environment Inputs
1.3 Handle Spacecraft Commands
1.4 Handle GPS Inputs
2.1 Produce Wildfire "911" Notifications
2.2 Produce Spacecraft Telemetry
2.3 Generate Thermal Ouput
2.4 Generate Thrust
Detected Wildfire
Spacecraft Pointing
Spacecraft Position
Thermal Control
Thruster Commands
Navigation Commands
Commands
Navigation Signals
"911" Wildfire
Telemetry
Thrust (Delta-V)
END

Fully implemented a virtual document with hyperlinks to model elements in Innoslate



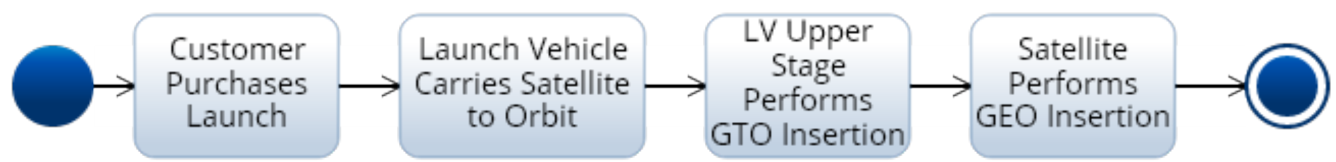




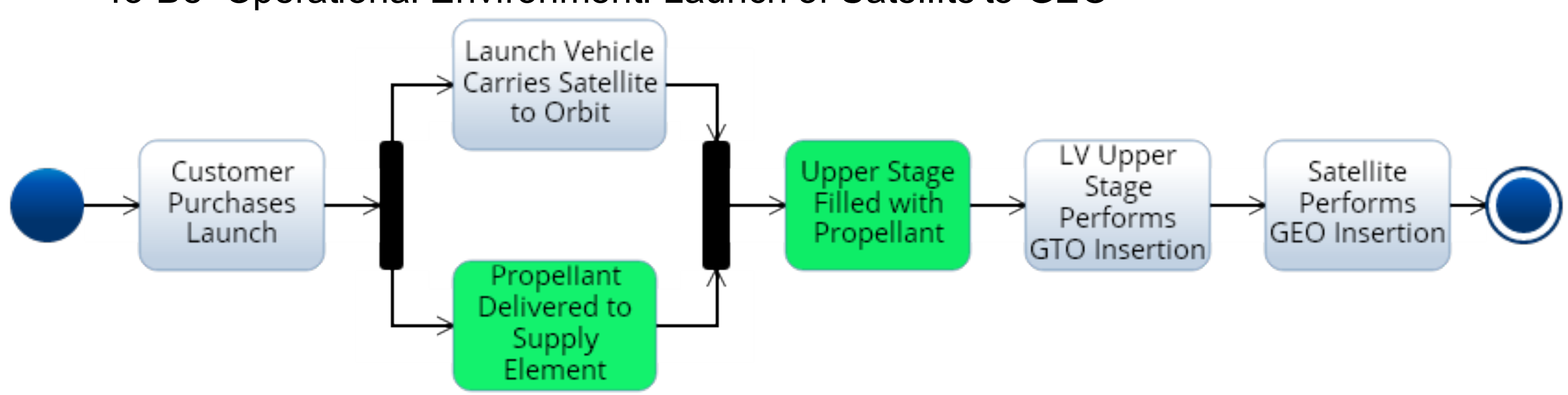
Characterize Trade Space

Define Use Cases

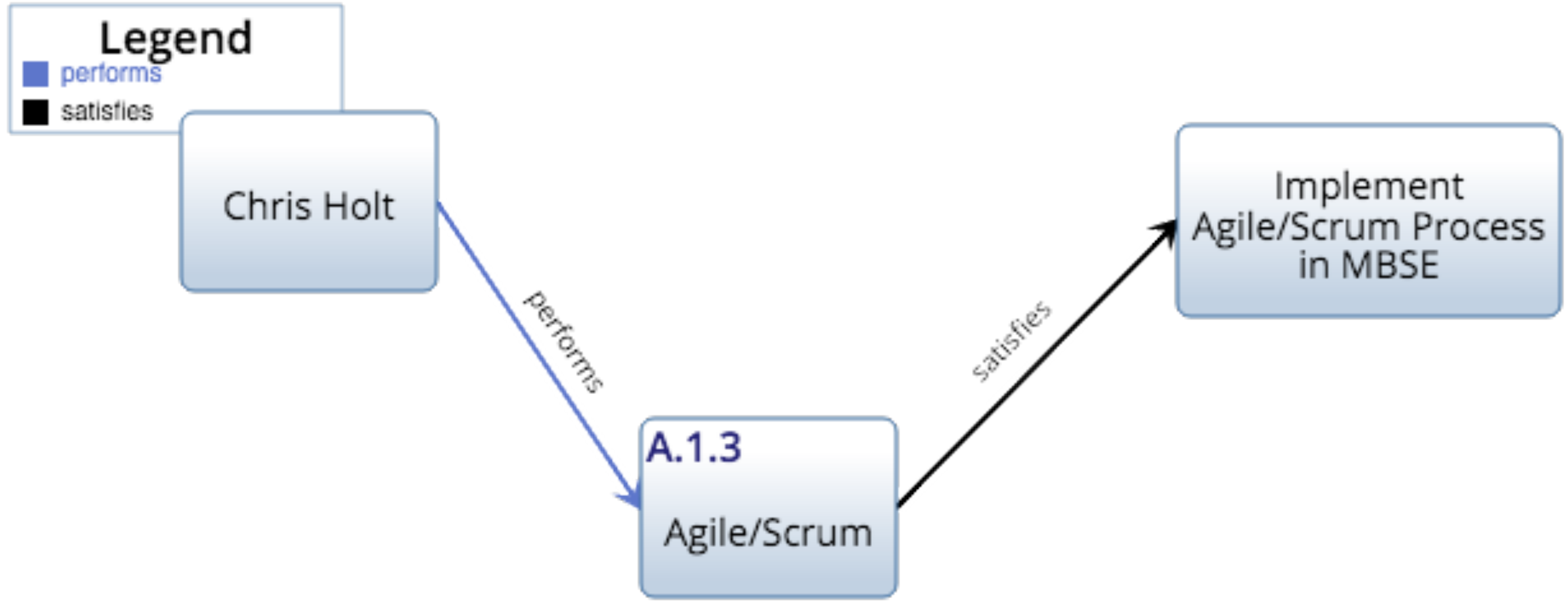
- Current Operational Environment: Launch of Satellite to GEO

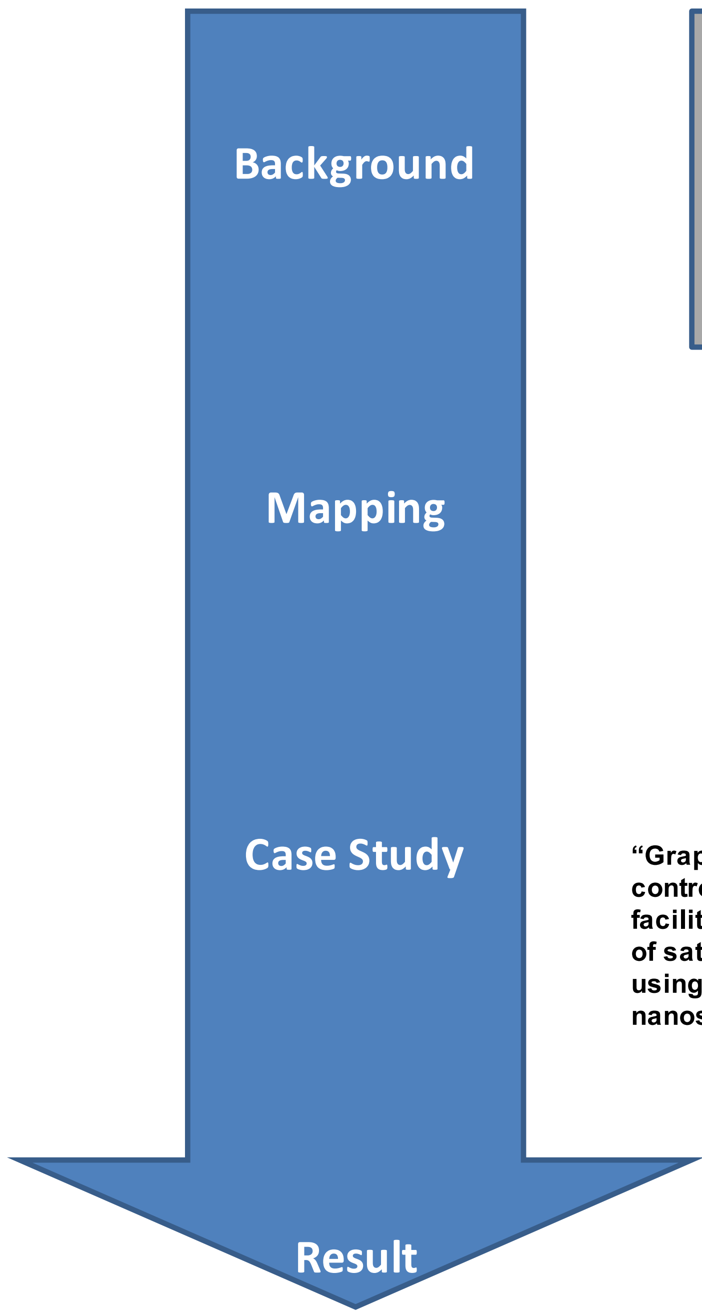


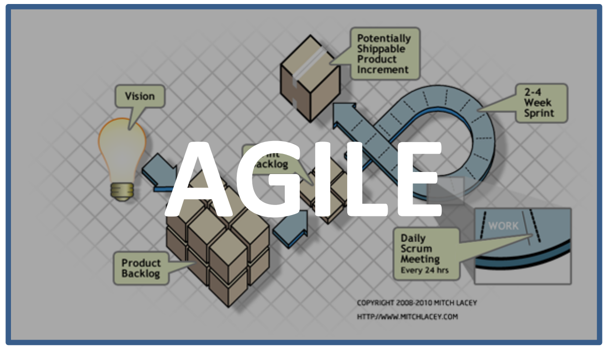
- “To Be” Operational Environment: Launch of Satellite to GEO

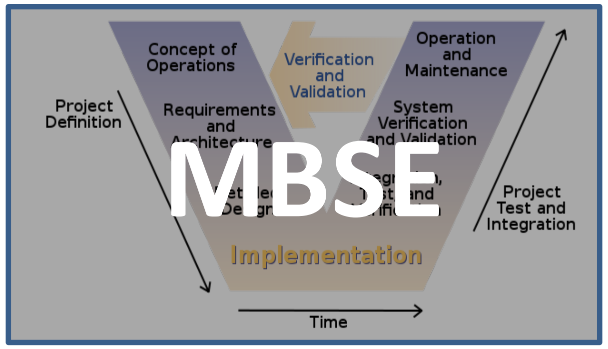


- Other Use Cases:
  - Between LEO and GEO: moving assets; extending satellite lifecycles
  - Other Cislunar: moving assets; lunar missions; Earth Moon Lagrange
  - Deep Space: Asteroid; Earth Sun Lagrange; Mars



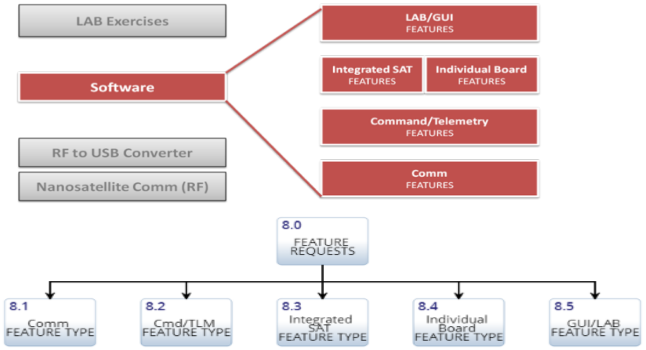




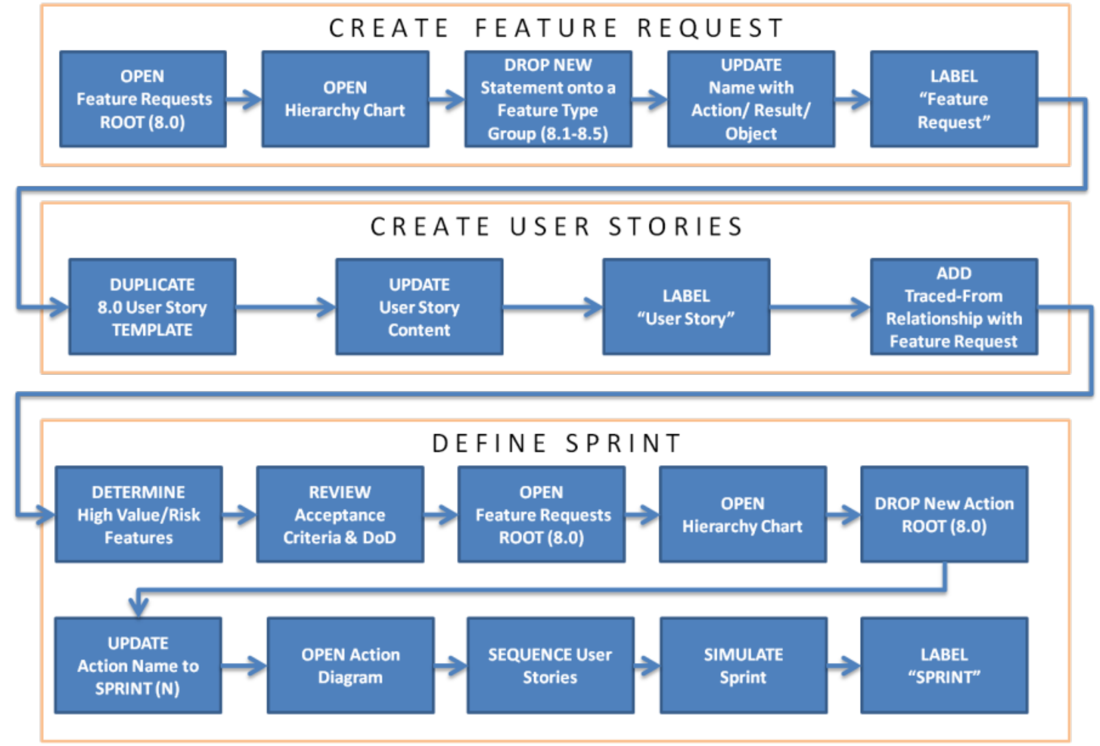


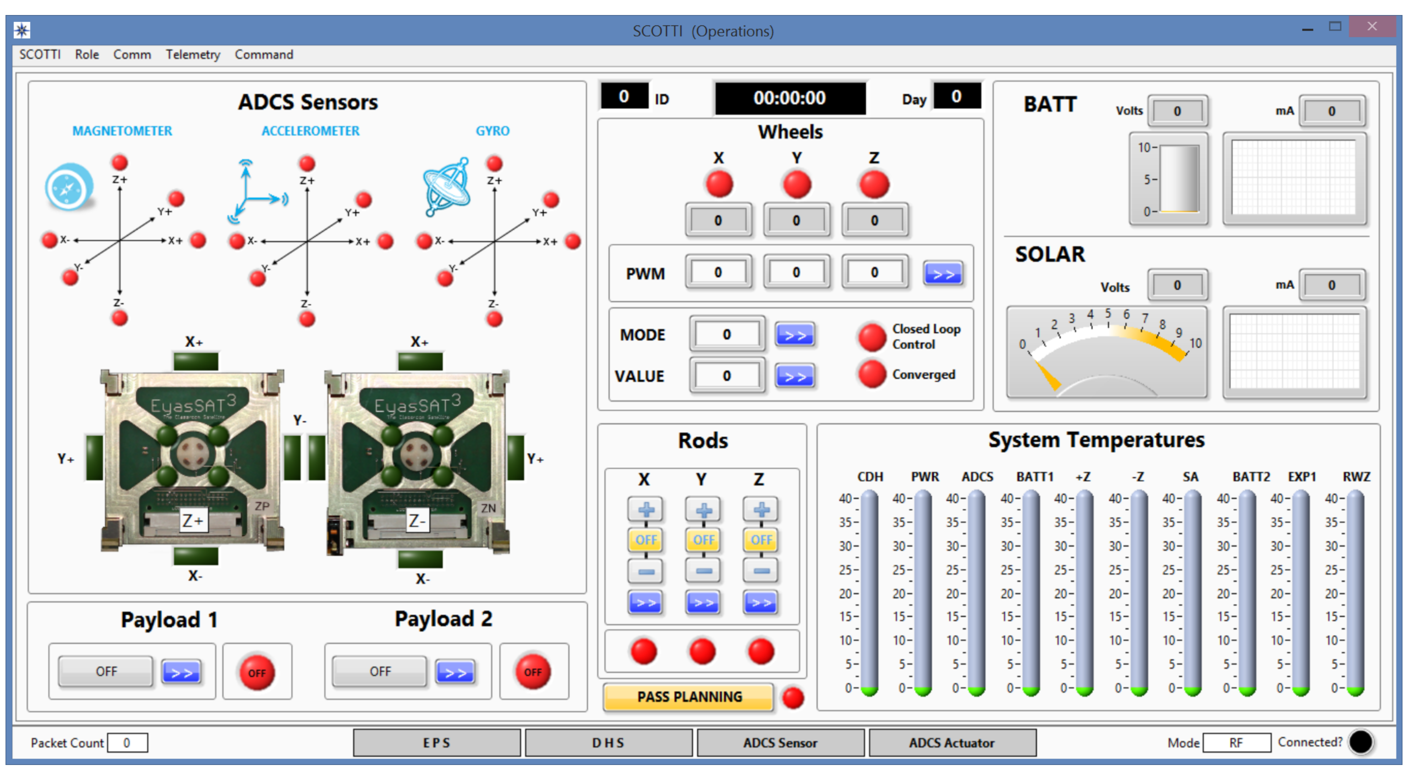
OPTION 3 AGILE	INNOSLATE Class	INNOSLATE Relationship
Feature Request	Statement	
User Story	Action	Traced From Statement (Feature Request)
Acceptance Criteria	Action	Decomposes Parents (User Stories)
Backlog	N/A	N/A
Sprint	Action	Decomposed By Action (User Stories)
Release	Asset	Performs Action (Sprints)

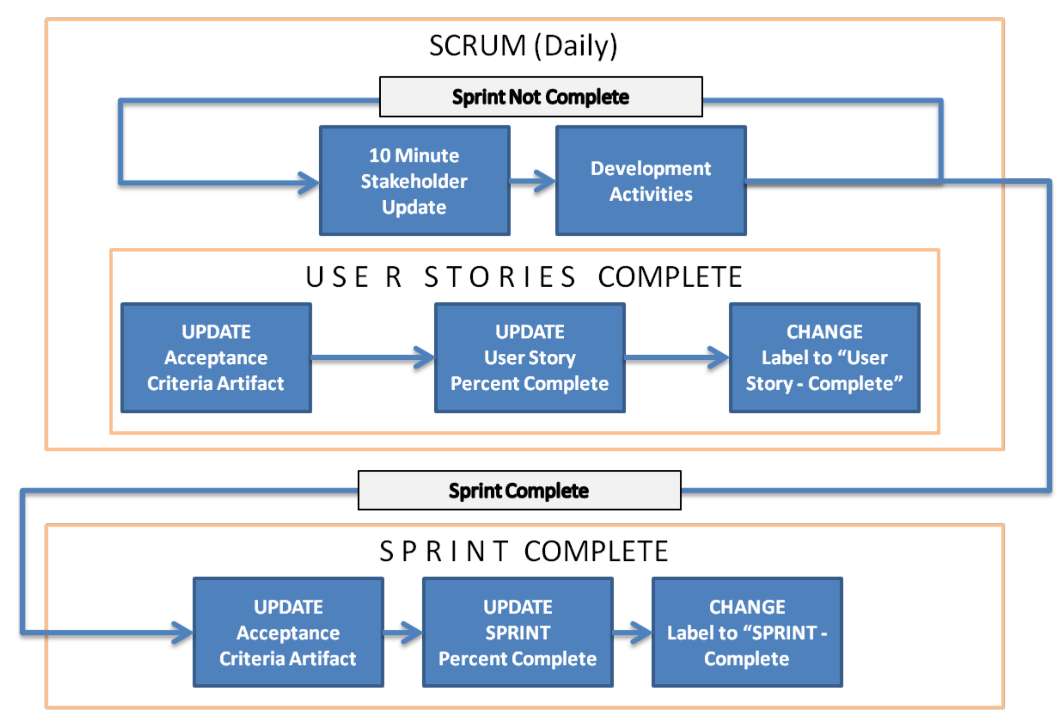
"Graphical ground control software which facilitates the learning of satellite subsystems using the ES3 nanosatellite"

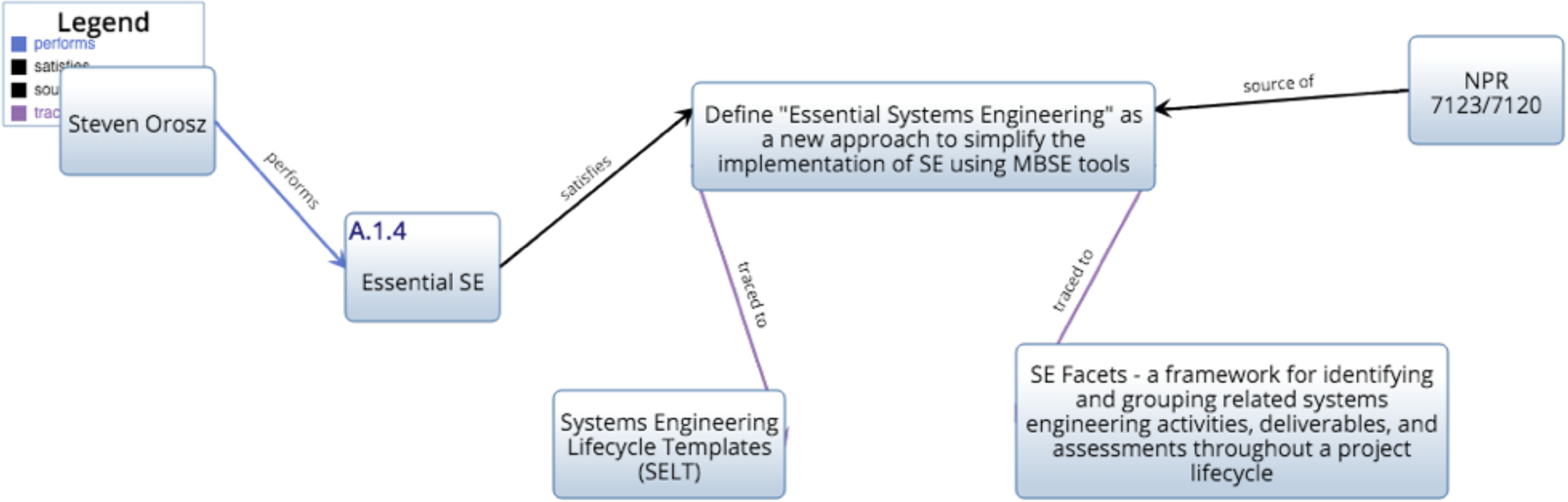


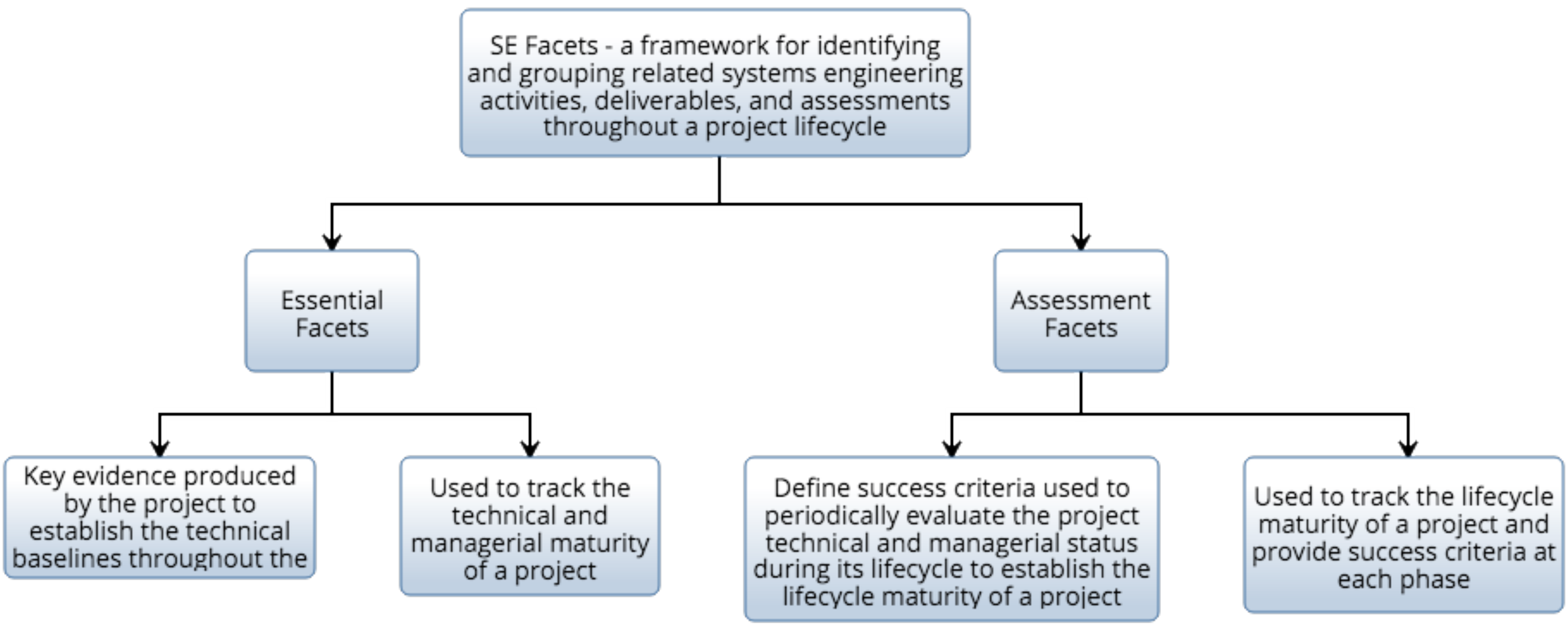
- **RESULT**:
  - –Process for implementing AGILE in a MBSE Tool.
  - –Example using the process
  - –A software product developed in a traceable way with reporting hooks that support program management.
  - –A software product developed with a method which encouraged scope change, ultimately giving the customer the most a desirable solution.

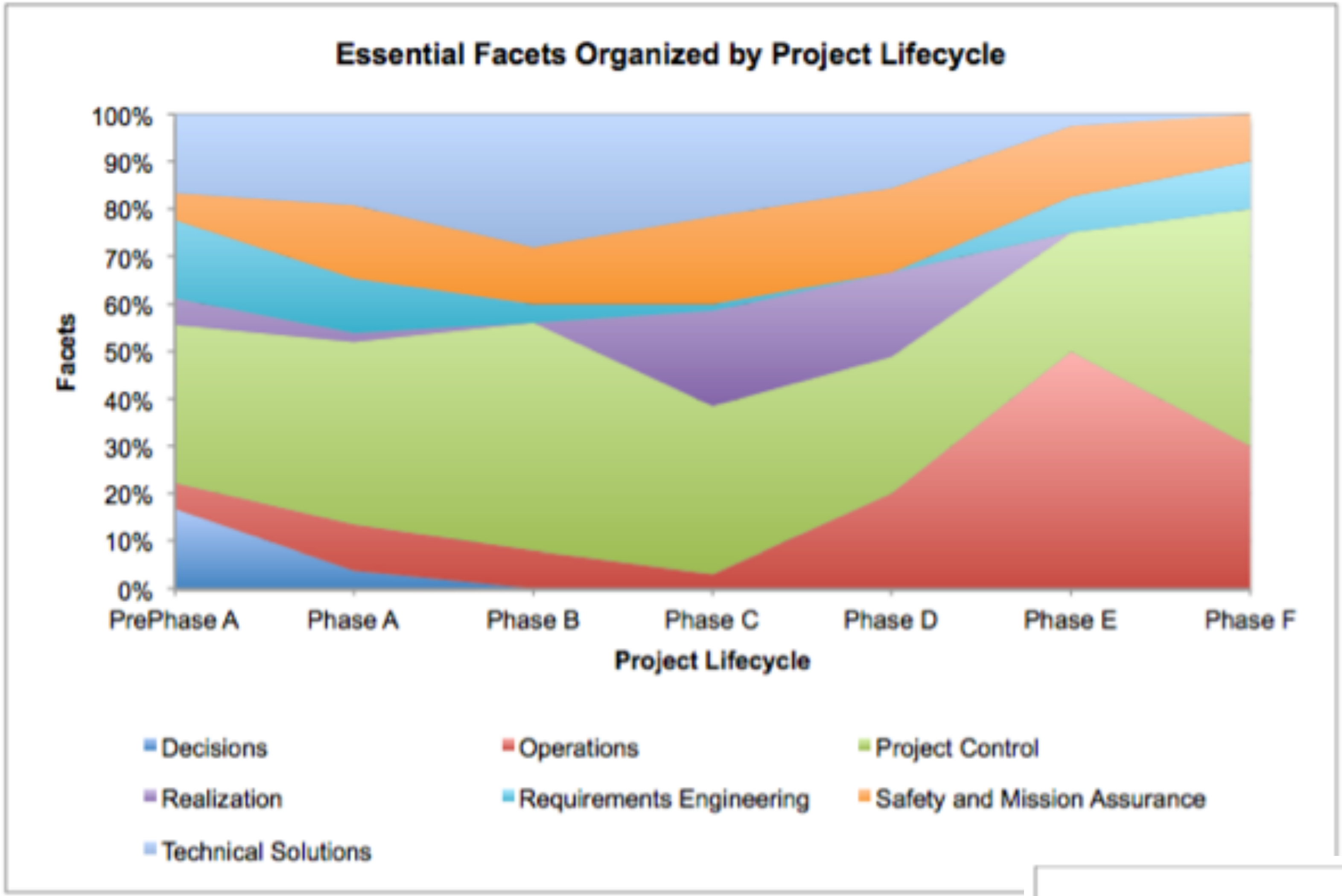


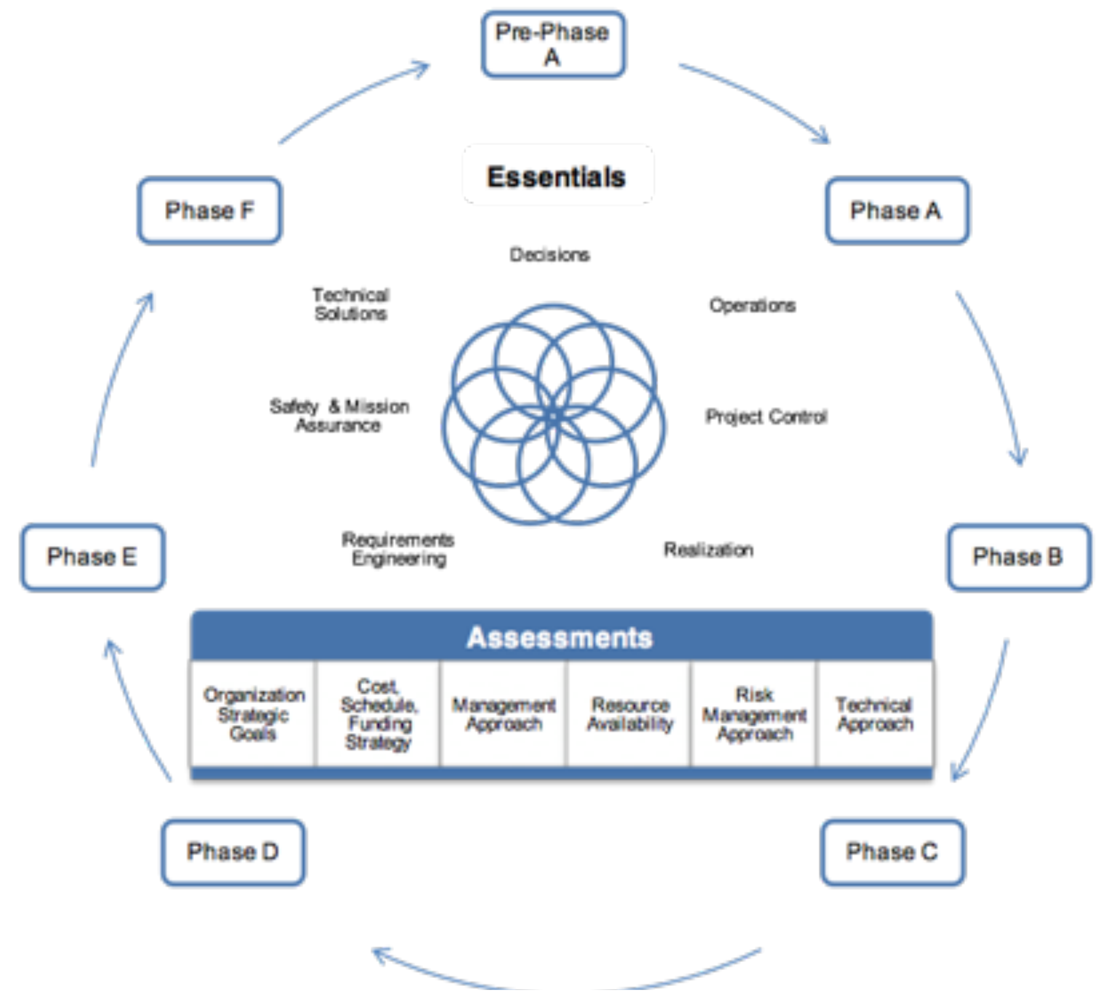





Legend
performs
satisfies
sou
trac
Steven Orosz
performs
A.1.4
Essential SE
satisfies
Define "Essential Systems Engineering" as a new approach to simplify the implementation of SE using MBSE tools
source of
NPR 7123/7120
traced to
traced to
Systems Engineering Lifecycle Templates (SELT)
SE Facets - a framework for identifying and grouping related systems engineering activities, deliverables, and assessments throughout a project lifecycle


SE Facets - a framework for identifying and grouping related systems engineering activities, deliverables, and assessments throughout a project lifecycle
Essential Facets
Assessment Facets
Key evidence produced by the project to establish the technical baselines throughout the
Used to track the technical and managerial maturity of a project
Define success criteria used to periodically evaluate the project technical and managerial status during its lifecycle to establish the lifecycle maturity of a project
Used to track the lifecycle maturity of a project and provide success criteria at each phase





Lifecycle Templates

1 PrePhase A

1.1 MCR

1.1.1 Essentials

1.1.1.1 Decisions

1.1.1.1.1 Mission Concept

NPR	Description	Evidence
MCR.EC.03.B	The concept has been developed to a sufficient level of detail to demonstrate a technically feasible solution to the mission/project needs and is ready to be base-lined after review comments are incorporated.	

Discussion

1.1.1.1.2 Alternative Concepts

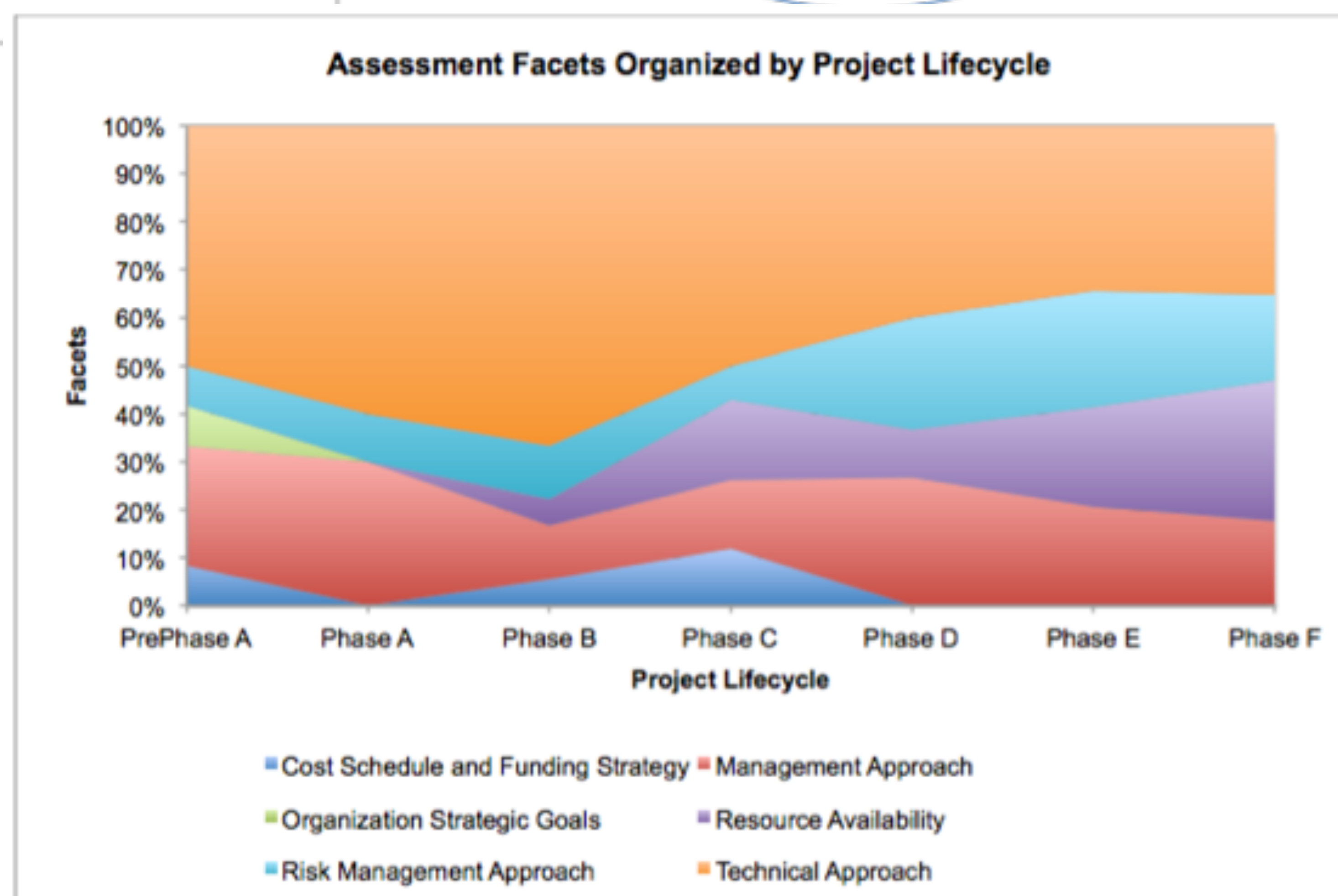
NPR	Description	Evidence
MCR.EC.05.B	Alternative concepts that have been analyzed and are ready to be reviewed.	

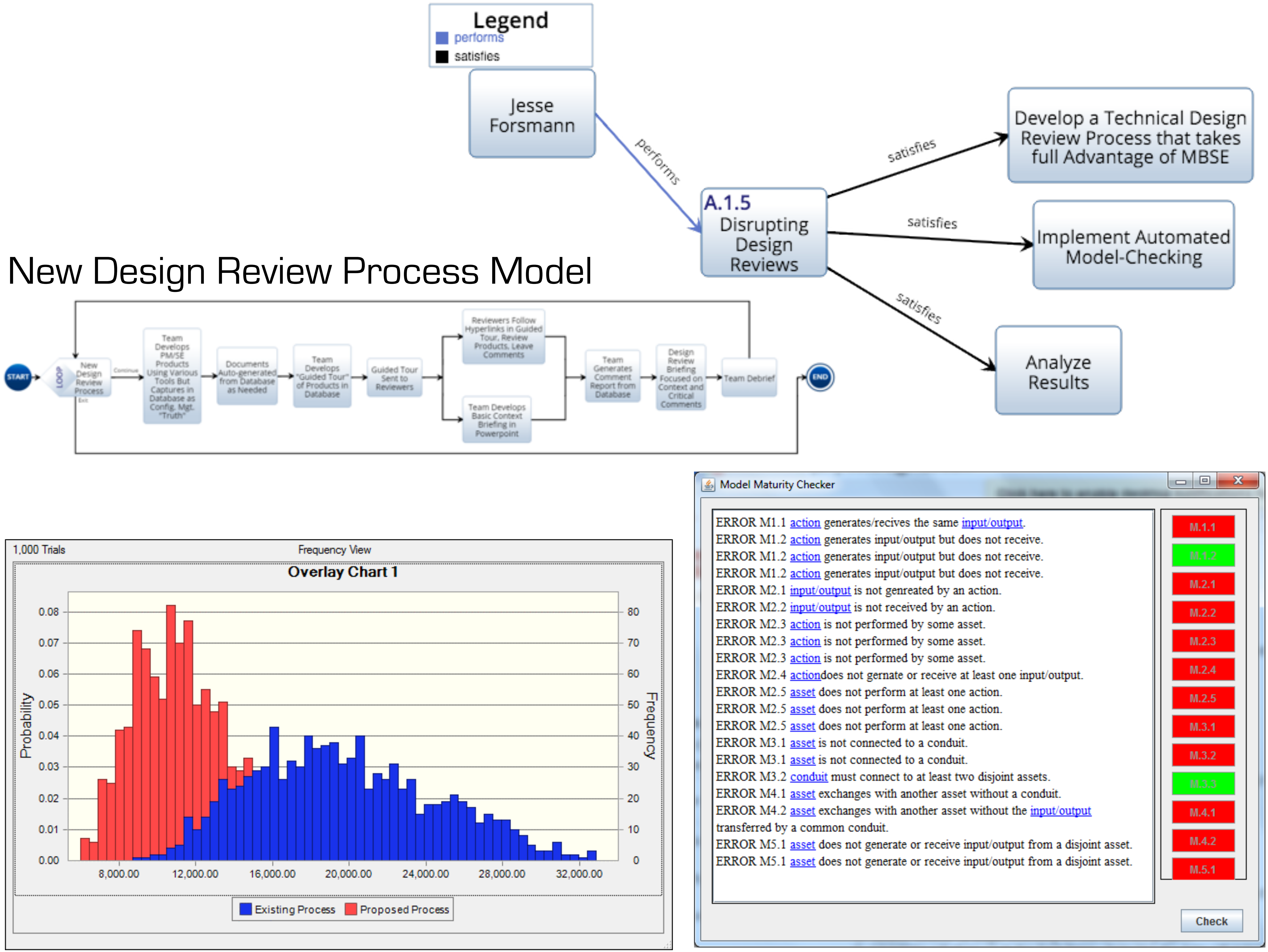
Discussion

1.1.1.1.3 De-scope Options

NPR	Description	Evidence
MCR.EC.05.D	Preliminary mission de-scope options.	

Discussion

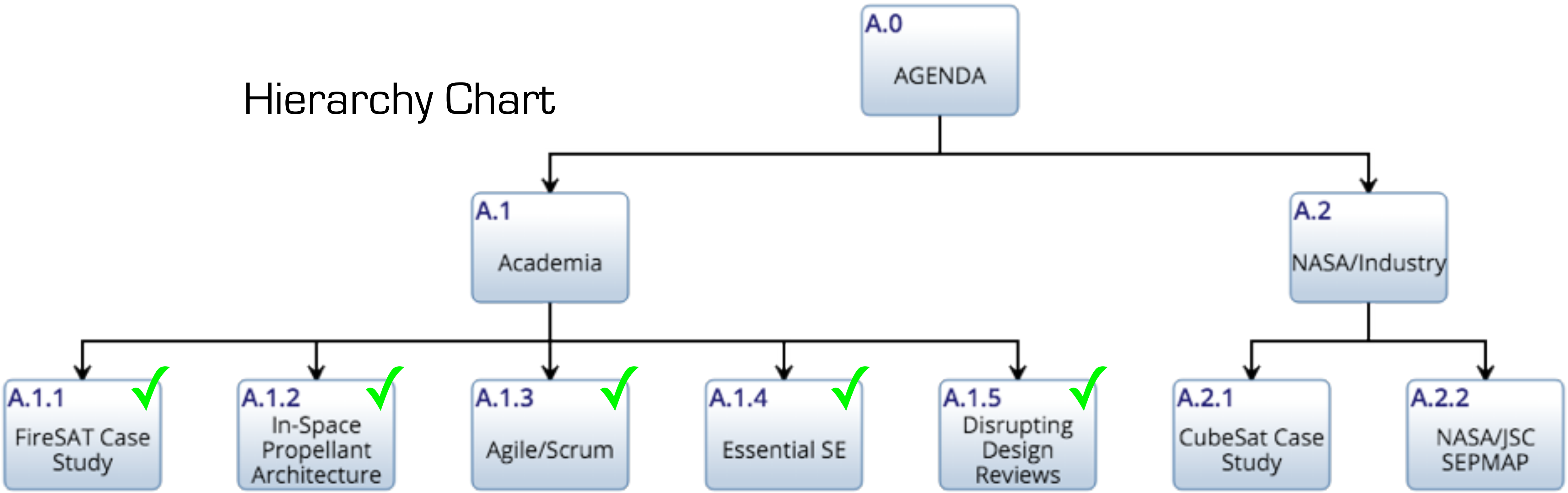




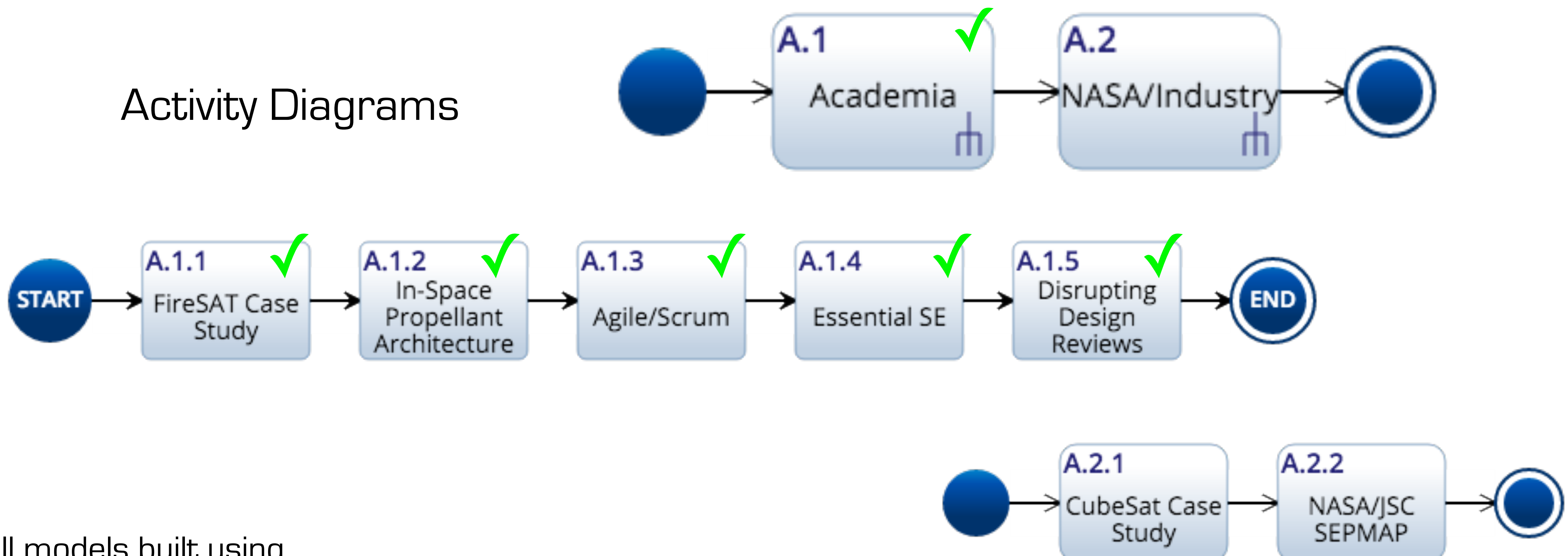
Legend
performs
satisfies
Jesse Forsmann
performs
A.1.5
Disrupting Design Reviews
satisfies
Develop a Technical Design Review Process that takes full Advantage of MBSE
satisfies
Implement Automated Model-Checking
satisfies
Analyze Results
New Design Review Process Model
START
LOOP
New Design Review Process
Continue
Exit
Team Develops PM/SE Products Using Various Tools But Captures in Database as Config. Mgt. "Truth"
Documents Auto-generated from Database as Needed
Team Develops "Guided Tour" of Products in Database
Guided Tour Sent to Reviewers
Reviewers Follow Hyperlinks in Guided Tour, Review Products, Leave Comments
Team Develops Basic Context Briefing in Powerpoint
Team Generates Comment Report from Database
Design Review Briefing Focused on Context and Critical Comments
Team Debrief
END
1,000 Trials
Frequency View
Overlay Chart 1
Probability
Frequency
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
80
70
60
50
40
30
20
10
0
8,000.00
12,000.00
16,000.00
20,000.00
24,000.00
28,000.00
32,000.00
Existing Process
Proposed Process
Model Maturity Checker
ERROR M1.1 action generates/recives the same input/output.
ERROR M1.2 action generates input/output but does not receive.
ERROR M1.2 action generates input/output but does not receive.
ERROR M1.2 action generates input/output but does not receive.
ERROR M2.1 input/output is not genreated by an action.
ERROR M2.2 input/output is not received by an action.
ERROR M2.3 action is not performed by some asset.
ERROR M2.3 action is not performed by some asset.
ERROR M2.3 action is not performed by some asset.
ERROR M2.4 actiondoes not gernate or receive at least one input/output.
ERROR M2.5 asset does not perform at least one action.
ERROR M2.5 asset does not perform at least one action.
ERROR M2.5 asset does not perform at least one action.
ERROR M3.1 asset is not connected to a conduit.
ERROR M3.1 asset is not connected to a conduit.
ERROR M3.2 conduit must connect to at least two disjoint assets.
ERROR M4.1 asset exchanges with another asset without a conduit.
ERROR M4.2 asset exchanges with another asset without the input/output transferred by a common conduit.
ERROR M5.1 asset does not generate or receive input/output from a disjoint asset.
ERROR M5.1 asset does not generate or receive input/output from a disjoint asset.
M.1.1
M.1.2
M.2.1
M.2.2
M.2.3
M.2.4
M.2.5
M.3.1
M.3.2
M.3.3
M.4.1
M.4.2
M.5.1
Check

Burn-down Status

Hierarchy Chart



Activity Diagrams



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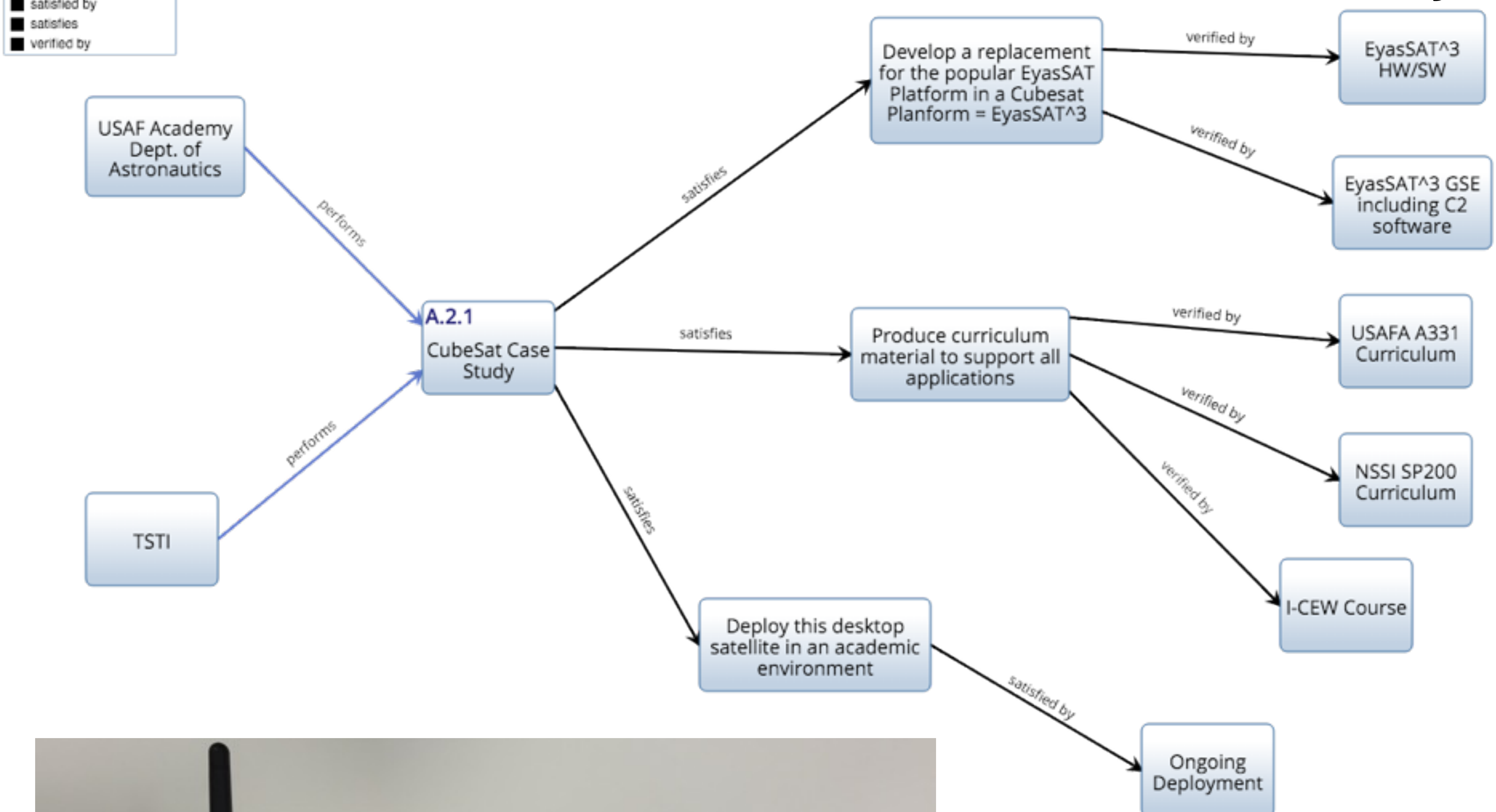
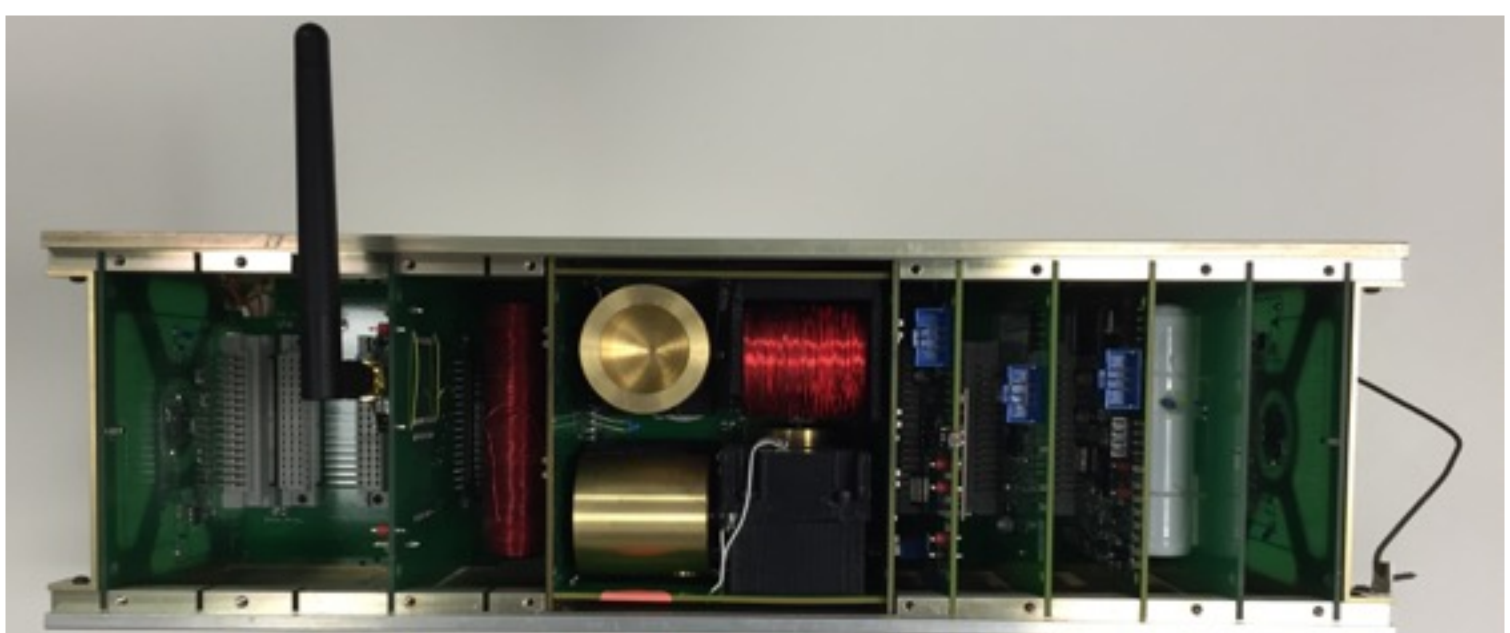
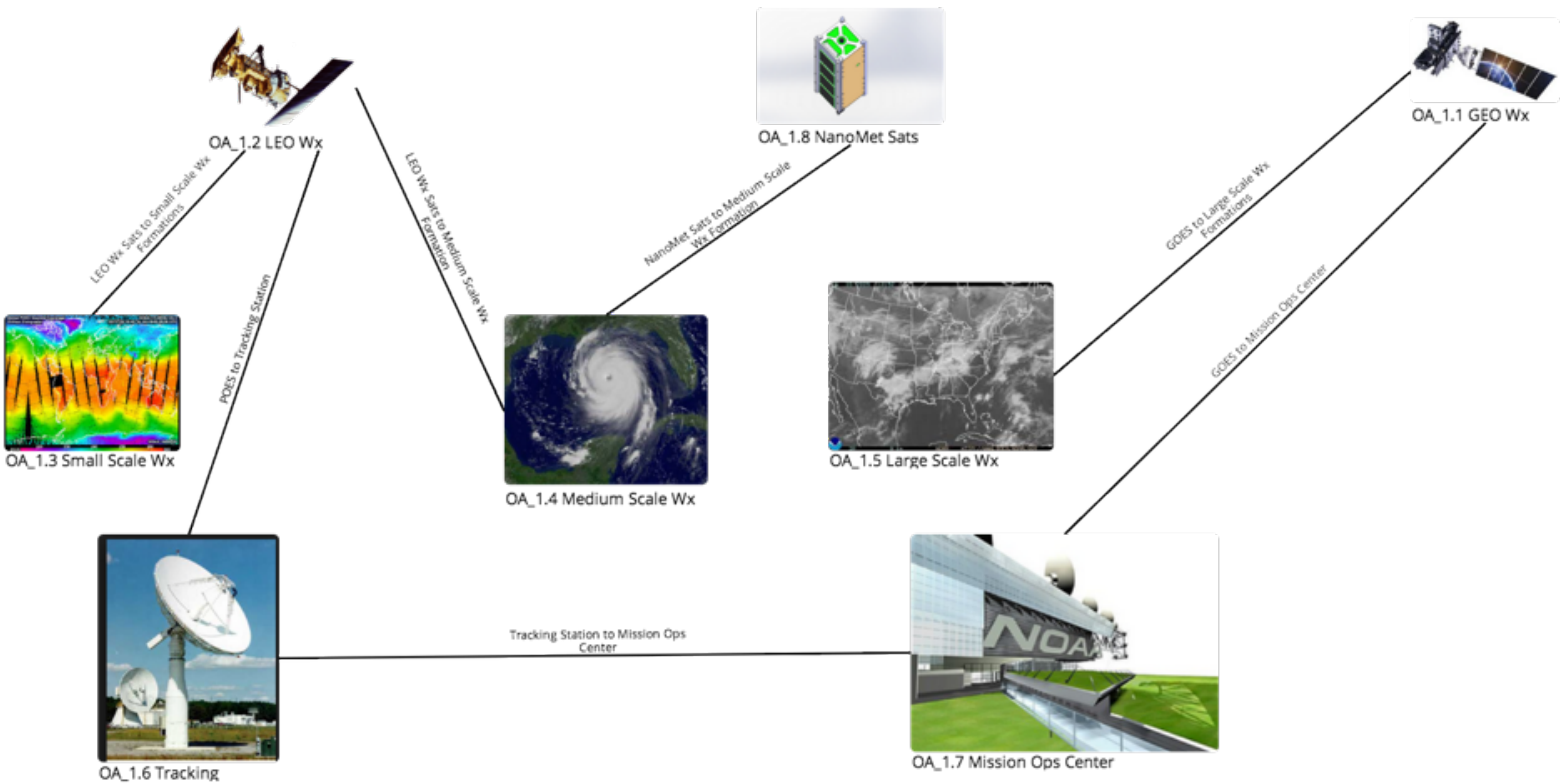
NanoMet: An End-to-End Cubesat SE Case Study





Con-Ops (To-be)

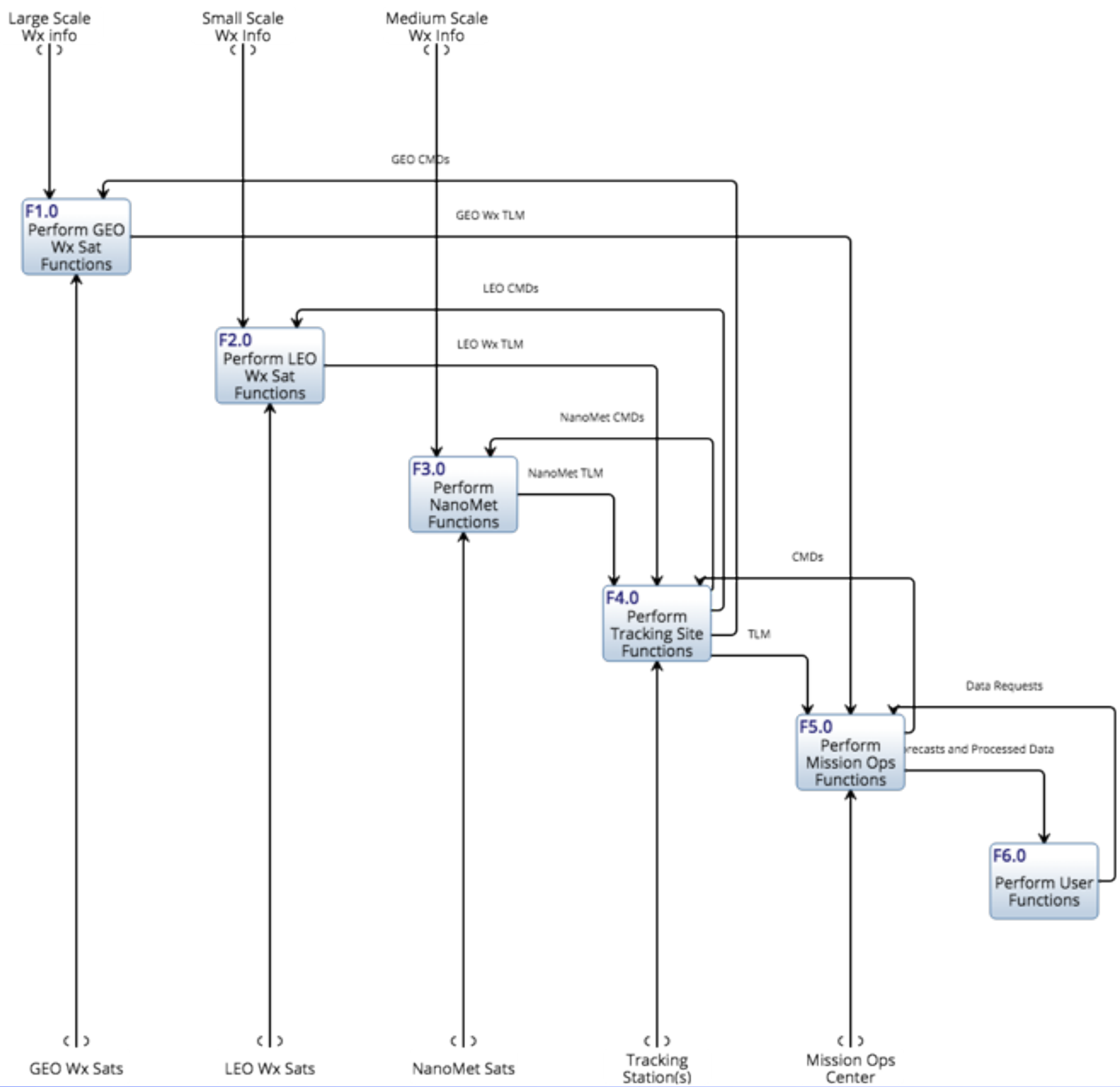


The proposed operational concept would deploy some number of NanoMet spacecraft into LEO on an on-demand, launch-available basis. They would operate from orbits of opportunity in an uncontrolled constellation that would provide supplemental coverage to existing anchor systems. NanoMet will interface to existing NOAA tracking a facilities at Wallops and Fairbanks. Mission operations will be conducted from NOAA's existing facility in Suitland, MD. Their operation will be added to the current workload.

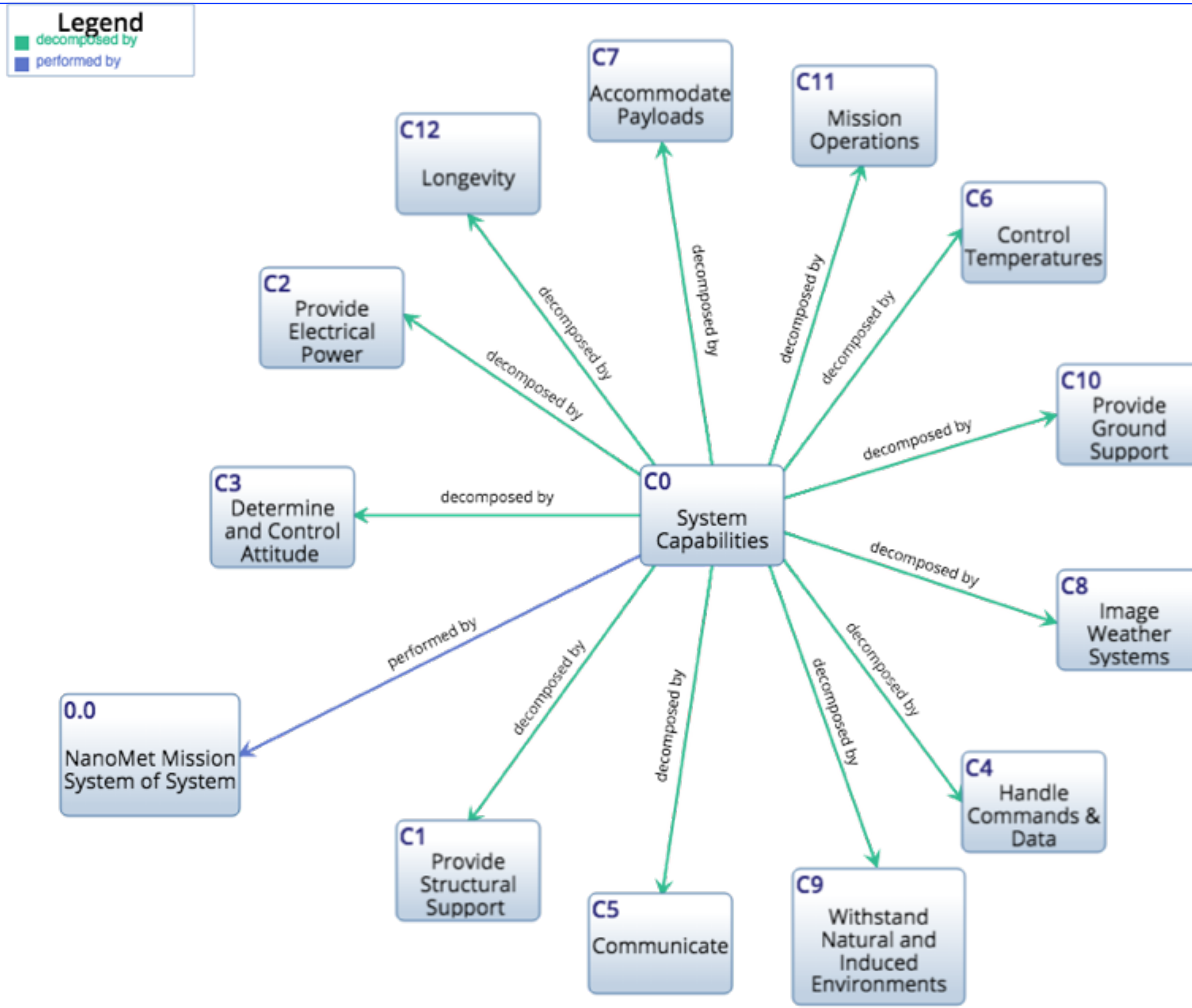
Operational Scenarios

Scenario	Description
Launch	During launch, each NanoMet satellite will be inert inside of the P-POD dispenser
Deploy/Boot Up	Upon commanded release from the P-POD, the deployment switch will open allowing the system to power on and boot up
Acquisition	During acquisition, the spacecraft will tumble based on initial tip off torque and await for command from the ground station to turn on its transmitter.
Commissioning	Once data is being reliably received by the ground station, the operations team will begin check out of the bus subsystems, begin 3-axis control of the platform
Maintenance	During maintenance mode, the spacecraft will suspend imaging activities while operators update software, perform momentum dumping or other activities.
Safe-Mode	During safe-mode the system will point solar arrays at the sun and await contact from the ground.
Imaging Campaign	During imaging campaigns (normal operations) each NanoMet will collect imagery as commanded by the operations team in consultation with users.

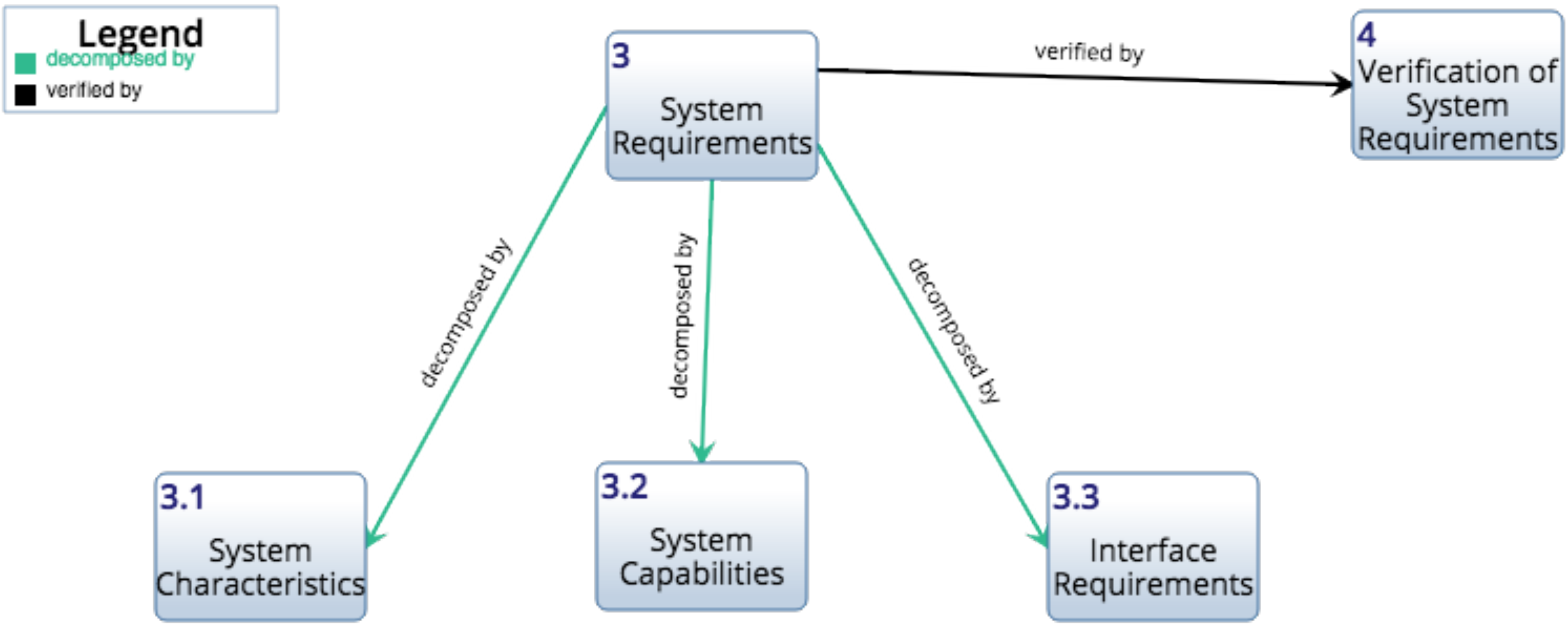
Functional Architecture - IDEF0



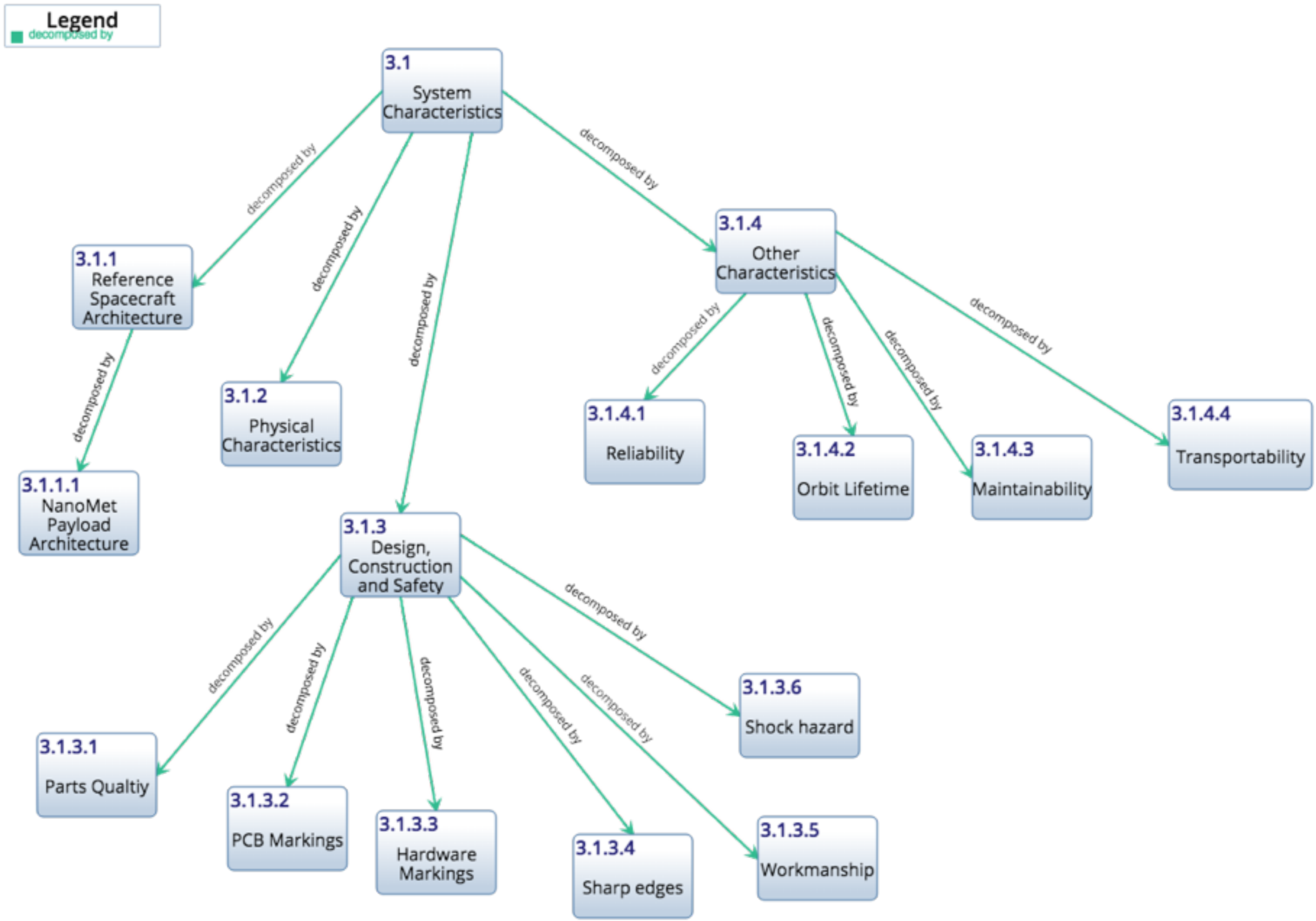
Functional Architecture - System Capabilities



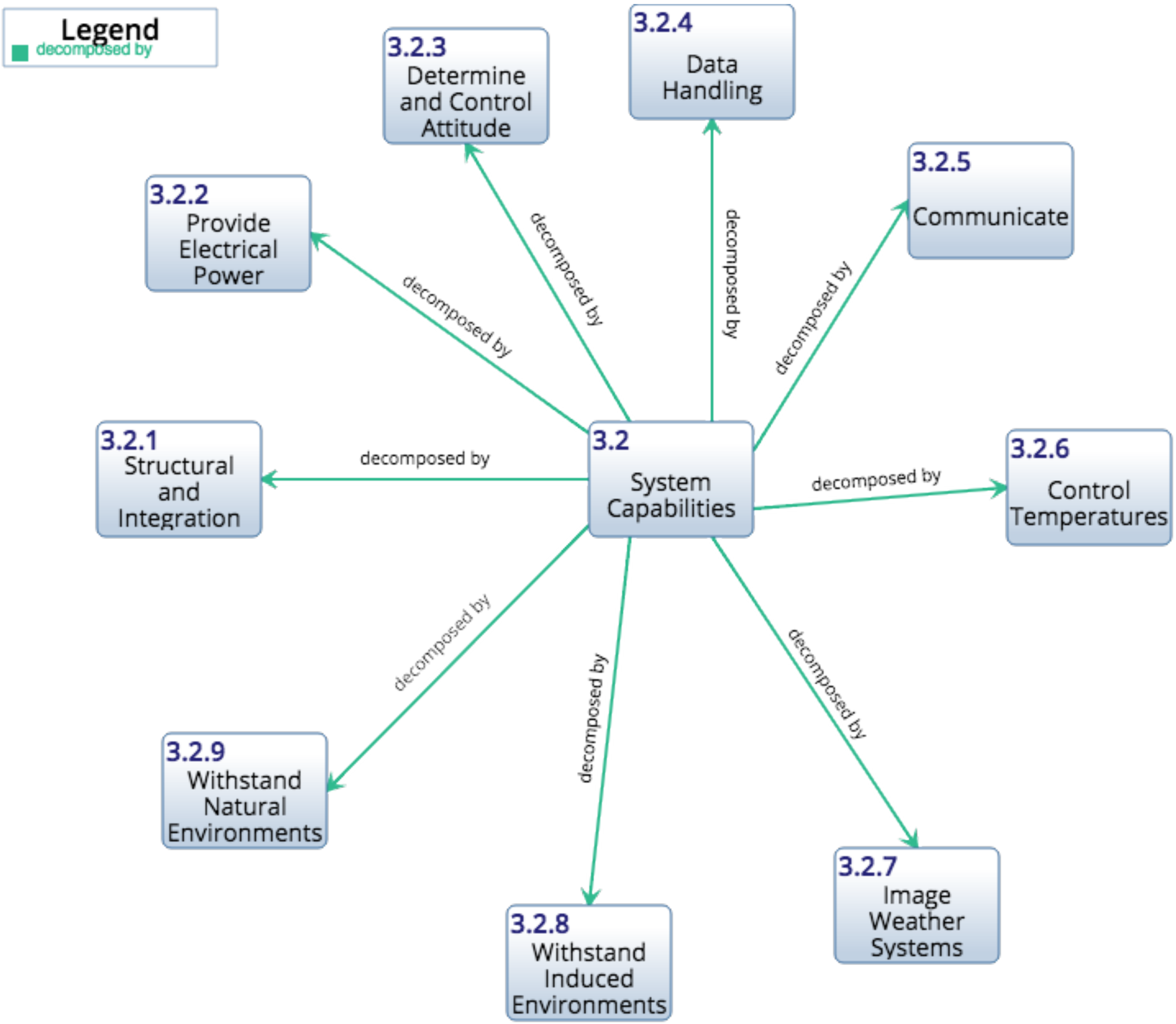
System Requirements - Top-Level Hierarchy



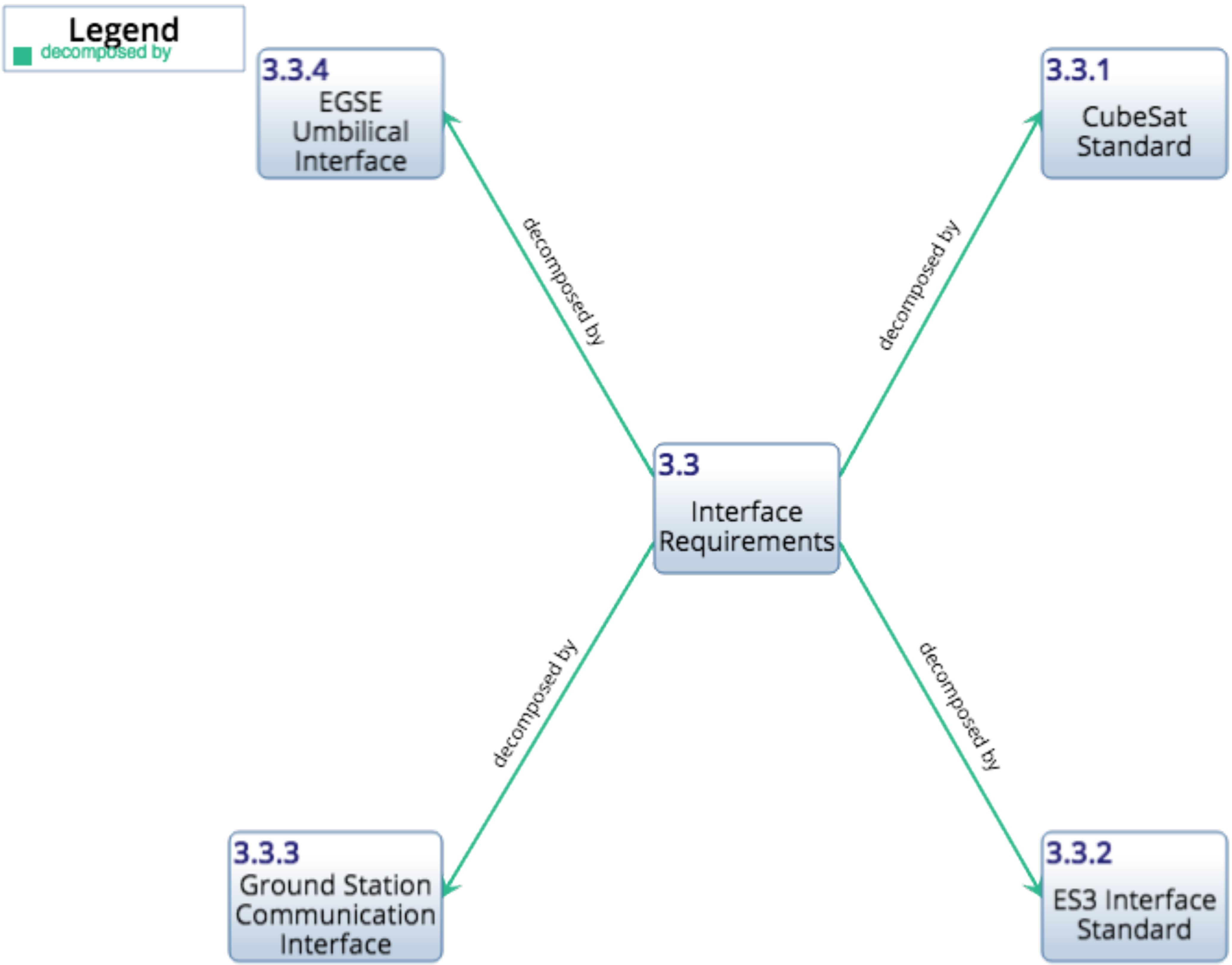
System Requirements - System Characteristics



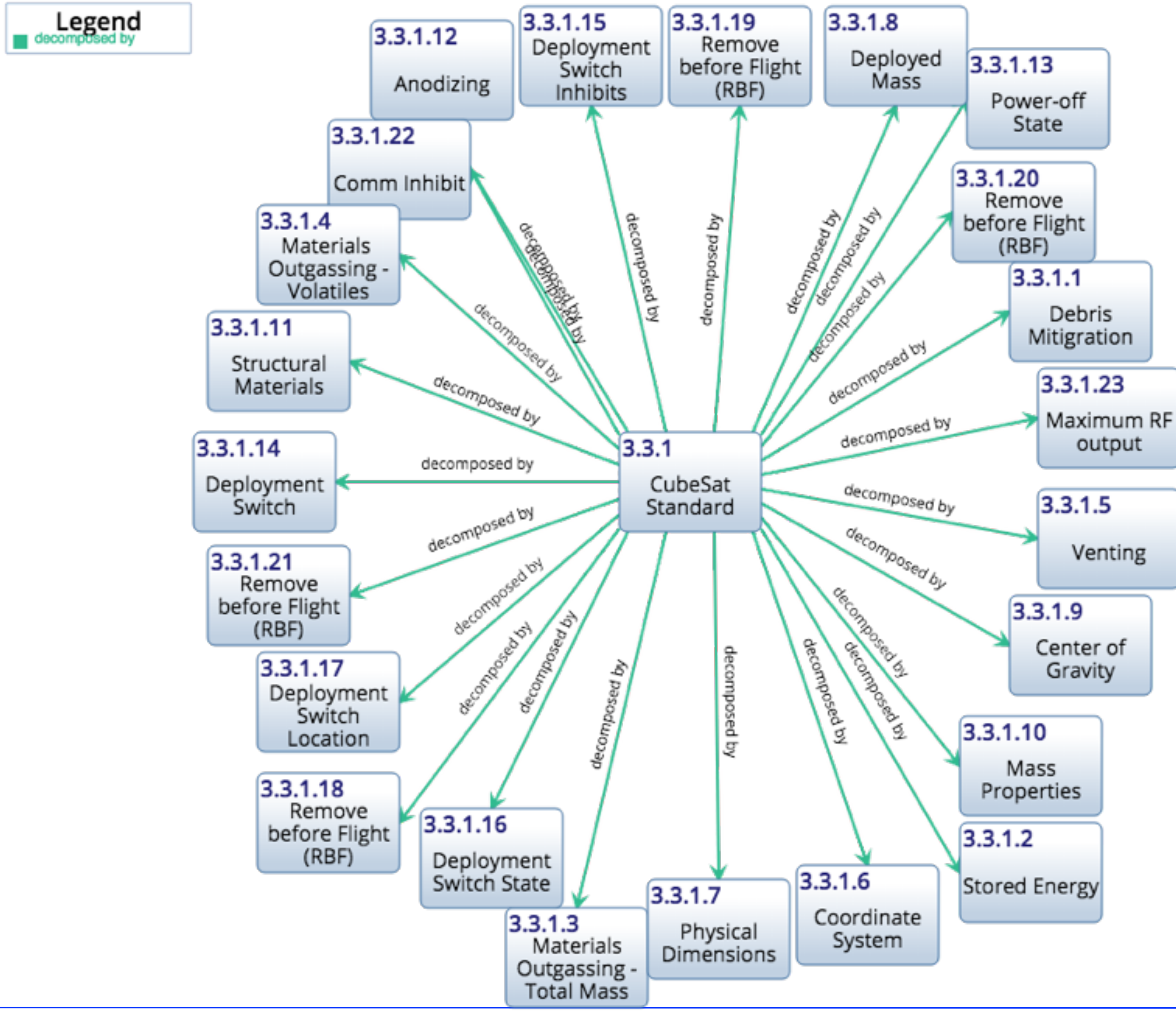
System Requirements - System Capabilities



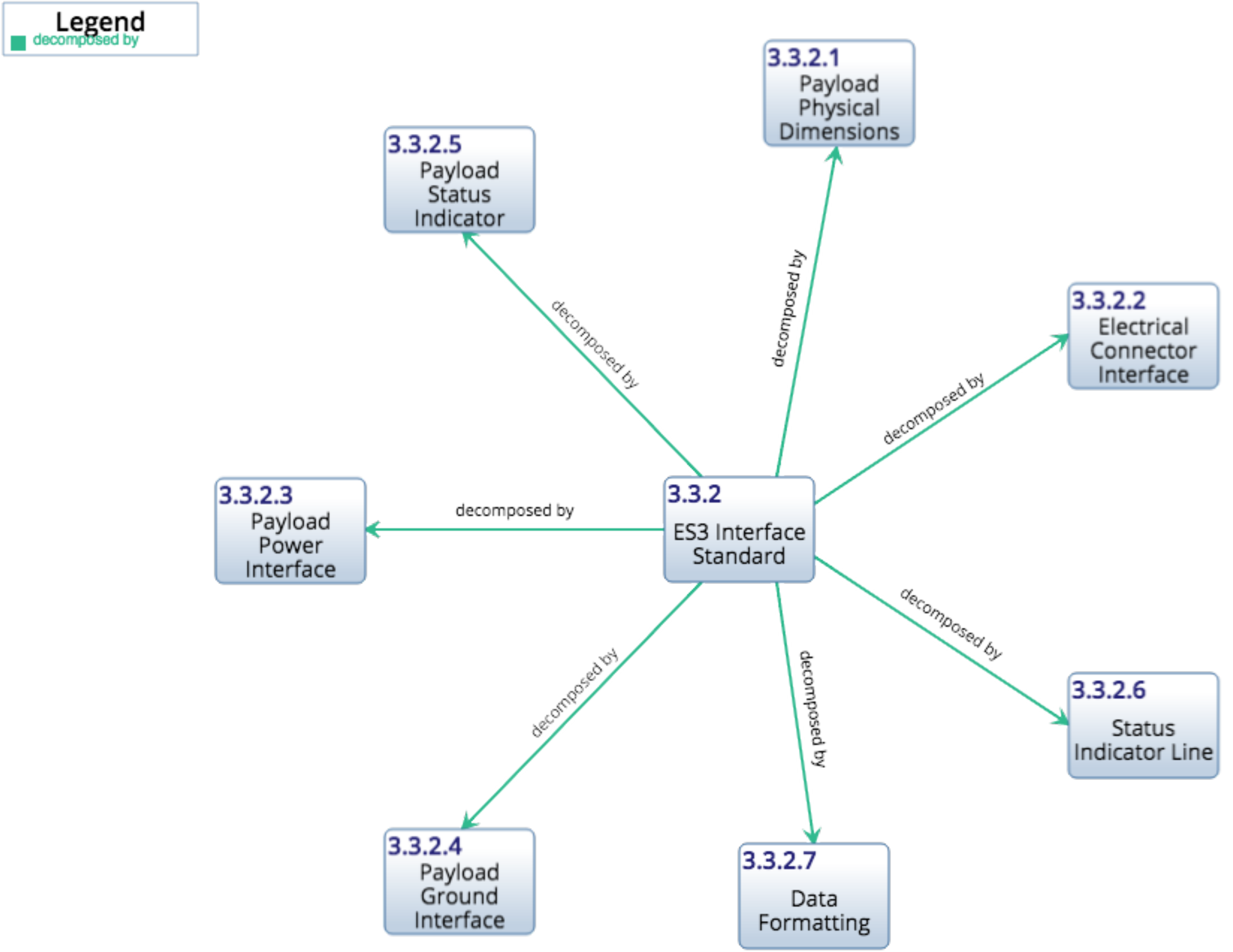
System Requirements - Interface Requirements



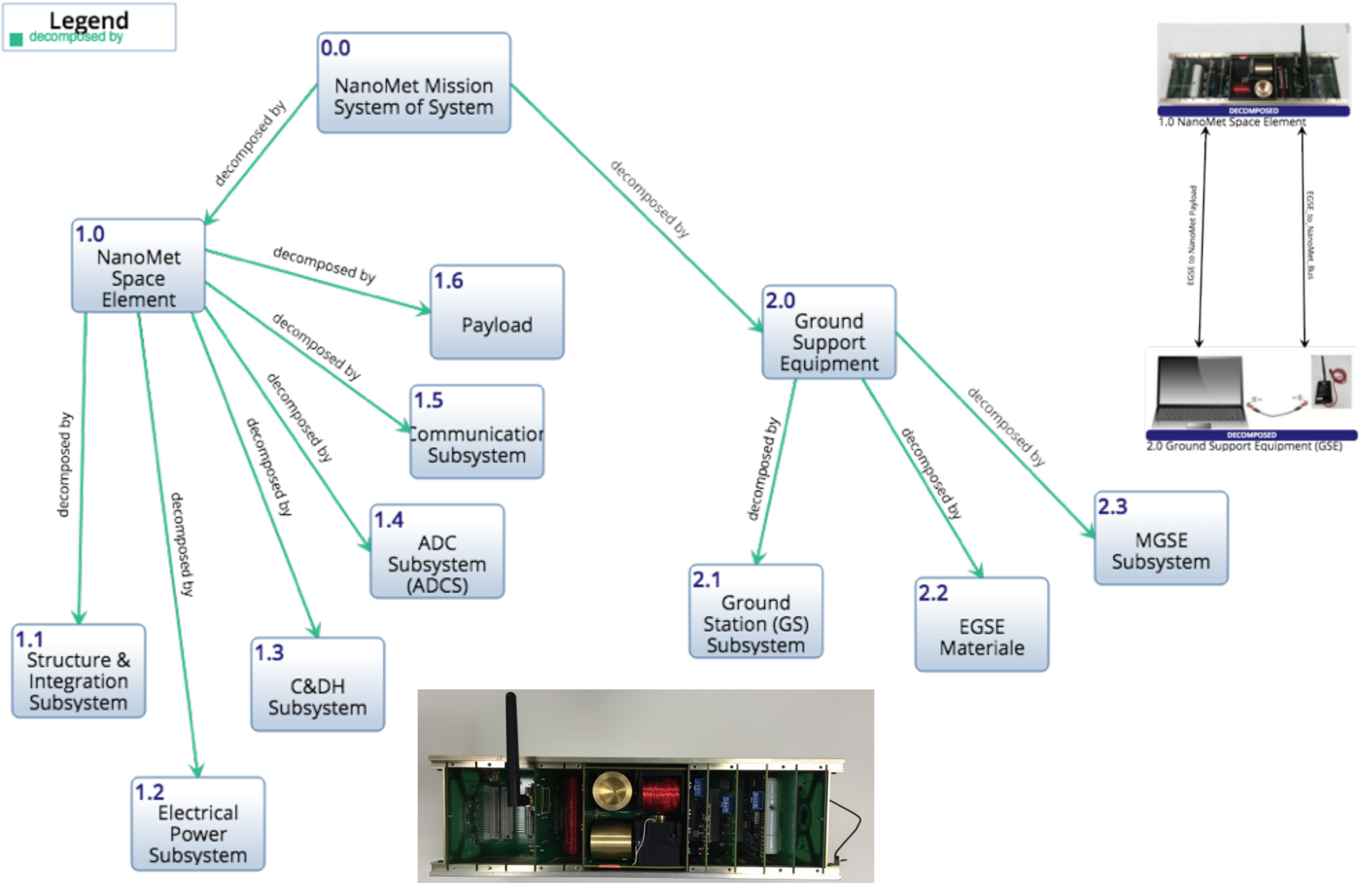
System Requirements - CubeSAT Standard



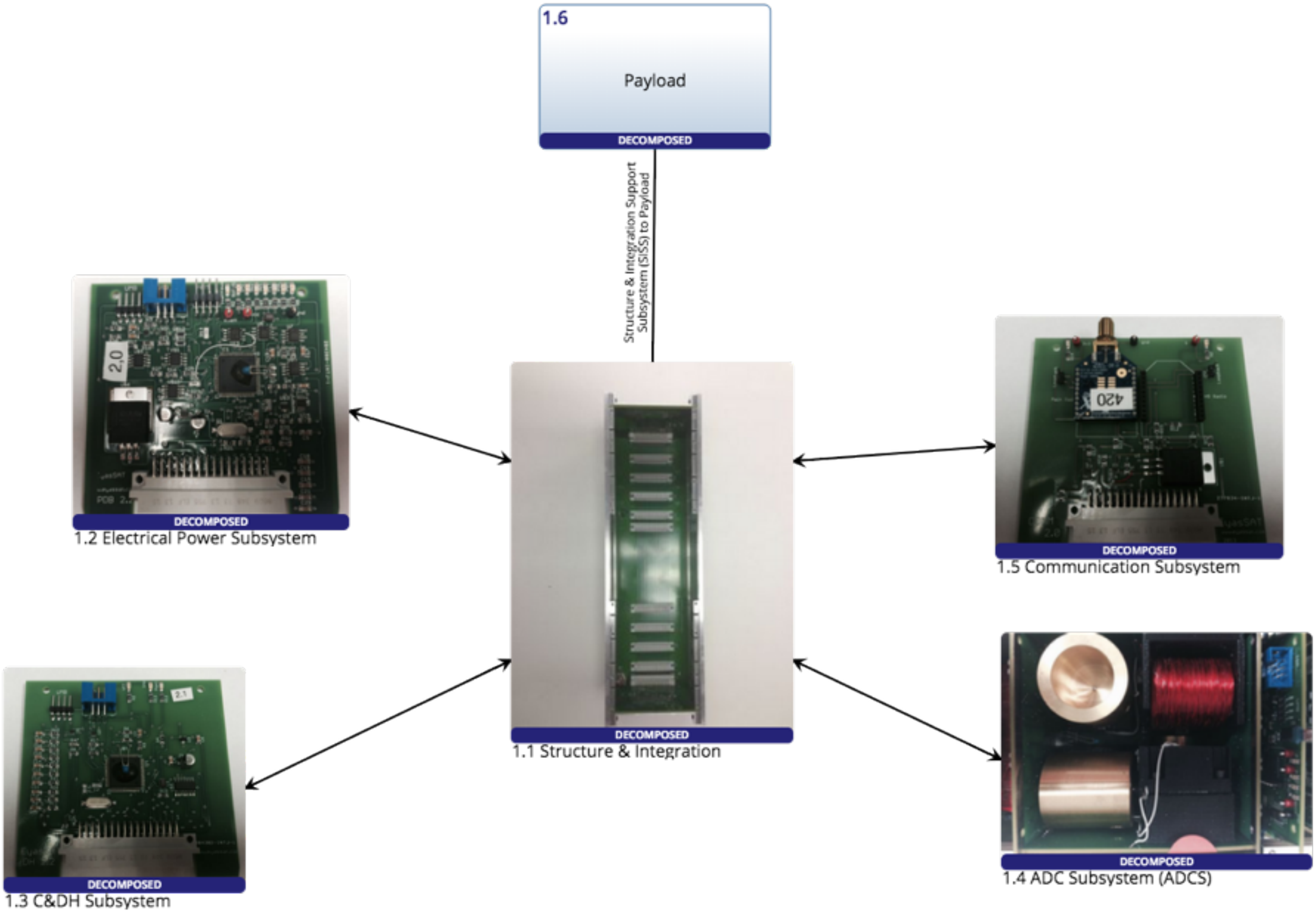
System Requirements - ES3 Interface



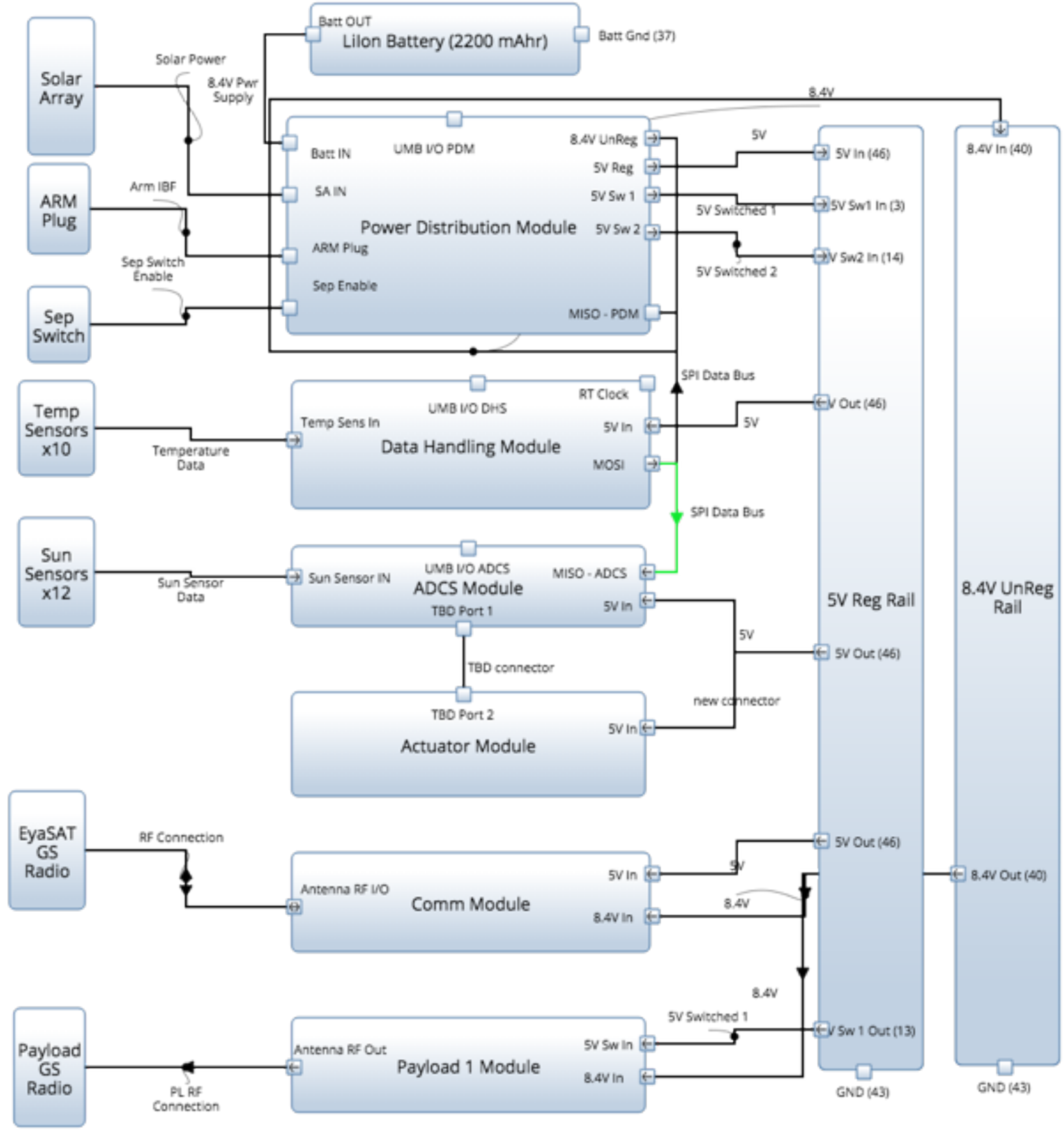
Physical Architecture - Top Level



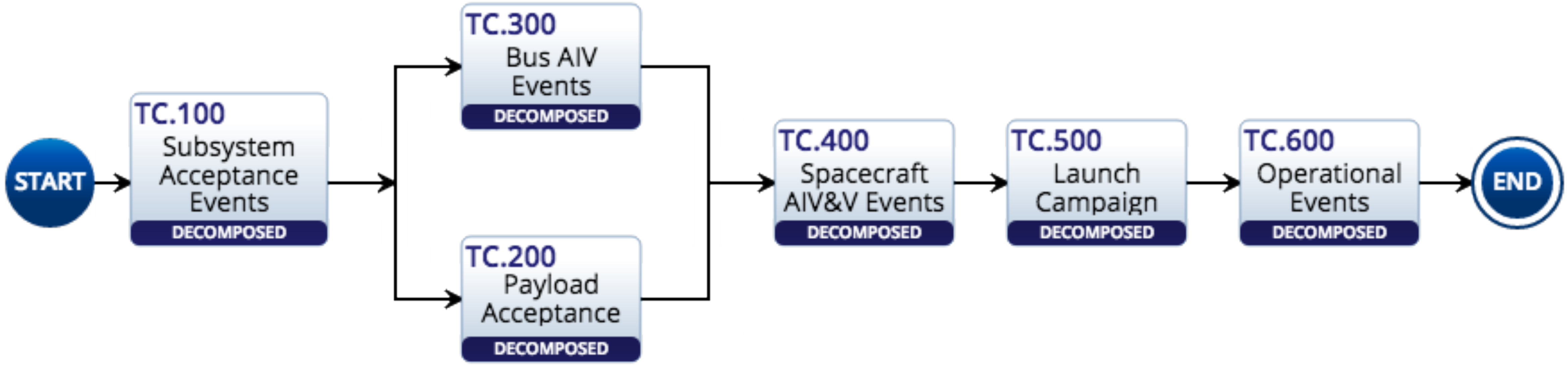
NanoMET Spacecraft Asset Diagram

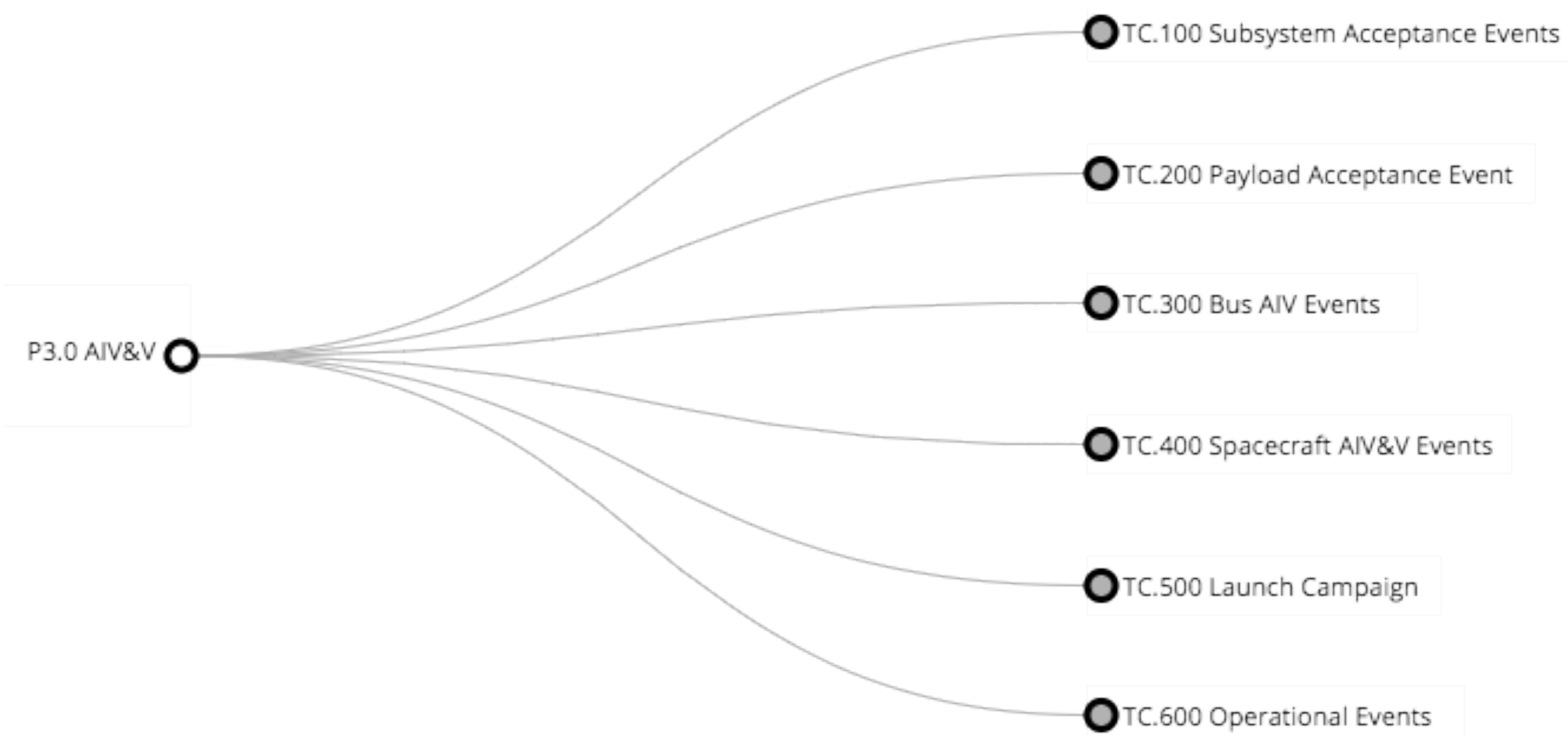


NanoMET Internal Block Diagram

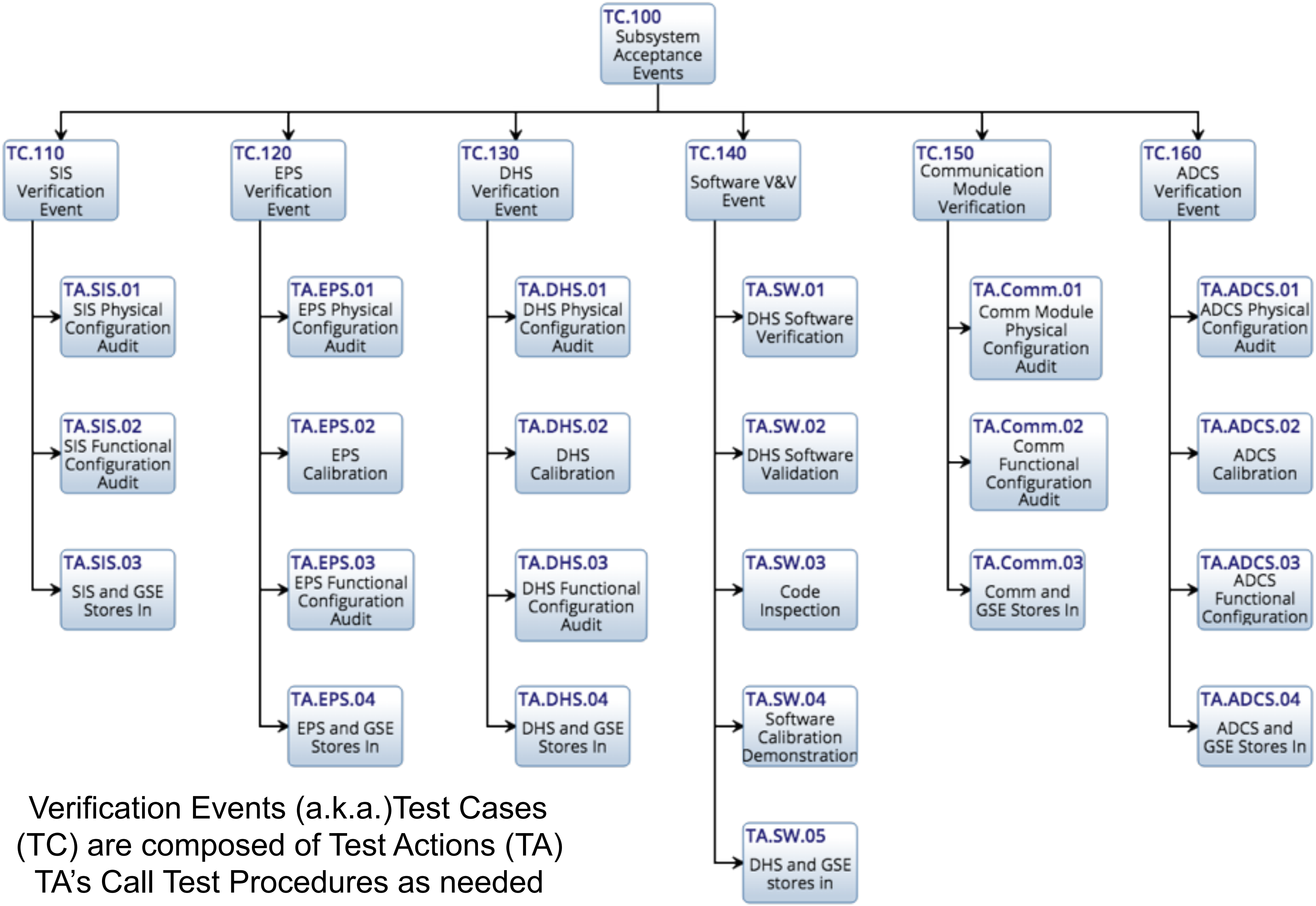


Strategic Verification Planning



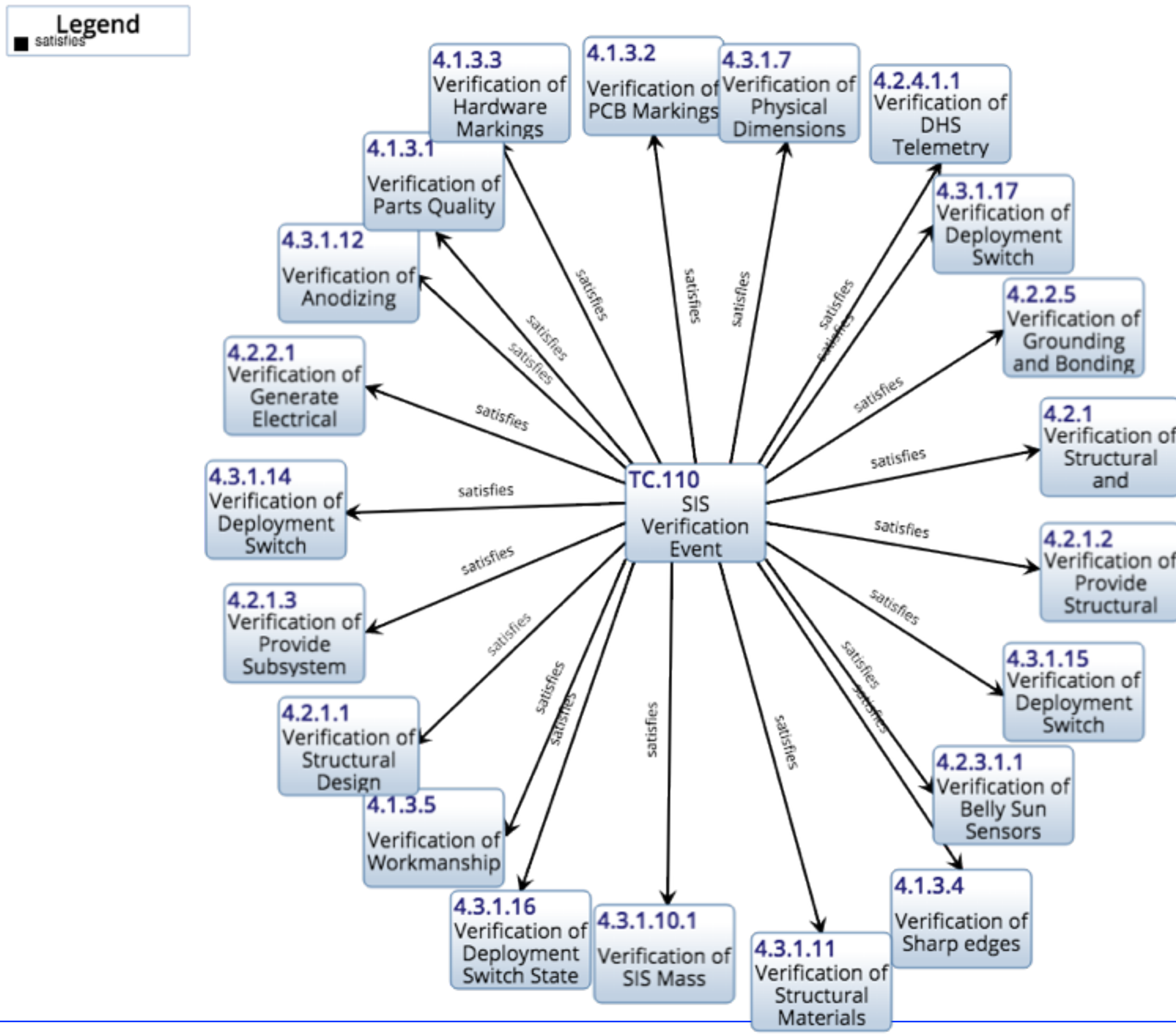


Tactical Planning - Subsystems

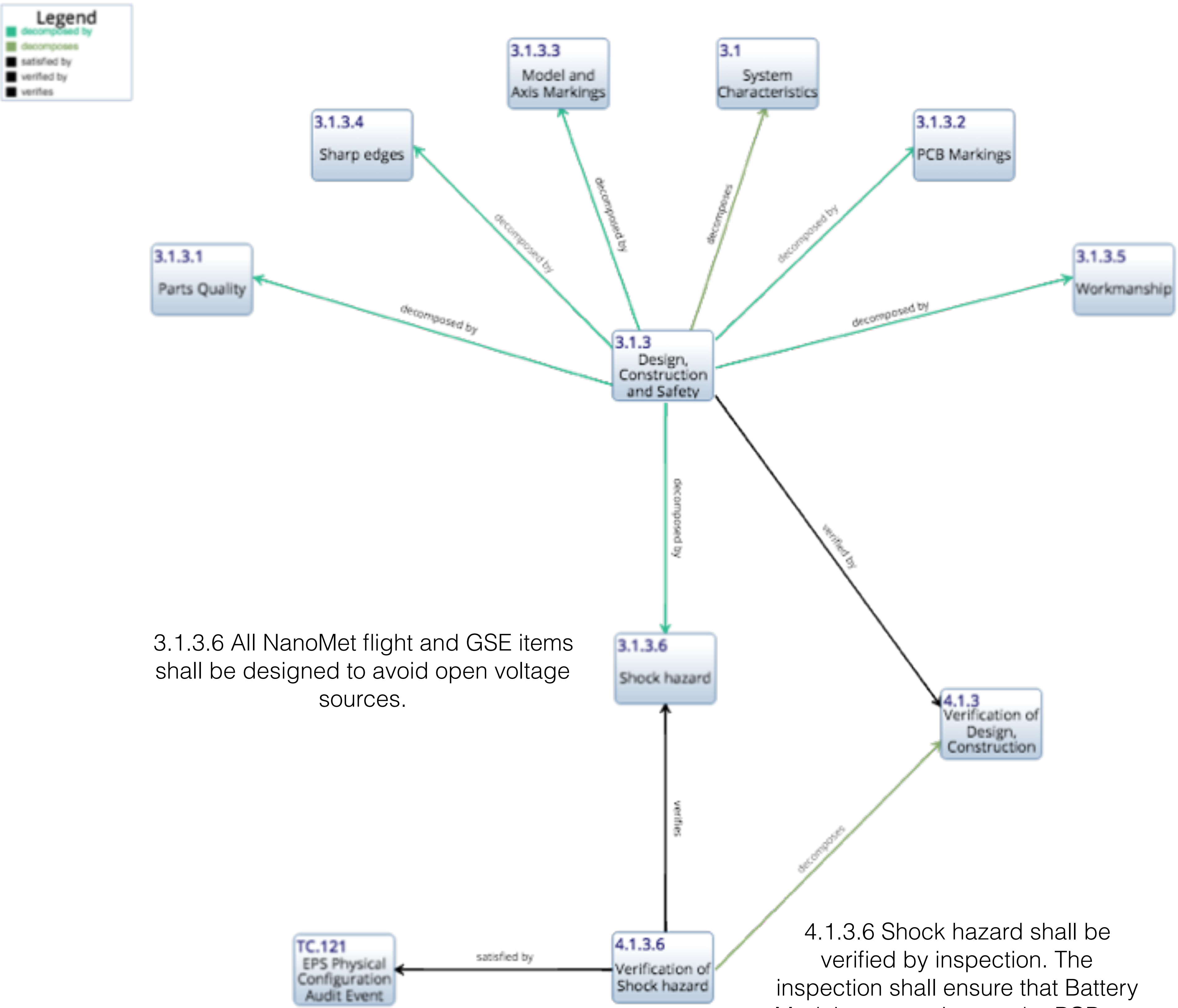


Verification Events (a.k.a.)Test Cases (TC) are composed of Test Actions (TA) TA's Call Test Procedures as needed

Successful Verification Events "Satisfy" Requirements



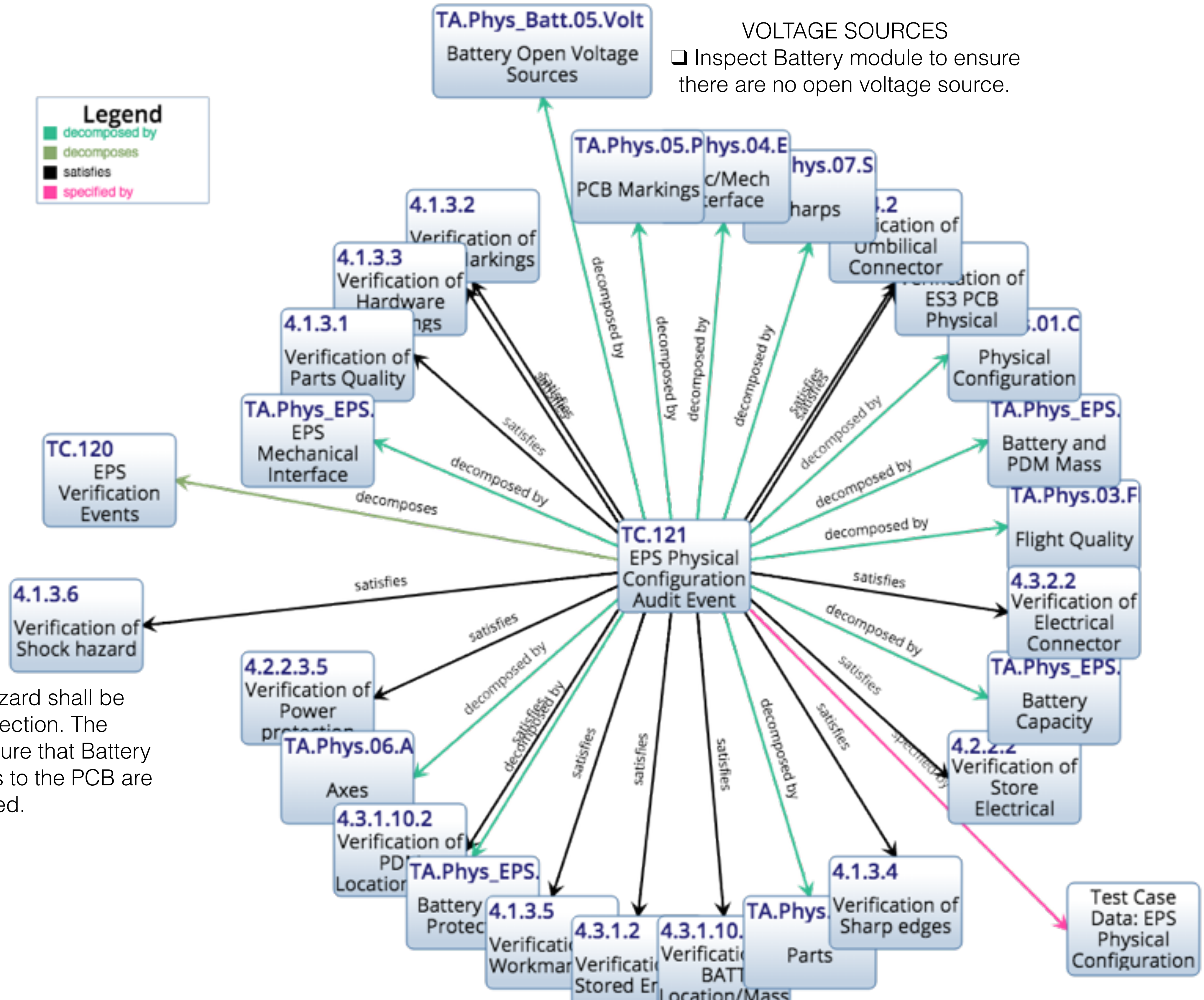
Example Requirement: “Day in the Verification Life…”



3.1.3.6 All NanoMet flight and GSE items shall be designed to avoid open voltage sources.

4.1.3.6 Shock hazard shall be verified by inspection. The inspection shall ensure that Battery Module connections to the PCB are insulated.

Example Requirement: “Day in the Verification Life…”



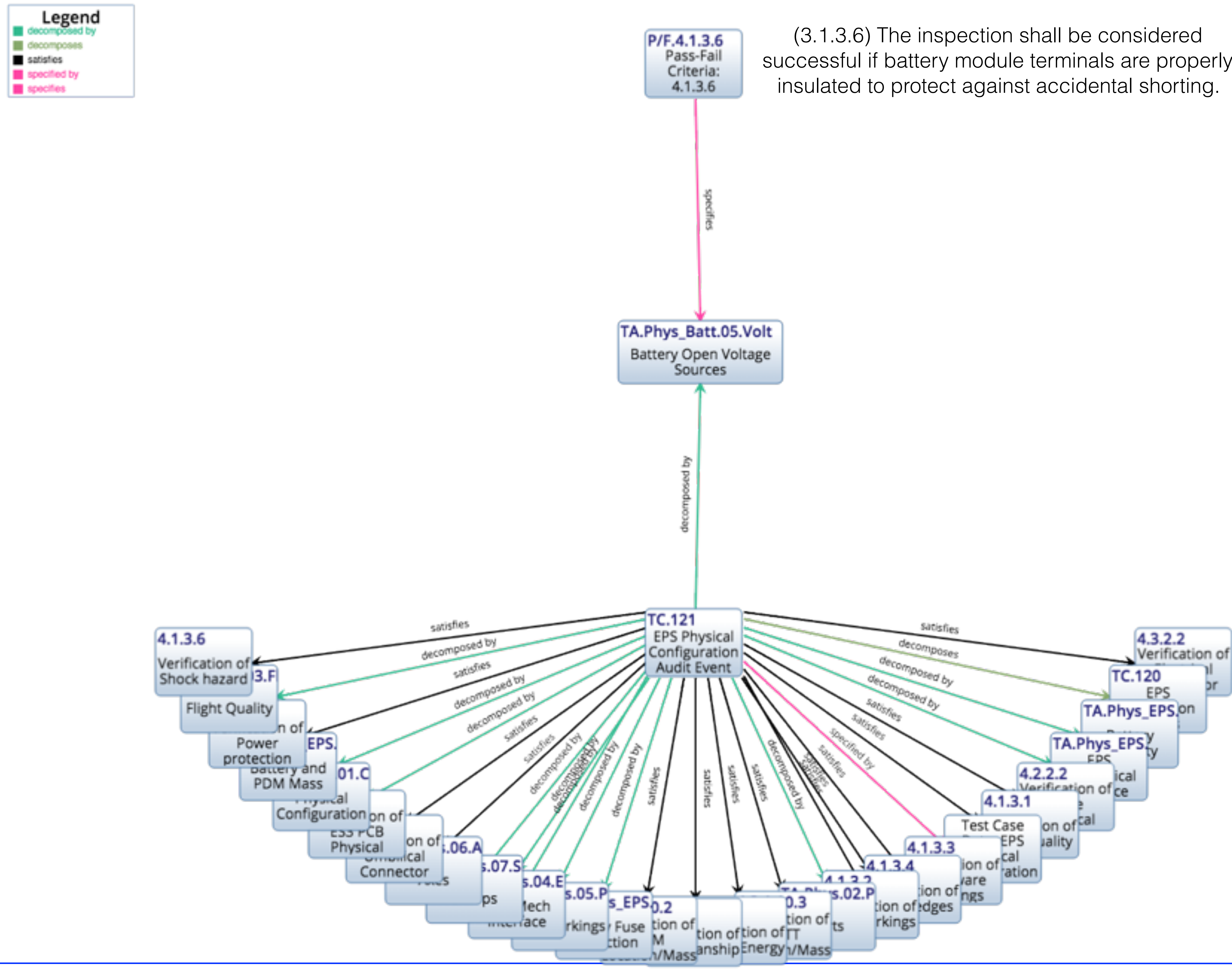
VOLTAGE SOURCES

- ❑ Inspect Battery module to ensure there are no open voltage source.

4.1.3.6 Shock hazard shall be verified by inspection. The inspection shall ensure that Battery Module connections to the PCB are insulated.

Example Requirement: “Day in the Verification Life…”

(3.1.3.6) The inspection shall be considered successful if battery module terminals are properly insulated to protect against accidental shorting.



Example Test Verification Matrix

Test Plan Auto-Generated by MBSE Tool (Innoslate)

Test Case	Verification Requirement		
	Number and Name	Description	Criteria
TC.110 SIS Verification Events	4.1.3 Verification of Design, Construction and Safety	System requirements shall be verified by inspection. The inspection shall look at the verification status of all subordinate requirements.	(3.1.3) The inspection shall be considered successful if all subordinate requirements have been successfully verified.
	4.2.1 Verification of Structural and Integration Support (SIS)	SIS requirements shall be verified by inspection. The inspection shall formally review the verification status of all subordinate requirements.	(3.2.1)The inspection shall be considered successful if all subordinate requirements have been successfully verified.
TC.111 SIS Physical Configuration Audit Event	4.1.3.1 Verification of Parts Quality	System parts quality shall be verified by inspection. The inspection shall involve a review of manufacture-provided design documentation.	(3.1.3.1) The inspection shall be considered successful if all parts are found to be Grade 3 or better.
	4.1.3.2 Verification of PCB Markings	PCB markings shall be verified by inspection. The inspection shall visually examine each PCB component.	(3.1.3.2) The inspection shall be considered successful if all PCBs are properly marked with hardware and firmware version numbers.
	4.1.3.3 Verification of Hardware Markings	Hardware markings shall be verified by inspection. The inspection shall visually examine each mechanical component to verify they include model and/or axis markings a appropriate for the component.	(3.1.3.3) The inspection shall be considered successful if all hardware is properly marked with model (PCBs) and axes (structural components).
	4.1.3.4 Verification of Sharp edges	Hardware markings shall be verified by inspection. The inspection shall visually examine each component using a sharp point tester (i.e. calibrated piece of cloth).	(3.1.3.4) The inspection shall be considered successful if no sharp edges are found.
	4.1.3.5 Verification of Workmanship	Hardware markings shall be verified by inspection. The inspection shall visually examine each component.	(3.1.3.5) The inspection shall be considered successful if all hardware is found to be assembled to flight-quality workmanship standard defined to be free of: loose parts, loose wires, loose connectors or loose solder joints.

Example Test Case “Work Order”

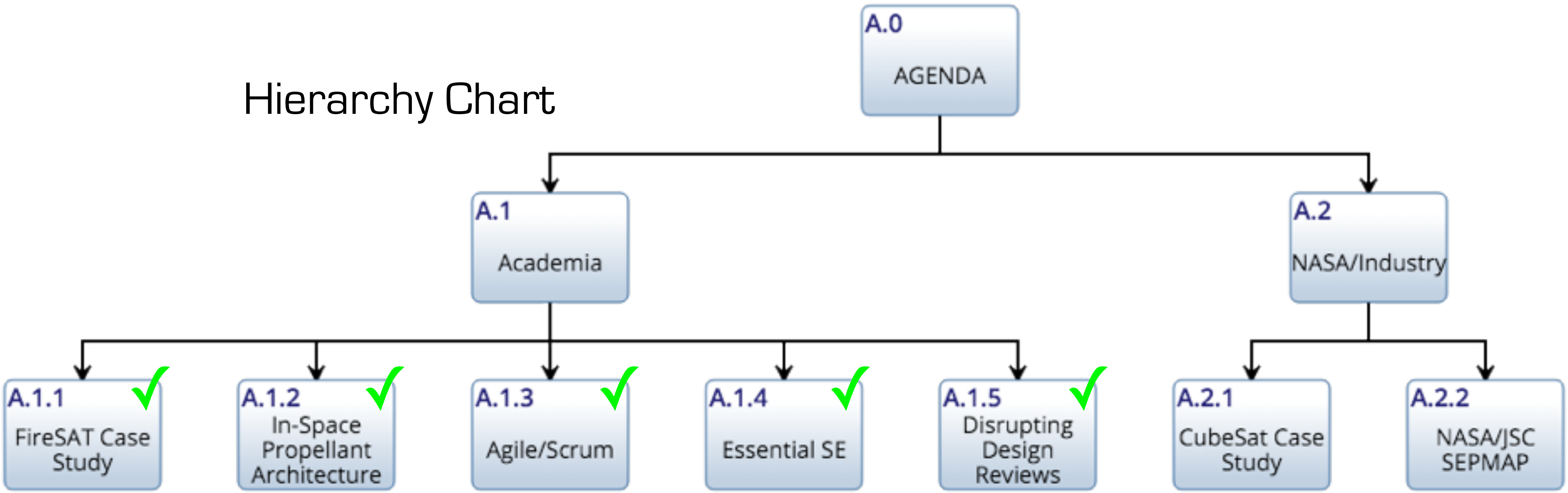
Test Plan Auto-Generated by MBSE Tool (Innoslate)

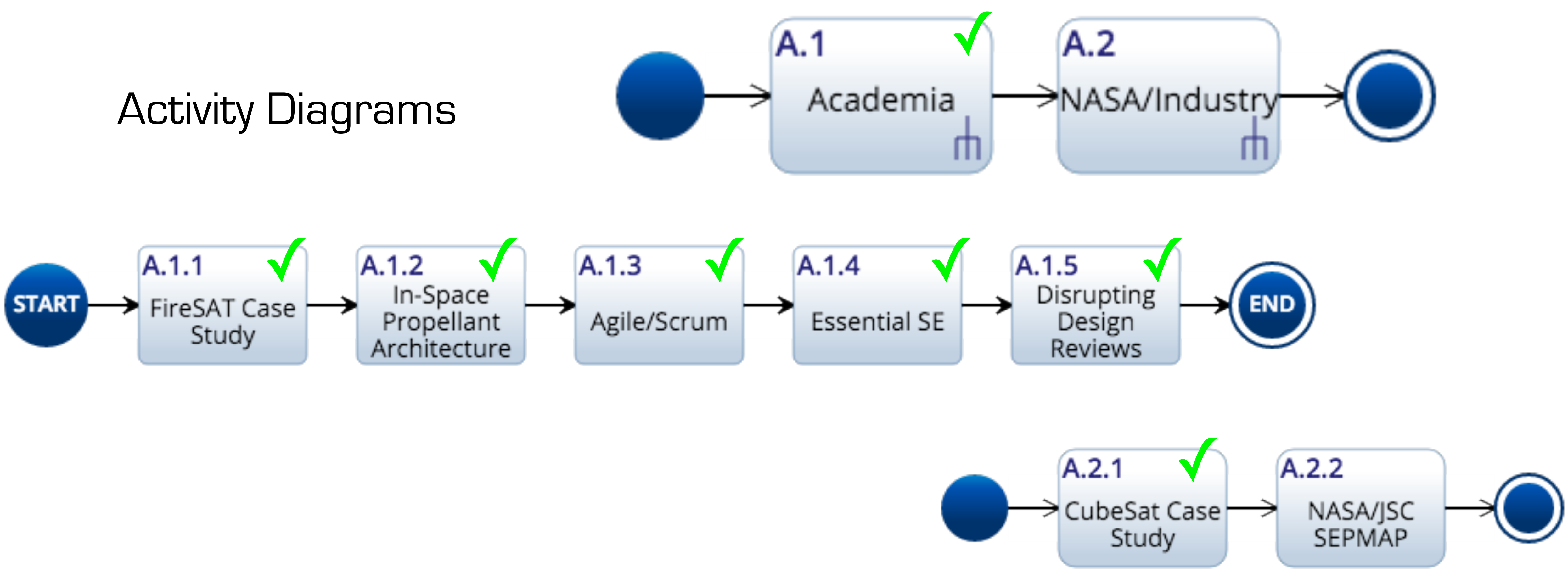
Test Case Number: TC.122	**Test Title:** EPS Functional Configuration Audit Event	**Tester Name:**	**Pass/Fail:**
Revision Number:	**Test Proctor:**	**Test Date:**	Fail
Estimated Execution Time:	30.0 minutes	**Actual Execution Time:**	
Approval Signature:		**Approval Date:**	
Test Objective:	The purpose of the Electrical Power Subsystem (EPS) Functional Configuration is verify all functional design requirements allocated to the EPS --- specifically the Power Distribution Module (PDM) and Battery Module -- that can be performed in a stand-alone configuration.		
Test Setup:	TEST ARTICLES Sign out from flight stores the following configuration end items: (1) Electrical Power Distribution Module (PMD) (2) Battery Module (Pack-1 Type). TEST EQUIPMENT Sign out from GSE stores the following items: - Calibrated Digital Multi-Meter (DMM) with Micro-clip Test Leads (Red and Black) - EyasSAT3 Test Box GSE - USB-to-USB cable - TTL to USB dongle - Magnifying Glass - EGSE Computer (with SCOTTI installed), - EGSE Computer Power Supply - 9V Power Supply with current measurement adapter TEST VENUES 1. Functional Configuration Audit Venue 2. Calibration Venue CAUTIONS AND WARNINGS 1. Handle all NanoMet hardware CAREFULLY (By the board edges or mounting connectors). DO NOT TOUCH circuit boards or connectors except as directed. 2. Keep all food and drink at least 10 feet from the hardware. 3. Take care not to cut your finger in case edges are actually sharp.		
Related Requirements or Configuration Change Requests (Number/Description):	3.2.2.1 - NanoMet solar array shall generate 700 mW (nominally 9 V at 80 mA) electrical power in full sun at 0 degree incidence angle. 3.2.2.3 - NanoMet Power Distribution Module (PDM) shall manage and distribute power including power conditioning, switching, internal monitoring and reporting of voltage, current and temperature states, and internal safing as refined by the following: 3.2.2.3.1 - NanoMet PMD shall employ a direct energy transfer method for battery charge regulation. 3.2.2.3.2 - NanoMet PDM shall supply unconditioned (raw battery) power to the power bus 8 +/- 1 V at up to 2200		

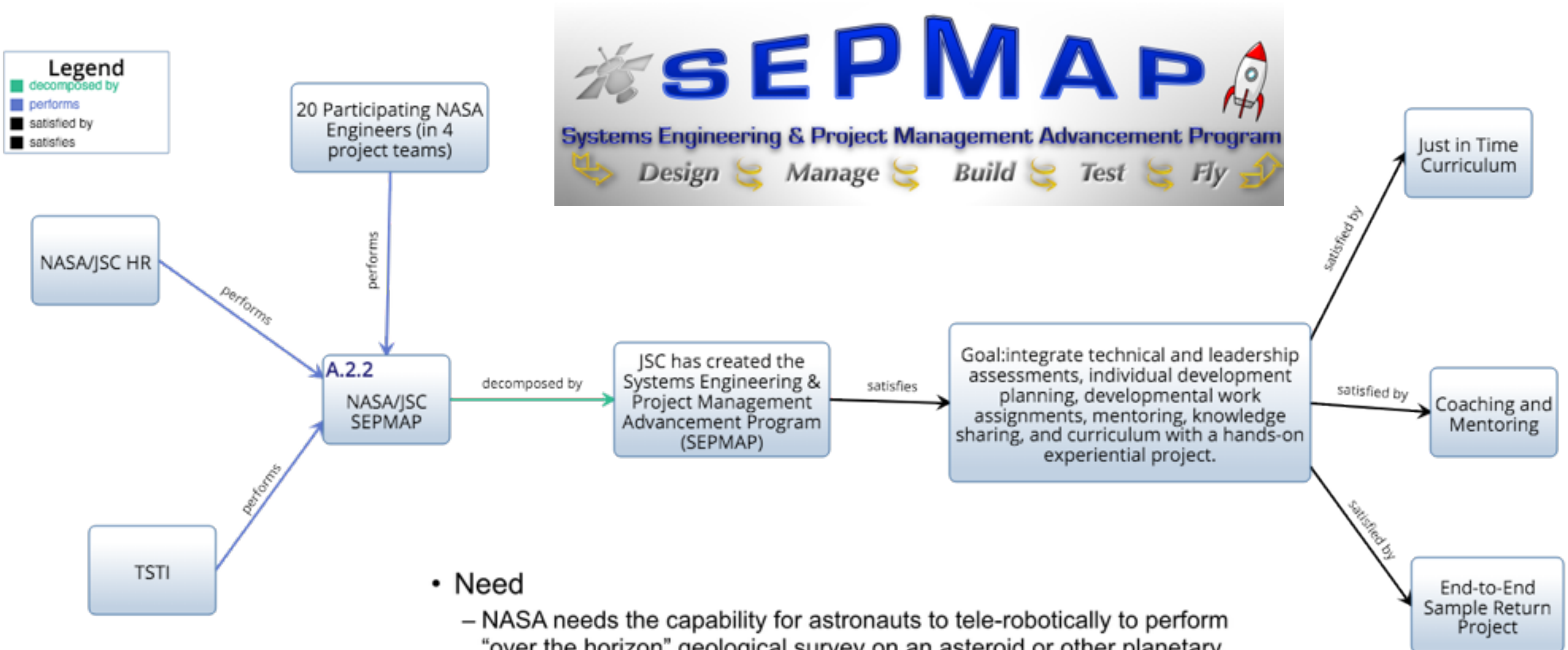
Example Test Case Procedures

No.	Test Action	Expected Results	Pass / Fail	Actual Results / Comments	CR/PR/DR No.
	from the test pin and power supply inputs) ❑Verify the green Vdc LED on the EyasSAT3 Test Box GSE is illuminated ❑Insert the Breakout Board into the front connector of the EyasSAT3 Test Box GSE ❑Configure DMM to read DC volts ❑Connect black clip lead to TP 37 on the Break Out Board ❑Connect red clip to TP 40 ❑Record battery voltage ❑Disconnect both clip leads from the Break Out Board				
4	BATTERY THERMISTOR TEST ❑Configure DMM to read ohms (Ω) ❑Connect black clip lead to TP 22 on the Break Out Board ❑Connect red clip lead to TP 28 ❑Record ambient battery module thermistor resistance (~ 8-12 kΩ) ❑Carefully touch the battery module thermistor ❑Record battery module thermistor resistance (should decrease in value) ❑Disconnect both clip leads from Break Out Board	(3.2.4.1.1) The test shall be considered successful if measured resistance from all temperature transducers (thermistors) varies as expected with temperature AND all telemetry values assigned to DHS are supplied and their calibrated values are within specified ranges as defined by the MASTER TELEMETRY DATABASE.			
5	BATTERY TEST TEARDOWN ❑Remove the Breakout Board from the EyasSAT3 Test Box GSE ❑Remove the Battery Module from the EyasSAT3 Test Box GSE ❑Turn off DMM	All procedures are implemented without incident.			
6	GSE SET UP ❑Remove the Sep Switch jumper from the EyasSAT3 Test Box GSE ❑Insert the PDM into the rear connector on the EyasSAT3 Test Box GSE	All procedures are implemented without incident.			

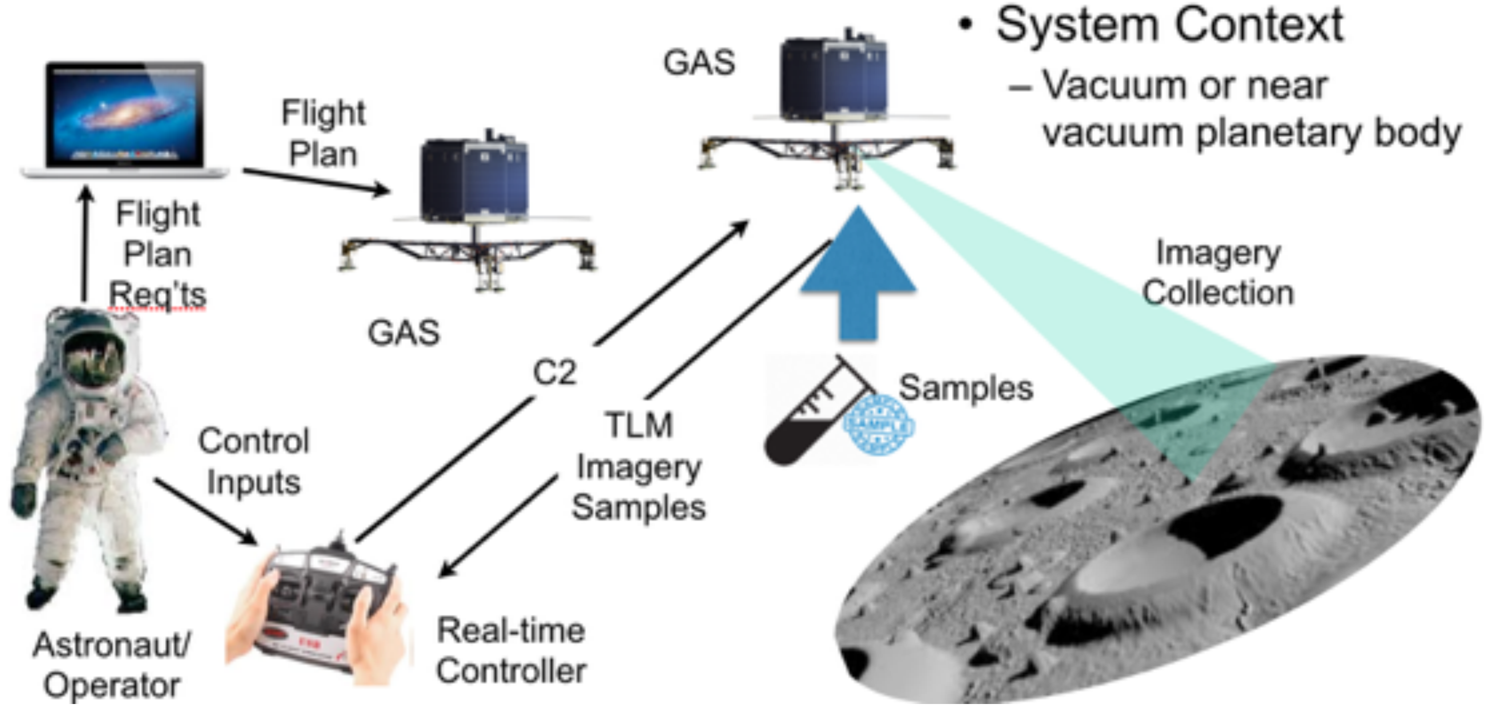
Burn-down Status





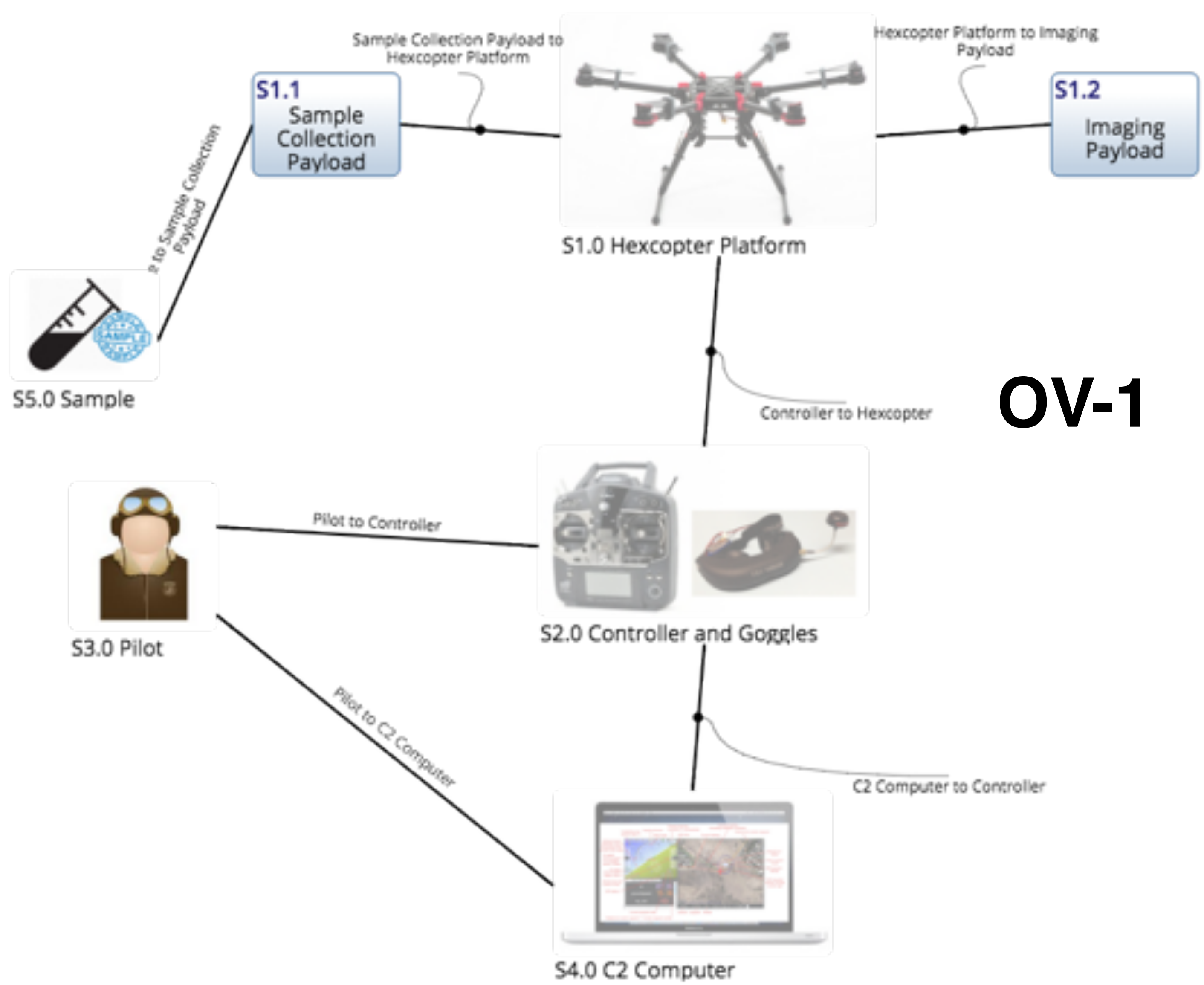


- Need
  - NASA needs the capability for astronauts to tele-robotically to perform "over the horizon" geological survey on an asteroid or other planetary body - a Geological Assistant System (GAS)
- System Context
  - Vacuum or near vacuum planetary body



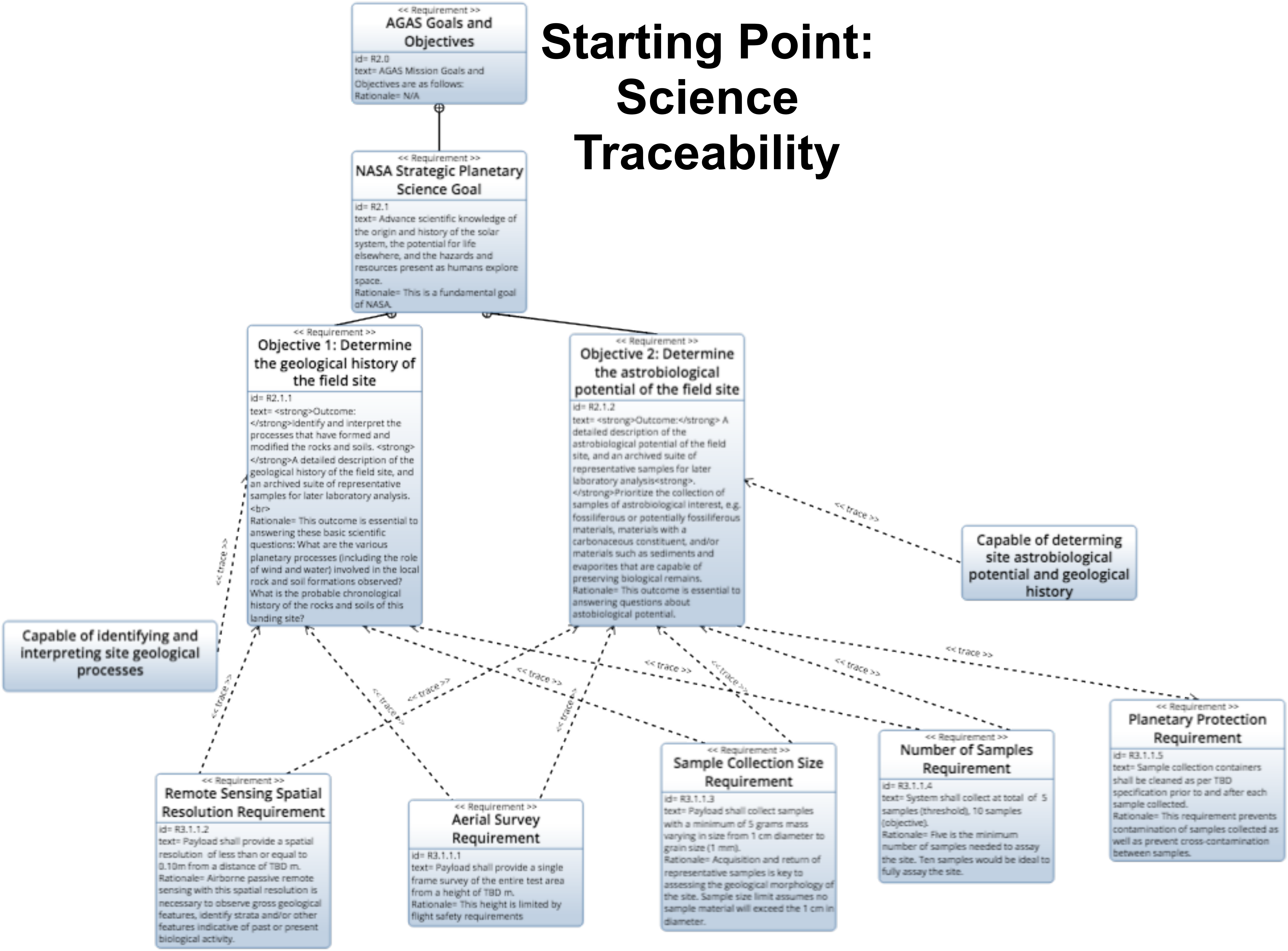
SEPMAP Ground Rules & Constraints

- 20 hand-picked NASA/JSC Engineers in a 16 month system engineering and project management development program
- 7 “just in time” leaning modules (SE, Space Mission Design, System V&V, Human Spaceflight, PM, etc.)
- “Real world” NASA science project to design, build, test and operate a sample return payload as part of an Analogous-Geological Assistant System (A-GAS) (It’s “a gas!”) on a UAV (provided)
- Use of MBSE was <u>mandated</u> for all teams for the entirety of the project (used for <u>all</u> SE and PM deliverables with the exception of MS Project for schedule as well as CAD and other analysis tools)
- Comply with <u>tailored</u> requirements from NPR 7123.1B and 7120.5



OV-1

Starting Point: Science Traceability



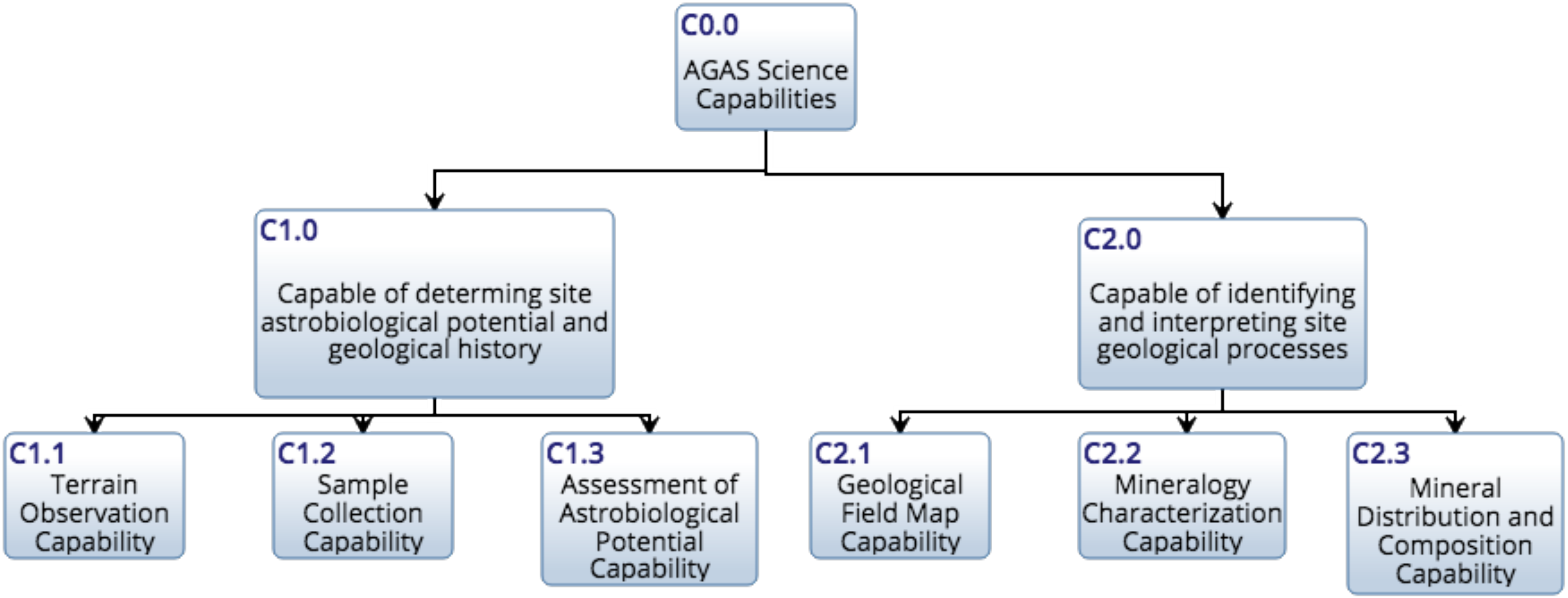
Requirements Matrix

Number	Name	Description	Rationale
R0.0	AGAS Project Guidance		
R2.0	AGAS Goals and Objectives	AGAS Mission Goals and Objectives are as follows:	N/A
R2.1	NASA Strategic Planetary Science Goal	Advance scientific knowledge of the origin and history of the solar system, the potential for life elsewhere, and the hazards and resources present as humans explore space.	This is a fundamental goal of NASA.
R2.1.1	Objective 1: Determine the geological history of the field site	Outcome: Identify and interpret the processes that have formed and modified the rocks and soils. A detailed description of the geological history of the field site, and an archived suite of representative samples for later laboratory analysis.	This outcome is essential to answering these basic scientific questions: What are the various planetary processes (including the role of wind and water) involved in the local rock and soil formations observed? What is the probable chronological history of the rocks and soils of this landing site?
R2.1.2	Objective 2: Determine the astrobiological potential of the field site	Outcome: A detailed description of the astrobiological potential of the field site, and an archived suite of representative samples for later laboratory analysis. Prioritize the collection of samples of astrobiological interest, e.g. fossiliferous or potentially fossiliferous materials, materials with a carbonaceous constituent, and/or materials such as sediments and evaporites that are capable of preserving biological remains.	This outcome is essential to answering questions about astobiological potential.
R3.0	AGAS Technical Requirements	AGAS Project Requirements are decomposed as follows:	N/A
R3.1	Functional Requirements	System Functional Requirements are decomposed as follows:	N/A
R3.1.1	Payload Functional Requirements	Payload functional requirements are decomposed as follows:	N/A
R3.1.1.1	Aerial Survey Requirement	Payload shall provide a single frame survey of the entire test area from a height of TBD m.	This height is limited by flight safety requirements
R3.1.1.2	Remote Sensing Spatial Resolution Requirement	Payload shall provide a spatial resolution of less than or equal to 0.10m from a distance of TBD m.	Airborne passive remote sensing with this spatial resolution is necessary to observe gross geological features, identify strata and/or other features indicative of past or present biological activity.
R3.1.1.3	Sample Collection Size Requirement	Payload shall collect samples with a minimum of 5 grams mass varying in size from 1 cm diameter to grain size (1 mm).	Acquisition and return of representative samples is key to assessing the geological morphology of the site. Sample size limit assumes no sample material will exceed the 1 cm in diameter.
R3.1.1.4	Number of Samples Requirement	System shall collect at total of 5 samples (threshold), 10 samples (objective).	Five is the minimum number of samples needed to assay the site. Ten samples would be ideal to fully assay the site.
R3.1.1.5	Planetary Protection Requirement	Sample collection containers shall be cleaned as per TBD specification prior to and after each sample collected.	This requirement prevents contamination of samples collected as well as prevent cross-contamination between samples.

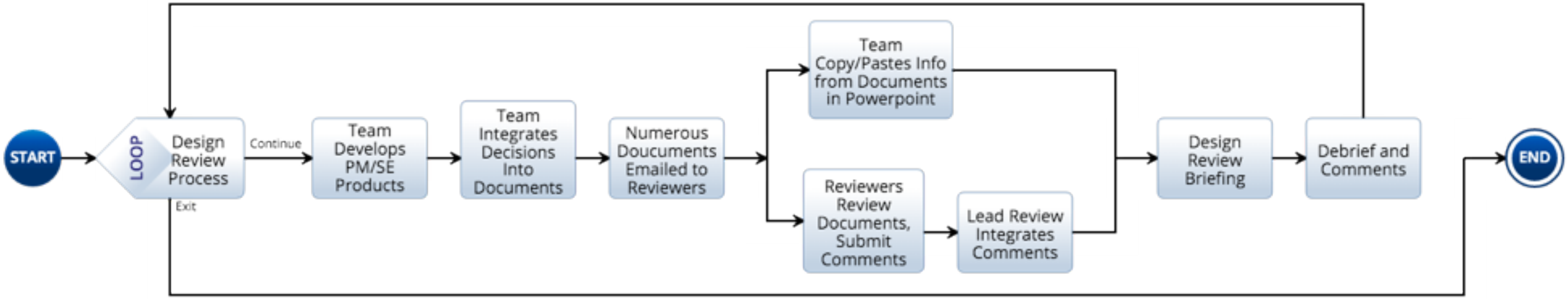
Requirements Matrix (cont'd)

Number	Name	Description	Rationale
R3.1.2	Platform Functional Requirements	Platform functional requirements are decomposed as follows:	N/A
R3.1.2.1	Tele and Auto Ops	System shall tele-robotically and/or autonomously navigate the defined test area (e.g. JSC Mars Yard) to perform all mission operations.	This is an operational requirement coming from AOD.
R3.1.2.2	Feedback	Operators shall deliver real-time/near-real-time (TBD) feedback to evaluators of system performance	This is an operational requirement needed for safe flight operations.
R3.1.2.3	POV Imagery	System shall provide real-time point of view (POV) imagery to operator	This is an operational requirement needed for safe flight operations.
R3.2	Operational Requirements	Project Operational Requirements are decomposed as follows:	N/A
R3.2.1	Start/End Point	All mission operations shall begin and end at the same pre-defined start position approximately 100 m from the test area.	This requirement provides a consistent start and end point for all teams.
R3.2.2	Test Area	Test area shall be contained within the JSC "Mars Yard" covering covering at least 2500 m2 (~50 m square).	For flight safety reasons, all operations are constrained to the Mars Yard.
R3.2.6	Time Limit	A single mission operation test campaign shall be completed in less than TBD minutes	A time limit is needed to bound the duration of operations.
R3.2.7	Geo Field Reporting	Teams shall deliver a comprehensive geo field report in no more than 7 days after each operational sortie.	This is a minimum time needed deliver the compiled data to principle investigators.
R3.2.8	Bio Assessment Reporting	Teams shall deliver a comprehensive biological assessment of the site in no more than 7 days after the operational sortie.	This is a minimum time needed deliver the compiled data to principle investigators.
R3.3	Interface Requirements	Interface requirements between the payload and platform are as follows:	
R3.3.1	Payload Mass	Payload mass not to exceed 3.6 kg (TBR).	Excess payload mass will severely limit actual operational flight time and may create stability and handling problems for the platform.
R3.3.2	Payload Mechanical Interface Requirement	Mechanical interface between payload and platform shall be TBD.	TBD
R3.3.3	Payload Electrical Requirement	Electrical interface between payload and platform shall be TBD.	TBD
R3.3.4	Payload Data Interface	Data interface between payload and platform shall be TBD.	TBD
R3.4	Environmental Requirements	TBD	TBD
R3.5	Reliability Requirements	TBD	TBD
R3.6	Safety Requirements	TBD	TBD
R3.7	Other Requirements	TBD	TBD

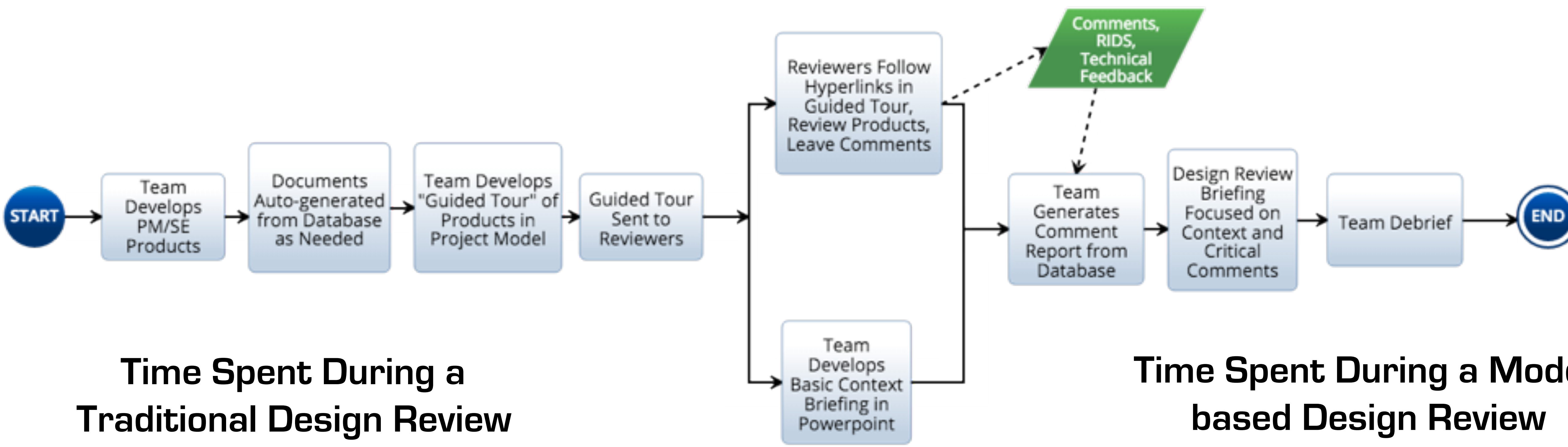
Capabilities



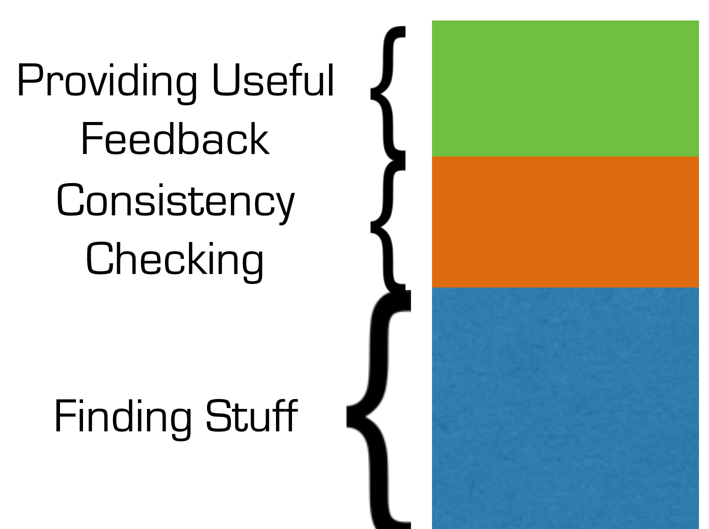
Traditional Document-based, Document—driven Design Review Process



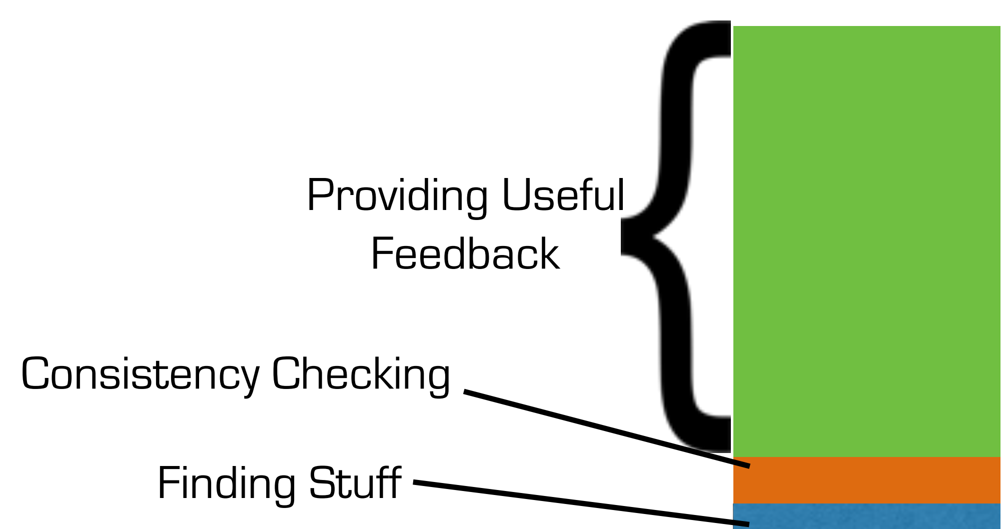
SEPMAP MBSE-based, Criteria-driven Design Review Process



Time Spent During a Traditional Design Review



Time Spent During a Model-based Design Review



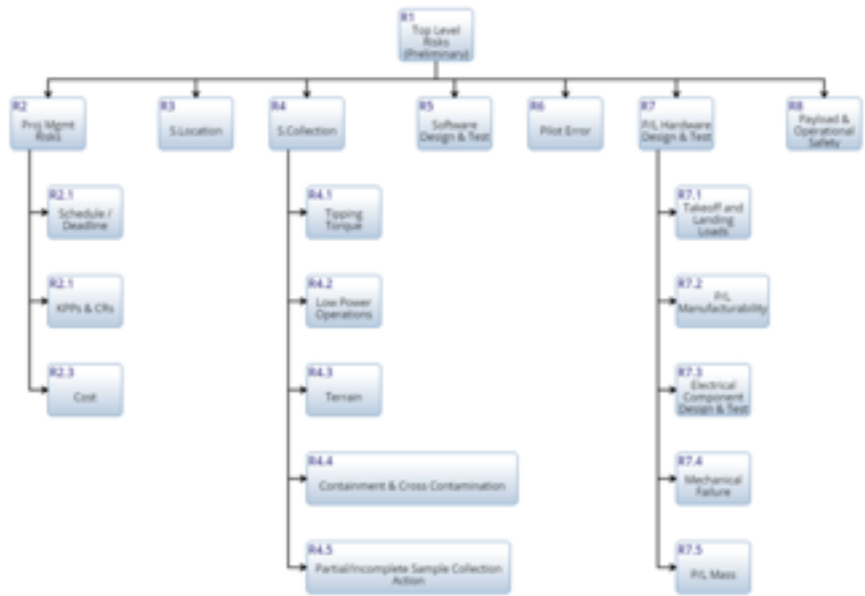
Templates developed for each design review with tailored entrance/success criteria. Evidence hyperlinked to MBSE or other model artifacts. Reviewers use this as a “bread crumb” trail through the model.

1.4.3 EC4.c

Updated risk assessment and mitigation.

Evidence/Comments:

The RASCALS have identified and characterized (in terms of severity/consequence and probability of occurrence) a total of 7 Top Level Project Risks and 13 "child" risks as indicated in the Risk Hierarchy Diagram and Risk Matrix Chart below.



	Negligible	Minor	Moderate	Serious	Critical
High					
Medium High					
Medium			R4.5		
Medium Low		R8 Payload &	R4.3 Terrain	R3 S.Location R7.4 Mechanical	R4 S.Collection
Low	R1 Top Level Risks R4.2 Low Power R2 Proj Mgmt R7 P/L Hardware			R2.3 Cost R2.1 Schedule / R2.1 KPPs & CRs R7.2 P/L R4.1 Tipping R7.3 Electrical	R6 Pilot Error R5 Software R4.4 Containment R7.5 P/L Mass R7.1 Takeoff and

1.4.14 EC4.n

Baseline operations concept. Evidence/Comments:

The project ConOps diagram is located here.

The current plan is to collect at least 5 samples from 5 different locations on one sortie and return safely to base to deliver the products. Additional samples will be collected on subsequent sorties. At the beginning the team was aiming on placing and connecting two nets for each site and for each servo, but due to footprint limitation and some technical difficulties observed during the prototype demo test, RASCAL team decided to extend the arm net and place one net per site and per servo. Final design will be documented after CDR, but for now the decision still in discussion phase.

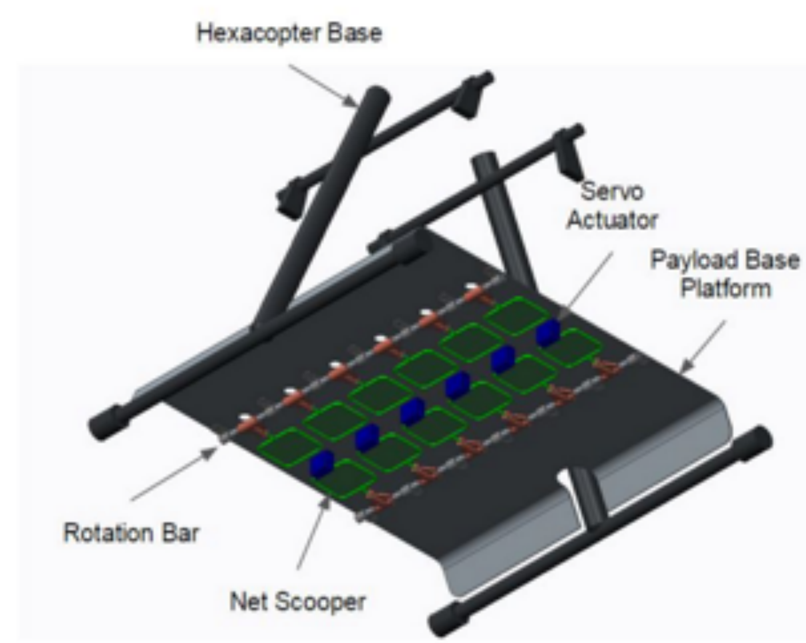
During the prototype / concept testing of one net, force loaded with rubber bands and/or springs, the team experienced some problems or issues with rotating the net all the way, 180 degree to collect "MARS" sample; and in several occasions the net stuck to the surface of the site (see video here).

A redesign of the net forward face by redefining its square shape to more pointed forward shape, to mirror the shape of the shovel, improved the net arm rotational and the collection of the samples. Then another issue encountered when RASCAL team were asked to be prepared to collect sample from hard surfaces, similar to concrete / cement surface. So the team went back to the drawing and design board and discussed several options and workarounds on how to meet this new requirement. One option was to implement two types of nets. One net has its original regular rectangular shape used on hard surface, and another net shape is the "shovel" shape used for soft or gravel surface. Also, the team was able to define a workaround scenario in case of the hard stoppage of the net to any surface, is to slowly lift off the hexcopter from its worksites, allowing the "stuck net" to rotate and collect samples as the hexcopter is flying off the ground.

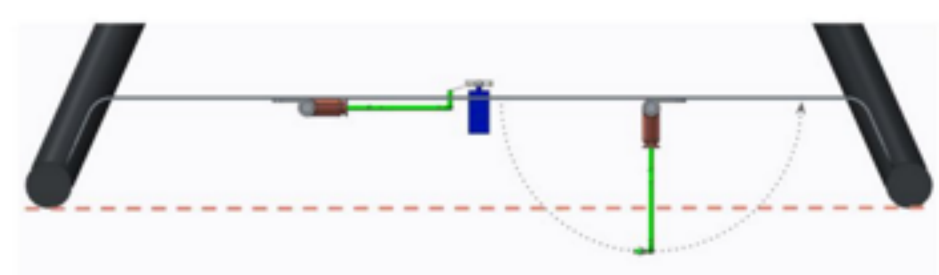
A presentation of the payload concept can be found here.

A video of a payload feasibility check can be found here

Net Scooper Concept Components from SRR:



Front View:



For the actual design dimensions, please click at the link below and download the draft drawing:

https://app.innoslate.com/project/p1EQKC1/database

Comment Report

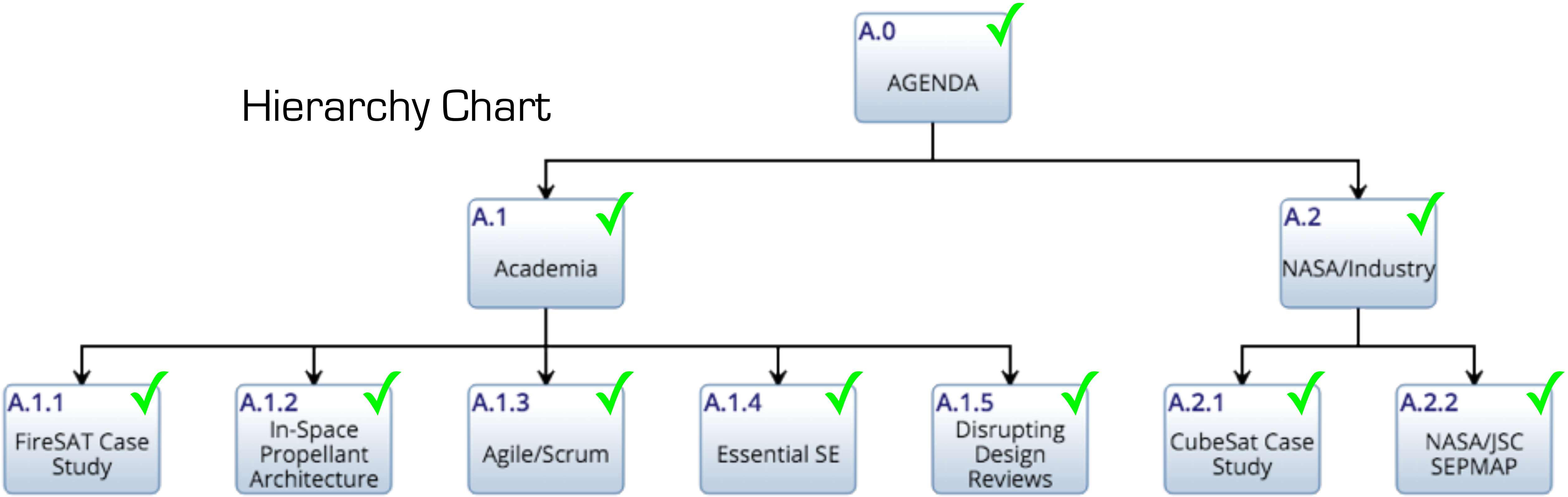
Entitv	Descriotion	Comment
	sites of scientific interest[*cr*] Collect samples in the size range of 1mm to 1 cm, density = 2-3 cm^3. [*cr*] Return samples to the operations team and PI without cross contaminating[*cr*] Generate a report detailing the samples collected. [*cr*] [*cr*] With PI, generate a detailed description of the astrobiological potential of the field site, and an archived suite of representative samples for later laboratory analysis.[*cr*] Generate a detailed description of the geological history of the field site, and an archived suite of representative samples for later laboratory analysis.[*cr*] [*cr*] [*cr*] [*cr*] Comments:	
MCR.1.3 Top-Level Requirements	Evidence:[*cr*] The RASCALS have identified their Top-Level Project Requirements as the following: [*cr*] [*cr*] AGAS shall Provide survey images required to determine sample collection sites[*cr*] AGAS shall collect at least 1 sample from 5 sites (minimum) and a total of minimum 5 samples.[*cr*] Cross-contamination of samples shall be prohibited[*cr*] AGAS shall return samples to PI from 5 different sites; at least one sample per site. [*cr*] The entire RASCALS project requirements set is located here.[*cr*] [*cr*] Comments: [*cr*] The Top-Level Requirements listed above are the 'non-negotiable' items as identified by stakeholders per the interviewed conducted thus far (also known as 'Key Performance Parameters' , or KPPs). In addition to the KPPs, the program architecture also dictates that the samples must be collected remotely using the hexcopter platform operated by NASA pilots. As such, the RASCALS KPPs are specific to the payload design and operation.	Wiley Larson (wileyjlarson@mac.com) commented: You've captured the idea. These are not stated as requirements but the RASCAL project reauirements look good.
		Jerry Sellers (jerry.sellers@mac.com) commented: Meets MCR Expectations: Yes. Ways to improve: It is always dangerous to paraphrase requirements. Better to restate them verbatim. Better still, link to to the actual requireemnets, add a comment and/or color code to show which are the KPPs. Suggestions: Same, see above.
MCR.1.4 WBS - PBS	Evidence:[*cr*] [*cr*] WBS Task Name 1 RASCALS 1.1 Project Milestones 1.2 PM/SE Role Rotation Schedule 1.3 Project Management Products 1.4 Systems Engineering Products 1.5 Safety & Mission Assurance 1.6 Hexacopter	Wiley Larson (wileyjlarson@mac.com) commented: This WBS is a nicely tailored version of the 7120 format. Looking at your WBS...primarilv too-level products look good.
		Jerry Sellers (jerry.sellers@mac.com) commented:

Quotes from Reviewers/Participants

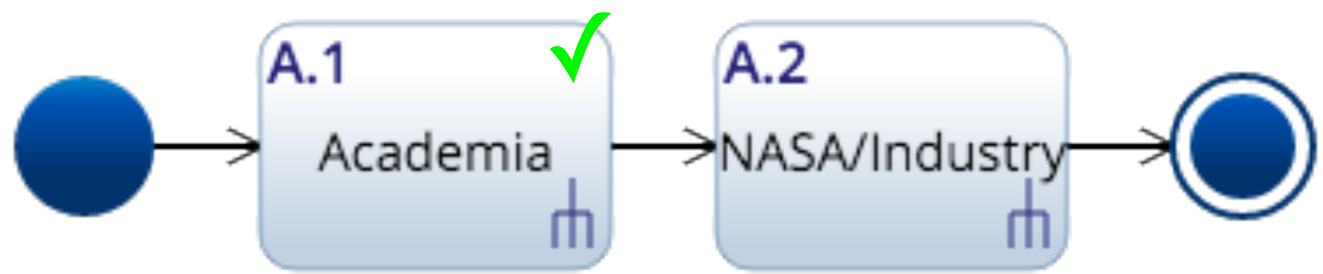
- *I like the way the MBSE approach gives a structured, systematic roadmap that covers the complete content of the project. It also helps the developer ensure they have captured all aspects of their project and not have inadvertently left something out.* - Reviewer
- *I found the review to be much more intuitive and to be easier because of the linked products, as well as the depth of content of each of the products.* - Reviewer
- *Model-based reviews risk being a trip through the trees without finding the forest. The team still needs to provide reviewers a big picture for context along with a detailed roadmap so they can find the details they are interested in.*- Program Participant
- *The model-based tool used by our teams helped keep reviewers focused and able to see all facets—requirements, concept of operations, architecture—at the touch of a button. All comments were gathered, organized and available for easy inspection anytime during the process*. - Reviewer
- *The model-based tool literally forced the design team to apply logic and rigor as they designed the system…consequently, our reviews became much more productive and useful.* - Reviewer
- *...turned an arduous, time-consuming task into an enjoyable, efficient activity for the review team.* - Reviewer
- *The model-based tool, by organizing the design information for reviewers, cut the time it took us to perform a review by one third!* - Reviewer
- *The tool has definitely made it better to provide input in one place and ensure all relevant input is captured. As a reviewer, it has been very easy to use the tool to check information and provide feedback. The ability for those giving reviews to track changes and edits in the system is great as well.* - Reviewer
- *The traditional way of having a presentation with lots of supporting paperwork is burdensome because you get lost in all the paperwork and sometimes the same information is in multiple places. The current process we have streamlines everything and is a time savings for all.* - Reviewer

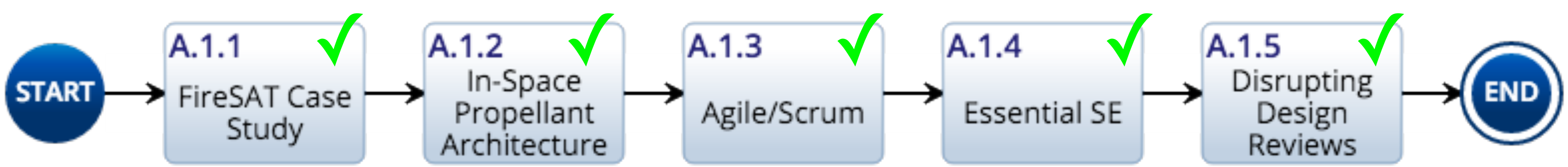
Burn-down Status

Hierarchy Chart



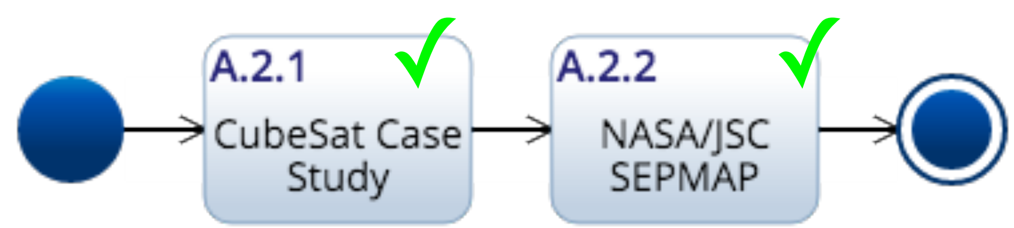
Activity Diagrams





All models built using Innoslate

Thank you for your attention!



Special Thanks to SPEC Innovations for their support of this research