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Method for CubeSat Thermal-Vacuum testing specification

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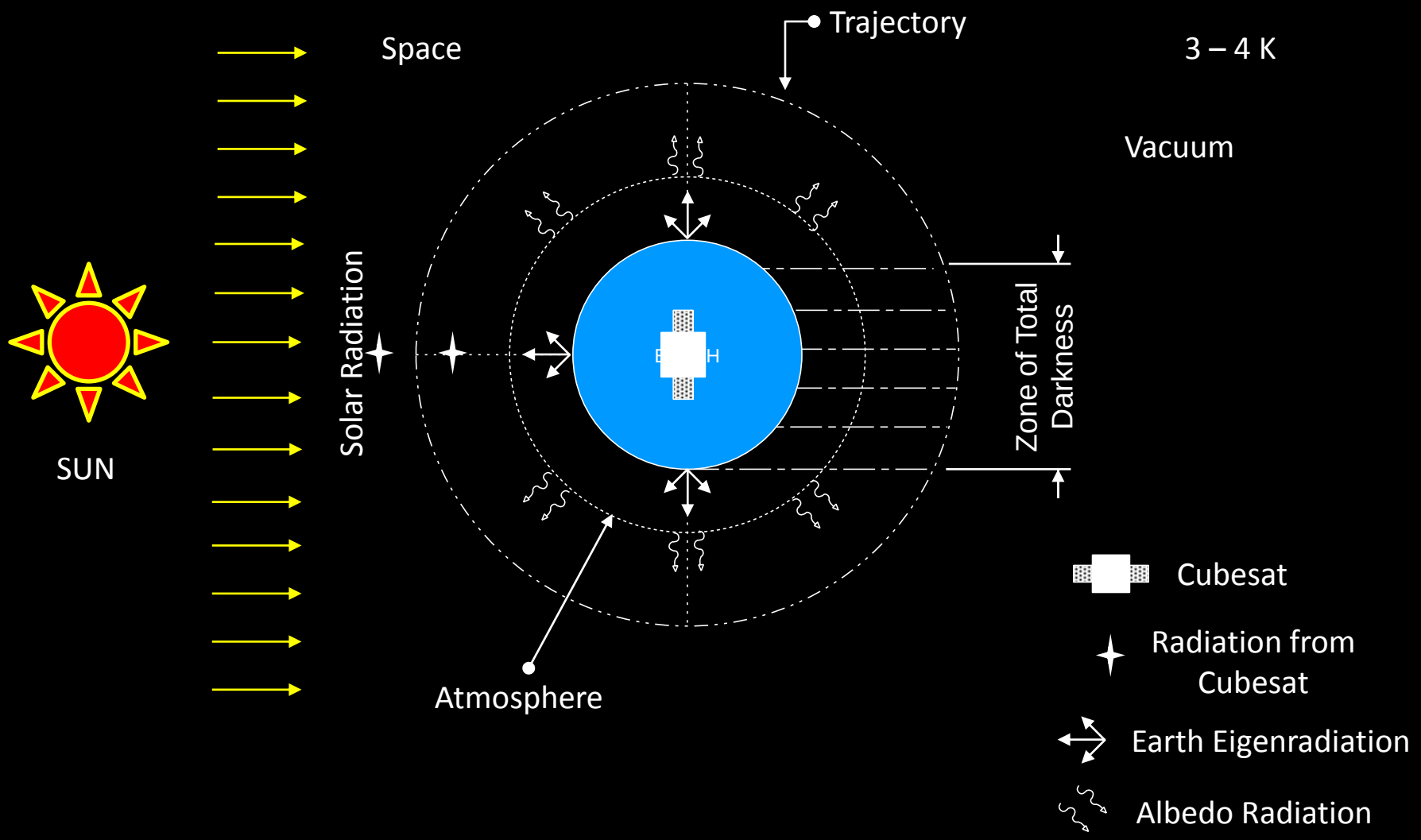
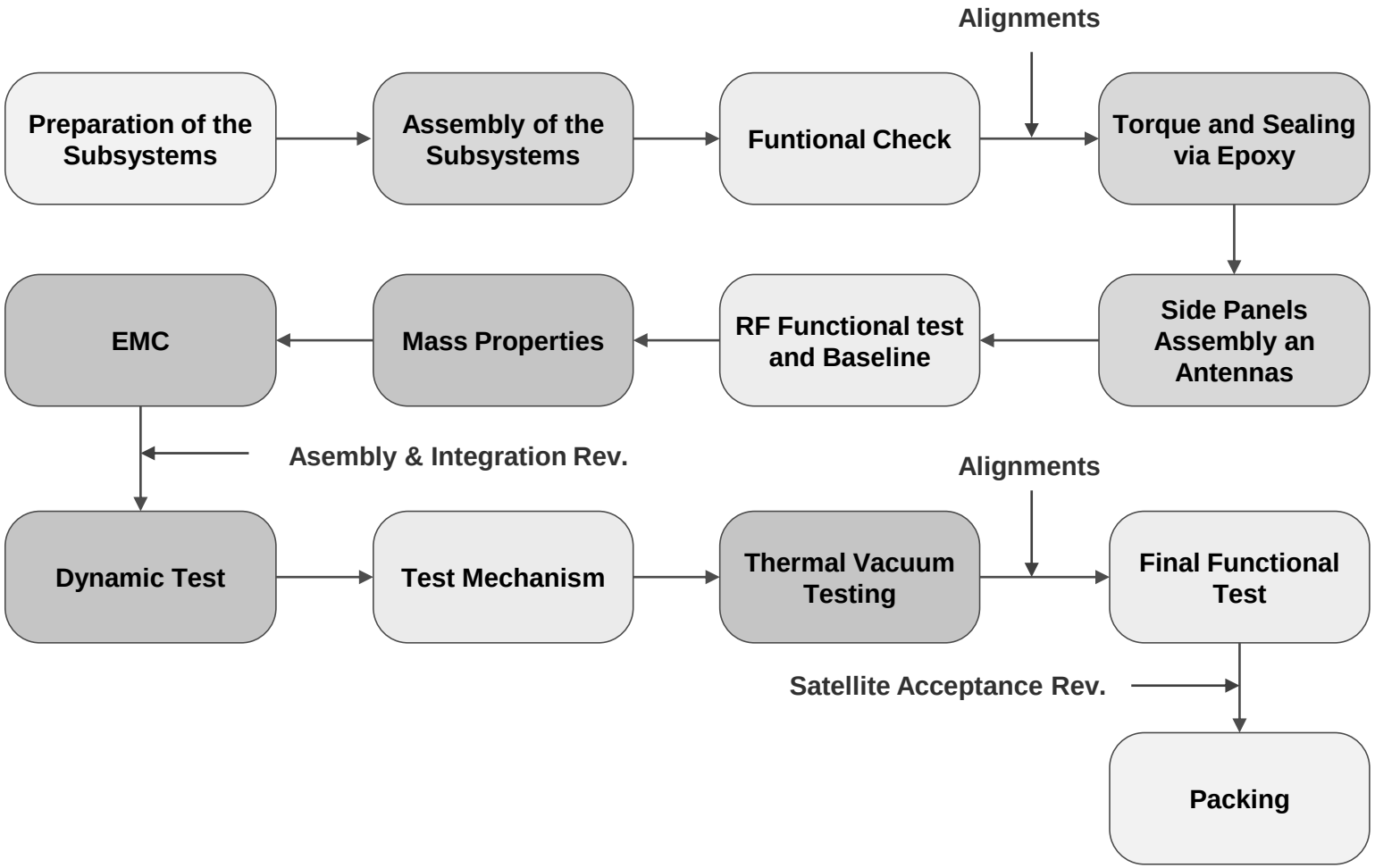
INTRODUCTION

- The CubeSat is a type of a small satellite developed for specific missions: space science, communications, technology verification, earth observation, military applications, and others.
- To survive the harsh launch and space environments, the CubeSats shall pass through a series of tests such as vibration, thermal-vacuum cycling test, Bakeout and visual inspection. Usually for CubeSat missions, reliability is regarded as low priority and most of tests are specified just for launch vehicle requirements attendance

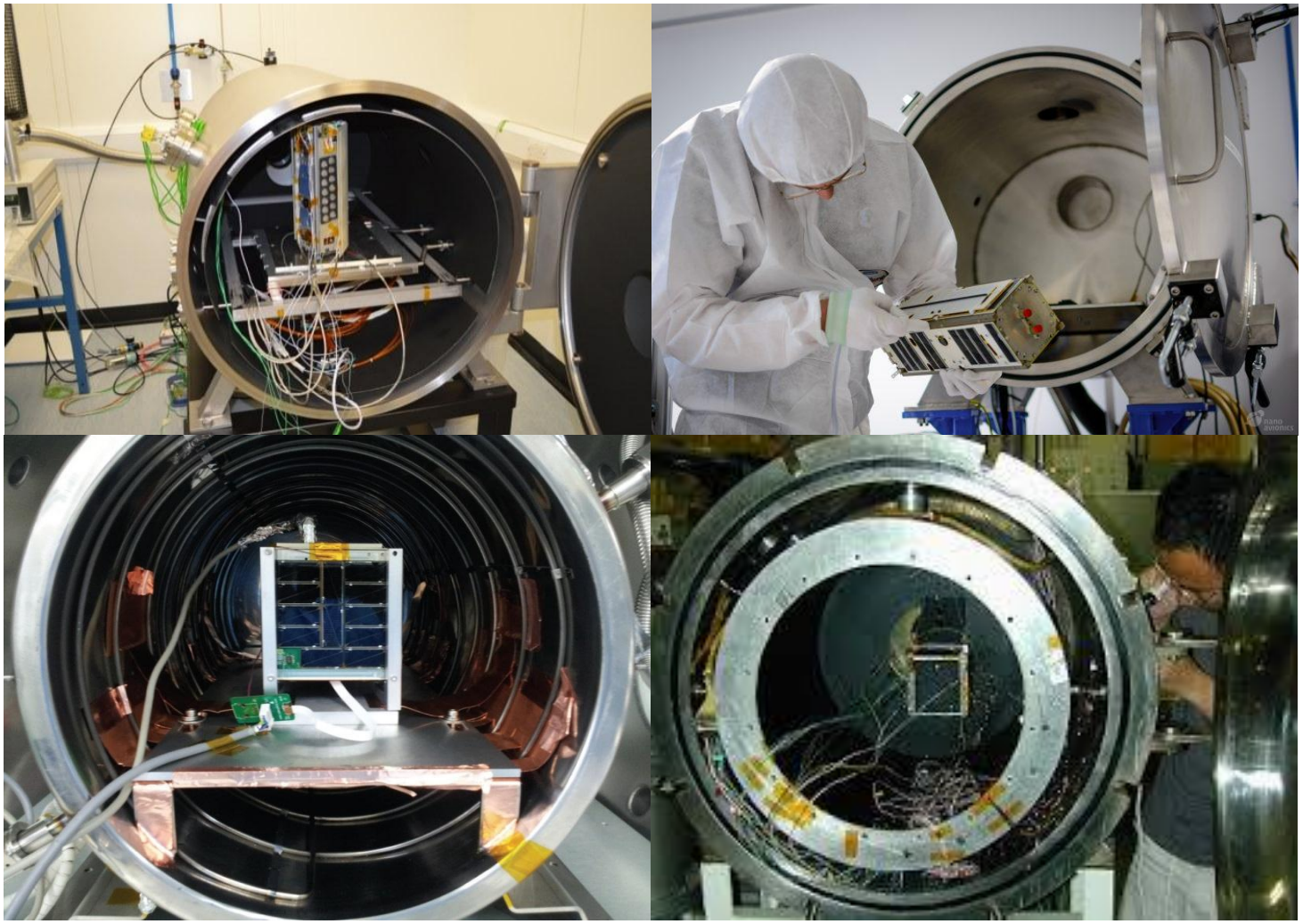
Space Environment



Typical sequence in a test program



Thermal Vacuum Test



DOCUMENTS

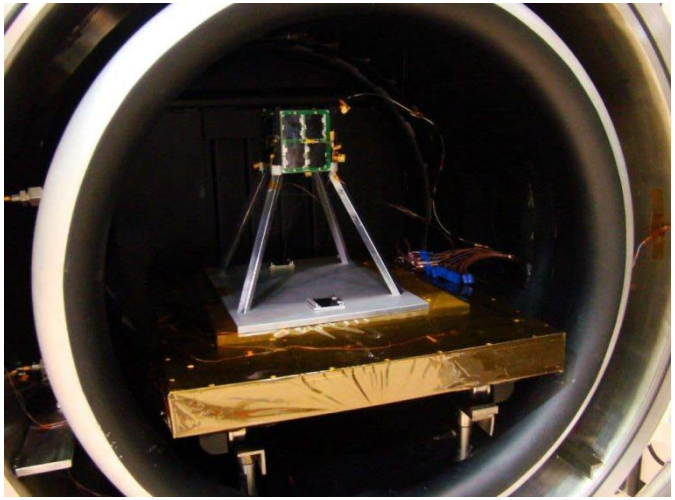
- **CubeSat Design Specification (CDS) Rev.13**
- **GSFC-STD-7000**
- **MIL-STD-1540D**
- **MIL-HDBK-340A**
- **ECSS-E-ST-10-03C**
- **TR-2004(8583)-1 Rev.A**
- **NASA LSP-REQ-317.01 Rev.B**

Testing Typical Specification items

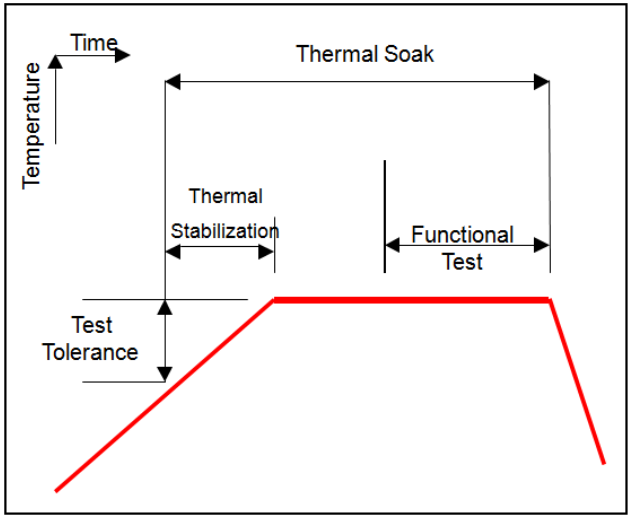
Definition: test specification describes several characteristics such as: test requirements, test approach, ground support equipment and tools, test sequence, test conditions (levels and duration), pass/fail criteria and schedule. (ECSS, 2012)

Typical CubeSat TVCT specification parameters

- Temperature Soaks;
- Temperature Transition;
- Temperature Stabilization;
- Soak time;
- Test Interfaces (M/E);
- Vacuum level;
- Pressure drop rate;
- Number of cycles;
- Tolerances;
- TVCT Functional Tests;
- Pass/Fail/Stop Criteria;
- Instrumentation information.



AESP-14 Cubesat TCVT.

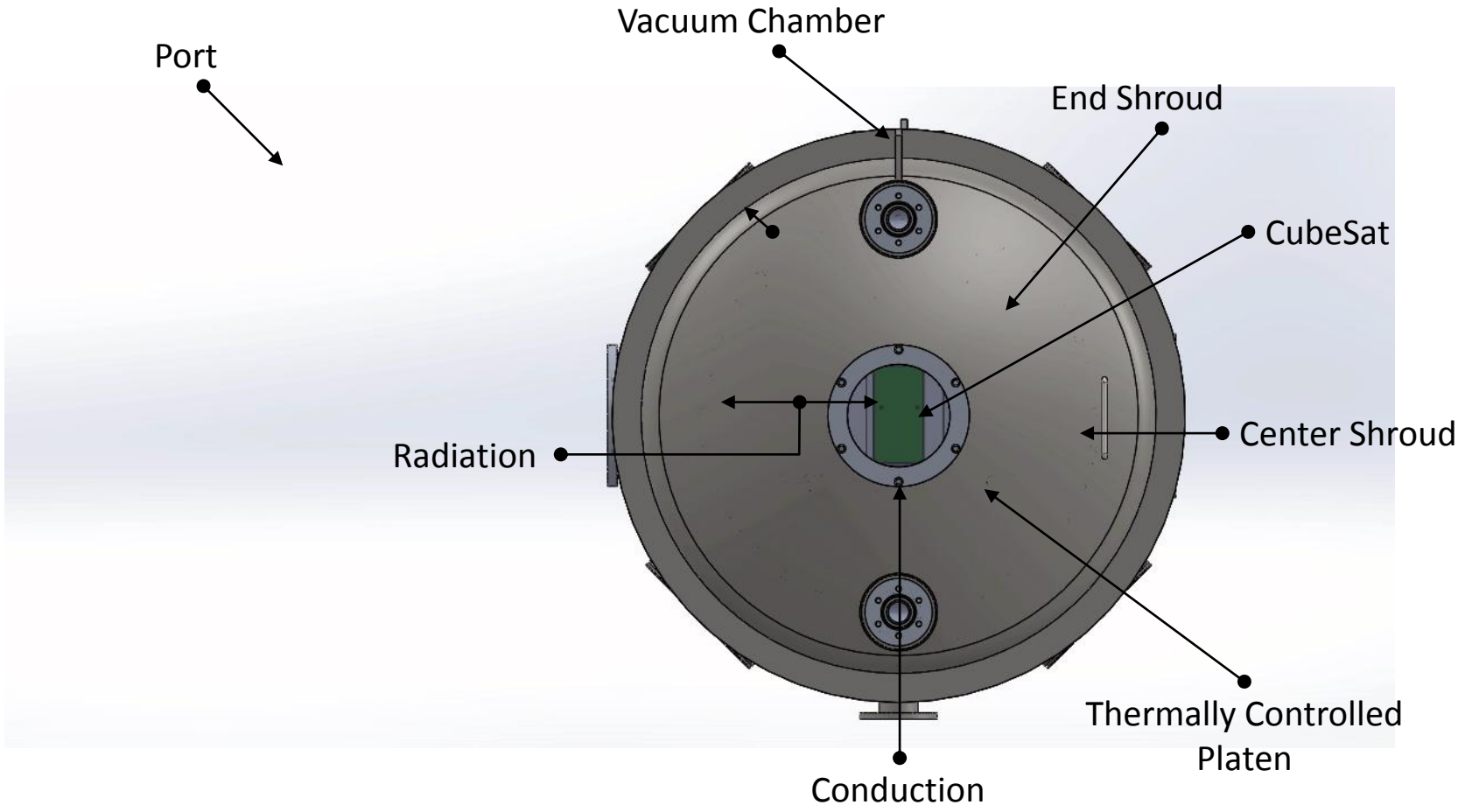


TVCT specifications.

CubeSat	Model	T_{max}	T_{min}	Vacuum level	Cycles
QB50	Protoflight	+50°C	-20°C	10^{-5}mBar	4
STEP Cube Lab	Flight	+35°C	-35°C	< 10^{-5} Torr	2
AAU CubeSat	Flight	+85°C	-10°C	<0,01Torr	1
SwissCube	Flight	+50°C	-45°C	<10^{-5} Pa	4

Example of different CubeSat test specification items.

Thermal Vacuum Test



Test Models

The most typical satellite models with their respective test purpose, parts and materials and functional testing are detailed below (Silva, A. C. 2012).

MODEL	TEST PURPOSE	PARTS AND MATERIALS	FUNCTIONAL TESTING
EM	a) To certify that the electrical function and performance specifications of the equipment are satisfied. b) To verify their interfaces with other equipment, subsystem and system.	a) Not need to have space qualification, either even so indispensable that it has qualified similar for space use available in the market.	a) Electrical function and performance test.
QM	a) To certify that the specifications of the equipment are satisfied. b) To allow the qualification of the equipment for functioning in the conditions of space, by means of functional and environmental tests in laboratory.	a) Qualified components.	a) Functional, environmental tests in the qualification levels.
FM	a) To certify that the specifications of the equipment are satisfied. b) To allow the acceptance of the equipment for functioning in the conditions of the space, by means of functional and environmental tests on satellite.	a) Full flight standards.	a) Functional and environmental tests according to Environmental Specification.

Satellite models, test purpose, parts and materials and functional testing.

Model Philosophy

Tests can be realized in different development stages along the project life cycle: qualification, acceptance, pre-launch, in-orbit and post-landing; in different levels: equipment, subsystem, element, segment or overall system; and in different models: engineering, structural, thermal, radio-electric, qualification, flight or protoflight and others. (ECSS, 2009)

Right below the most common model philosophy are described (ECSS-E-ST-10-03C, 2012).

Prototype approach:

- Qualification testing conducted on qualification model (QM) with qualification levels and duration.
- Acceptance testing conducted on flight model (FM) with acceptance levels and duration.

Protoflight approach:

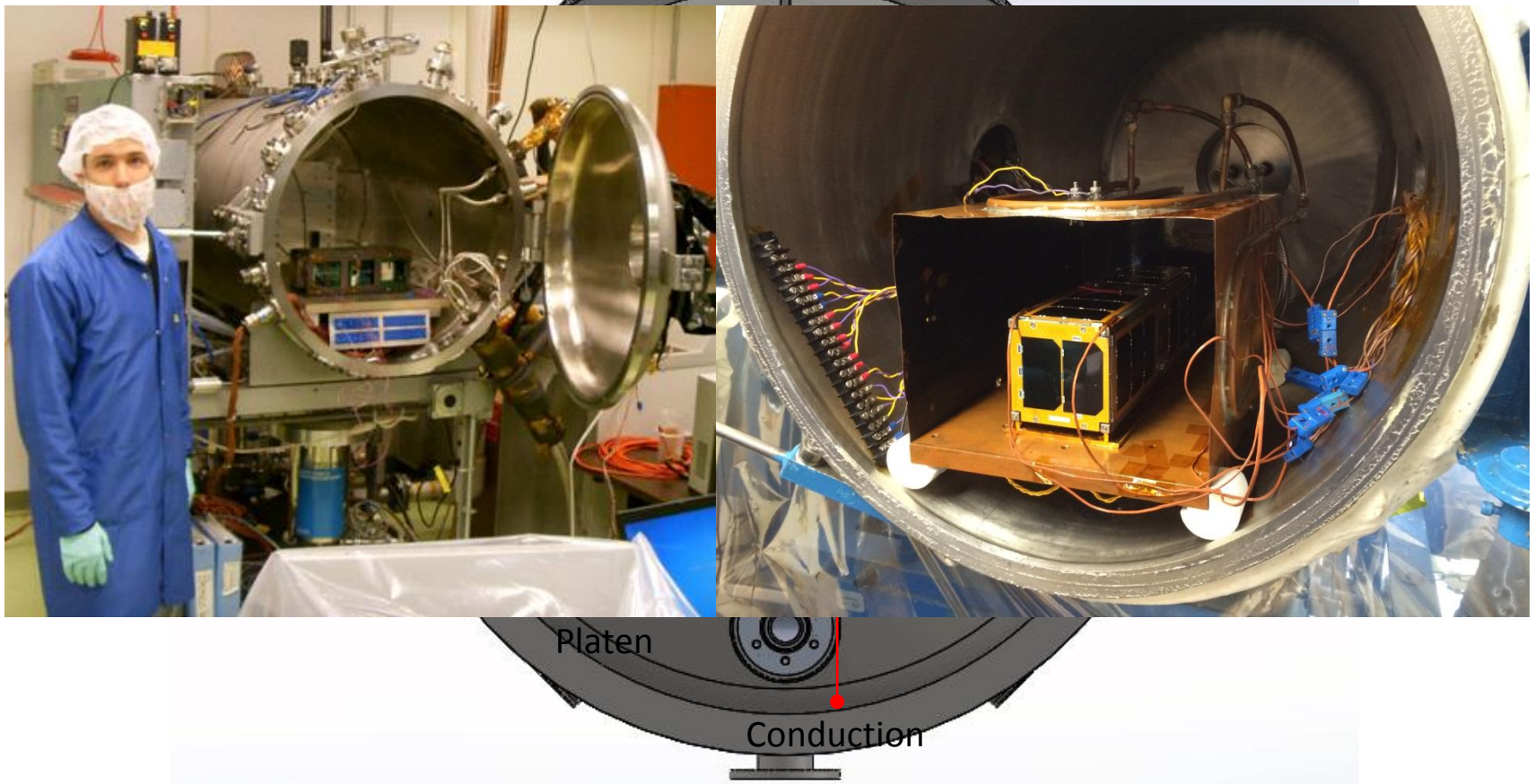
- Qualification testing conducted on the same model to be flown (PFT), generally with qualification levels and reduced duration (acceptance).

Test Execution

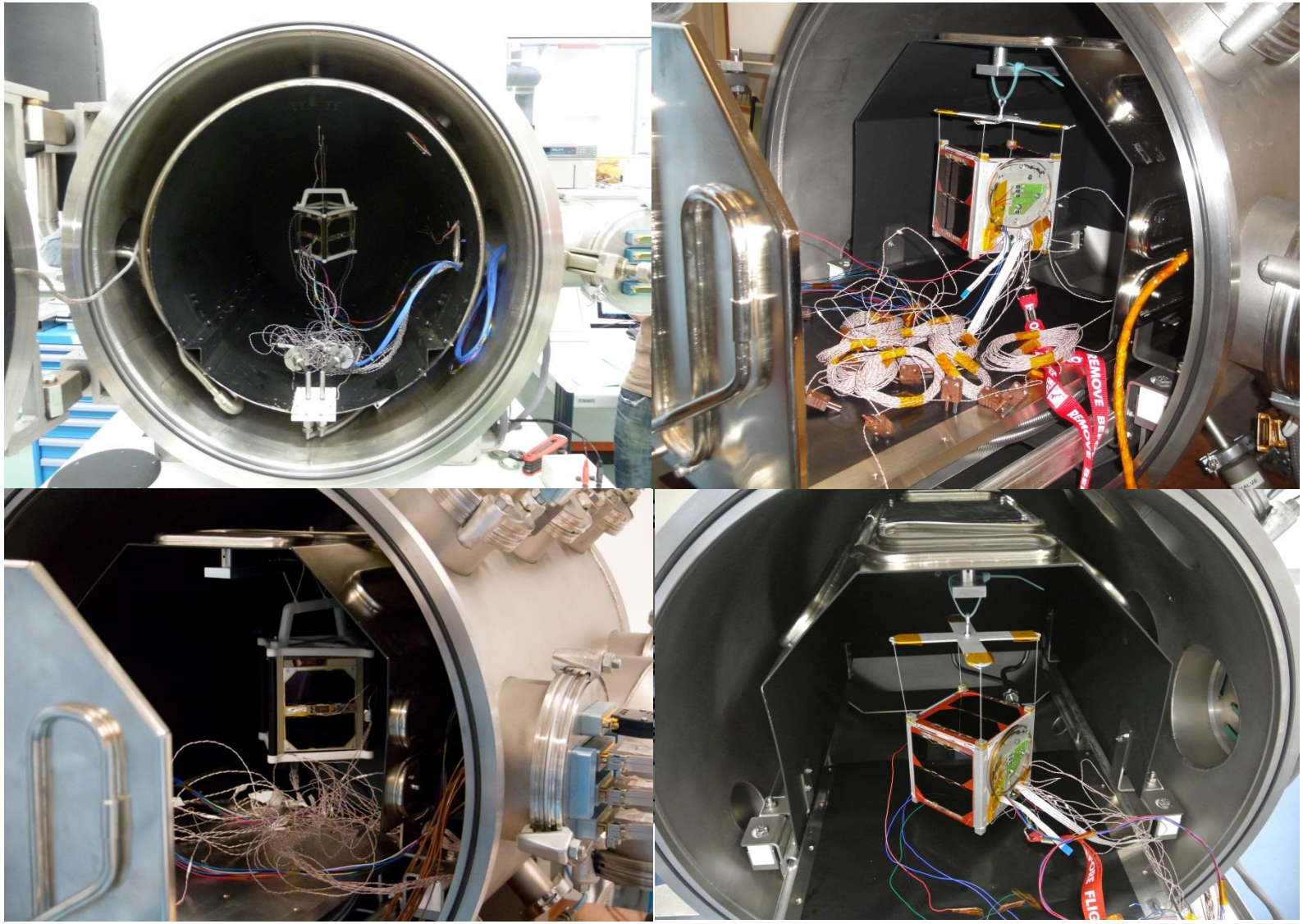
The development of a CubeSat TVCT can be divided in three different phases:

1. Set-up and instrumentation: functional tests, thermo-couples attachment, Cubesat installation inside TVC;
2. Test readiness review (TRR): check Cubesat, specifications, facility, equipment, human resources;
3. Start test: high vacuum, start thermal cycling, functional tests.

CUBESAT INSTALLATION INSIDE TVC



CUBESAT INSTALLATION INSIDE TVC



TVCT As is

- For the the vast majority of CubeSats, reliabilty is regarded as low priority.
- Test requirements are met only to meet launch vehicle requirements.
- Several launchers do not reques TVCT.

[redacted] **Environment Levels** [redacted]

7 Thermal cycling

Table 8: Thermal cycling test characteristics

Characteristic		Qualification	Acceptance	Proto-flight
Test		Recommended	Recommended	Recommended

Although not required by the Launch Service Provider, performing thermal cycling is (highly) recommended.

Figure x: Example of a launch requirement for TVCT.

4.1 Random Vibration

Random vibration testing shall be performed as defined by the launch provider

4.2 Thermal Vacuum Bakeout

Thermal vacuum bakeout shall be performed to ensure proper outgassing of components. The test specification will be outlined by the launch provider.

4.3 Shock Testing

Shock testing shall be performed as defined by the launch provider.

4.4 Visual Inspection

Visual inspection of the CubeSat and measurement of critical areas will be performed per the appropriate CAC (Appendix C).

4.5 CubeSat Testing Philosophy

The CubeSat shall be subjected to either a qualification or protoflight testing as defined in the CubeSat Testing Flow Diagram, shown in Figure 88. The test levels and durations will be supplied by the launch provider or P-POD integrator.

Figure x: Abcense of TVCT in the CubeSat design specification. (CDS, 2014)

Several CubeSat projects do not run a TVCT. Some use very generic specifications, others use same specifications from a standard for a different class of satellite, or even use parameters from a similar CubeSat already flown.

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