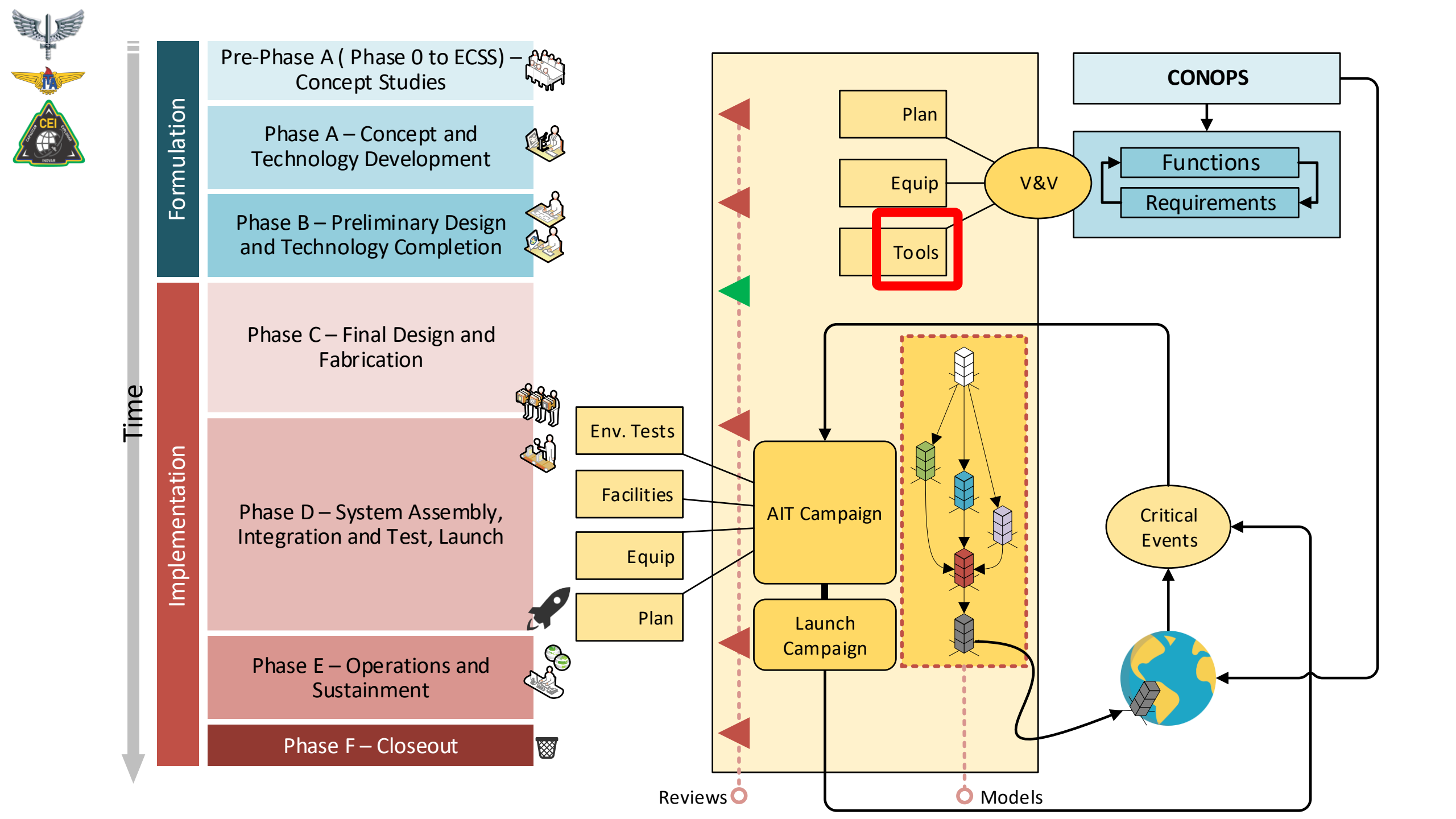
Tools and Processes to Verification

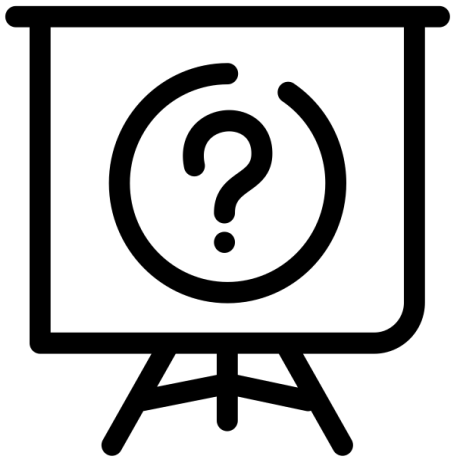
[SIS-08][LEC-003]

Date	SES	In Class	Deliverables
Aug, 1	01	[LEC-000] Course Introduction [LEC-001] SE Review	-
Aug, 8	02	[LEC-002] Global Verification Process	[PRD-001] [redacted]
Aug, 15	03	[LEC-003] Tool and Processes to Verification	[PRD-002] [redacted] Product Tree
Aug, 22	04	[LEC-004] Life Cycle, Reviews & Baselines	[PRD-003] Revised Requirements
Aug, 29	05	[LEC-005] Model Philosophy	[PRD-004] Verifications per Requirement through the Life Cycle
Sep, 5	06	[LEC-006] Preparing to test Campaigns	[PRD-005] Models
Sep, 12	07	[LEC-007] Planning V&V	[PRD-006] Test Articles, Procedures & VCD
Sep, 19	08	[TST-001] V&V Conceptual Questions [PRD-007] DRAFT V&V Plan Presentation	[PRD-007] DRAFT V&V Plan (DVM)
Sep, 26	Week off		
Oct, 03	09	[LEC-008] AIT Process	[PRD-008] End to End Test Articles
Oct, 10	10	[LEC-009] Critical Events & Environmental Tests	[PRD-009] AIT Activities through the Life Cycle
Oct, 17	11	[LEC-010] Testing Facilities	[PRD-010] Vehicle and On-Orbit Testing
Oct, 24	12	[LEC-011] Planning AIT	[PRD-011] Facilities
Oct, 31	13	[LEC-012] GSEs [LEC-013] SCOE/OCOE	[PRD-012] AIT Flows & Activity Log
Nov, 07	14	[LEC-014] Launching Campaign	[PRD-013] GSEs
Nov, 14	15	[LEC-015] Trends / MBSE / Industry 4.0	[PRD-014] AIT Task Sheets [PRD-015] Vehicle Integration & Launching Plan
Nov, 21	16	[TST-002] AIT Conceptual Questions [PRD-016] V&V & AIT Plans Presentation	[PRD-016] V&V & AIT Plans
Nov, 28 Dez, 05	EXAM: Design of an AIT Facility to ITA's SmallSat Projects		

CONOPS


Time
Formulation
Implementation
Pre-Phase A (Phase 0 to ECSS) – Concept Studies
Phase A – Concept and Technology Development
Phase B – Preliminary Design and Technology Completion
Phase C – Final Design and Fabrication
Phase D – System Assembly, Integration and Test, Launch
Phase E – Operations and Sustainment
Phase F – Closeout
CONOPS
Functions
Requirements
Plan
Equip
Tools
V&V
Env. Tests
Facilities
Equip
Plan
AIT Campaign
Launch Campaign
Critical Events
Reviews
Models

How do we organize the projects?



LEVEL

Verification Levels

- The requirement verification shall be performed incrementally at different verification levels. The number and type of verification levels depend on the complexity of the project and on its characteristics. The typical verification levels for a space project are:
  - **I. Equipment**(Example: valves, batteries);
  - **II. Subsystem** (Example: electrical power, attitude control);
  - **III. Element**(Example: launcher, satellite, ground station);
  - **IV. System** (Example: manned infrastructure system).
- The identification of the critical verification levels is driven by technical and programmatic considerations (e.g. functional architecture, overhead cost)

System Hierarchy (1/2)

- **Mission**-An individual system or groups of systems operated to meet a specific set of objectives.
- **System**-A composite of hardware, software, skills, personnel, and techniques capable of performing and/or supporting an operational role. A complete system includes related facilities, equipment, materials, services, software, technical data, and personnel required for its operation and support to the degree that it can be considered a self-sufficient unit in its intended operational and/or support environment.
  - The system is what is employed operationally and supported logistically. (More than one system may be needed to conduct a mission.)

System Hierarchy (2/2)

- **Segment-**A grouping of elements that are closely related and which often physically interface. It may consist of elements produced by several organizations and integrated by one.
- **Element**-A complete, integrated set of subsystems capable of accomplishing an operational role or function.
- **Subsystem**-A functional grouping of components that combine to perform a major function within an element.
- **Component**-A functional subdivision of a subsystem and generally a self-contained combination of items performing a function necessary for subsystem operation. A functional unit viewed as an entity for purpose of analysis, manufacturing, testing, or record keeping.
- **Part**-A hardware element that is not normally subject to further subdivision or disassembly without destruction of designated use.

Hierarchical Level Names and Examples

Hierarchical Level Name	Examples
Mission	Needs + Objectives + Operation of Everything Necessary to Meet the Objectives
System*	Total System = Spacecraft + Launch Vehicle + Ground Support Equipment + Communications Systems (TDRSS, etc.) + NASCOM + POC + Science Data Center + ...+ Personnel
Segment	Flight = Spacecraft Bus + Instruments + Launch Vehicle +...
Element	Spacecraft = Structure + Power + C&DH + Thermal + ...
Subsystem	Power = Solar Arrays + Electronics + Battery + Fuses + ...
Component	Solar Arrays = Solar Cells + Interconnects + Cover Glass + ...
Part	Solar Cells

- Any given system can be organized into a hierarchy composed of segments and/or elements of succeedingly lower and less complex levels, which may in themselves be termed “systems” by their designers.
- In order to avoid misunderstandings, hierarchical levels for a given mission must be defined early.

Space System

Segment System Element

Subsystem A

Subsystem B

Components

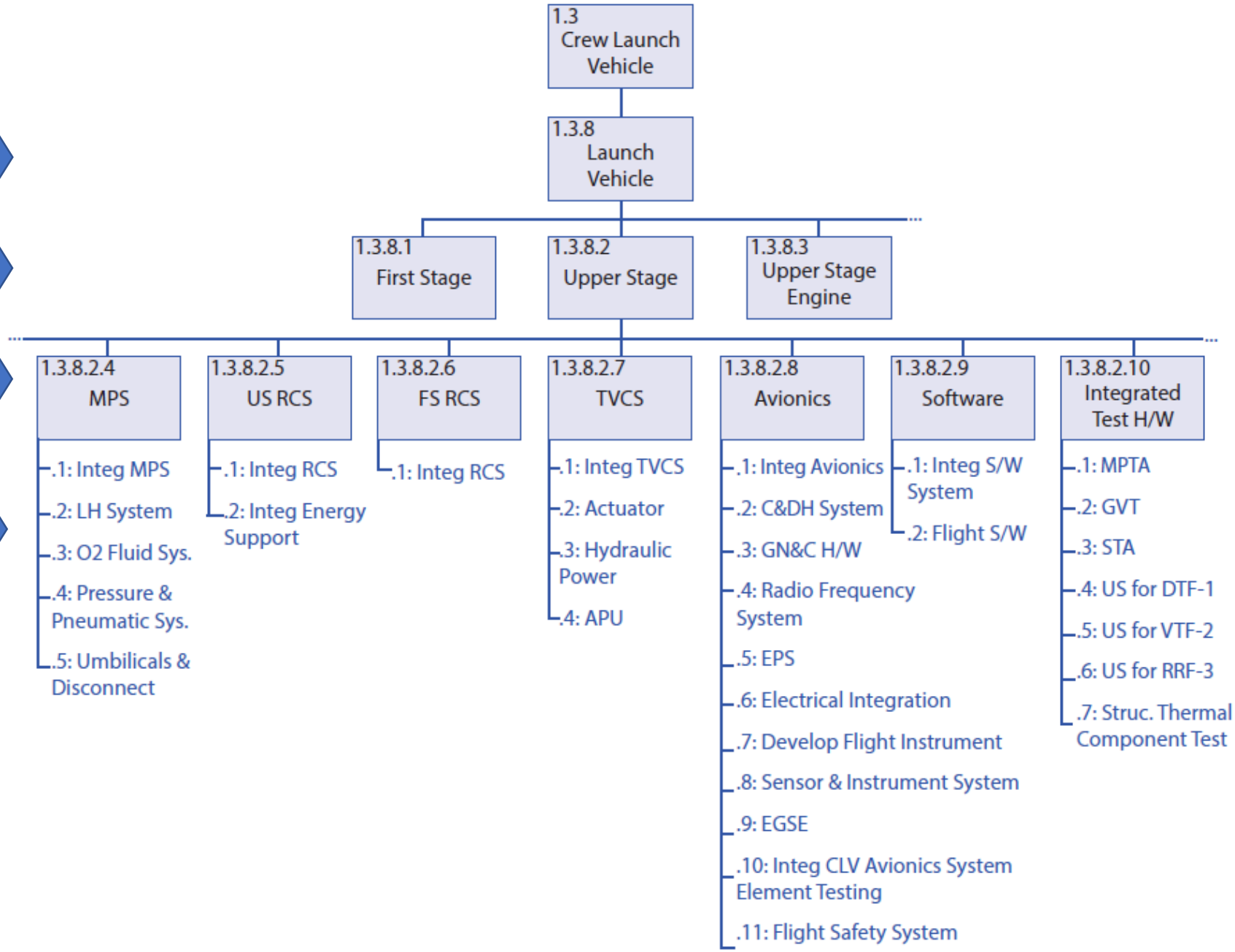
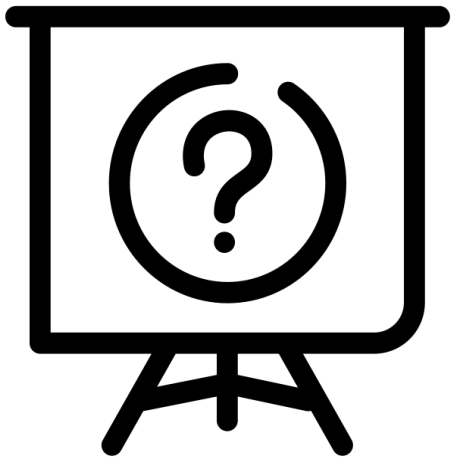


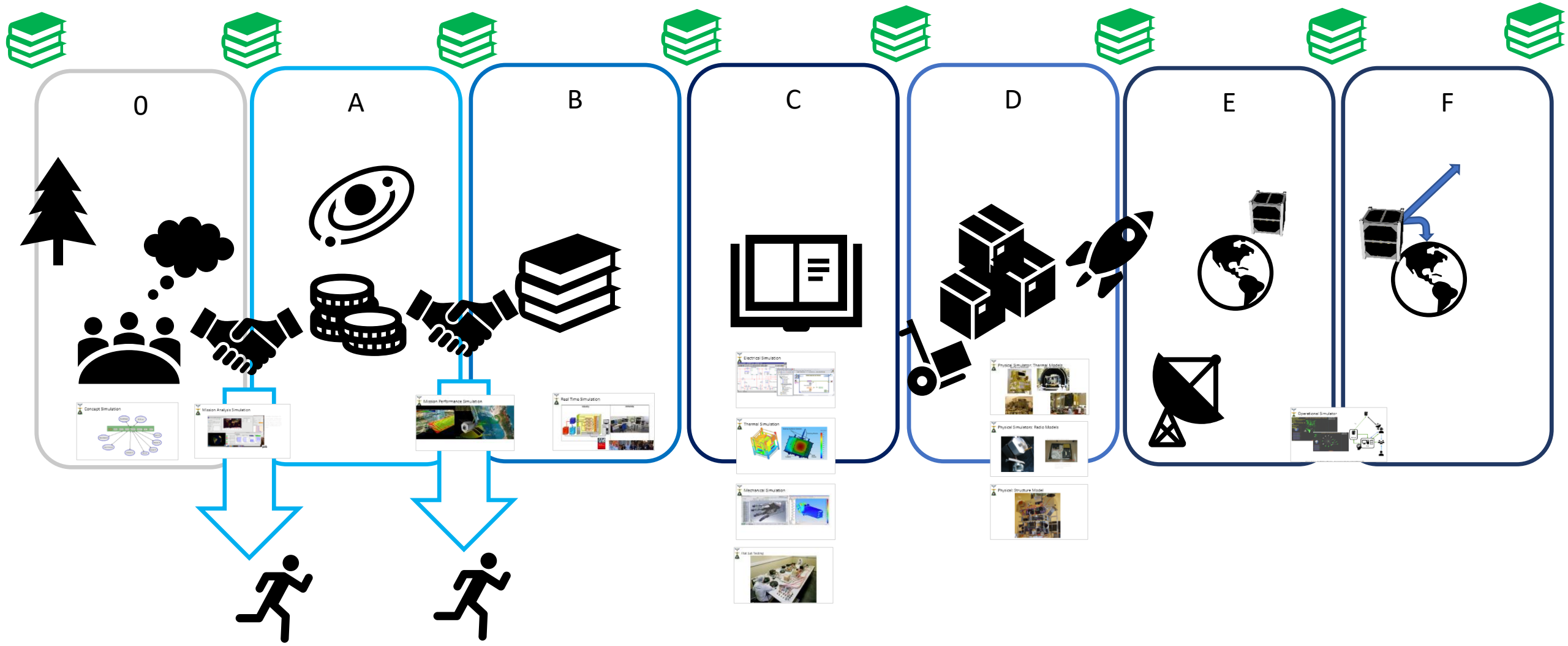
FIGURE G.1-1 PBS Example

What tools does Space Engineering use to V&V?

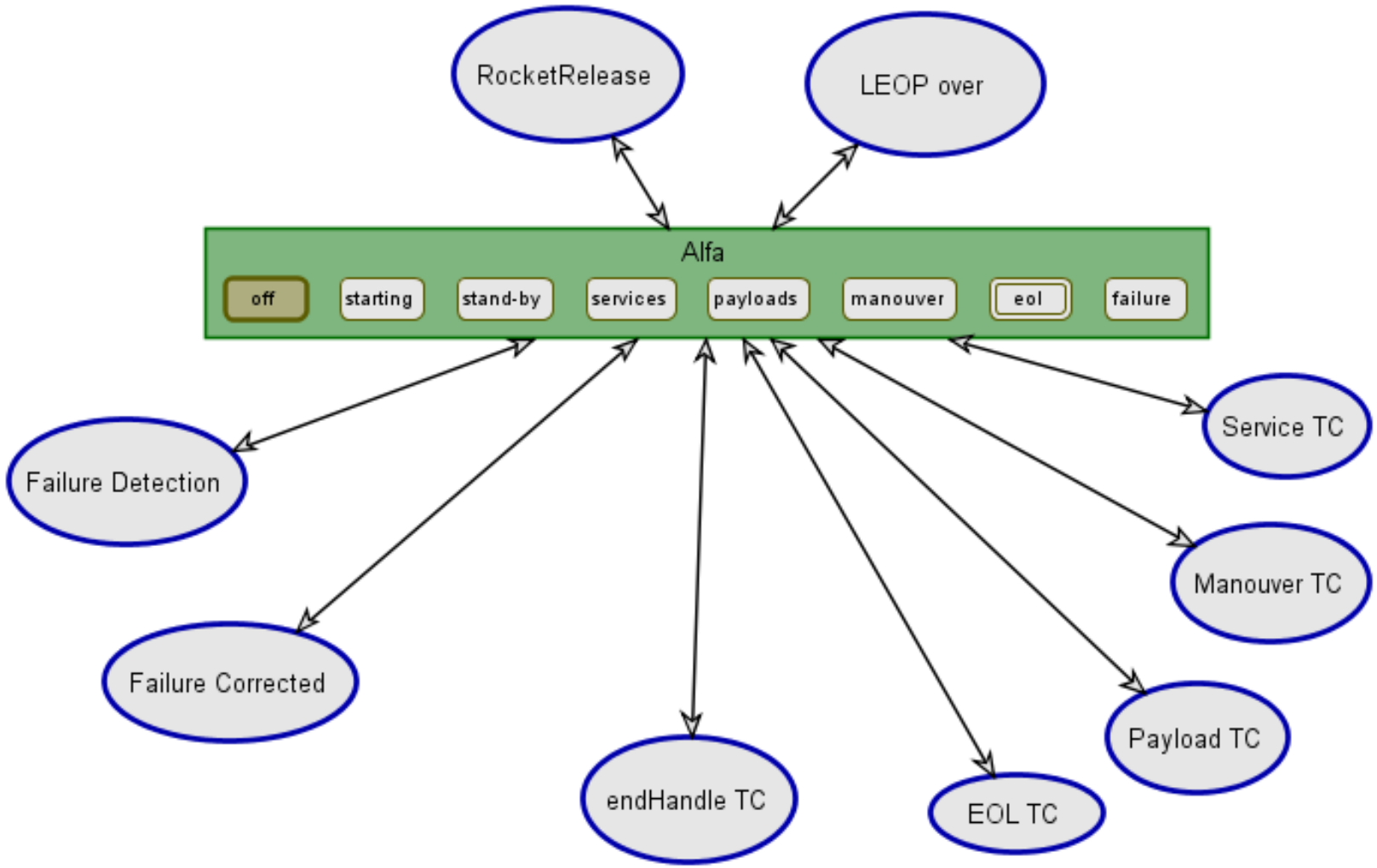


MODELS & SIMULATIONS

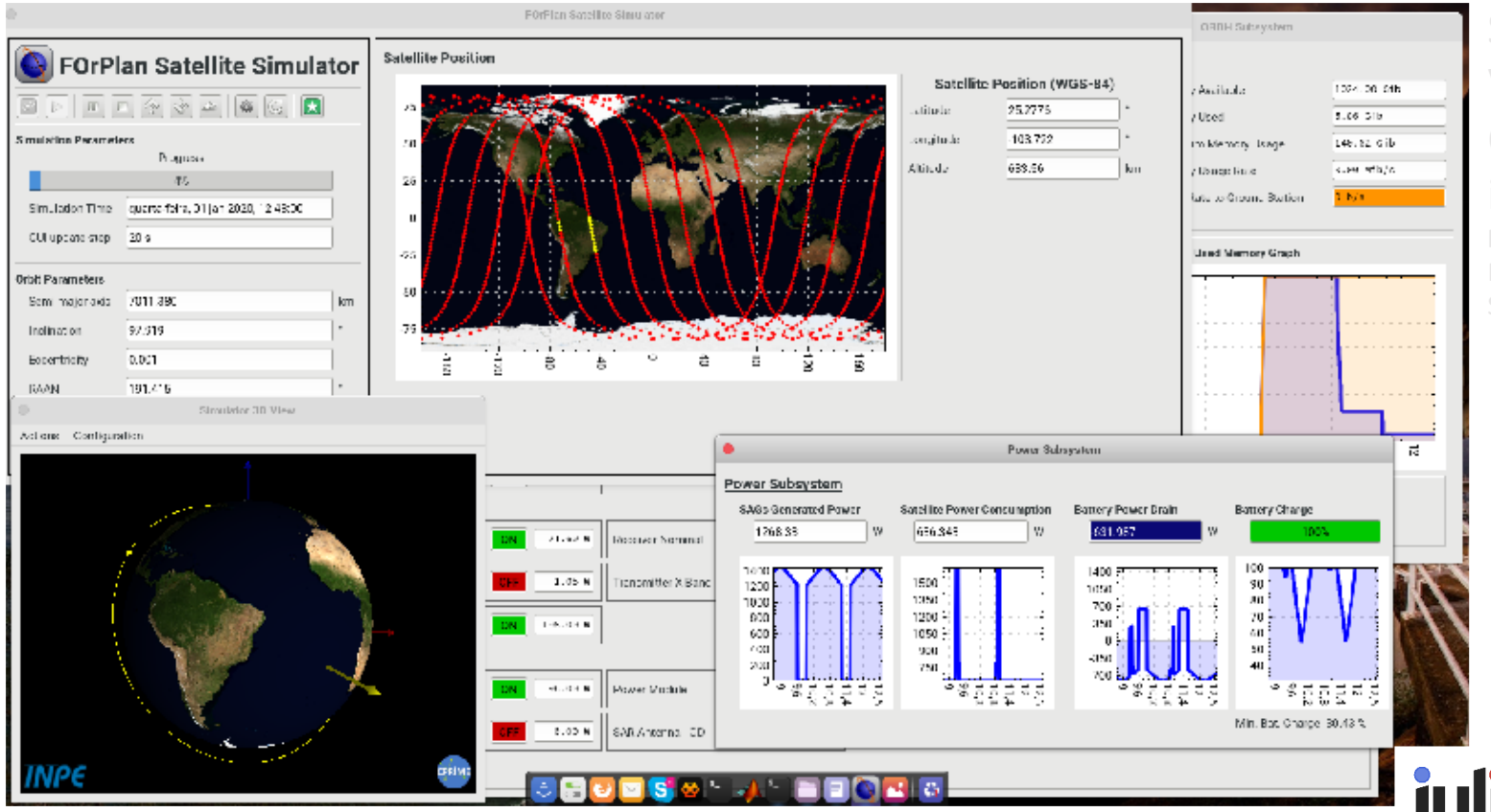
Simulations in the Lifecycle



Concept Simulation



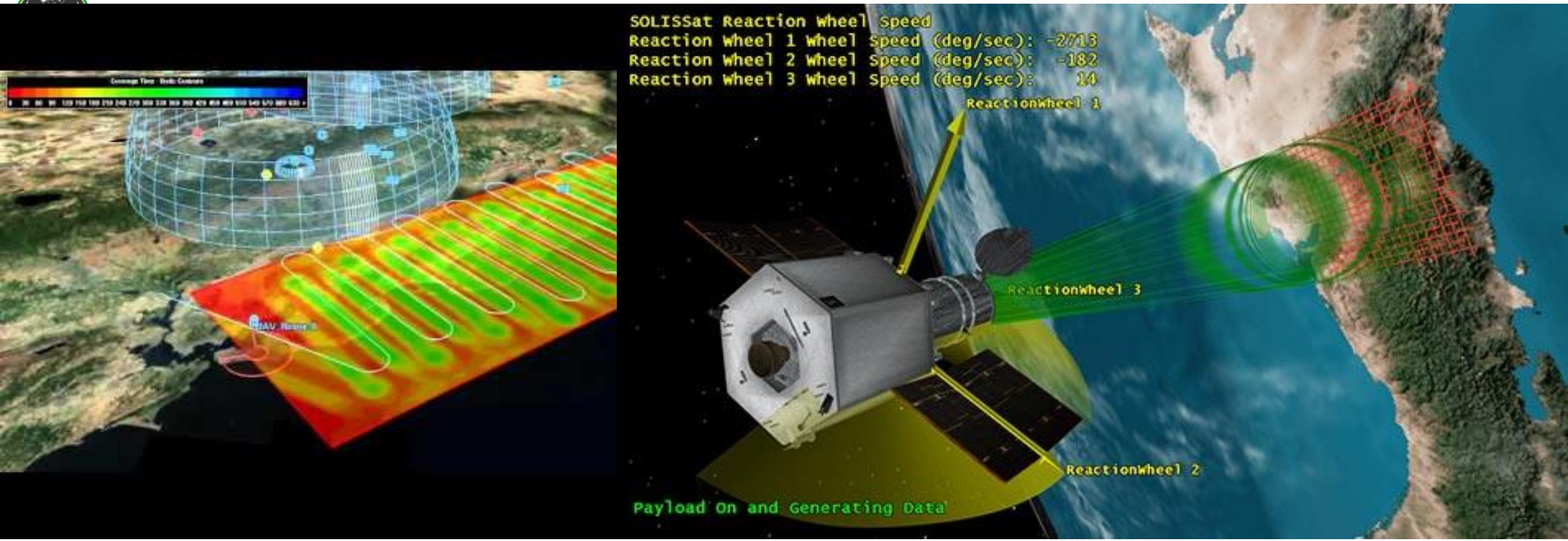
Mission Analysis Simulation



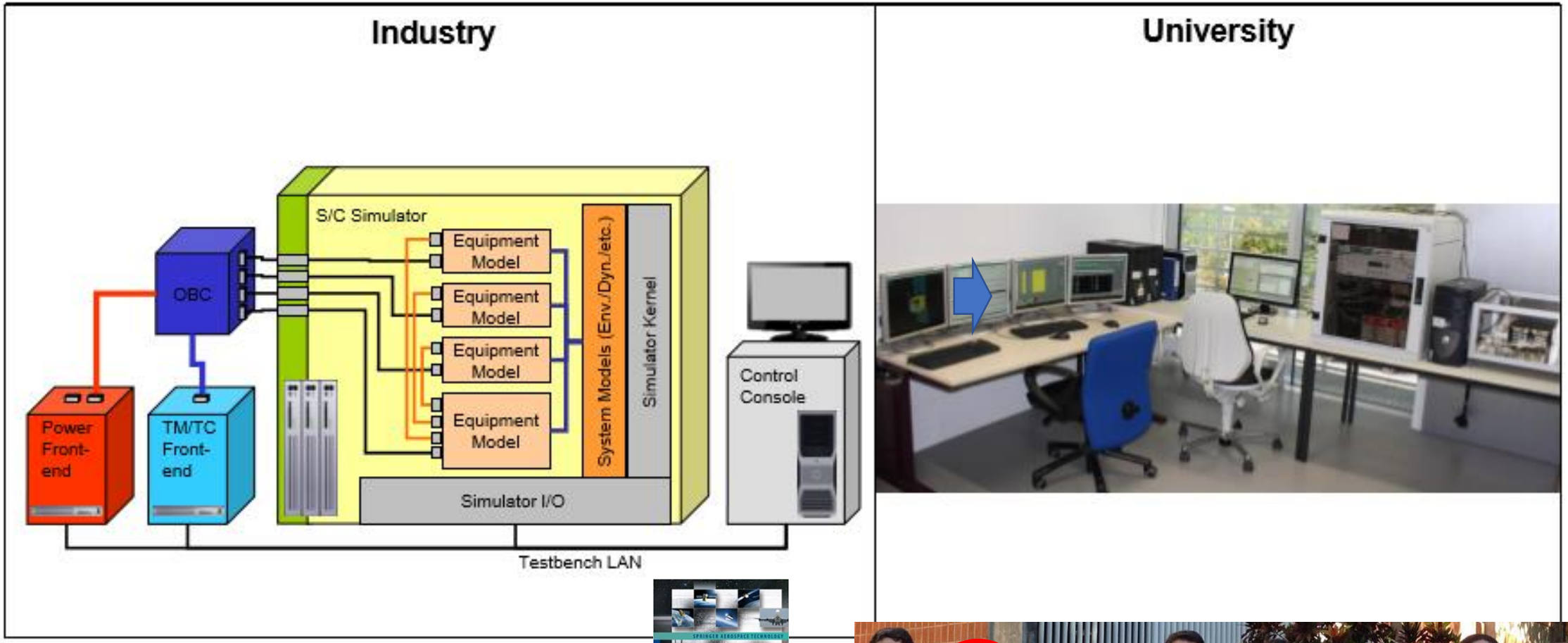
Satellite Simulator for Verification of Mission Operational Concepts in Pre-Phase A Studies

Ronan A. J. Chagas, Arcélio C. Louro, Fabiano L. de Sousa, Willer G. dos Santos

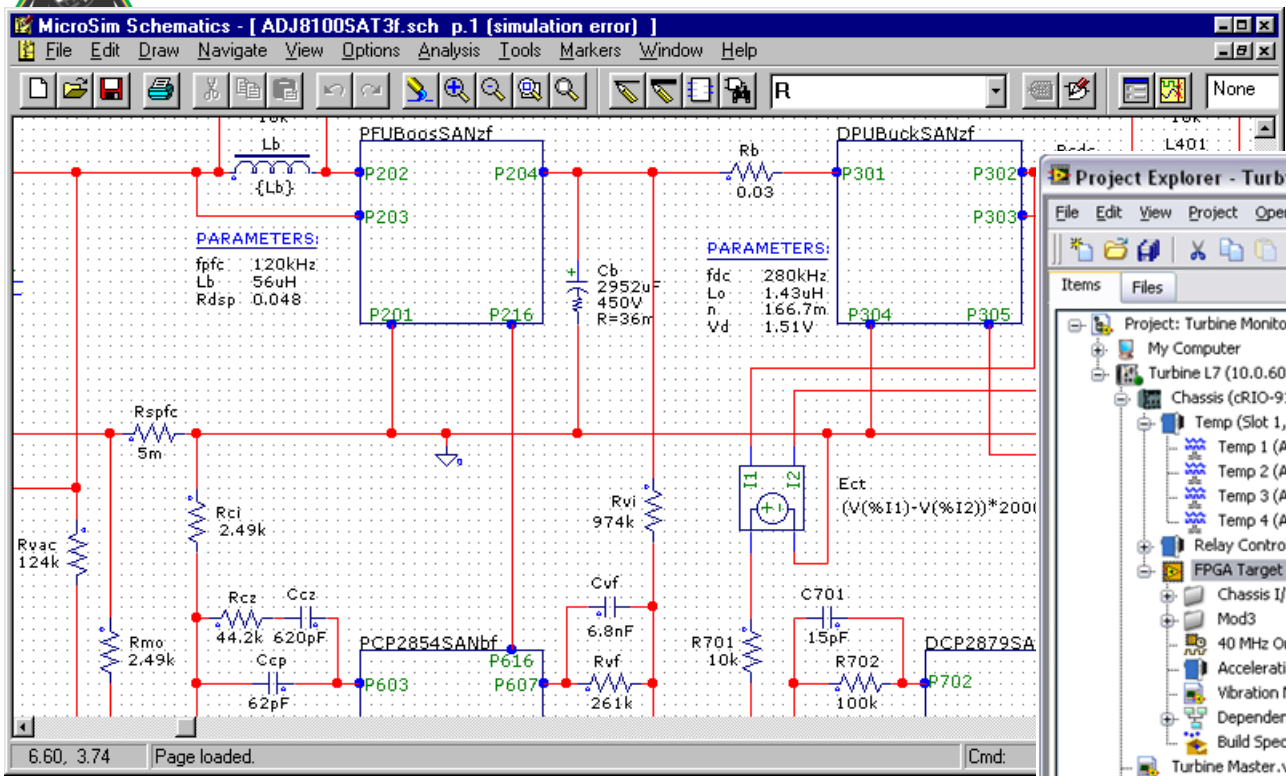
Mission Performance Simulation

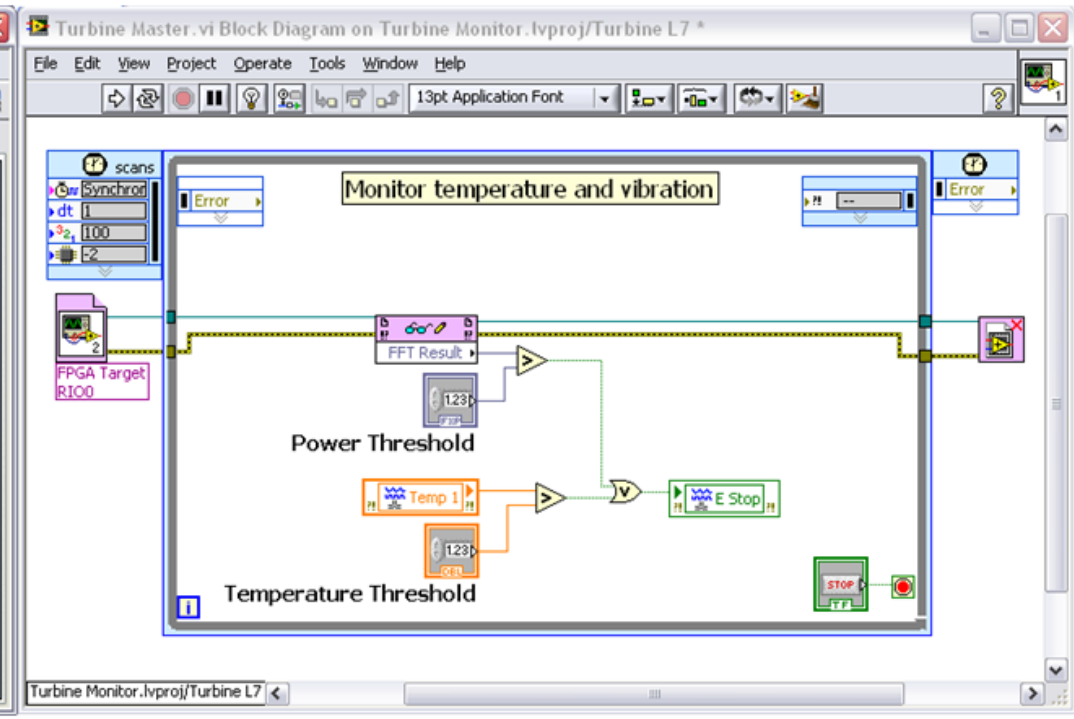


Real Time Simulation

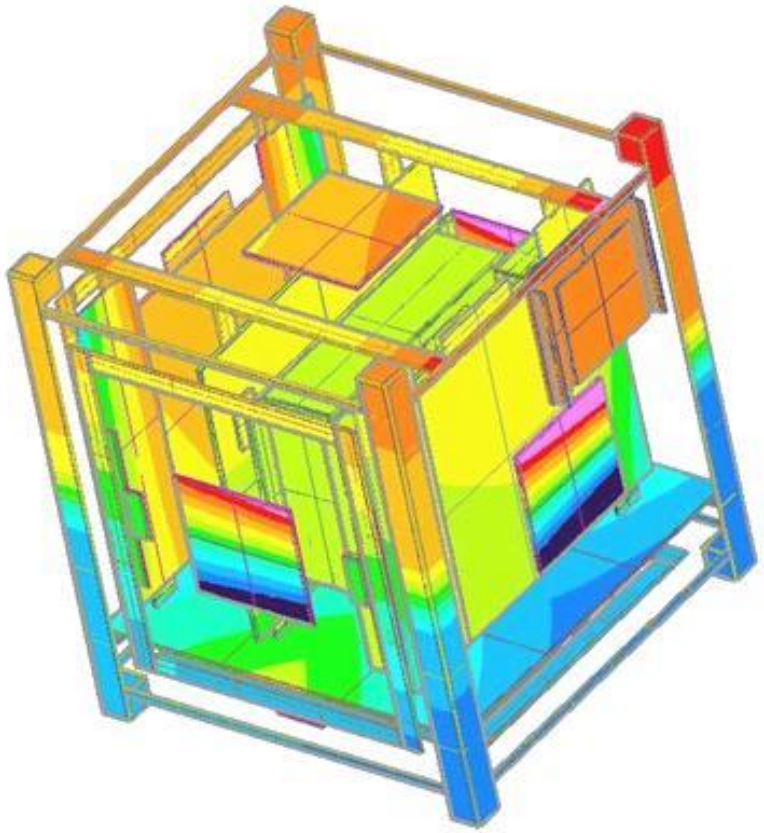


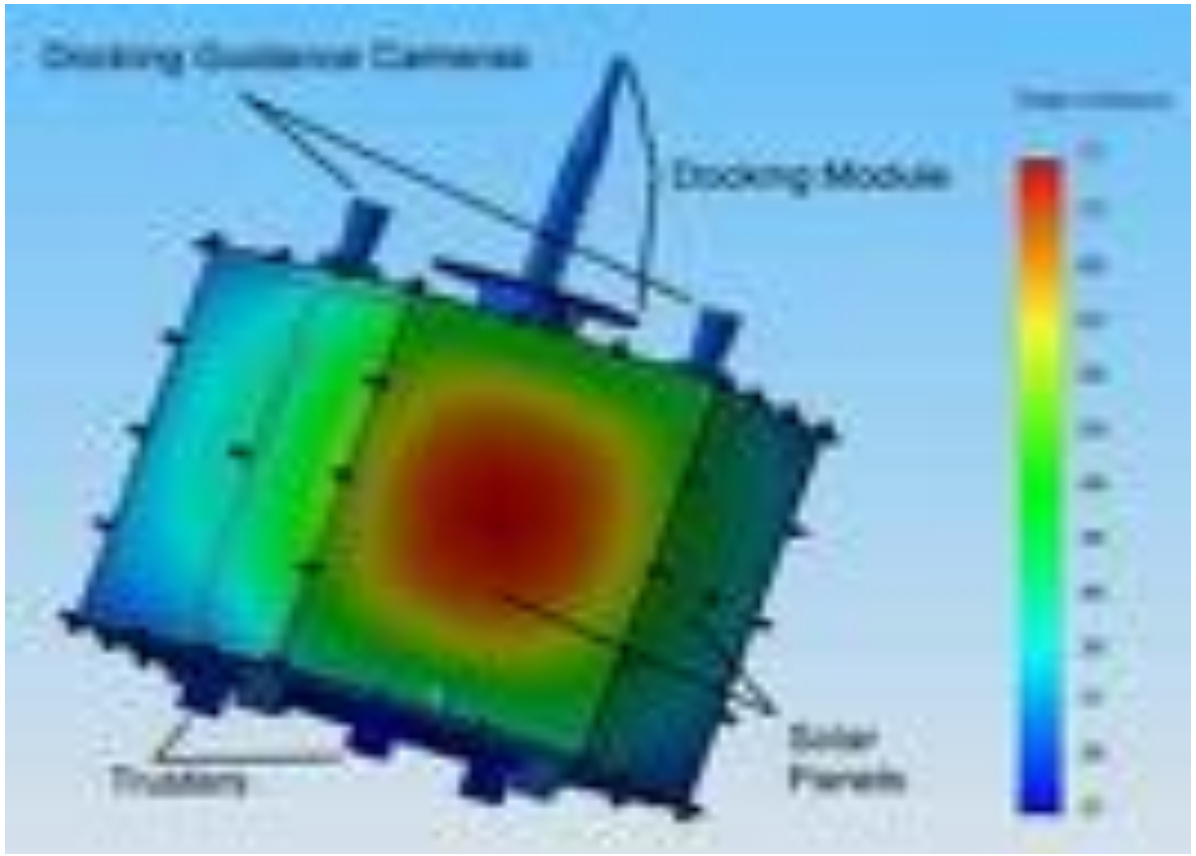
Electrical Simulation



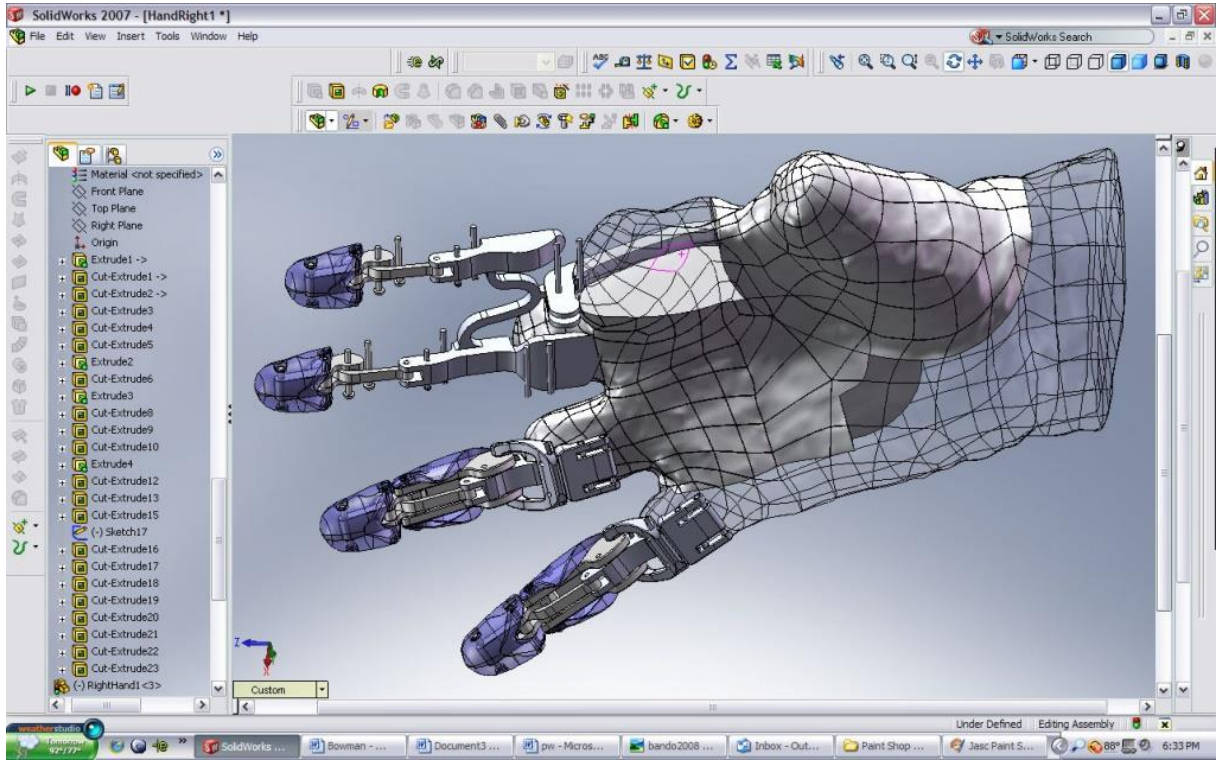


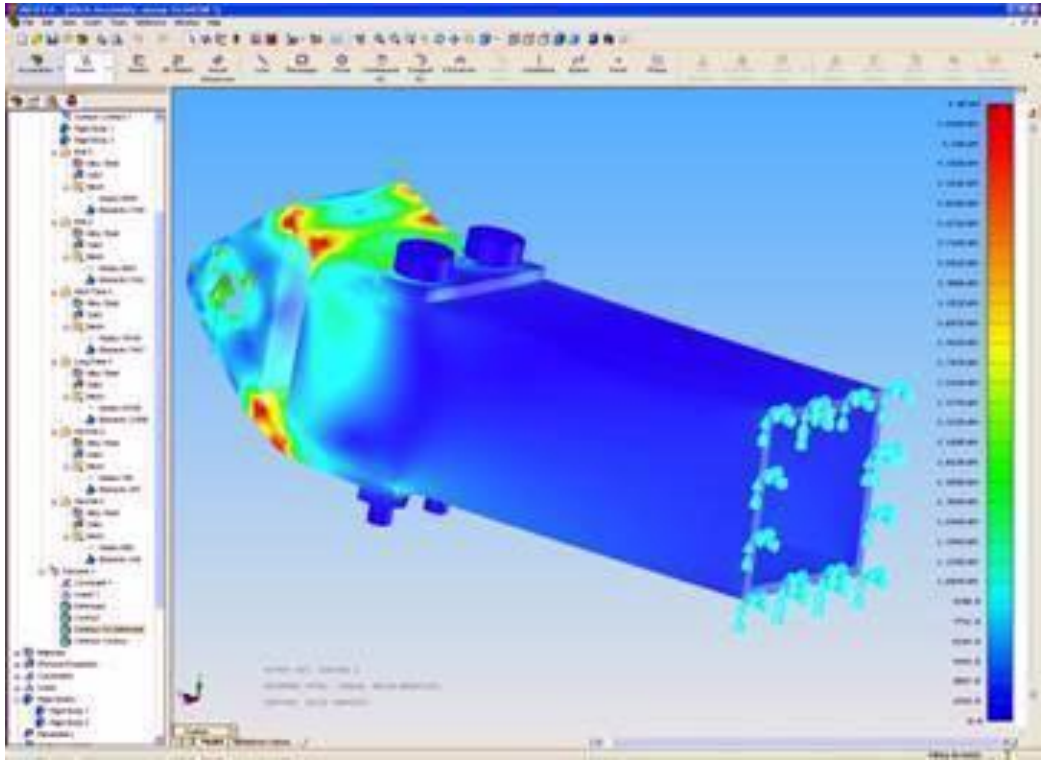
Thermal Simulation



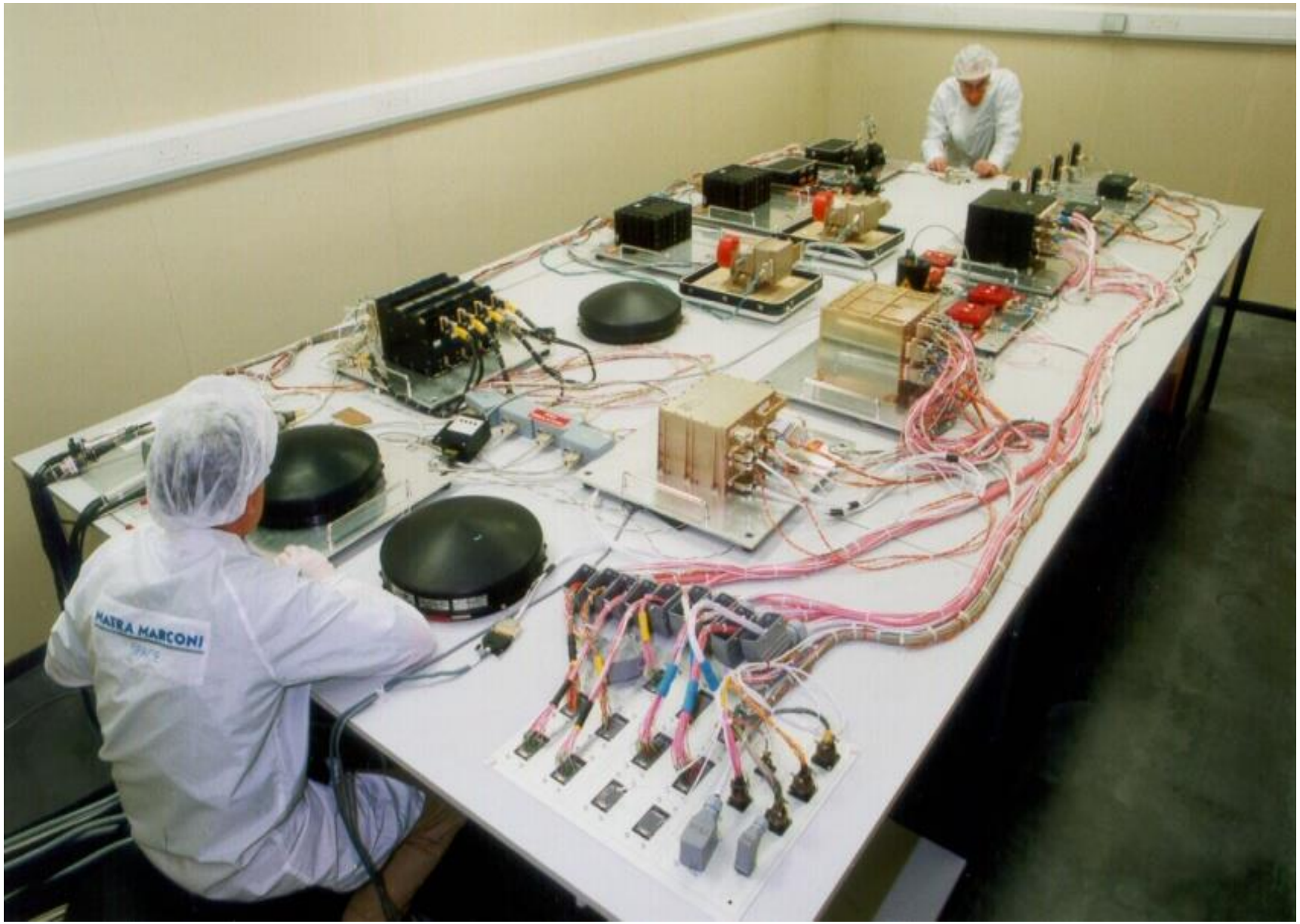


Mechanical Simulation

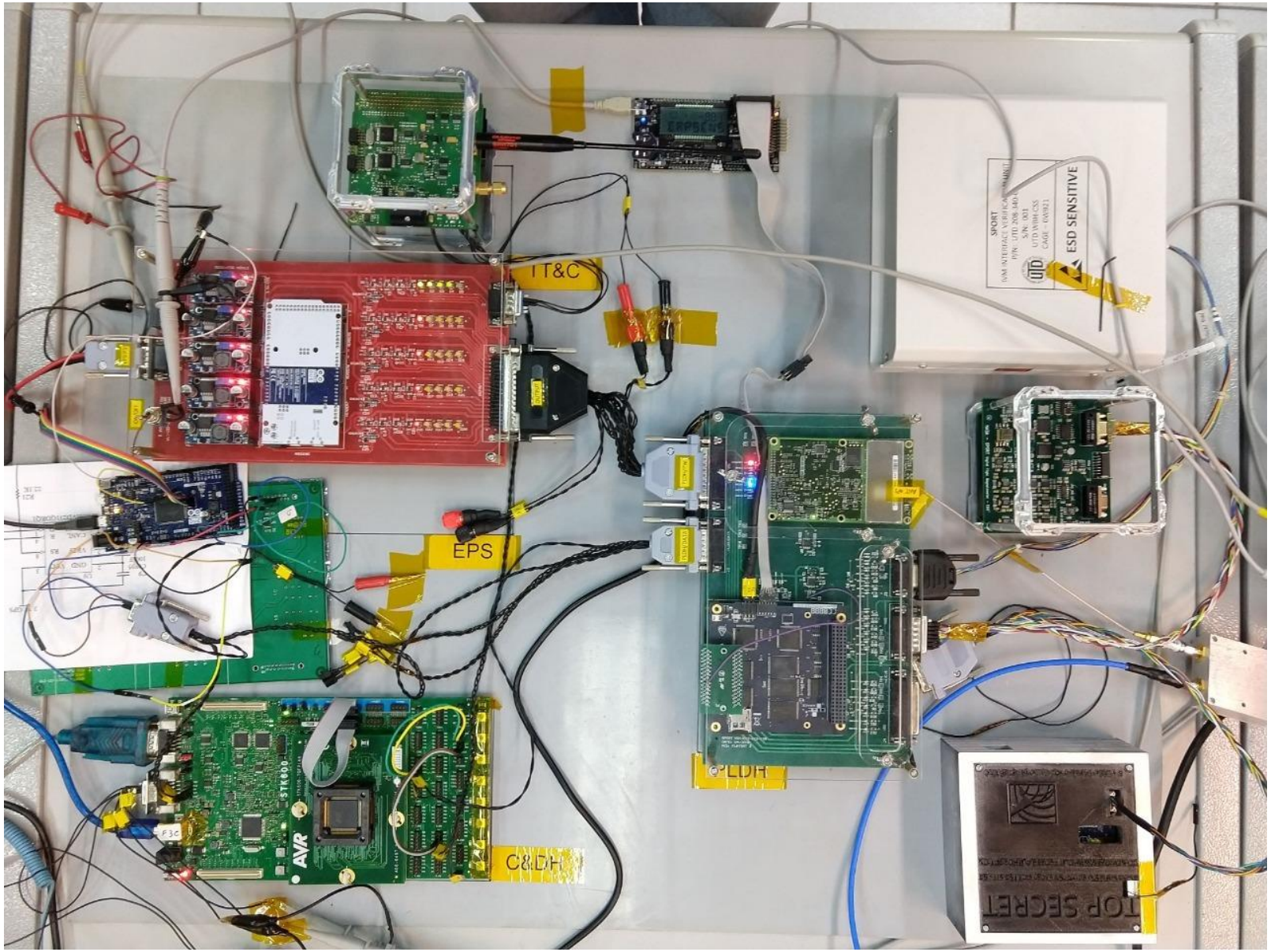




Flat Sat Testing



SPORT’s FLATSAT

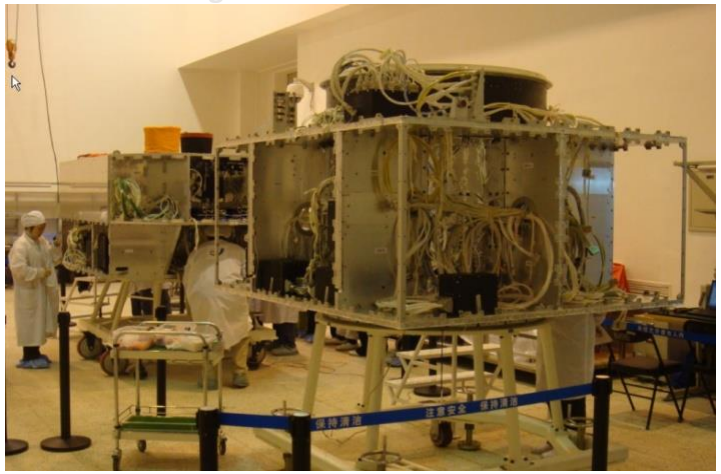


Physical Simulator: Thermal Models

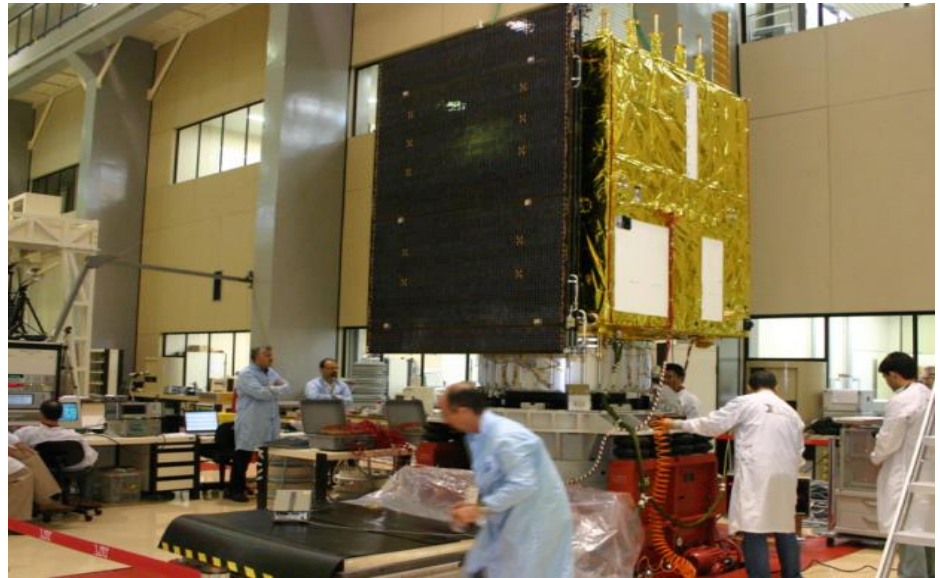
Modelo Térmico de satélite japonês

Modelo Termo-estrutural do CBERS-2B

Modelo de Engenharia do Satélite CBERS-3

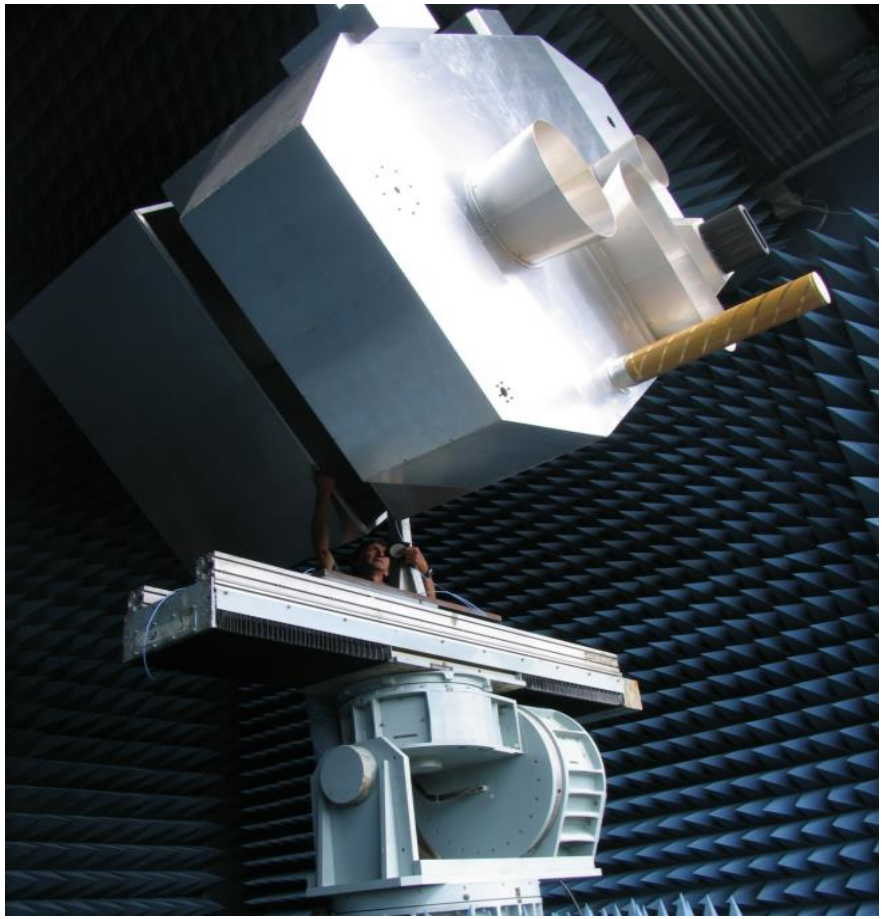


Modelo de Voo do satélite CBERS-2B



Physical Simulators: Radio Models

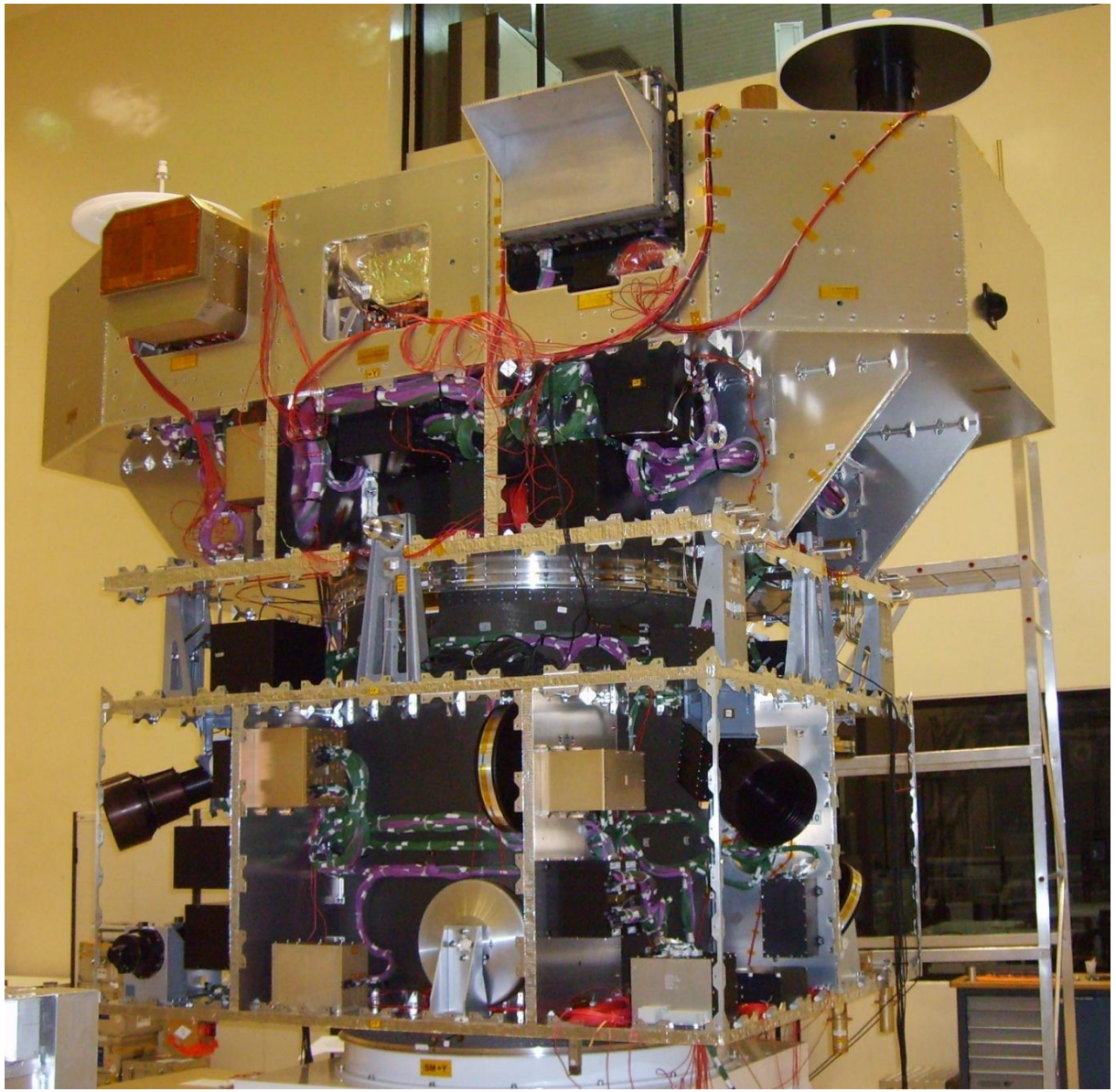
Modelo RADIOELÉTRICO do CBER-3



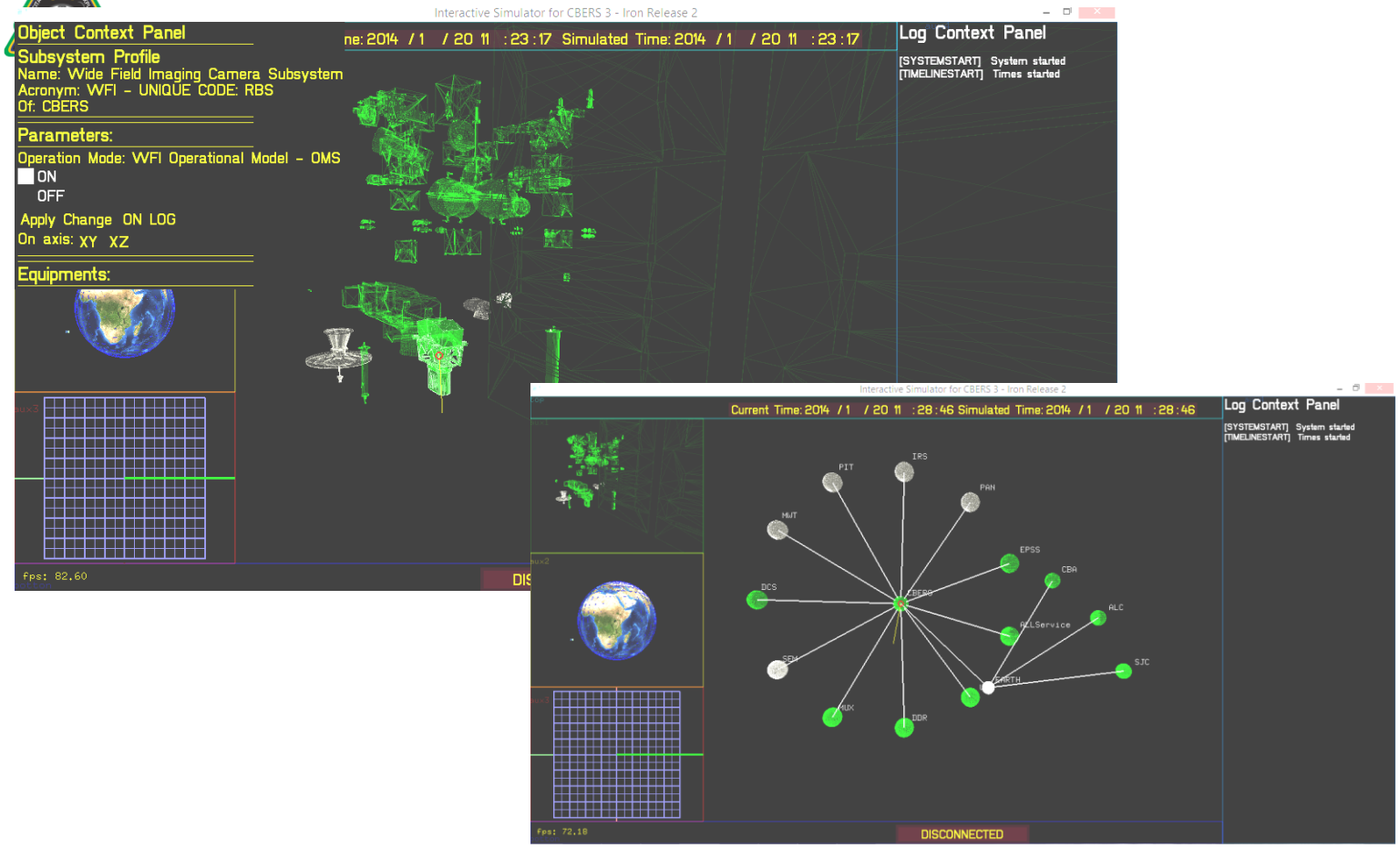
RF Suitcase dos satélites SCD-1 e SCD-2

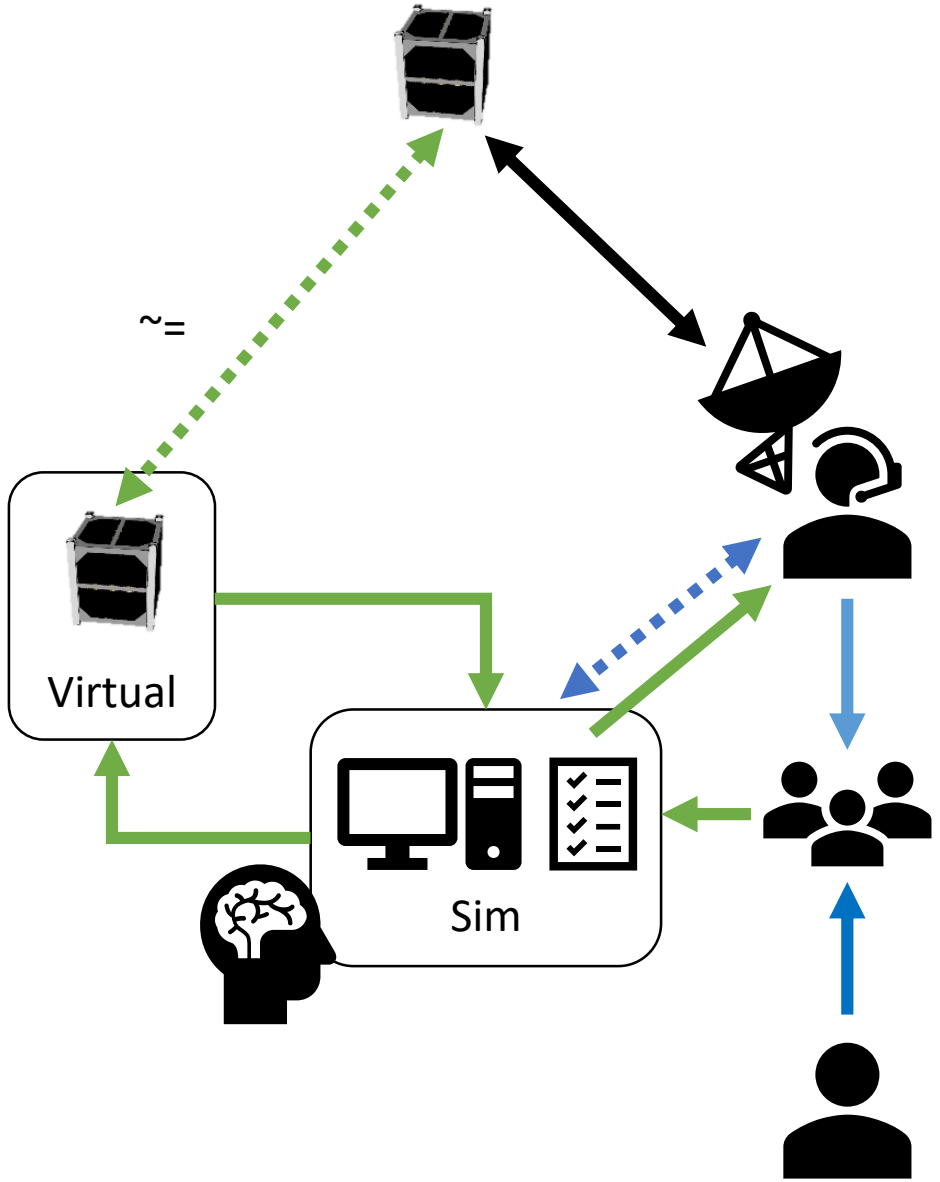
Simula a transmissão e recepção de sinais em RF dos satélites SCD-1 e SCD-2, para teste das antenas das estações terrenas.

Physical: Structure Model



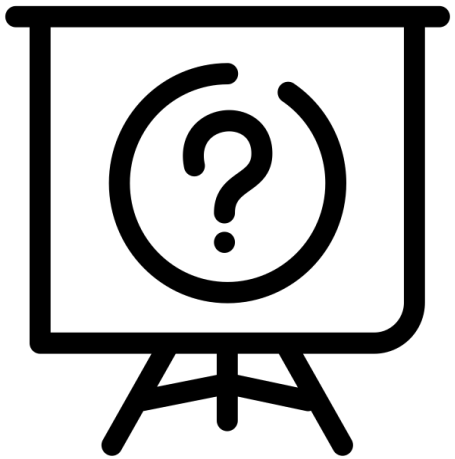
Operational Simulator





Ref.: Larry B. Rainey - Space Modeling and Simulation – roles and applications throughout the System Life Cycle. 2004.

How do we tie requirements with the verifications?



DVM – Design Verification Matrix

PROJECT REQUIREMENTS

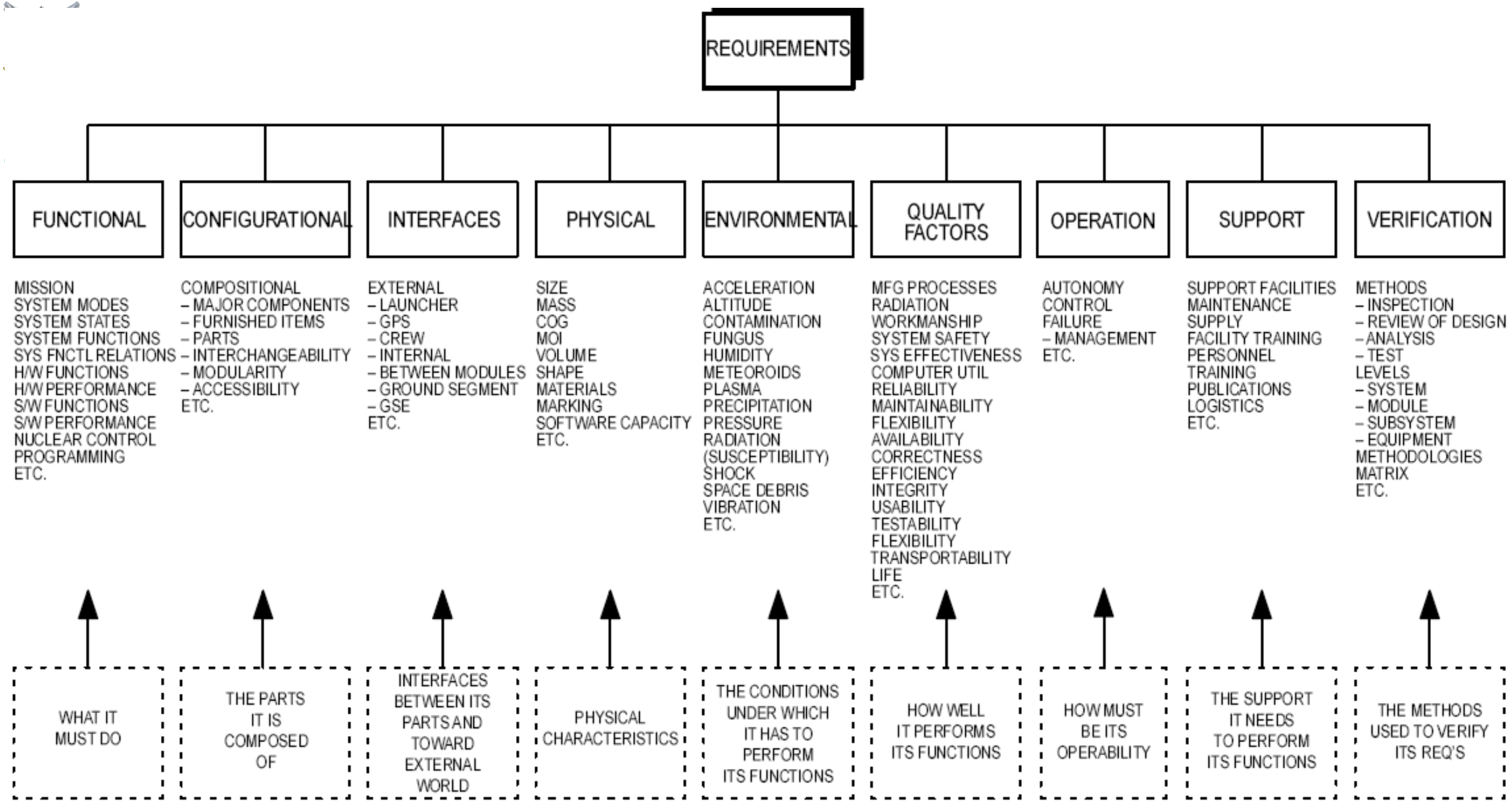
- As a basis for the verification process, mandatory technical requirements shall be properly specified for each product.
- The requirements shall be:
  - generated and allocated **top-down** at the
  - **different project levels** in order to form a tree of
  - **Technical Specifications** and **Interface Control Documents** containing consistent
    - performance,
    - design,
    - interface,
    - environmental,
    - operational and
    - support requirements.

Requirement Genaration

- Space System requirements are typically identified and grouped in relationship to their primary objective in specifying the system.
- When space system requirements are generated consideration shall be given to:
  - the system’s functional objectives, its characteristics and interfaces,
  - the environmental conditions under which it will perform,
  - the quality and operational factors,
  - the necessary support and
  - the verification aspects, this providing
  - operational, functional and physical views of the system and its constituents.

Requirement Attributes

- In order to facilitate the verification implementation in terms of planning, execution, control and reporting, the requirement generation and allocation activity shall ensure specific requirements characteristics. Each requirement shall be:
  - **traceable;**
  - **unique** and associated to a proper identifier (for instance a document and sub clause number;
  - **single** and not a combination of several requirements;
  - **verifiable** using one or more approved verification methods;
  - **unambiguous**;
  - **referenced** as necessary to other requirements (with applicable document and subclause identification) and should be associated with a specific title.


REQUIREMENTS
FUNCTIONAL
CONFIGURATIONAL
INTERFACES
PHYSICAL
ENVIRONMENTAL
QUALITY FACTORS
OPERATION
SUPPORT
VERIFICATION
MISSION
SYSTEM MODES
SYSTEM STATES
SYSTEM FUNCTIONS
SYS FNCTL RELATIONS
H/W FUNCTIONS
H/W PERFORMANCE
S/W FUNCTIONS
S/W PERFORMANCE
NUCLEAR CONTROL
PROGRAMMING
ETC.
COMPOSITIONAL
– MAJOR COMPONENTS
– FURNISHED ITEMS
– PARTS
– INTERCHANGEABILITY
– MODULARITY
– ACCESSIBILITY
ETC.
EXTERNAL
– LAUNCHER
– GPS
– CREW
– INTERNAL
– BETWEEN MODULES
– GROUND SEGMENT
– GSE
ETC.
SIZE
MASS
COG
MOI
VOLUME
SHAPE
MATERIALS
MARKING
SOFTWARE CAPACITY
ETC.
ACCELERATION
ALTITUDE
CONTAMINATION
FUNGUS
HUMIDITY
METEOROIDS
PLASMA
PRECIPITATION
PRESSURE
RADIATION
(SUSCEPTIBILITY)
SHOCK
SPACE DEBRIS
VIBRATION
ETC.
MFG PROCESSES
RADIATION
WORKMANSHIP
SYSTEM SAFETY
SYS EFFECTIVENESS
COMPUTER UTIL
RELIABILITY
MAINTAINABILITY
FLEXIBILITY
AVAILABILITY
CORRECTNESS
EFFICIENCY
INTEGRITY
USABILITY
TESTABILITY
FLEXIBILITY
TRANSPORTABILITY
LIFE
ETC.
AUTONOMY
CONTROL
FAILURE
– MANAGEMENT
ETC.
SUPPORT FACILITIES
MAINTENANCE
SUPPLY
FACILITY TRAINING
PERSONNEL
TRAINING
PUBLICATIONS
LOGISTICS
ETC.
METHODS
– INSPECTION
– REVIEW OF DESIGN
– ANALYSIS
– TEST
LEVELS
– SYSTEM
– MODULE
– SUBSYSTEM
– EQUIPMENT
METHODOLOGIES
MATRIX
ETC.
WHAT IT MUST DO
THE PARTS IT IS COMPOSED OF
INTERFACES BETWEEN ITS PARTS AND TOWARD EXTERNAL WORLD
PHYSICAL CHARACTERISTICS
THE CONDITIONS UNDER WHICH IT HAS TO PERFORM ITS FUNCTIONS
HOW WELL IT PERFORMS ITS FUNCTIONS
HOW MUST BE ITS OPERABILITY
THE SUPPORT IT NEEDS TO PERFORM ITS FUNCTIONS
THE METHODS USED TO VERIFY ITS REQ'S

Requirement Allocation - DVM

- **The verification strategy shall be reflected in**
  - a **verification matrix** which shows for all requirements
  - the selected **verification methods** for (how)
  - the different **verification levels** in (what)
  - the applicable **verification stages**. (when)

Requirement No.	Document	Paragraph	Shall Statement	Verification Success Criteria	Verification Method	Facility or Lab	Phase[a]	Acceptance Requirement?	Preflight Acceptance?	Performing Organization	Results
Unique identifier or each requirement	*Document number the requirement is contained within*	*Paragraph number of the requirement*	*Text (within reason) of the requirement, i.e., the "shall"*	*Success criteria for the requirement*	*Verification method for the requirement (analysis, inspection, demonstration, test)*	*Facility or laboratory used to perform the verification and validation.*	*Phase in which the verification and validation will be performed.*	*Indicate whether this requirement is also verified during initial acceptance testing of each unit.*	*Indicate whether this requirement is also verified during any pre-flight or recurring acceptance testing of each unit*	*Organization responsible for performing the verification*	*Indicate documents that contain the objective evidence that requirement was satisfied*

DVM ("Design Verification Matrix" ESA)

Ref.	Requirement	Stages	Verification Methods		
			Sys	Sub	Equ
x.1	Requirement 1	Qua	T, A	A	T
		Acc			T
x.2	Requirement 2	Qua	I, R	R	I
		Acc	I		I
		Pre	I		
		Orb	T		

Verification Stages:

Qua - Qualification stage
Acc - Acceptance stage
Pre - Pre-Launch stage
Orb - In Orbit stage

Verification Method

T - Test
A - Analysis
I - Inspection
R - Review of Design

Verification Levels

Sys - System
Sub - Subsystem
Equ - Equipment

DVM ("Design Verification Matrix" NASA)

. Specification Requirements, Compliance, and Verifications (By Spec #)

Space Flight Systems

6149-EP0001-01 Requirement				Method:		Verification			Last Modified	
Paragraph	Title	Requirement	Verification Methodology	Qual	Acc	#	Name	Type	Date	By
3.1.1.1	Physical Interfaces	The ExPCA shall provide interfaces for its installation on and its removal from the EXPRESS Pallet via the CFE ExPA through extravehicular activity (EVA) and extravehicular robotics (EVR).	Inspection of data from Boeing pertaining to the CFE ExPA will verify EVA and EVR attachment requirements as specified in SSP 52055.	I	I	190	BFG Inspection: Check to ID drawing	I		
3.1.1.2	Electrical Interfaces	All electrical interfaces shall be through SSQ 22680 type connectors located on the ExPCA.	Inspection of connectors will verify SSQ22680 type, unless otherwise specified and approved.	I	I	190	BFG Inspection: Check to ID drawing	I	2000-07-27	Mark Hyman
3.1.1.2.1 [1]	Power Inputs	The ExPCA shall [1] have two (2) power inputs (MAIN and AUXILIARY) of 120 vdc, 25 amperes (A) each from the Umbilical Mechanism Assembly (UMA) on the International Space Station Payload Attach System (PAS).	Review of schematics, inspection to the BFG ID drawings and the WCA will provide visual verification of two 120V, 25 A inputs so present. The QTP and ATP will provide test verification of these inputs	I, A,T	I,T	190 191	BFG Inspection: Check to ID drawing Analysis via WCA test via STE	I A	2000-07-27	Mark Hyman
3.1.1.2.1 [2]	Power Inputs	The ExPCA shall [2] have a third power input (STAY ALIVE) of 28 vdc, 5 A (TBR) while the ExPCA is in the Orbiter cargo bay.	Inspection of schematics, AU and ExPCA ID drawings will provide verification of 28V Orbiter input. The WCA provides the analytical compliance. Formal QTP and ATP will provide the test compliance	I, A,T	I,T	190 191	BFG Inspection: Check to ID drawing Analysis via WCA test via STE	I A	2000-07-27 2000-07-27	Mark Hyman Mark Hyman

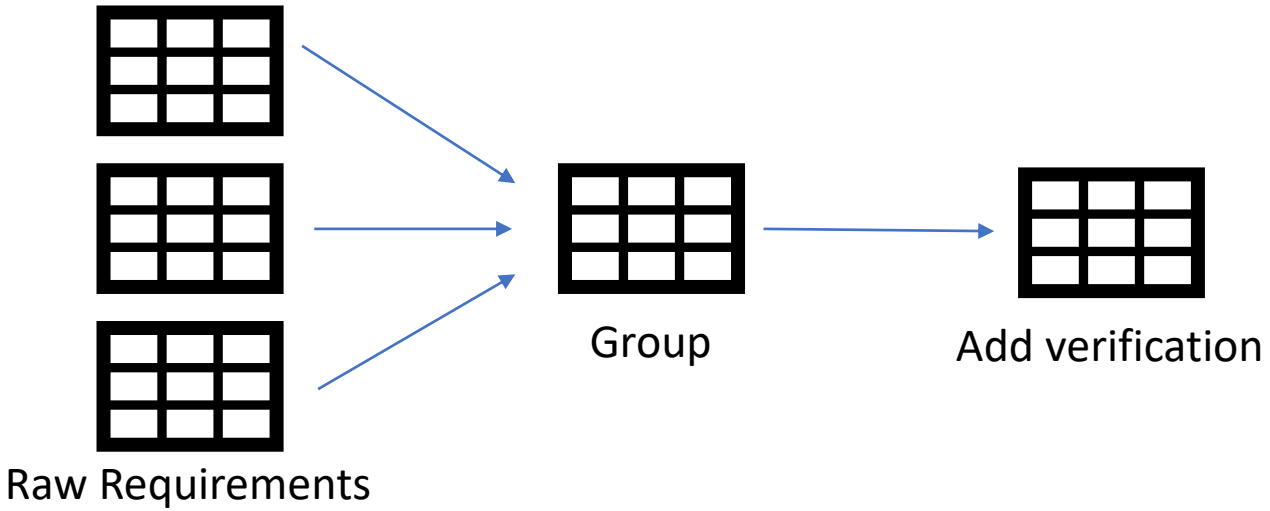
How we do here... And how you will do! ☺

1. Req # // Title Requirement // Requirement Text // Rationale // Level
2. Verification Method
3. Verification Success Criteria
4. V&V Phase (Project Phase and Models) column shows the Project Phase or/and Models when the requirement is checked.
5. V&V Documents (Procedures, Reports, Certificates, …) column shows the reference documents describing the V&V Activities, Facilities, Objectives, Methods, Results and other documents for respective “Verification Method” column.
6. V&V Compliance (Status and Justifications) column shows the V&V Acceptance Requirement Status and respective Justifications if necessary.

CLASS ENDING

Assignments

- [PRD-003] – Revised Requiremens
  - Get the Requirements
  - Add the **Verication Method** & **Verification Success Criteria**
  - Review / Reorganize in one spreadsheet adding the **levels**
  - Indicate which **Subsystem** will be involved (Lead / Secundaries) in subsystem level



Grading Criteria:

1. Coherent Method x Success
2. Level Reorganization
3. Reading of the function and indicates the target subsystem in subsystem level (xx xx)
4. Suggestions for rewriting requirements, to be verifiable