CRITICAL EVENTS & FACILITIES

[SIS-08][LEC-009][LEC-010]

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

Oct, 21th – 10 – Events + Facilities

Oct, 24th – 11 – Planning

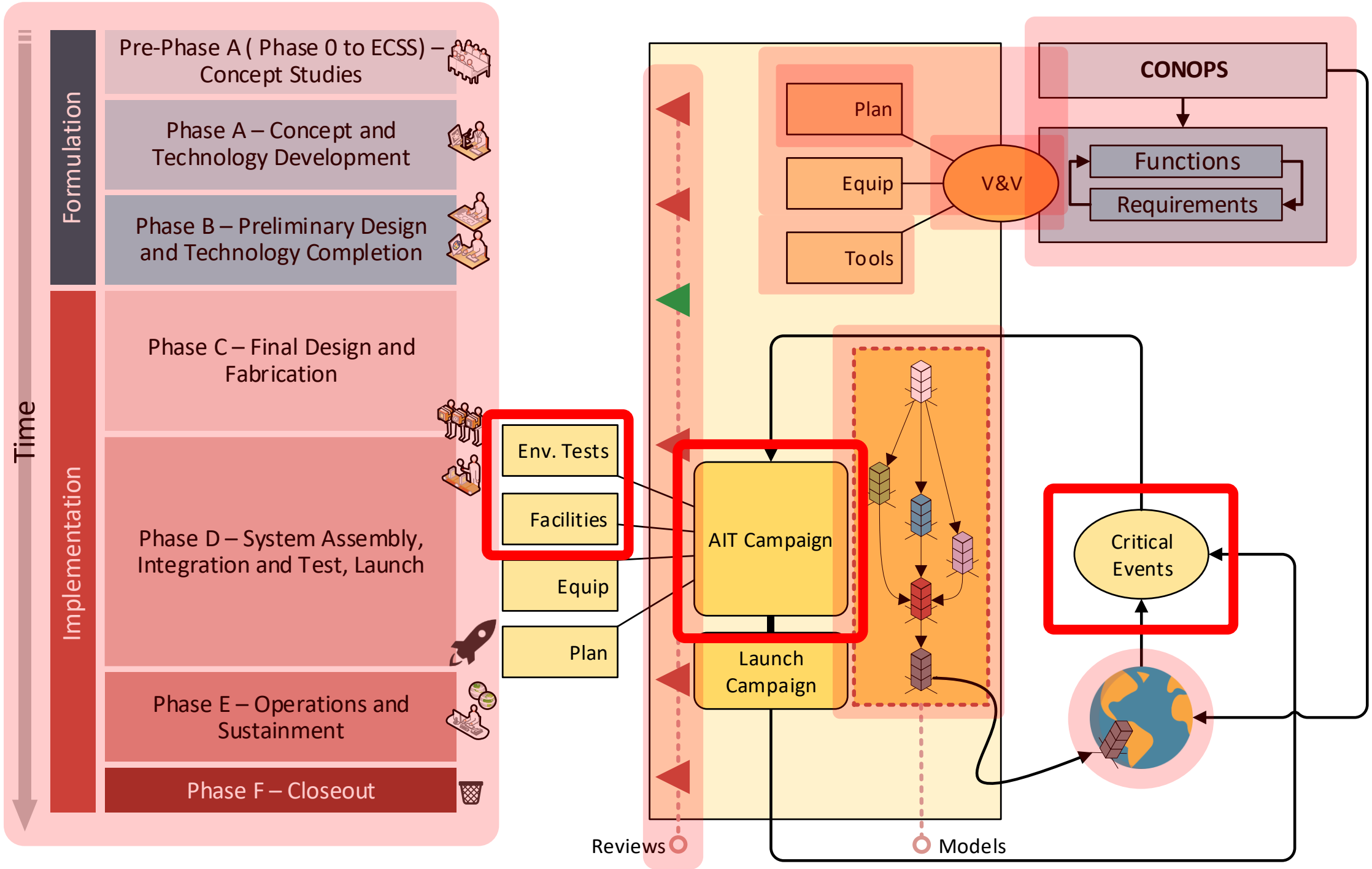
Oct, 31th – 12 – Equips

Nov, 07th – 13 – Launching

Nov, 14th – 14 – Ending

Nov, 21th – 15 – TST-002

Nov, 21th – 16 – CEI-AIT


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
Env. Tests
Facilities
Equip
Plan
AIT Campaign
Launch Campaign
Plan
Equip
Tools
V&V
CONOPS
Functions
Requirements
Critical Events
Reviews
Models

Summary

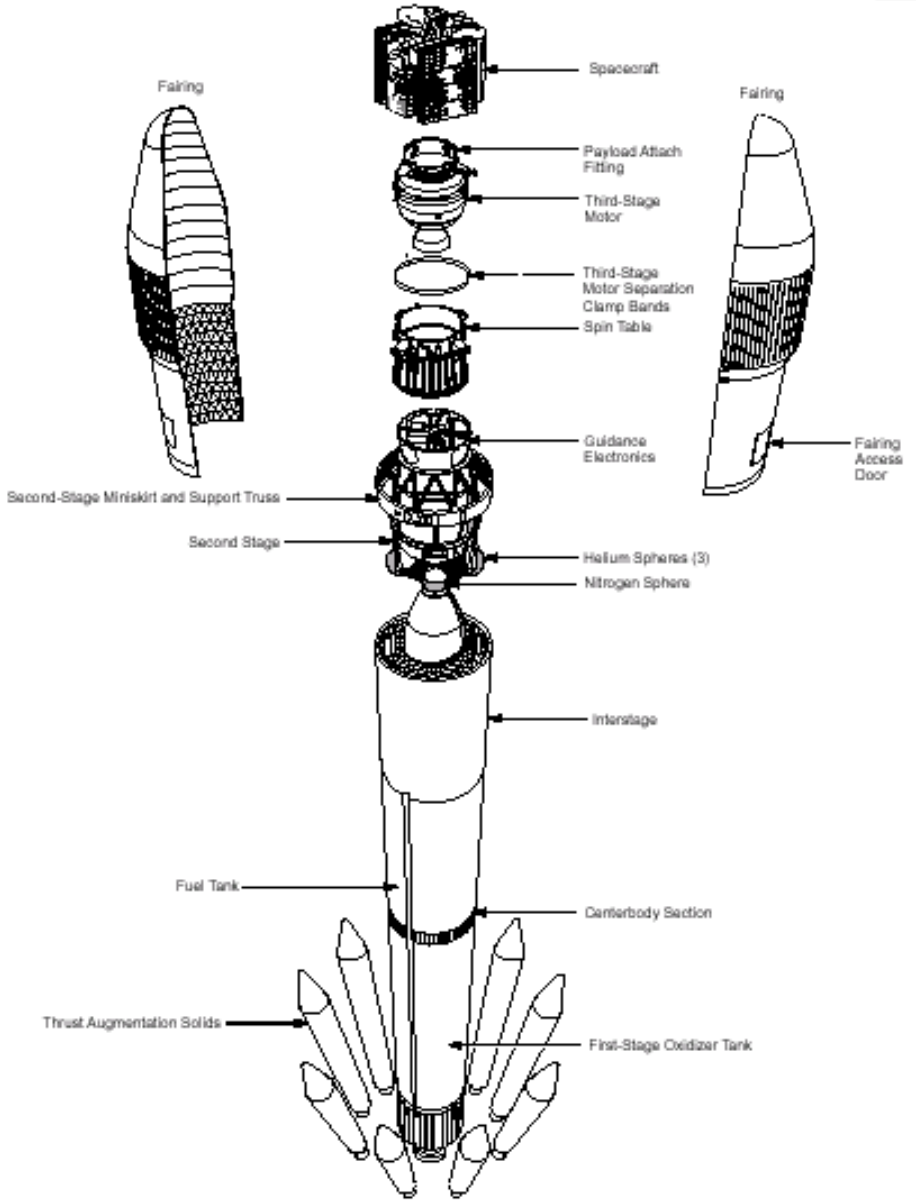
CRITICAL EVENTS

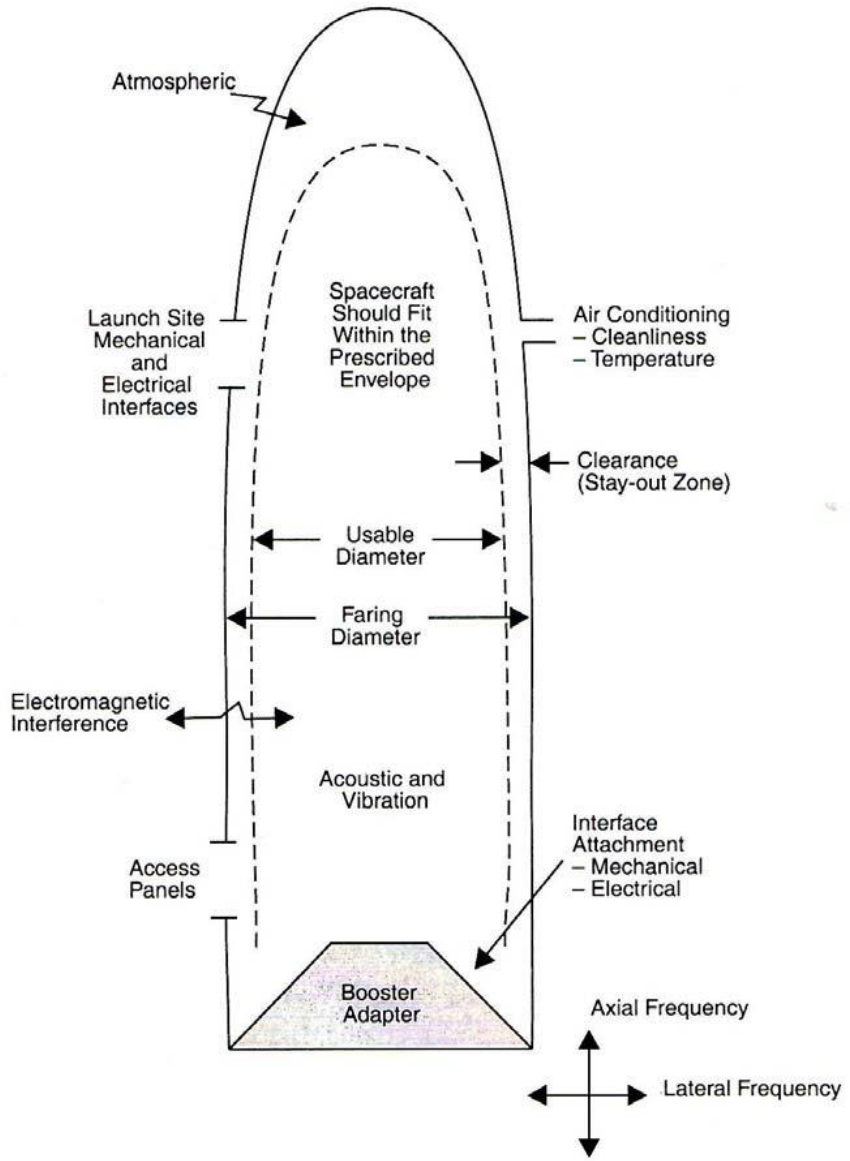
FACILITIES

CRITICAL EVENTS

LAUNCHING

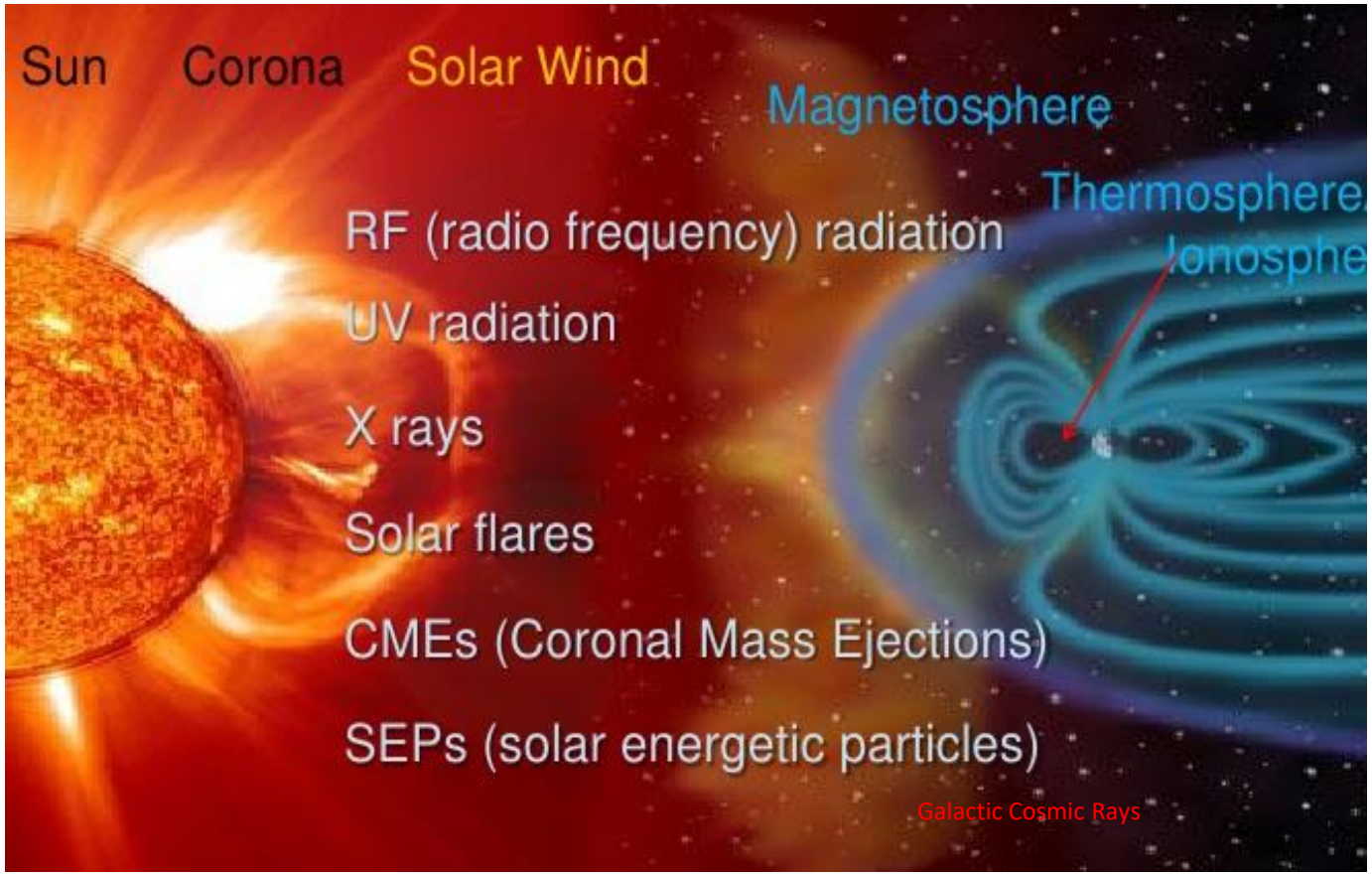
EVERYTHING MUST FIT INSIDE THE FAIRING ENVELOP



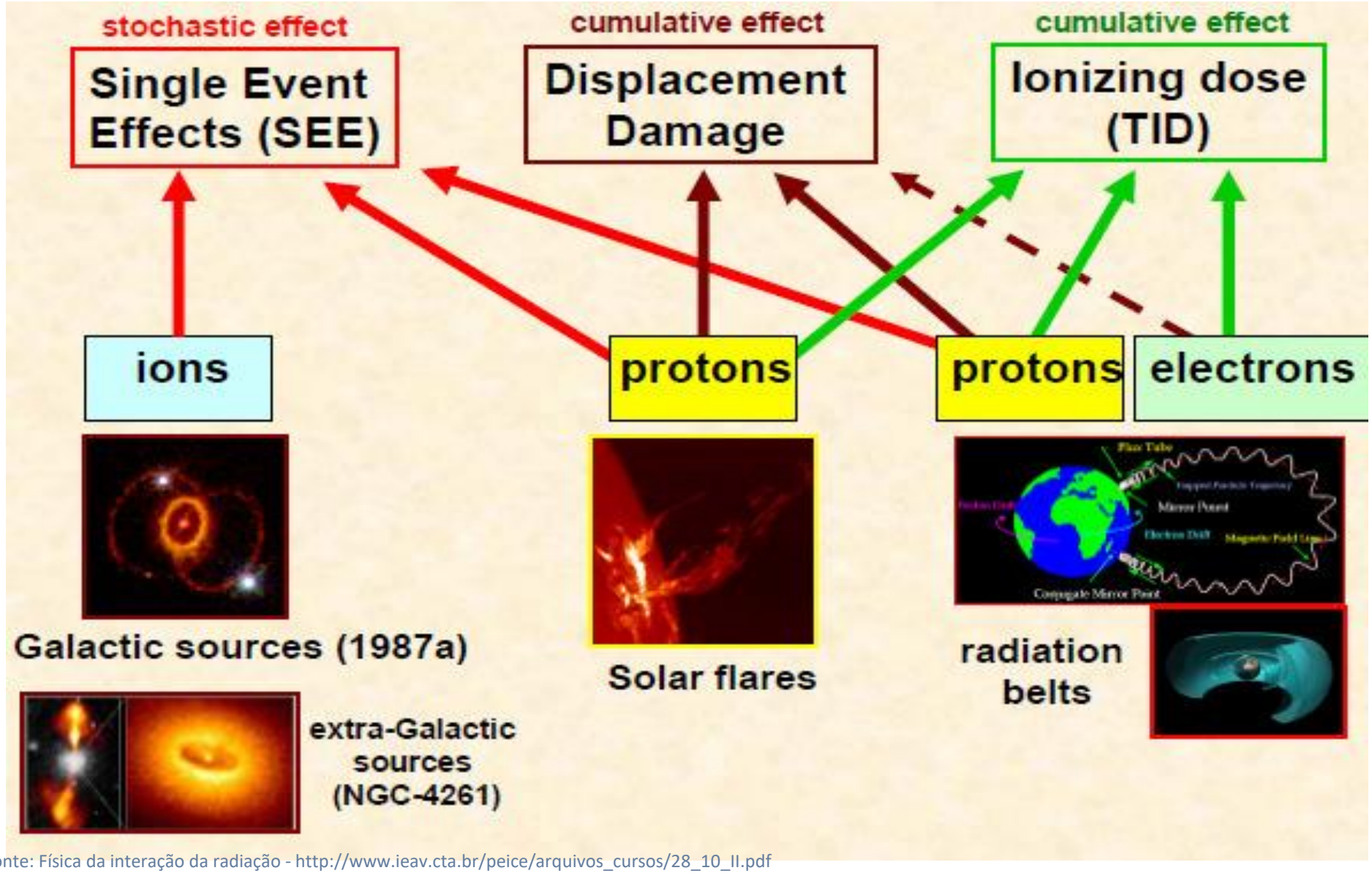


Solar Radiation

- Variation/manifestations of the Sun's magnetic field:
  - Solar Flare
  - Corona Mass Ejections
  - Sunspot
- Solar Wind.



Radiation



Fonte: Física da interação da radiação - http://www.ieav.cta.br/peice/arquivos_cursos/28_10_II.pdf

Micrometeorites and Debris

- **Micrometeorites** – solid micro fragments from space

- **Debris** – space residue from spaceships / launchers – human-made.

Temperature Variation

- Solder Fatigue in electronic equipment.
- Mitigation: thermal control

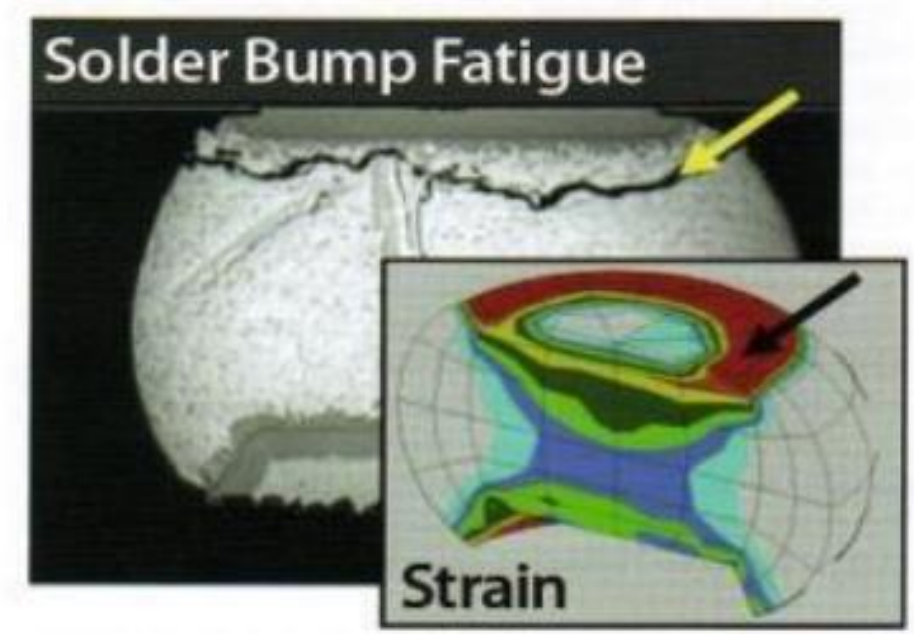
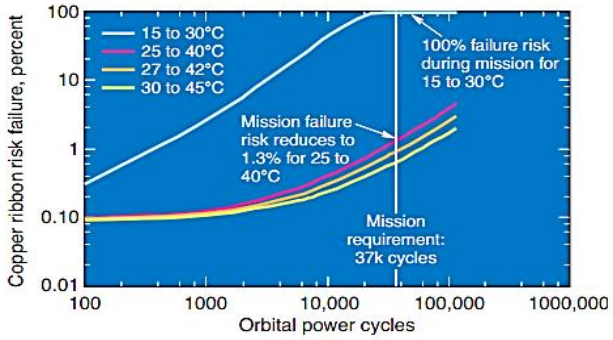
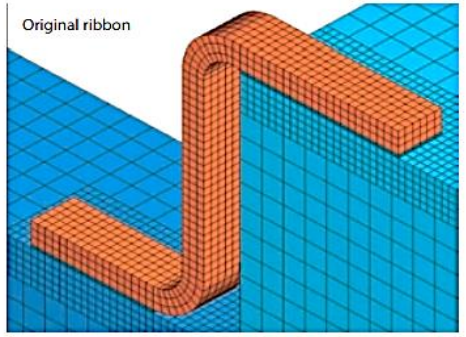
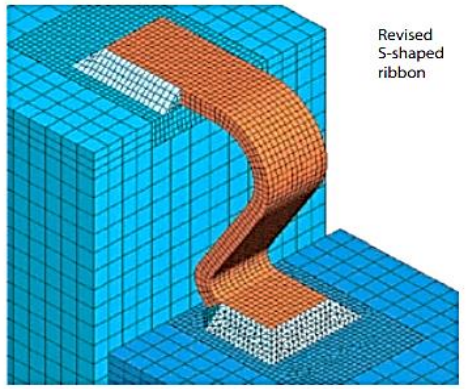


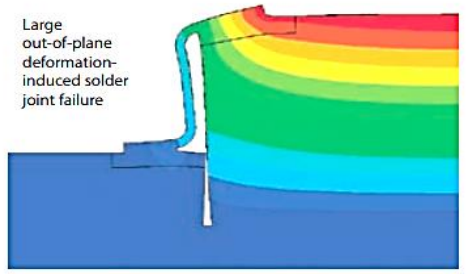
Figure 1 BGA Solder Ball Fatigue and FEA Fracture Model



Stress analyses performed by Aerospace showed that the functional failure of a transmitter during system-level thermal vacuum testing was caused by the large mismatch in thermal expansion between a copper ribbon and the composite circuit board, which resulted in solder-joint cracking. Probability analyses showed that the transmitters in mission use and awaiting launch would fail due to the large number of mission power cycles within the critical temperature range. Aerospace showed that changing the operational temperature limits would allow the existing flight units to be used as-is and helped develop a modified S-shaped ribbon, which significantly improved the fatigue margin for future units.



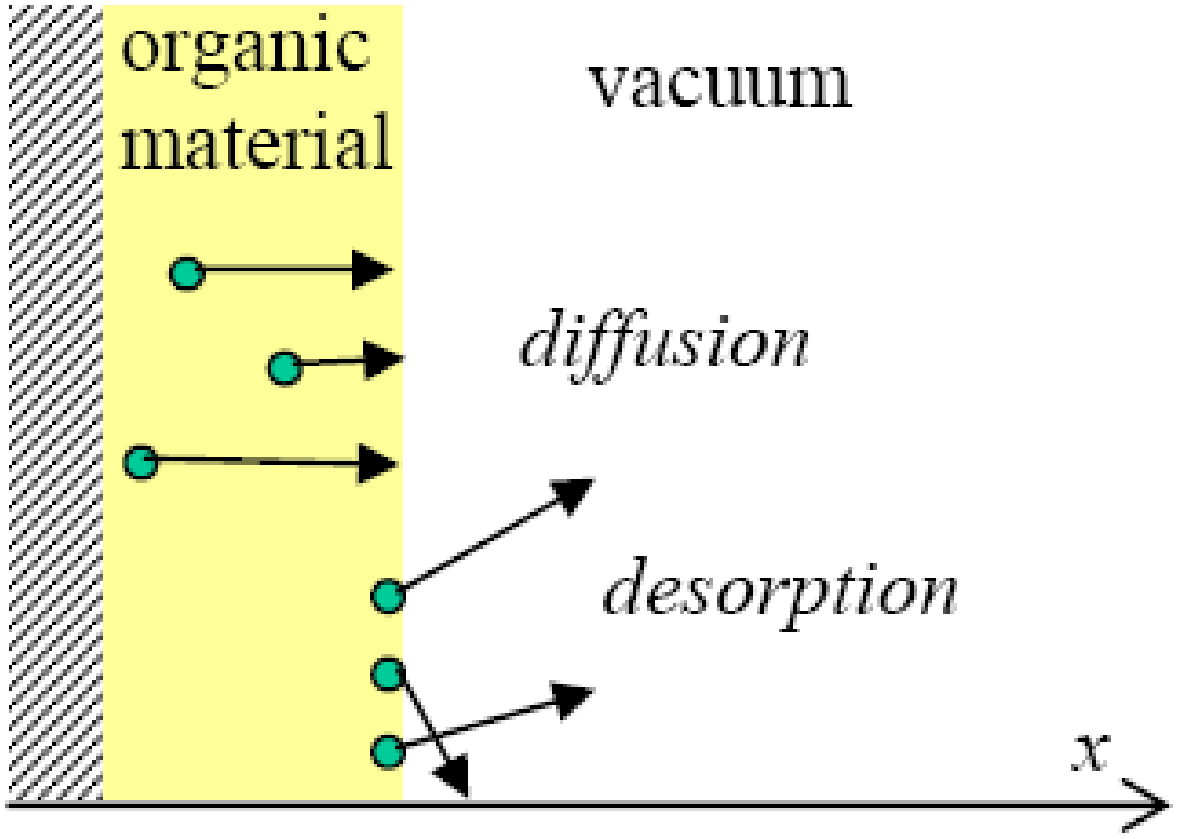




Fonte: Predicting Mechanical Failure of Electronic Assemblies, Enold Pierre-Louis

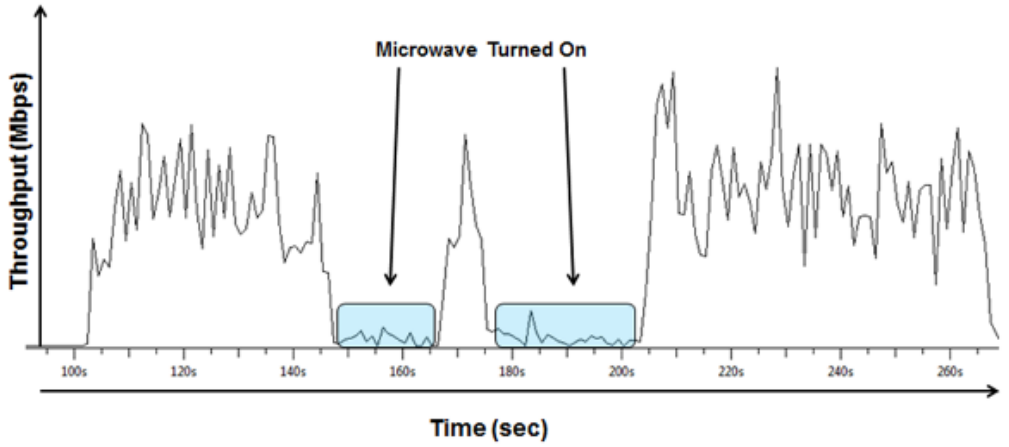
OUTGASSING / OFFGASSING

- Sublimation
- Evaporation
- Material outgassing is accompanied by **mass loss**
- The presence of contamination can degrade the performance of spacecraft hardware.



RF INTERFERENCE

- EMI can be defined as electromagnetic energy which affects the functioning of an electronic device. Sources of EMI can sometimes be naturally occurring environmental events, such as electrical storms and solar radiation; but often, the EMI source is another electronic device or electrical system.



https://www.com-power.com/emi-emc-differences.html

RF COMPATIBILITY

- EMC is a measure of a device's **ability to operate as intended** in its **shared operating environment** while, at the same time, not affecting the ability of other equipment within the same environment to operate as intended. Evaluating how a device will react when exposed to electromagnetic energy is one component of this, known as immunity (or susceptibility) testing.
- Measuring the amount of EMI generated by the device’s internal electrical systems – a process known as emissions testing – is another.

FAIRING OPENING

BOOSTER SEPARATION

ROCKET-SATELLITE CONNECTION

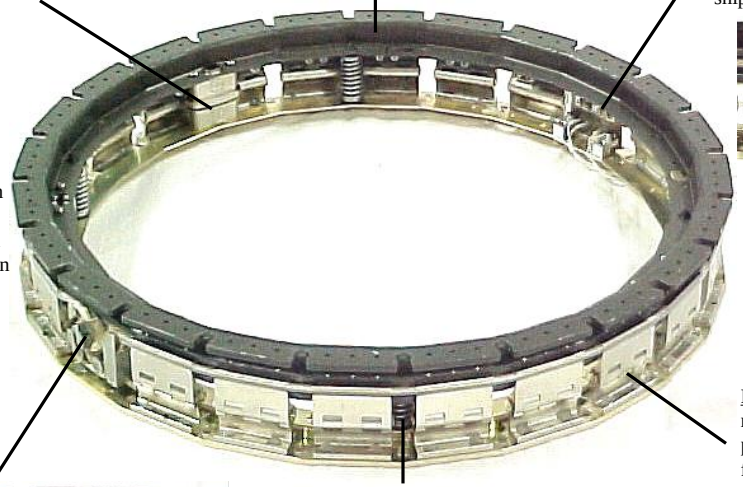
PLANETARY SYSTEMS CORPORATION

Lightband Description

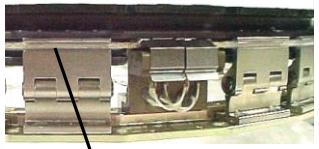
<u>Upper and lower rings</u> The mechanical interface to adjoining vehicles. Specify the bolt pattern you need and specify any special features to bond or rivet directly into adjoining structures. The Lightband meets your interface requirement.

<u>Separation Electrical Connectors</u> Allow signal and power between adjoining vehicles. Zero-force pins for ultra low tip-off. Many can be used in user specified locations.

<u>Separation Switch</u> Switch power on or off as a function of separation. Redundant normally open (NO) and normally closed (NC). Place them on lower or upper ring.



<u>De-tensioner</u> Initiates separation by cutting retaining line with redundant radiant heaters. Non pyro-technic. No gas or debris is generated. Personnel and shipment hazards eliminated.



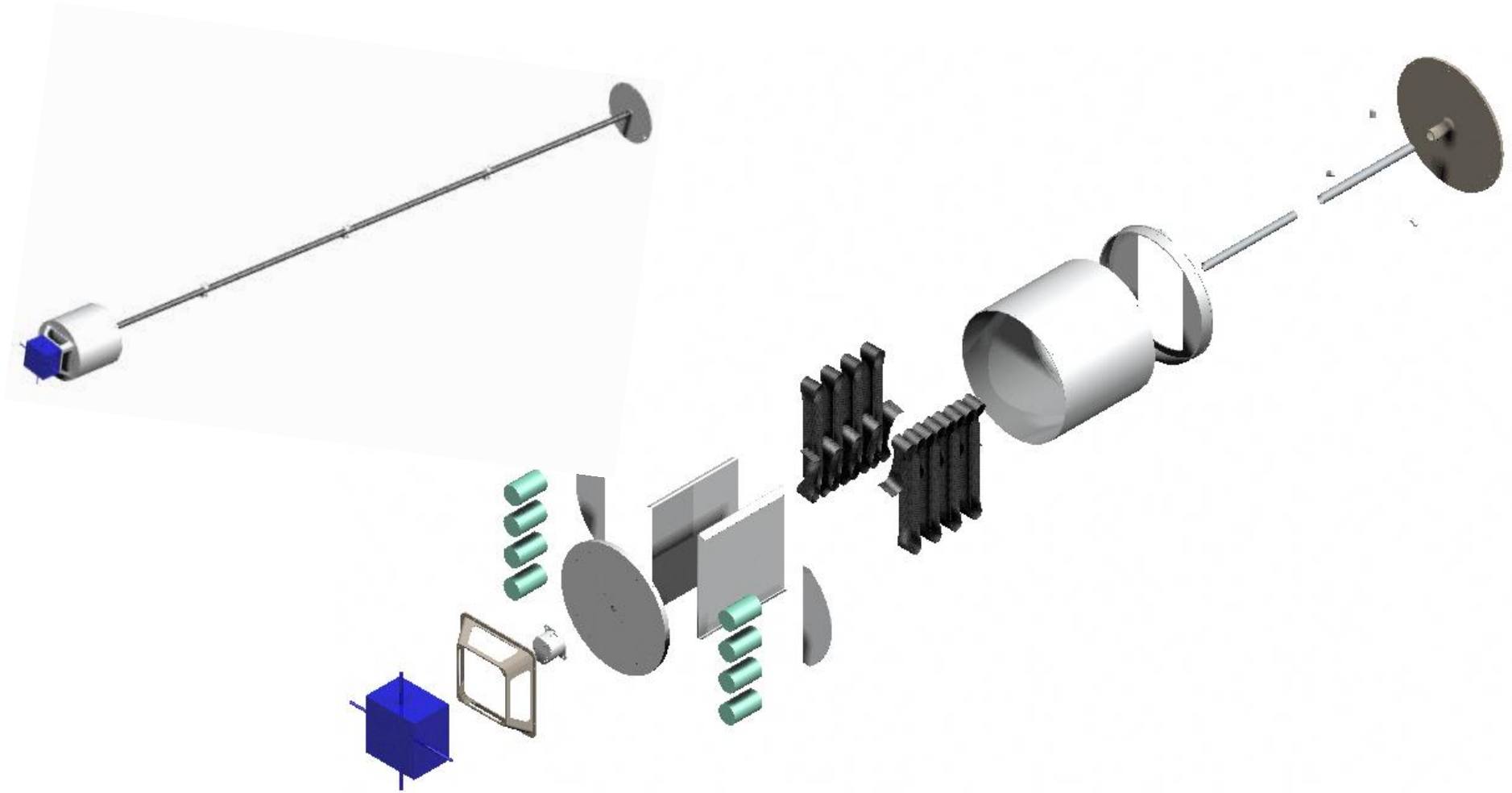
<u>Retaining Line</u> Tensioned to join the Lightband halves.

<u>Tensioner</u> Sets the Lightband for flight by tensioning the retaining line with single turn of a torque wrench. Built in load cell redundantly verifies tension.

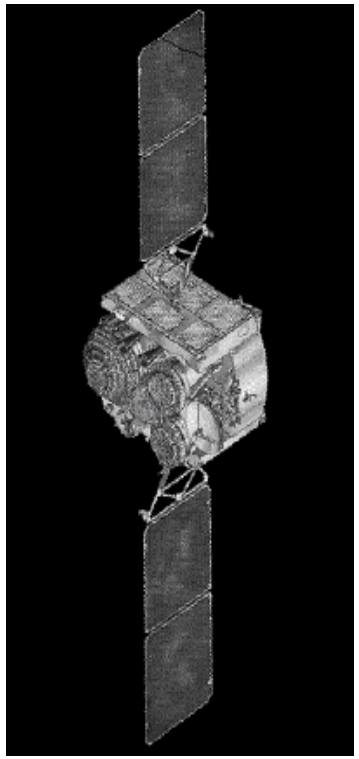
<u>Precision Separation Springs</u> Impart separation velocity. Add more for more velocity or to compensate for CG offsets. Angle them to spin-up.

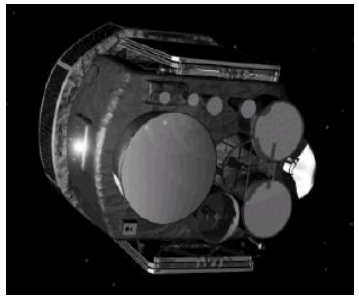
<u>Precision Hinged 'Leaf'</u> Unlatches and rotates to release. Grooves for shear pins eliminate dependence on friction for shear strength

DEPLOYABLES (BOOMS)

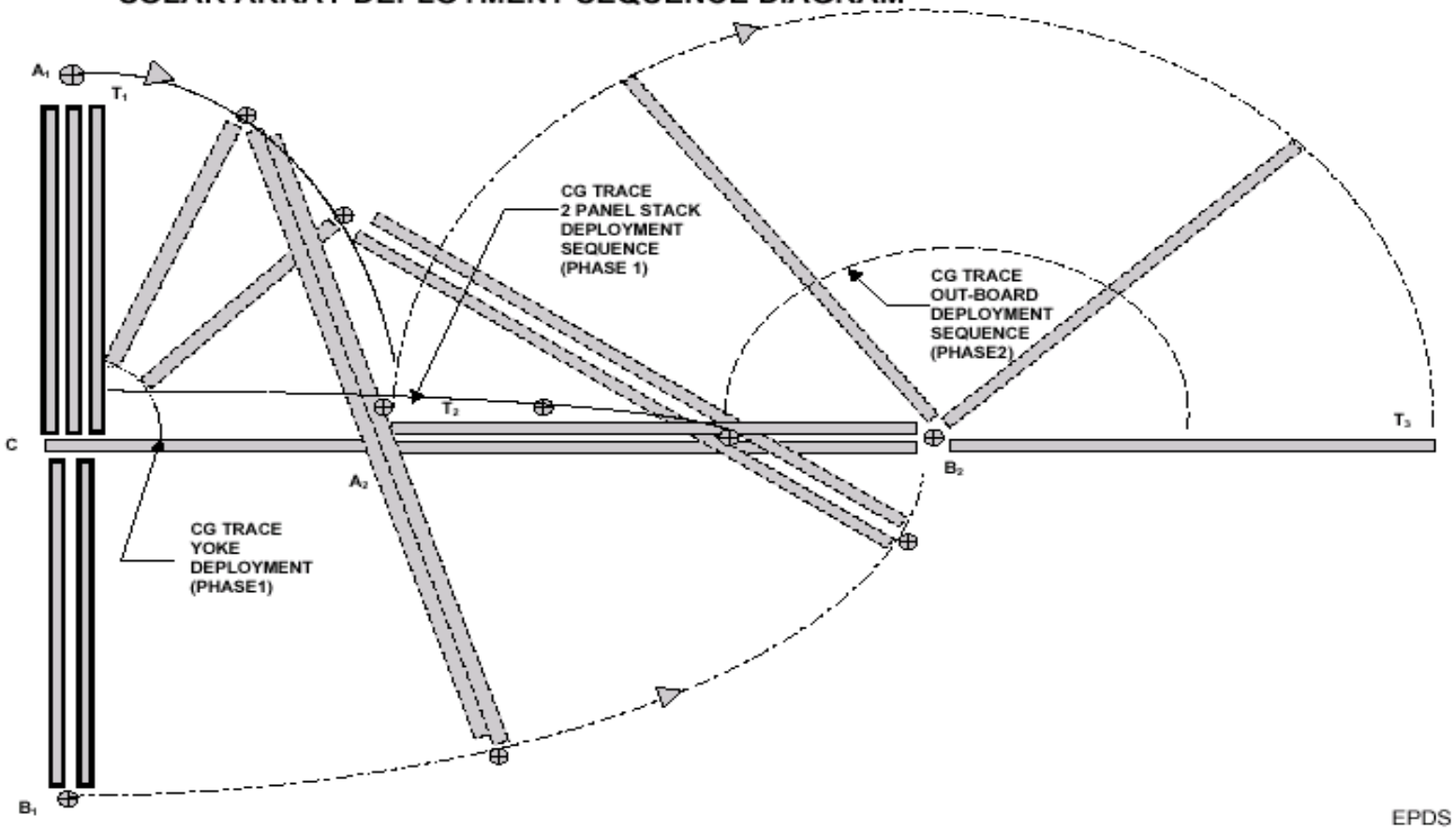


SOLAR ARRAY DEPLOY



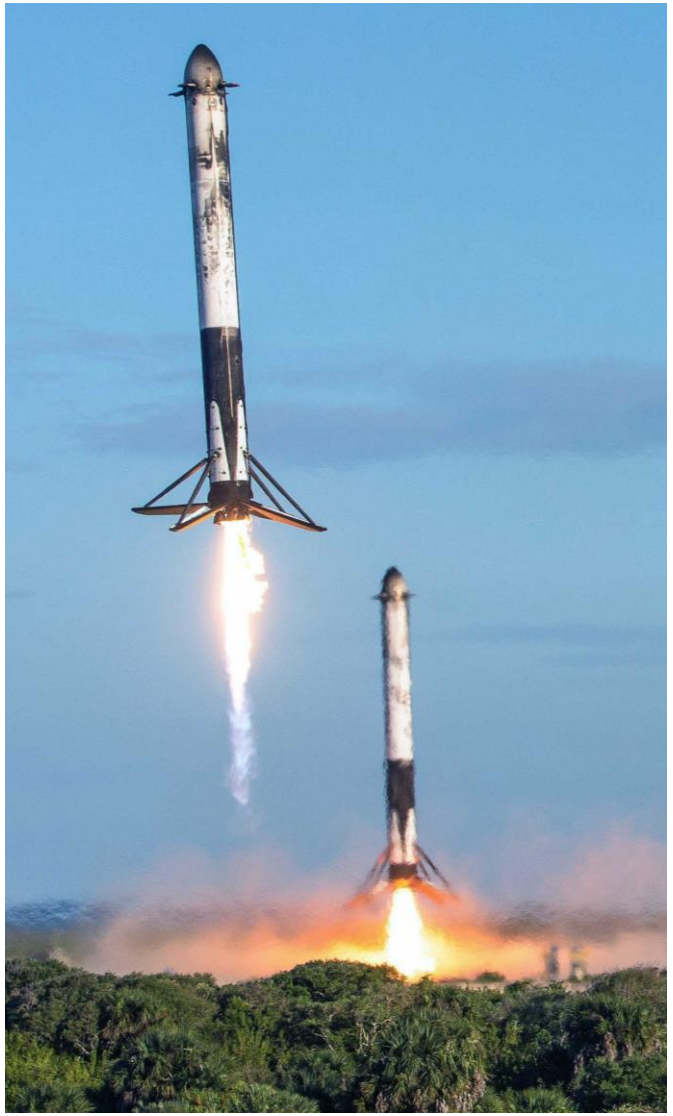


- **SOLAR ARRAY DEPLOYMENT SEQUENCE DIAGRAM**



REENTRY

LANDING



FACILITIES

PUPOSE OF AN AIT FACILITY

- The AIT building is an environmentally controlled laboratory constructed to **accommodate the testing requirements of both ground-based instruments and fully qualified space-flight hardware**.

- It is specifically designed to **permit the assembly, integration and test** or verification of spacecraft components, equipment, instruments, satellite modules and systems.

CONSIDERATIONS

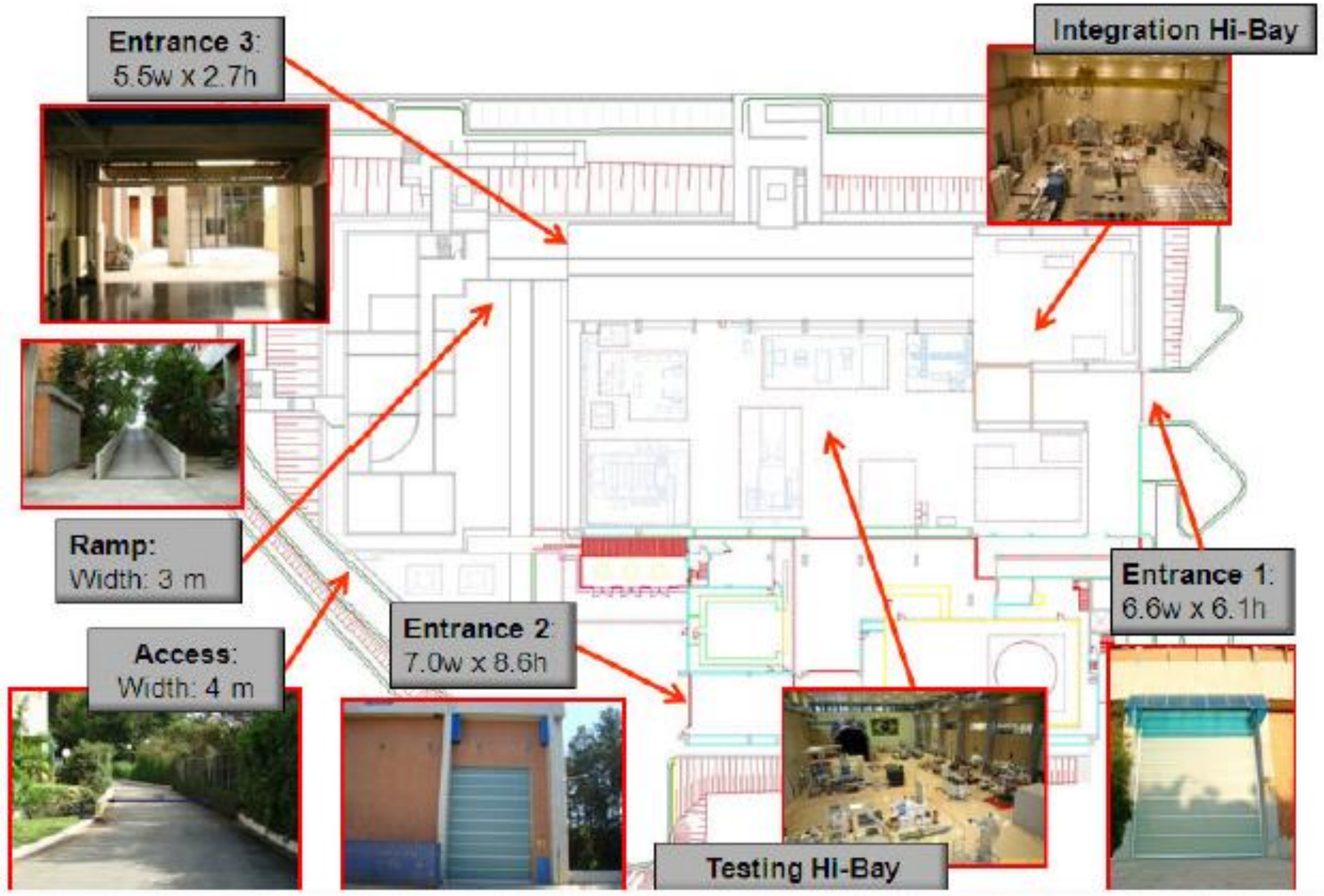
- Be it a manned or unmanned mission, for scientific research or as a space transportation, a spacecraft with its payload must be able to:
  - withstand the **rigors of the liftoff and ascent environment** occur during the launch phase, and,
  - the **extreme thermal condition**s and **operational environment** experienced by the spacecrafts and its payload once it is in orbit.
- This include:
  - the effects of intense acoustic and vibration generated by **engine ignitions during liftoff**,
  - Shocks generated during **separation of stages and fairing**,
  - Shocks during **deployment of solar panels**,
  - **temperature variation, vacuum condition, solar radiation** and many other effects experienced by the spacecraft.

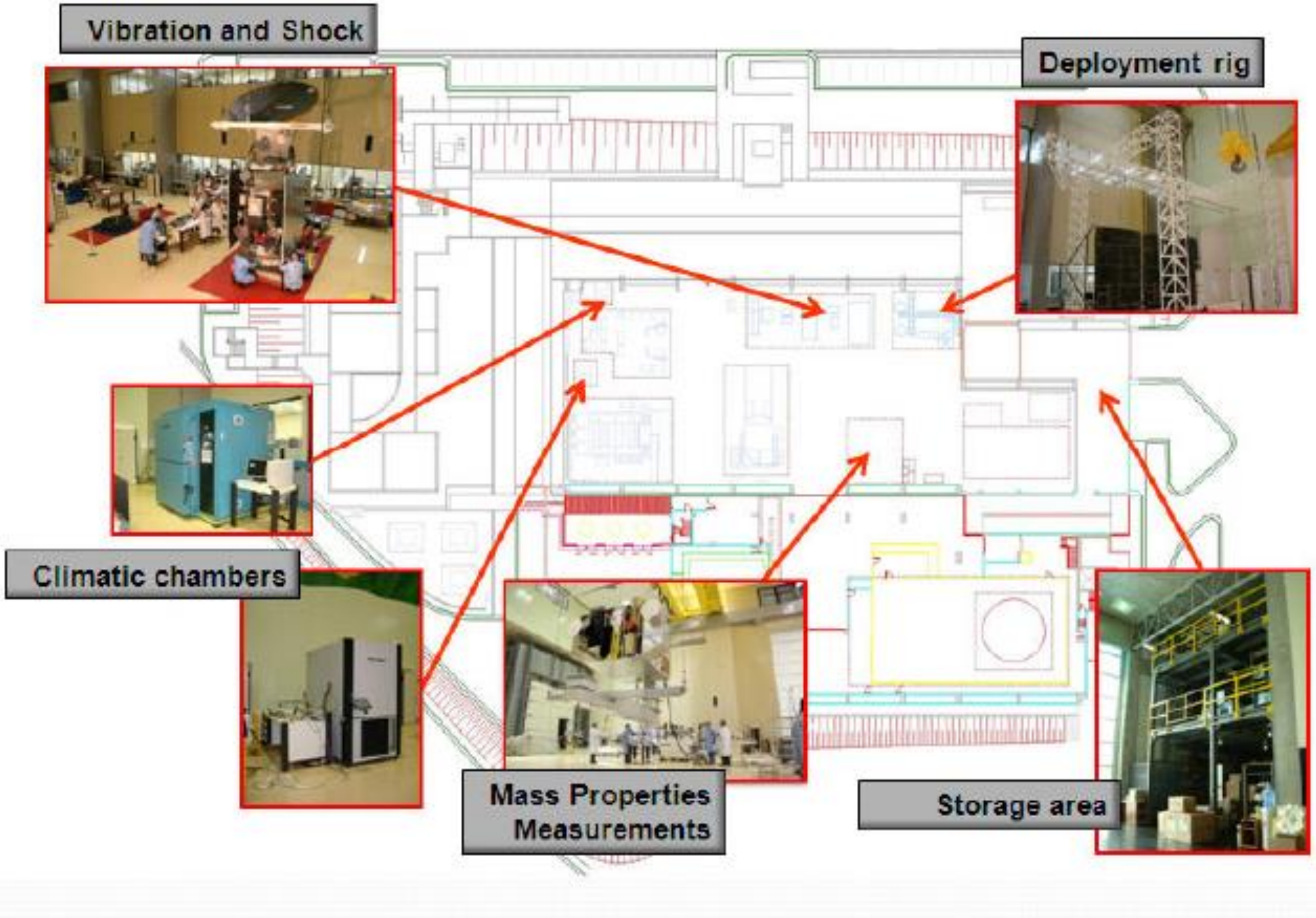
- Both mechanical and thermal effects introduced a lot of constraints on the structure design of a spacecraft and therefore, it must be thoroughly tested up to the system components to ensure the survivability of the spacecraft and its payload in space.

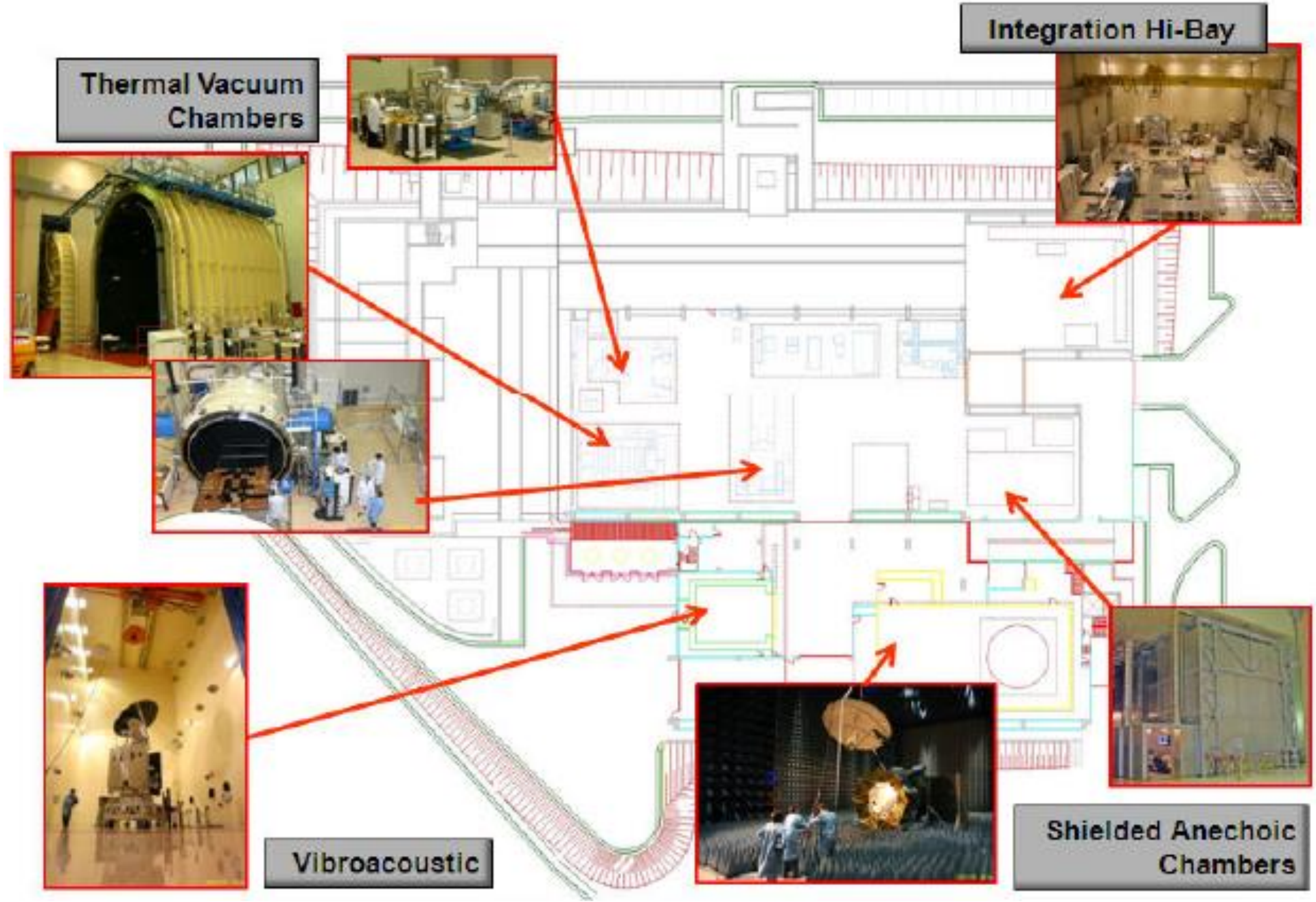
CONSIDERATIONS

- There are several AIT centers that have been developed to cater the needs of spacecraft manufacturers for a complete, simulated testing before launch.
- Each centre housed similar test facilities such as the **vibration test facility, thermal vacuum chamber, electromagnetic chamber and acoustic test facility.**
- Systems used for measurement before and after each test like the **mass properties and alignment system** are also common in most AIT centers.
- What differ from one facility with another are the specification of the test equipment and the size of the equipment under test.

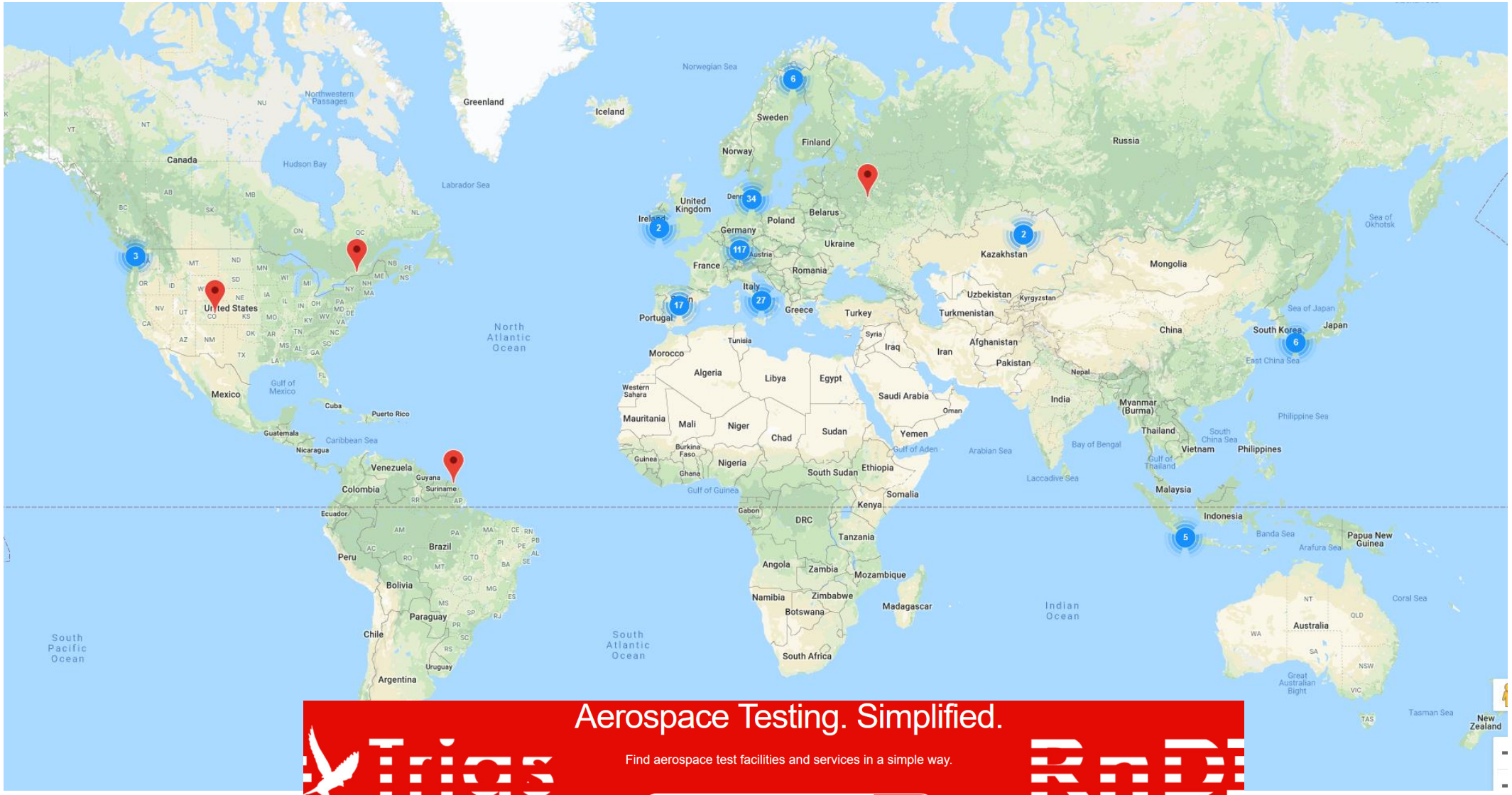
LIT – Laboratório de Integração e Testes


Entrance 3:
5.5w x 2.7h
Integration Hi-Bay
Ramp:
Width: 3 m
Access:
Width: 4 m
Entrance 2:
7.0w x 8.6h
Entrance 1:
6.6w x 6.1h
Testing Hi-Bay

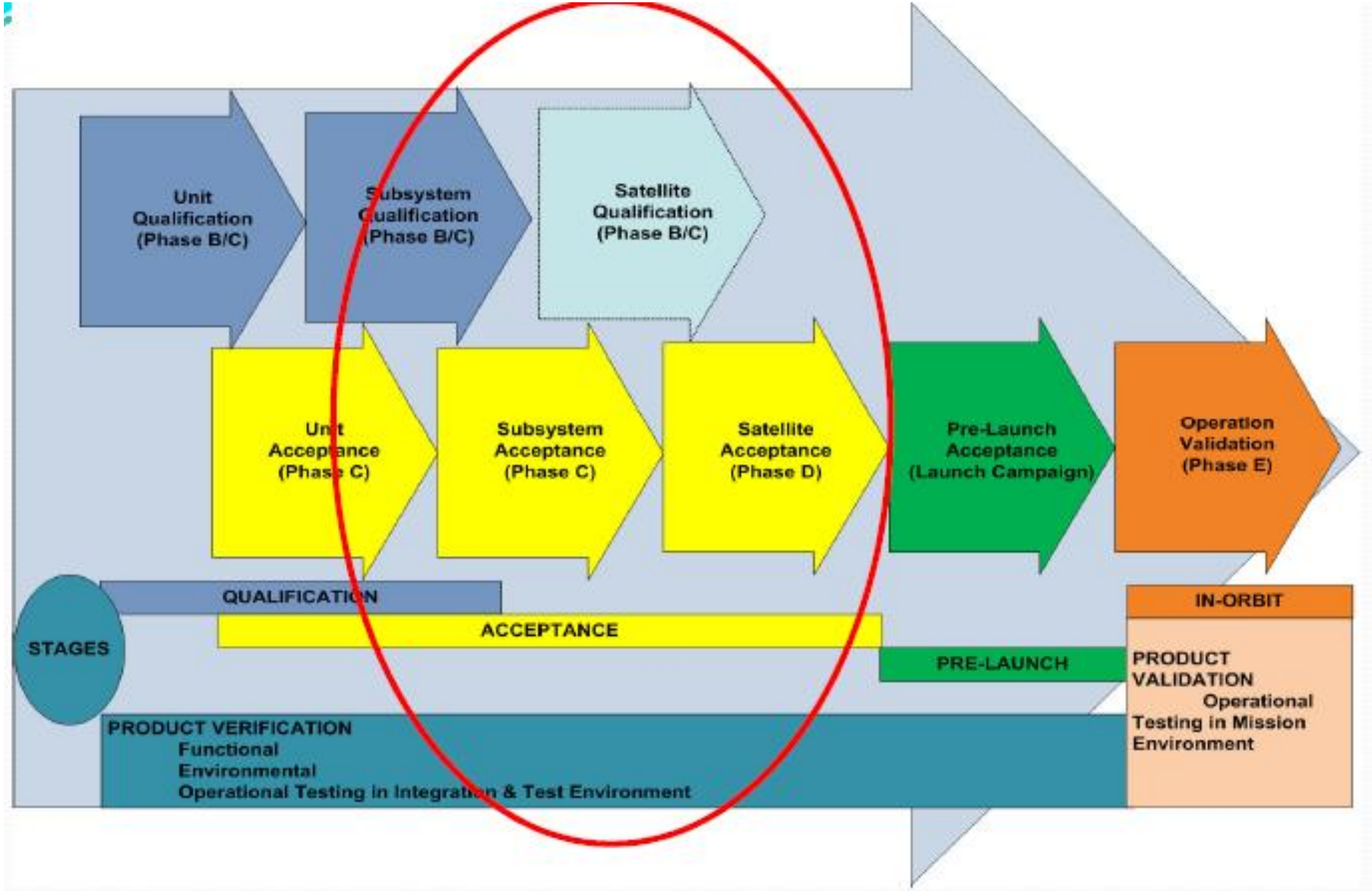

Vibration and Shock
Deployment rig
Climatic chambers
Mass Properties Measurements
Storage area


Integration Hi-Bay
Thermal Vacuum Chambers
Vibroacoustic
Shielded Anechoic Chambers

Around the world: https://triasrnd.com/



AIT FACILITY ACTIVITIES



Vehicle/Satellite Qualification Tests

- Alignments
- Functional tests
- Mass properties
- Leakage
- EMC / EMI
- Shock/Separation
- Acoustic
- Vibration
- Thermo Balance
- Vacuum temperature cycling
- Magnetic Balance

Vehicle/Satellite Acceptance Tests

- Alignments
- Functional tests
- Mass properties
- Leakage
- EMC / EMI
- ~~Shock/Separation~~
- Acoustic
- Vibration
- ~~Thermo Balance~~
- Vacuum temperature cycling
- Magnetic Balance

Required/Evaluation Qualification Tests

TEST	SEQ	LAUNCHER	UPPER	SAT
ALIGHMENT (1)	1		ER	R
FUNCTIONAL (2)	2	R	R	R
MASS	3	R	R	R
LEAKAGE (1)	4	R	R	R
EMC	5	R	R	R
SHOCK/SEPARATION	6	R	R	R
STATIC LOAD	7		ER	R
ACOUSTIC	8	ER	ER	R
VIBRATION	9	ER	ER	R
THERMO BALANCE	10	-	ER	R
VACUUM TEMPERATURE CYCLING	11	-	ER	R
MAGNETIC BALANCE	12		ER	R

R= Required - ER= Evaluation Required - ⇒ test sequence

(1) At the start and end of the sequence and before and after environmental tests

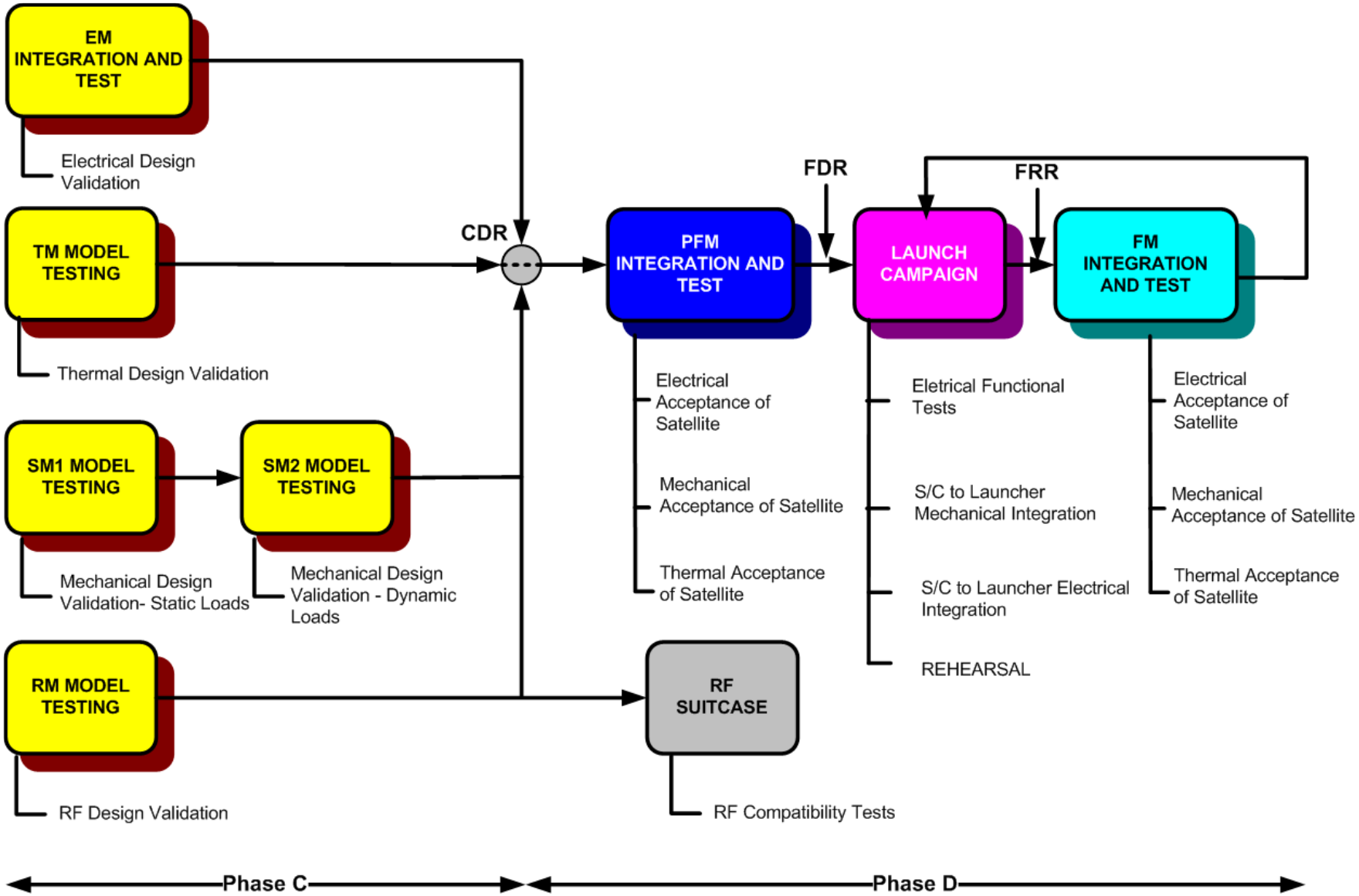
(2) Electrical and mechanical performance tests shall be conducted prior to, during and following each environmental test, as appropriate

Required/Evaluation Acceptance Tests

TEST	SEQ	LAUNCHER	UPPER	SAT
ALIGHMENT (1)	1		ER	R
FUNCTIONAL (2)	2	R	R	R
MASS	3	R	R	R
LEAKAGE (1)	4	R	R	R
EMC	5	R	R	R
ACOUSTIC	6	ER	R	R
VIBRATION	7	ER	R	R
VACUUM TEMPERATURE CYCLING	8	-	R	R
MAGNETIC BALANCE	9			R

R= Required - ER= Evaluation Required - ⇒ test sequence
(1) At the start and end of the sequence and before and after environmental tests
(2) Electrical and mechanical performance tests shall be conducted prior to, during and following each environmental test, as appropriate

SYSTEM MODELS - EM, SM, TM, RM, PFM/FM SEQUENCE



COMMON TEST FACILITIES

- These are required to fulfill the subsystem/system testing requirement and may include some or all of the following facilities :
  - Satellite integration clean room;
  - Vibration Tests facility – dynamic tests;
  - Vibration Test facility – static load tests;
  - Acoustic Test facility;
  - Mass Properties, Dynamic Bal & Spin tests facility;
  - Thermal Vacuum Test facility;
  - EMC Tests facility;
  - Antenna Gain & Pattern Diagrams facility;
  - Solar Array Test facility;
  - Magnetic Tests facility;
  - Global leakage test facility;
  - Space Qualified welding facility;

- The test facility also must be equipped with:
  - a) cranes,
  - b) vacuum systems,
  - c) compressed air systems,
  - d) Fire detection and protection and environmental monitoring
  - e) system which monitor the clean room temperature, air pressure as well as humidity.
- These are considered as necessities for the operation of a satellite test facility.
- Besides the above-mentioned areas, the AIT building also housed office space for engineers, technicians and administration staffs, meeting rooms, and utilities such as
  - a) bathroom, security and control room,
  - b) communication room as well as network room.
- These areas are kept in normal environment condition.

FACILITIES X MODELS

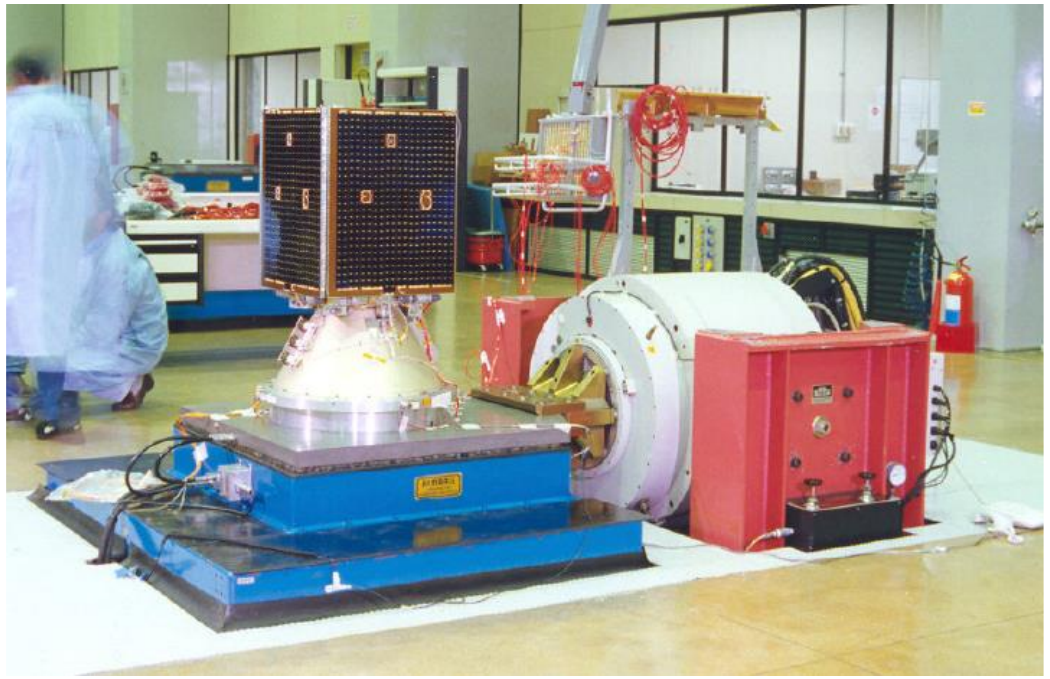
Test Facilities	Satellite Models				
	RM	SM	TM	EM	FM
Satellite integration clean room;		X	X		X
Vibration Tests facility – dynamic tests;		X			X
Vibration Test facility – static load tests;		X			
Acoustic Test facility;					X
Mass Properties, Dynamic Bal & Spin tests facility;					X
Thermal Vacuum Test facility;			X		X
EMC Tests facility;				X	X
Antenna Gain & Pattern Diagrams facility;	X				
Solar Array Test facility;					X
Magnetic Tests facility;					X
Global leakage test facility;					X
Space Qualified welding facility;					X

FACILITIES SYSTEM TESTS X MODELS

System Tests	Satellite models							
	SM1	SM2	TM	RM	EM	SIM	FM3	FM4
Electrical tests					X		X	X
EMI/EMC tests					X			
Launcher compatibility test		X						
Control Segment compatibility test						X		
Application Segment Compatibility test						X		
Magnetic balance							X	X
Radio coverage test				X				
Mass properties measurement		X					X	X
Alignments							X	X
S/C to Launcher separation test		X						
SAG deployment test (s/s level)		X					X	X
Leakage test							X	X
Static load test	X							
Sinusoidal Vibration Test		X					X	X
Acoustic Noise Test		X					X	X
Thermal Balance Test (TBT)			X				X	
Thermal Vacuum Test (TVT)							X	X

VIBRATION TEST SYSTEM:

- The Vibration Test System is used to simulate the low frequency caused by the launch vehicle during launch process, to ensure that the satellite can withstand the maximum expected flight environment.

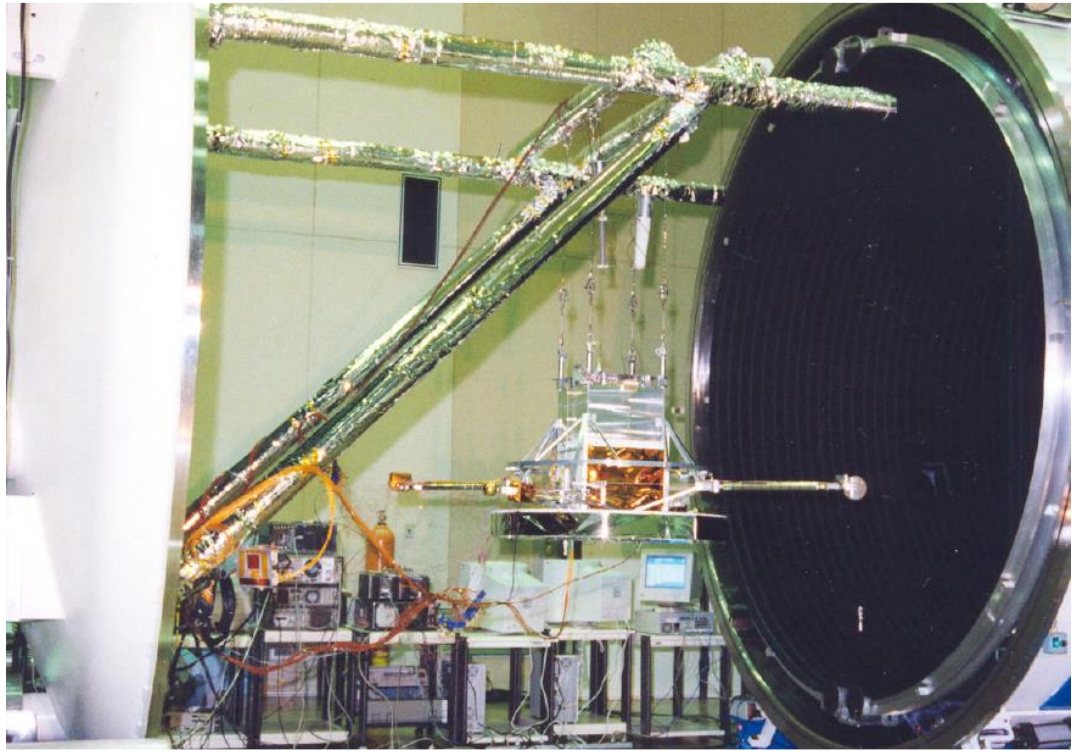


REVERBERATION ACOUSTIC TEST FACILITY

- The acoustic chamber is used to simulate the launch process, where tremendous amount of noise generated in the exhaust plume flowing from the nozzle as the launch vehicle lifts off.
- The exhaust gas velocity maybe as high as 10,000 feet per second and some of the acoustic energy reflects off the ground and propagates into the vehicle's nosecone.
- This energy is radiated as sound pressure into the internal volume of the nosecone, where the satellite is in the launch vehicle.

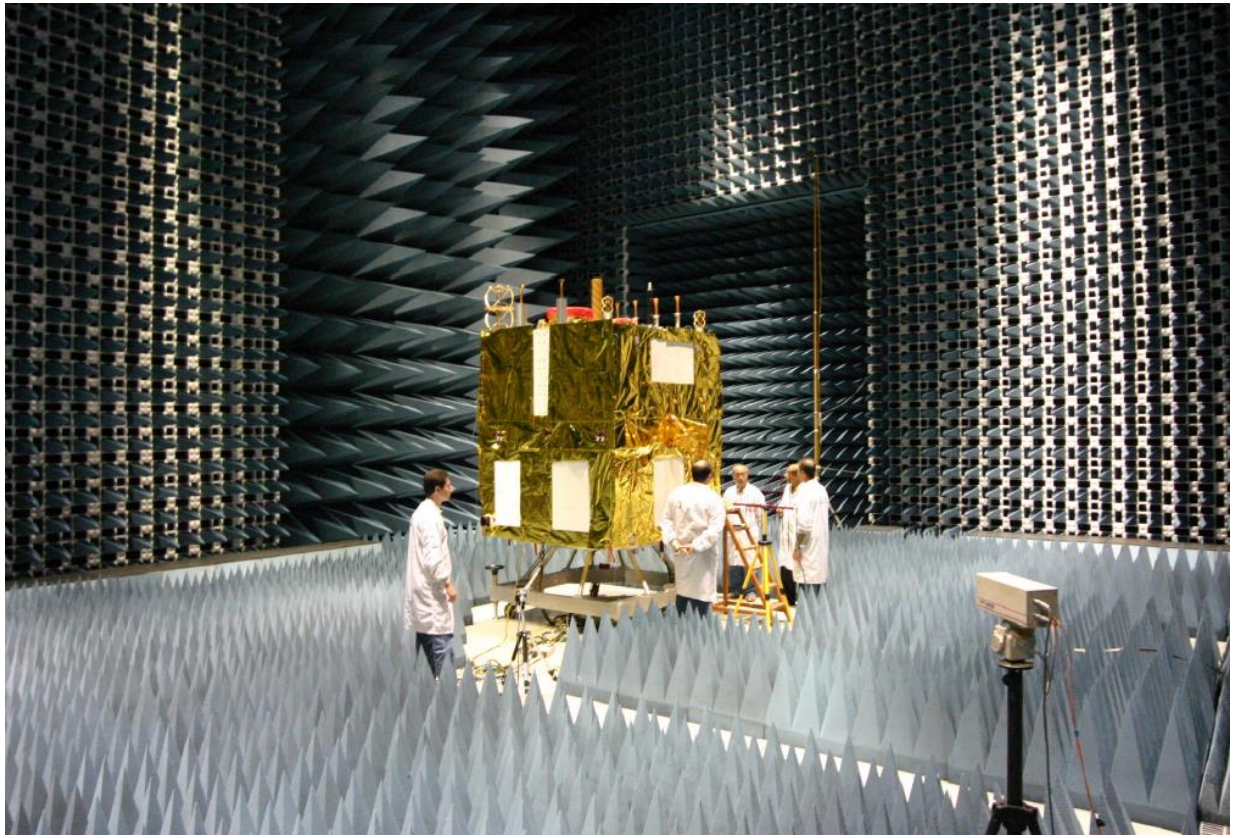
THERMAL VACUUM CHAMBER

- Thermal vacuum chambers are used to simulate the environment in space where the satellite will be orbiting.
- At times when the satellite is facing sun, temperature can go up to 100°C and above, and at times when the satellite is in eclipse; the satellite can be exposed to a temperature of -100°C and below.
- Therefore, it is critical that the satellite is tested and verified that it will be able to operate under space's extreme hot and cold environment and near vacuum condition.
- The system will be able to support thermal vacuum tests, thermal balancing tests and thermal cycling tests.
- The satellite will be placed securely in the chamber and air will be pumped out to reach a certain level of pressure.



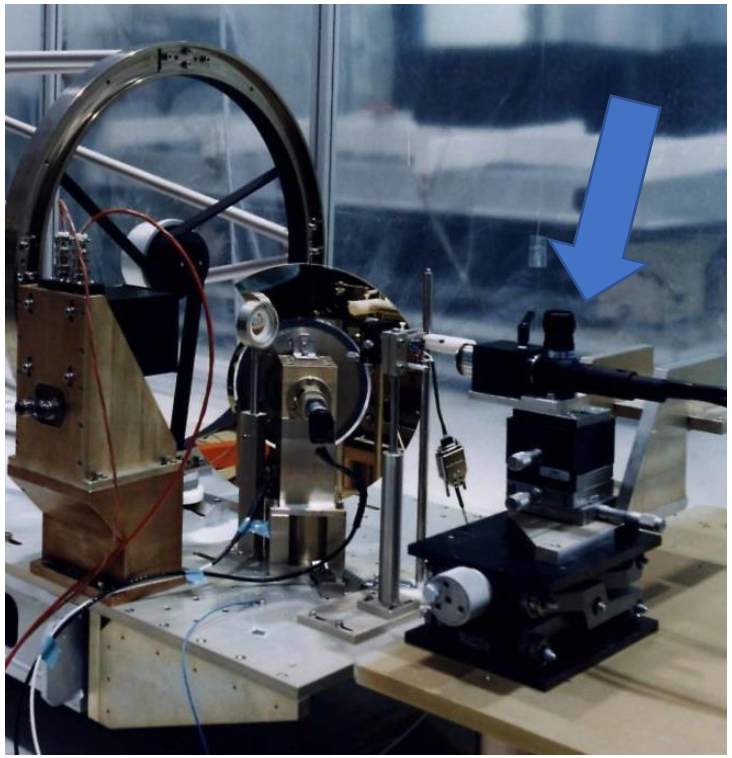
ELECTROMAGNETIC COMPATIBILITY TEST CHAMBER

- The EMC chamber is used to test the electrical and electronic parts in a satellite will not generate electromagnetic disturbances, which may influence other parts of the satellite.
- In other words, it deals with problems of noise emission as well as noise immunity of the electrical and electronic components and system



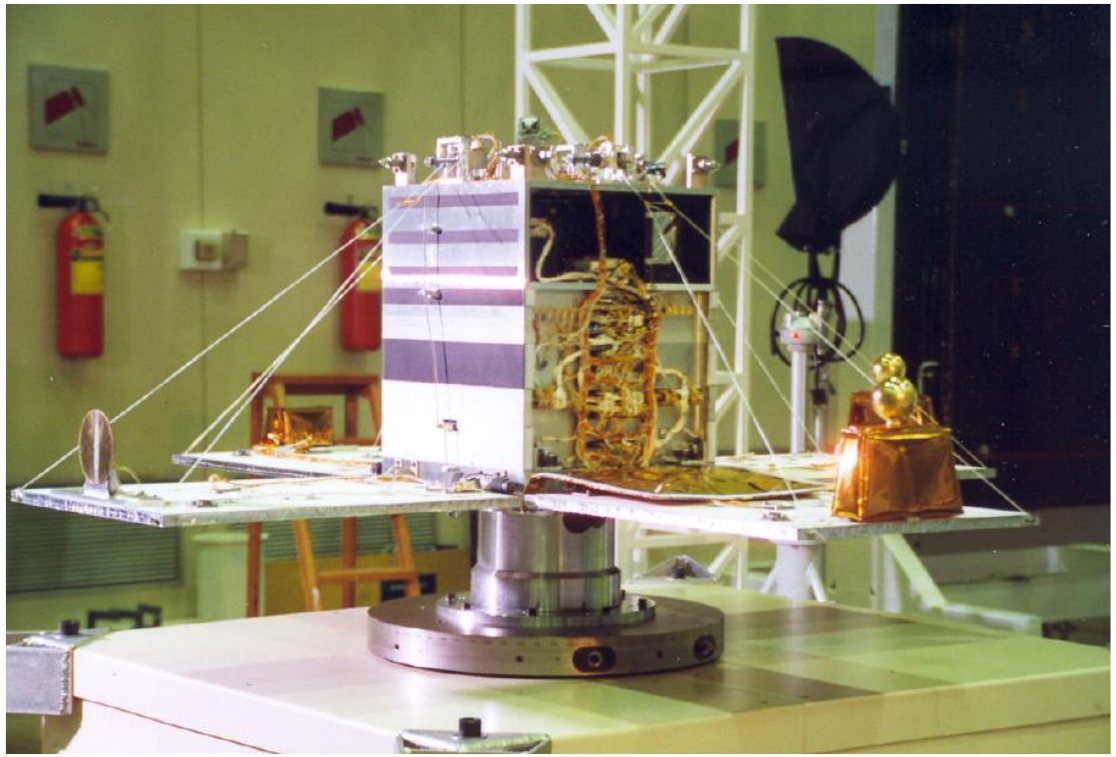
ALIGNMENT MEASUREMENT SYSTEM

- The alignment measurement is used to undertake precision geometrical alignment measurement specifically for satellite component alignment



MASS PROPERTIES MEASUREMENT SYSTEM

- The success of a satellite mission is highly dependent on the accuracy of the measurement of its mass properties before flight and the proper ballasting of the satellite to bring the mass properties within tight limit.
- The mass property measurement system will be used to determine and measure precisely and accurately the physical properties of the satellite, its subsystems and payloads, i.e.
  - a. to determine the center of gravity and
  - b. moment of inertia of the satellite in order to provide for satellite positioning control during orbit insertion and attitude control



Summary

- Receiving Equipment
- Clean Rooms
- Assembling
- Integration
- Construction of Facilities
  - Equipment Distribution
  - Infrastructure Required

Class Ending

Homework

- Each group:
  - **Research laboratories and equipment** regarding the critical events (distributed to each group): (some examples)
  - STRU: Related to rocket vibrations (acoustic, shocks, launching)
  - AOCS: related to mass properties, alignment
  - OBC: related to functions
  - TT&C: related to electromagnetic compatibility, antennas
  - EPS: related to temperature / power dissipation

  - **Create a presentation to next class (50min to all ~ 10min each)**