International Spring School on Forefront Alloys and Advanced Materials for Extreme Conditions

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Sardinia, Italy

Space engineering
Process of satellite hardware development

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ADMATIS

Admatis
Advanced Materials In Space

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Benefeits of space activities

Benefits of space activities

- **Transportation**
  The number of peoples and goods to be moved from one point of the Earth to the other is rapidly increased. Global Navigation Satellite Systems (GNSS), like GPS, GLONASS, Galileo provide accurate pisitioning and navigation information to aviation, maritime, rail and road transit.
- **Communication**
  Sharing large amount data become the normal way of life. Information to be exchanged can be voice, video or data. The space based technologies offer cost effective solutions for all people particular for ones who live in far-to-reach areas.
- **Defence**
  Secure communication, targeting, ultraprecise positioning, on-line satellite images etc.

Benefits of space activities

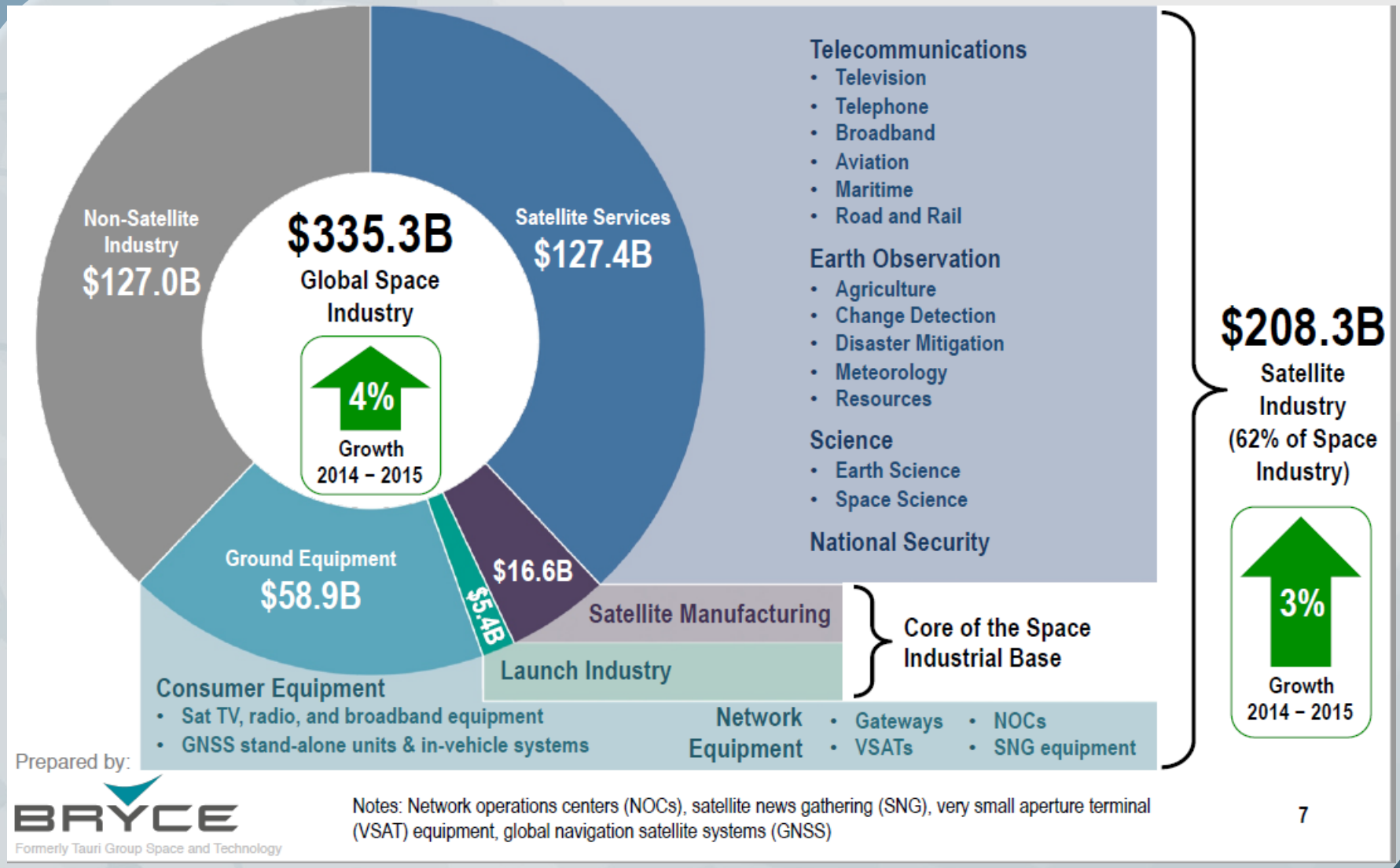
- **Agriculture**
  soil conditions, water availability, weather, climate changes, snow coverage, prediction of outputs
- **Environment**
  monitoring the impacts of human actions on the Earth's environment, eg. Deforestation, soil degradation, pollution of athmosphere and climate change
- **Disaster Management**
  In last 25 years there has been an increase in the frequency, intensity and unpredictability of disasters, such as earthquakes, hurricanes, floods, landslides and wildfires. Disaster management aims to lessen the impacts of disasters, minimising losses of life and property. Space technology helps in the prevention, early warning, response and reconstruction.

Benefits of space activities

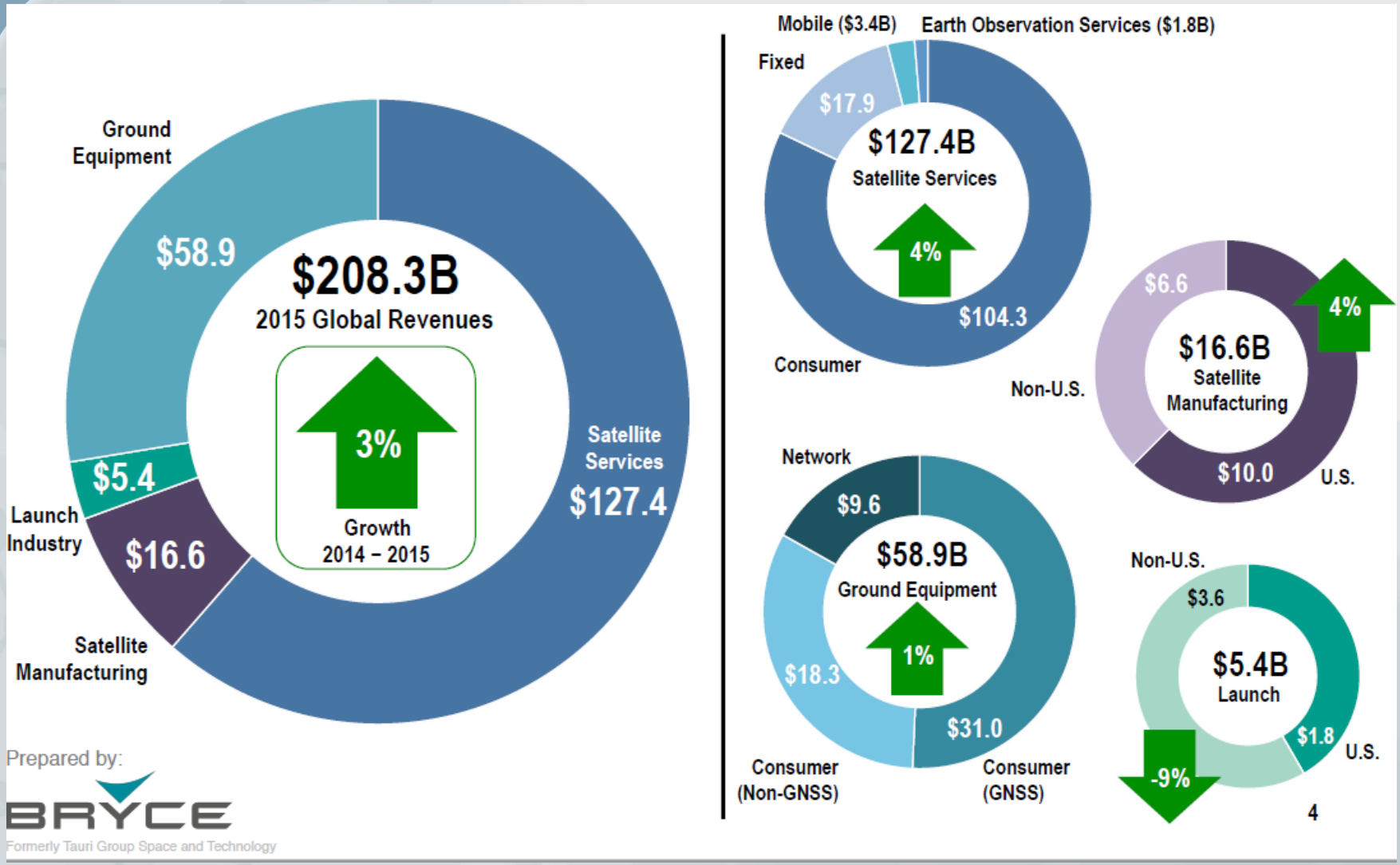
- **Education**
  Acces to knowledge: Technologies like web and videoconferencing and voice over Internet protocol allow educators and students to create virtual classrooms, regardless of physical locations.
  Inspiration: students who has a connection with space has a more chance to became scientist or high-tech engineer.
- **Human Settlements**
  50% of the people lives in cities. They grow rapidly and space-based technology provide uniwue tools for planning. (streets, transports, water and electricity management, waste, green areas etc.)
- **Research & Develoment**
  Lots of technologies developed for space applications have on ground utilization (scratch resisitant lenses, freeze drying, radial tyres etc.). Explorations to understand the universe and look for life on other planets.

Space market

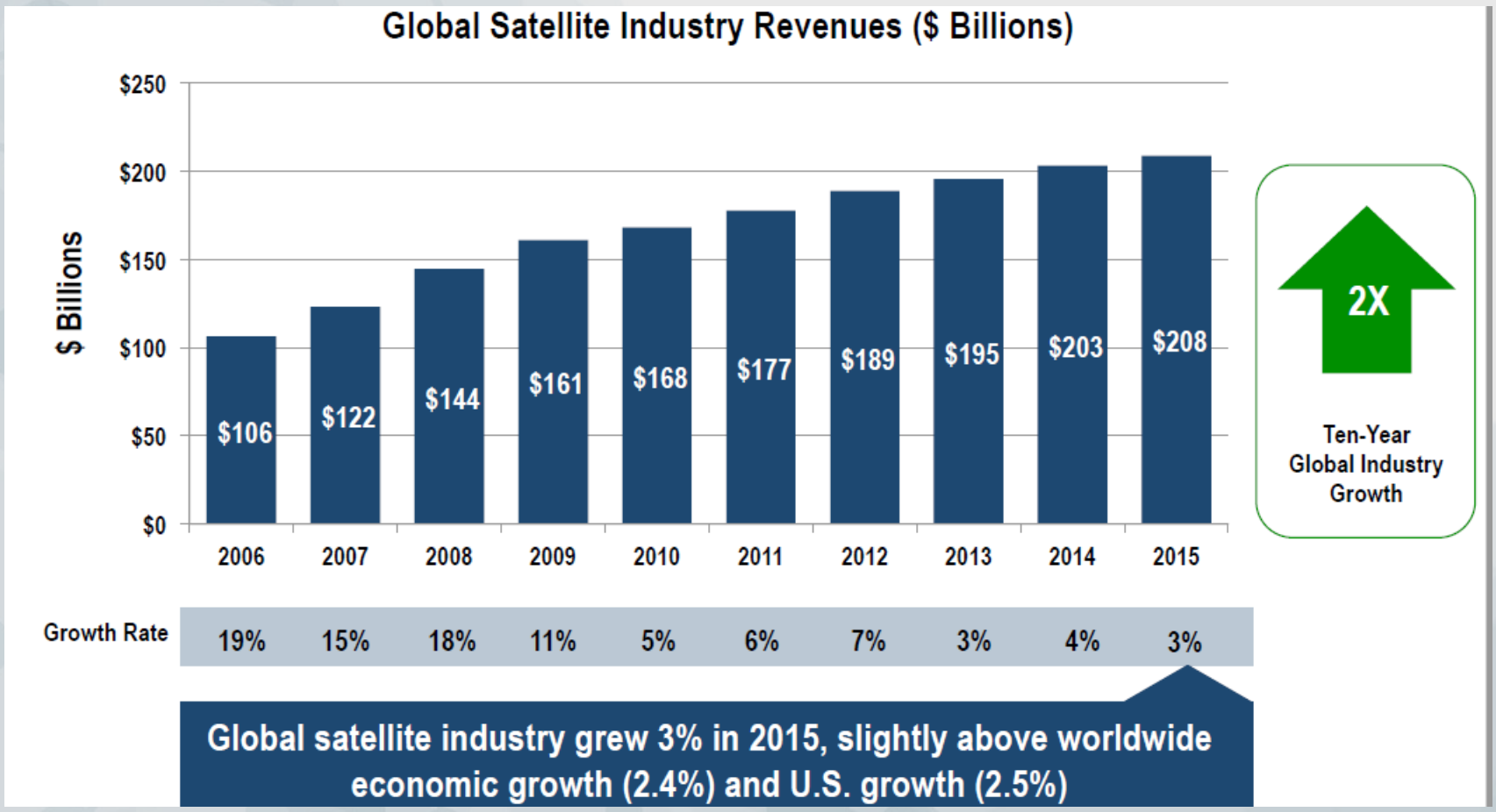
Global Space Industry 2015



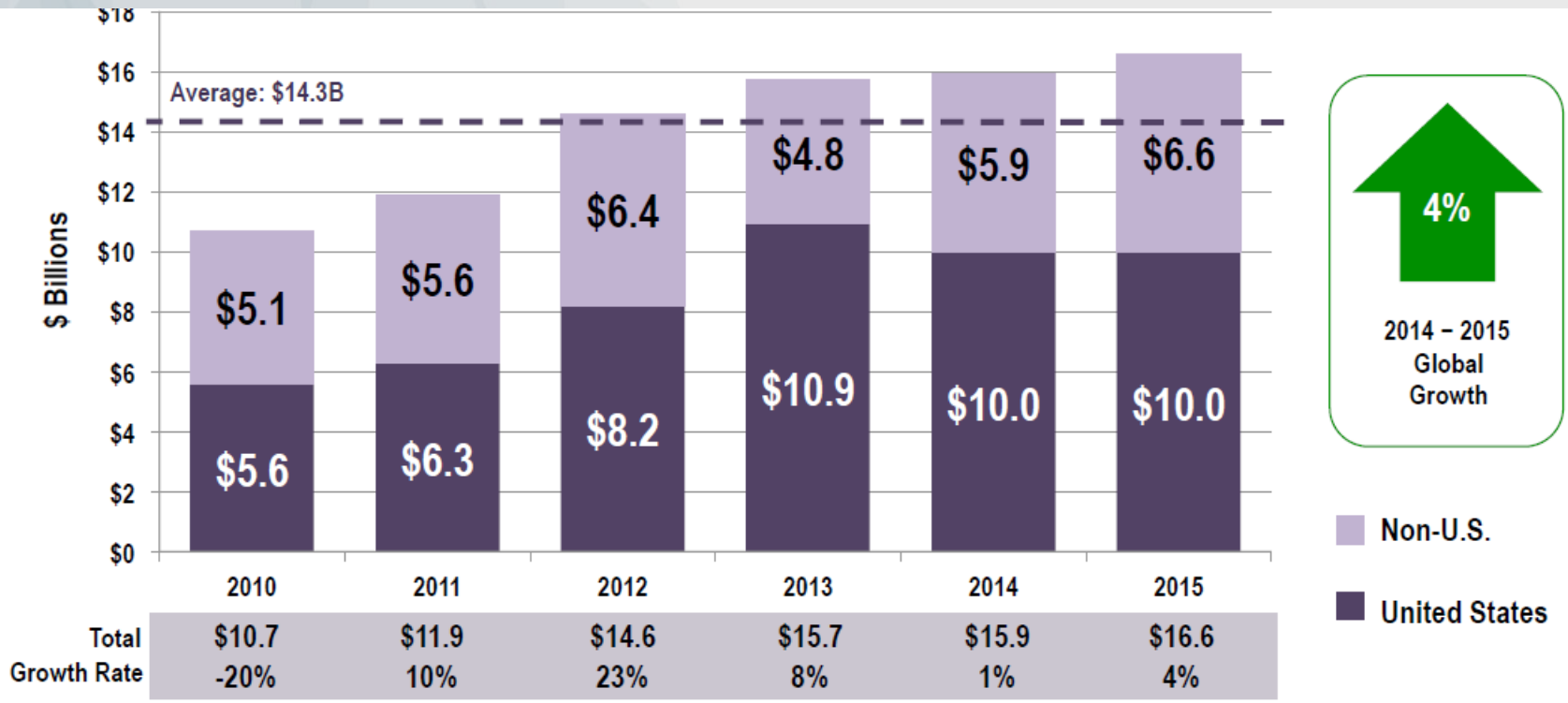
Satellite Industry 2015



Size of the global space industry



Satellite Manufacturing Market

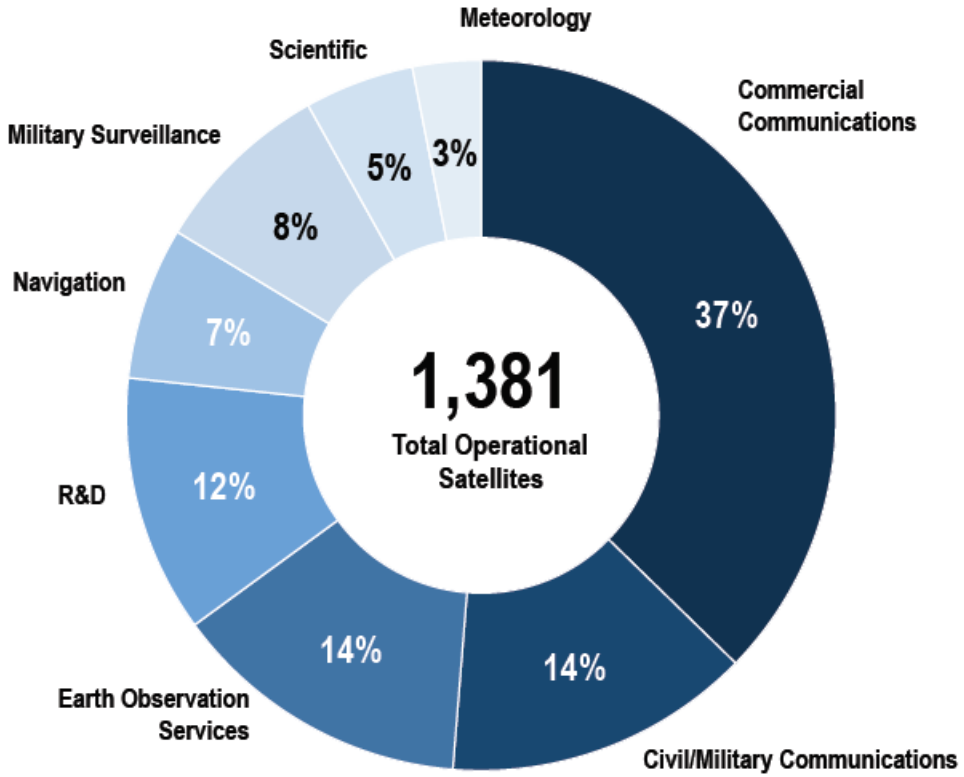


- Worldwide 2015 revenues totaled $16.6 billion
- U.S. share of global revenues was 60%, a decrease from 63% in 2014

NOTE: Satellite manufacturing revenues are recorded in the year the launch was conducted. Do not include satellites built by governments or universities. Data based on unclassified sources.

Prepared by:

Operational Satellites



- Number of satellites increased 39% over 5 years, compared to 986 reported in 2011
  - » Average number of satellites launched per year in 2011-2015 increased 36% over previous 5 years
  - » Small and very small satellites deployed in LEO contribute to this growth
  - » Average operational lives of certain satellite types (such as GEO communications satellites) are becoming longer
- 59 countries with operators of at least one satellite (some as part of regional consortia)

Prepared by:
BRYCE
Formerly Tauri Group Space and Technology

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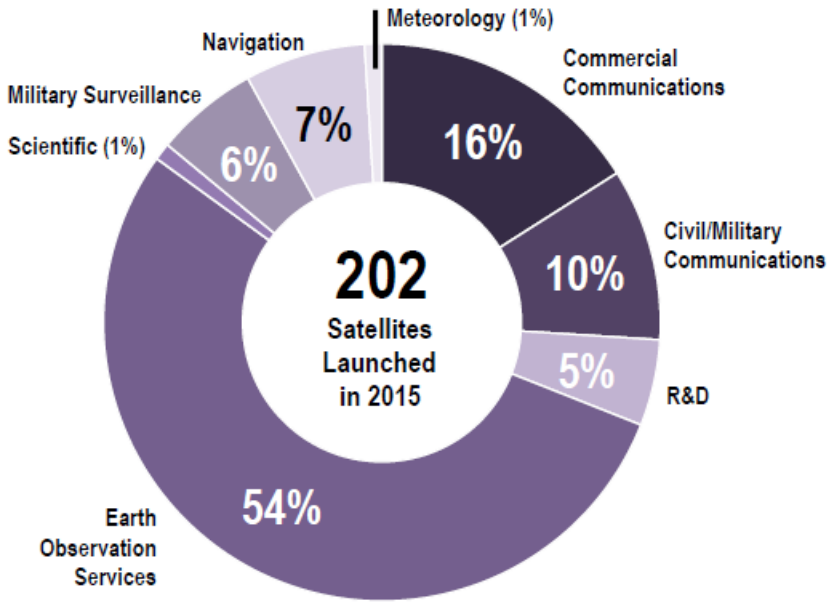
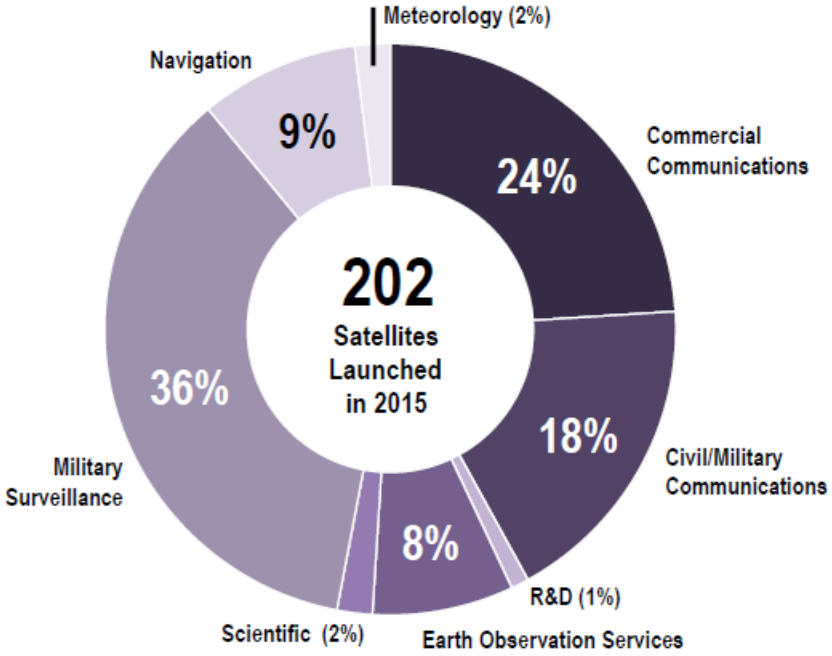
Launched Satellites 2015

- 202 satellites launched in 2015, about the same as in 2014
- 108 CubeSats launched, representing 53% of total
- Most CubeSats were commercial Earth observation



Number of Spacecraft Launched by Mission Type (2015)

- Communications satellites represented 42% of total revenues
- Military surveillance satellites accounted for 36% of 2015 revenues, compared to 38% in 2014
- CubeSats represent less than 1% of total value



Value of Spacecraft Launched by Mission Type (2015)

Prepared by:

Satellites

Definition of satellite

Satellite is an artificial object which has been intentionally placed into orbit.

Types of satellite

- military
- civilian

- Astronomical satellites
  observation of distant planets, galaxies and other space objects
- Earth observation satellites
  cameras faced to the surface of Earth
- communications satellites
  data exchange
- navigation satellites
  positioning of objects
- weather satellites
  remote sensing of environmental data thats are inputs for models

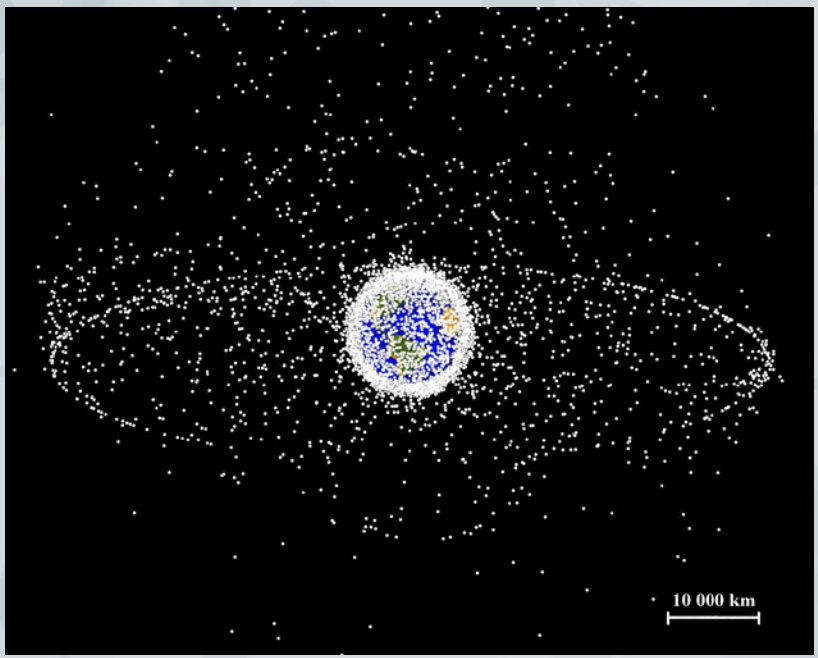
Amount of satellites

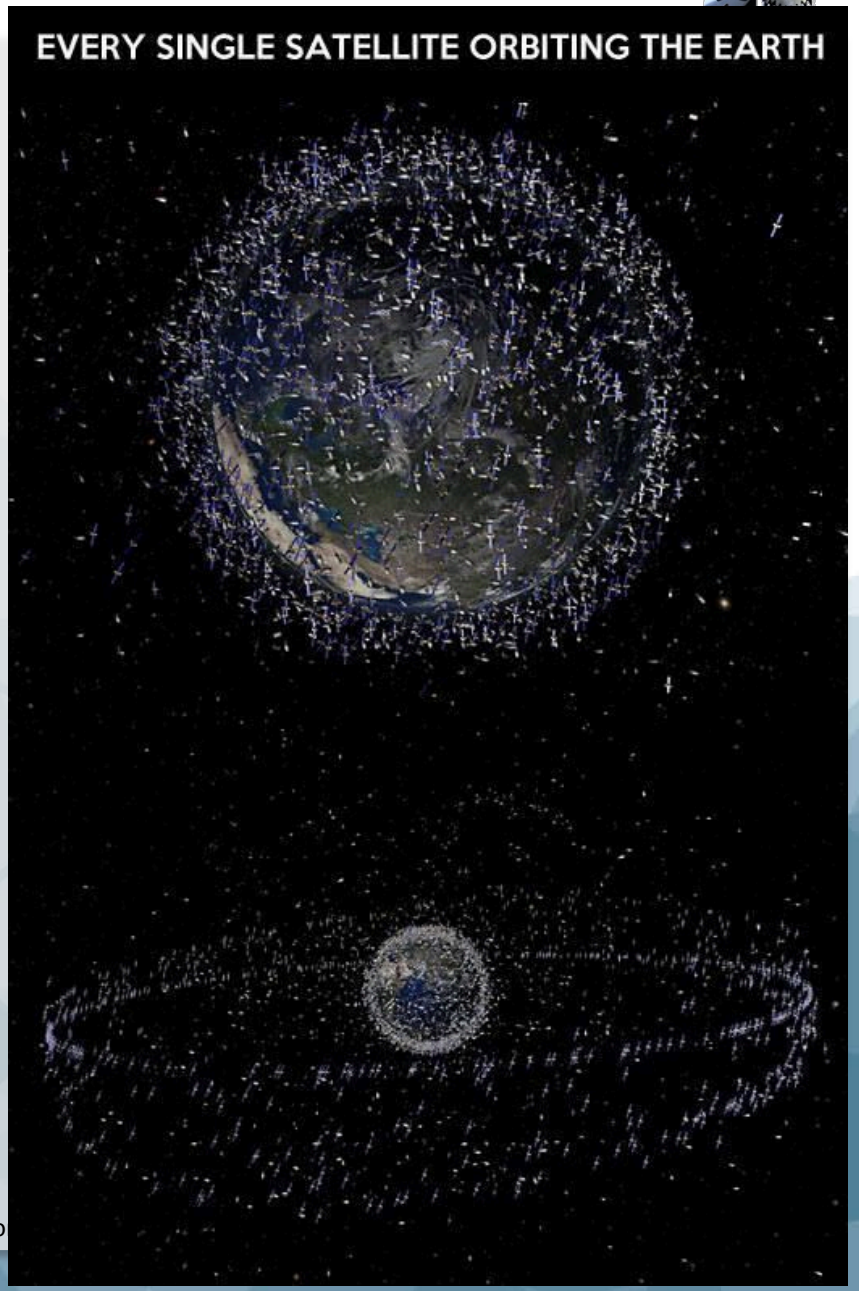
cc. 7 000 satellites have been launched

cc. 5 000 remained in orbit

cc. 1 300 are in operational mode

99% are around the Earth and 1% around the Moon, Mercury, Venus, Mars, Jupiter, Saturn and Sun





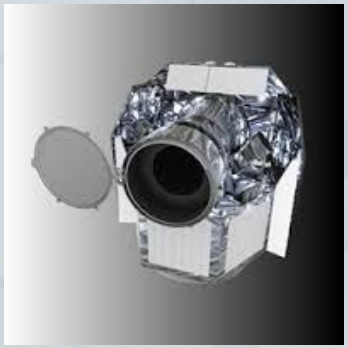
Size of satellites

- large satellite (> 1 000 kg)
- medium-sized satellites (1 000 – 500 kg)
- minisatellites (500 – 100 kg)
- microsatellite (100 – 10 kg)
- nanosatellite (10 – 1 kg)
- picosatellite (< 1 kg)

Sentinel-2, 1 500 kg

Masat, 1 kg

Telecom satellite, 5 – 7 t

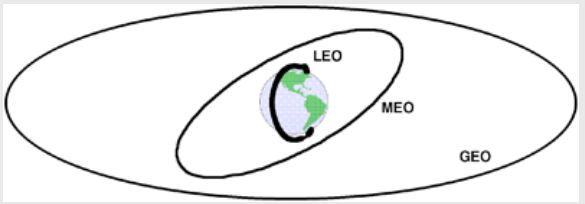


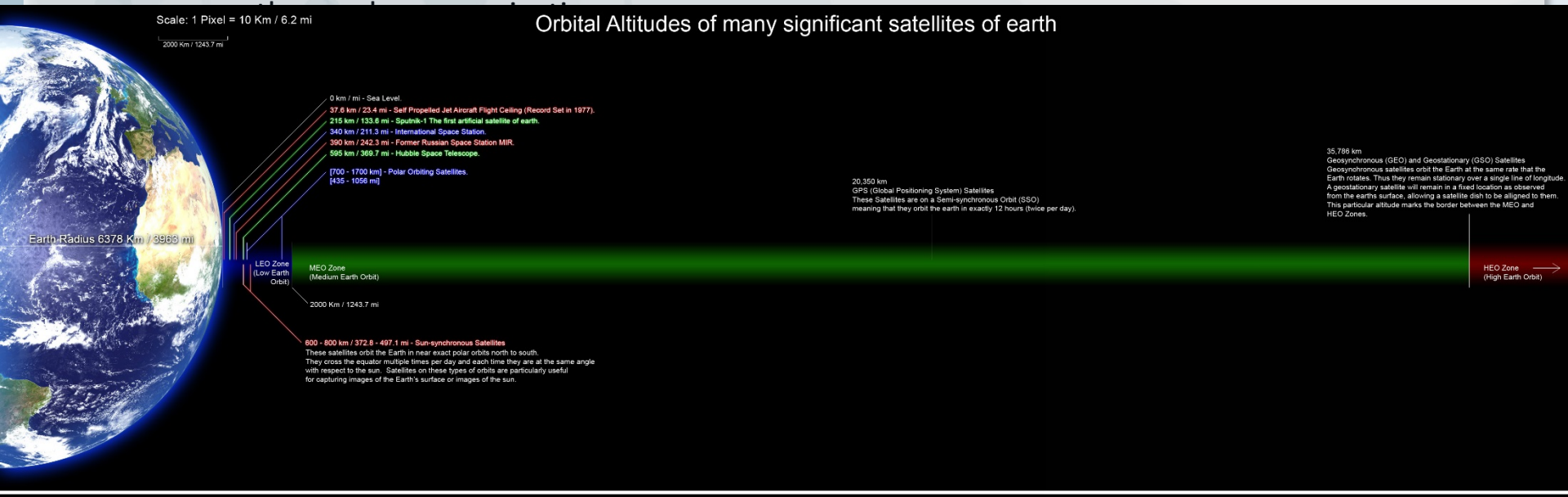
CHEOPS, 250 kg

Orbits of satellites

Altitude classification

- Low Earth orbit (LEO): 200 – 2 000 km
  orbital period: 1,5 – 2 hours
  max. satellite visible time: 20 min
  Earth observation, weather, communication, ISS, Hubble,
- Medium Earth orbit (MEO)
  orbital period: 12 hours
  navigation (GPS, GLONASS, Galileo)
- Geosynchronous orbit (GEO): 36 000 km
  orbital period: 24 hours (same as Earth rotation period)





The subsystems of a spacecraft

- **ATTITUDE AND ORBIT CONTROL SUBSYSTEM (AOCS)**

The satellite must face to a given point or object at all times. The attitude control system allows the satellite to remain pointed correctly. These are often very small motors compared to the propulsion system.

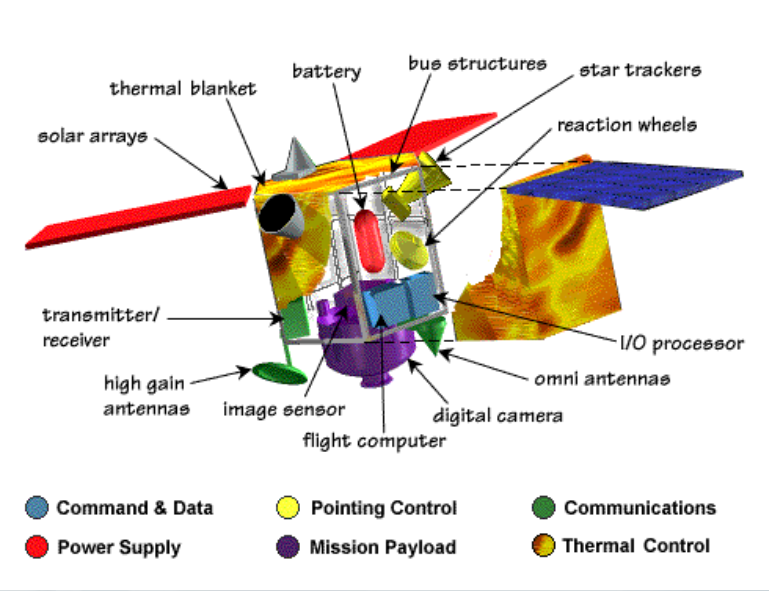
The orbit control (propulsion) system is to get the satellite into orbit. Other chemical or electrical motors are used to move the satellite back into the correct orbit when either atmospheric drag, magnetic fields or the solar winds deflect the satellite out of it's correct trajectory. These motors boost it back to the correct altitude, speed the satellite up, slow it down.

- **POWER**

Solar panels are used in combination with batteries to provide a constant source of electrical power on the satellite. The batteries are used when the satellite is not in direct sunlight, and allows the satellite to continue to function.

- **COMMUNICATIONS**

The communications subsystem handles all transmit and receive communications functions. Antennas has significant roles.



The subsystems of a spacecraft

- **SUPERSTRUCTURE**

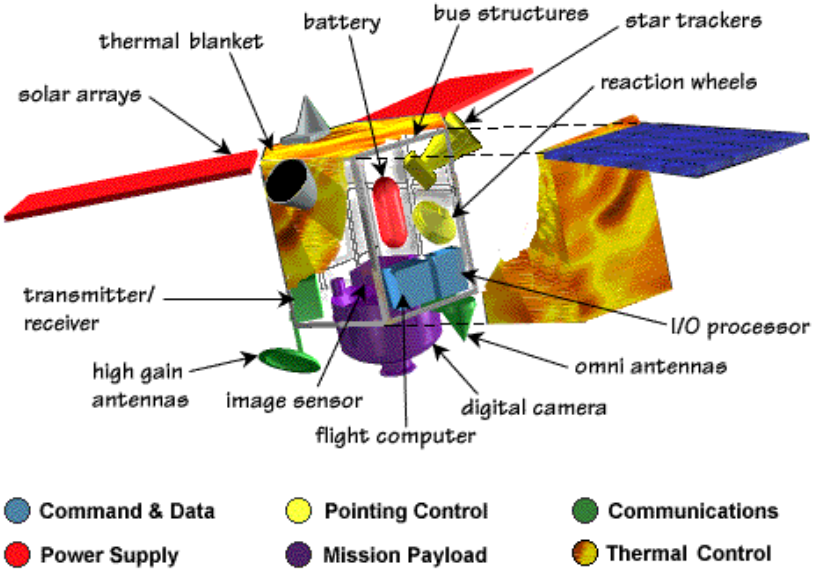
The satellite must survive the violent forces of the rocket ride into space. The superstructure of the satellite not only supports it in space, but reduces the shock and vibration the internal components might suffer during the launch.

- **THERMAL**

The goal of the thermal system is to regulate the temperature of the satellite's components. Too hot or too cold, or too great temperature gradient may cause fatal problem of the satellite.

- **TELEMETRY, TRACKING, COMMAND AND MONITORING (TTC&M)**

The satellite must inform the satellite operations center what it's current state is. For example temperatures, voltages, currents, status of sensors, status of software, as well as a host of other internal functions.



Characteristics of Space Project

General characteristics

- Closed society
- Most important the reliability
- Importance of heritage
- Risks are in focus
- Large added value
- Strategical importance
- Not really price sensitive

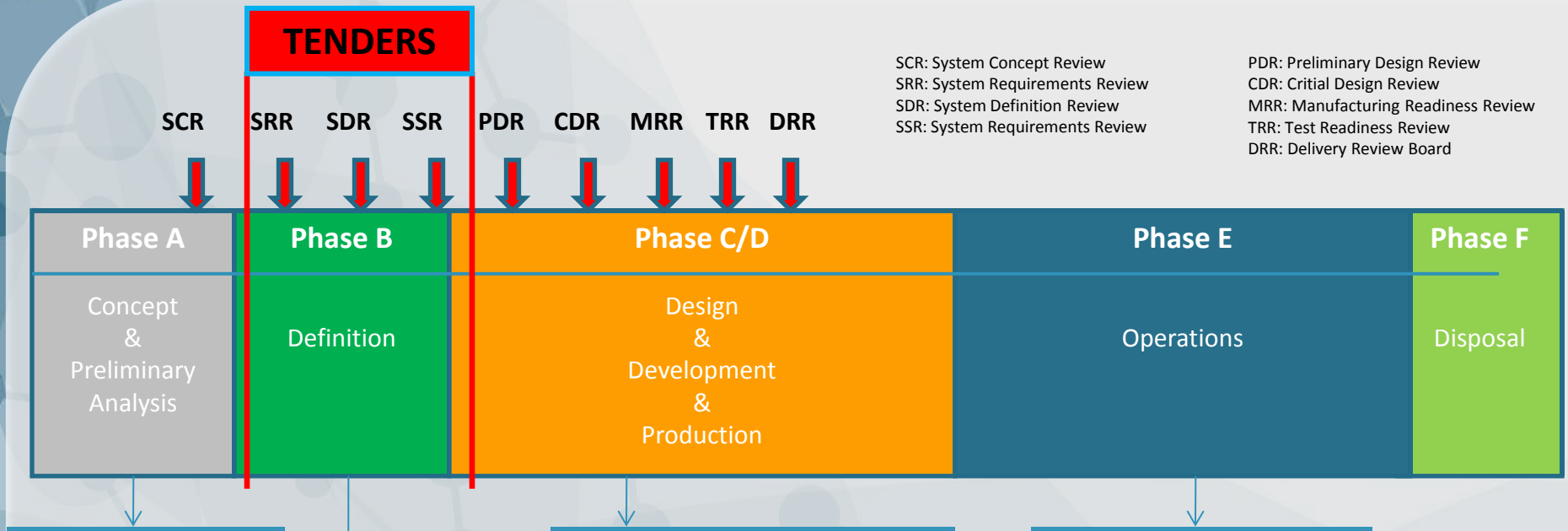
Main goals

1. It has to work
2. Risk reduction
3. Traceability

   Shall be known who is the manufacturer of raw materials, who was the QA at manufacturing site, who were the trades, who made what in each manufacturing steps, what are the applied processes, deviations / waivers etc.

Innovative and conservative parallel.

Project Phasing and Planning



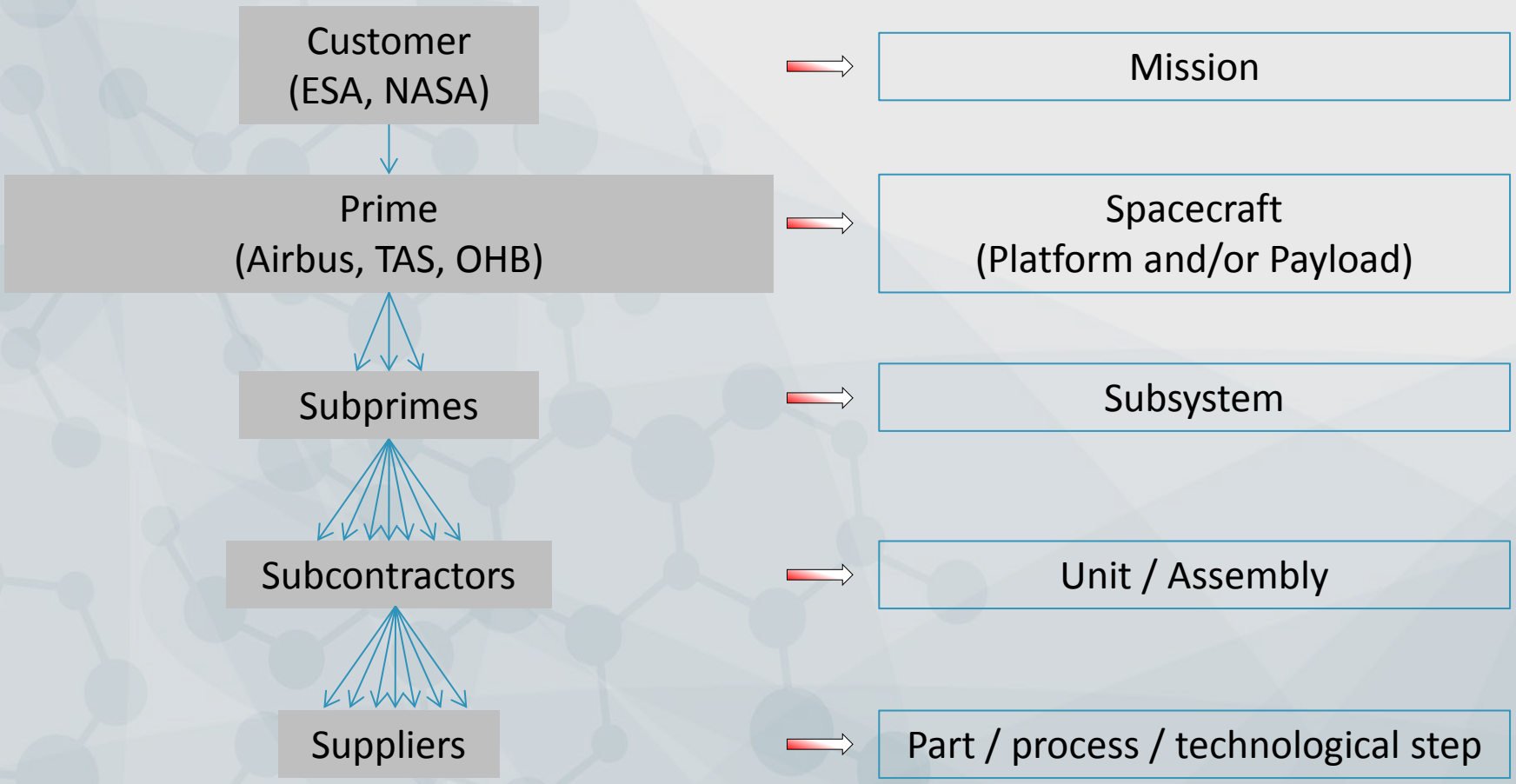
Preliminary Plan
- what to build
- when to launch
- mission
- lifetime

Converting the preliminary plan into a baseline technical solution
- define requirements (SRR)
- determine schedule
- specifications to initiate system design and development (SSR)

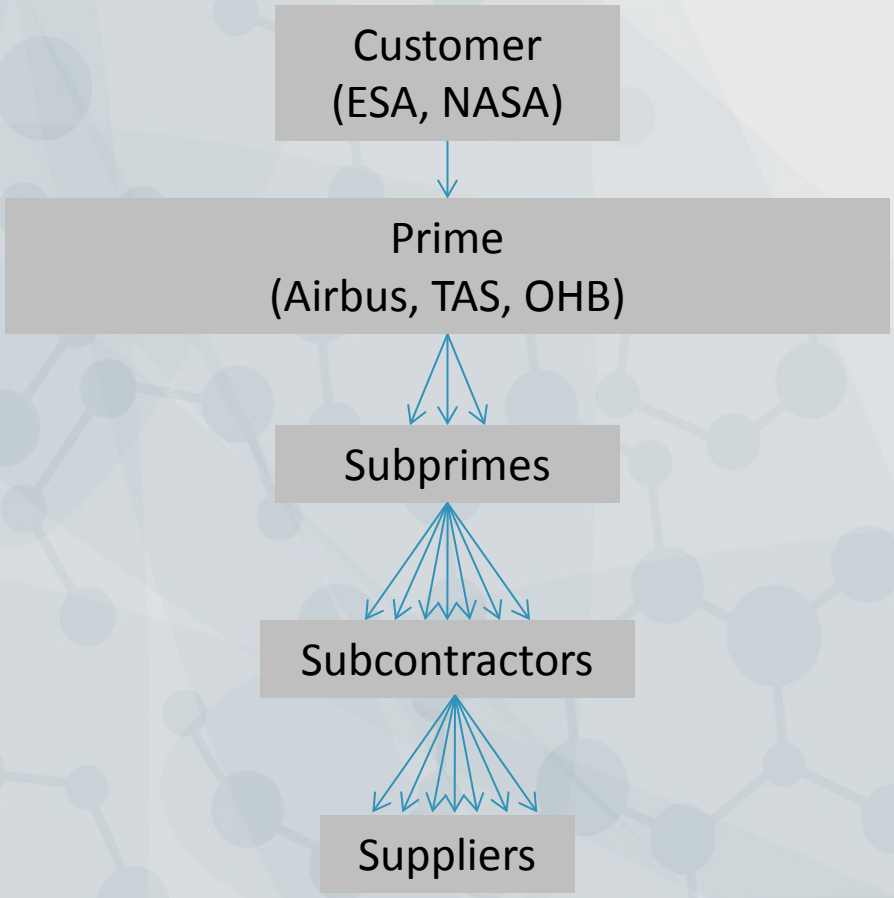
Design&Production
- create subsystems
- Invitation To Tender (ITT)
- design equipments
- select materials, processes
- procurement
- manufacturing
- tests
- integration

Mission
- launch
- cruise
- experiments/services
- data acquisition
- data analysis

Supplier chain



Requirement evolution



TAILORING

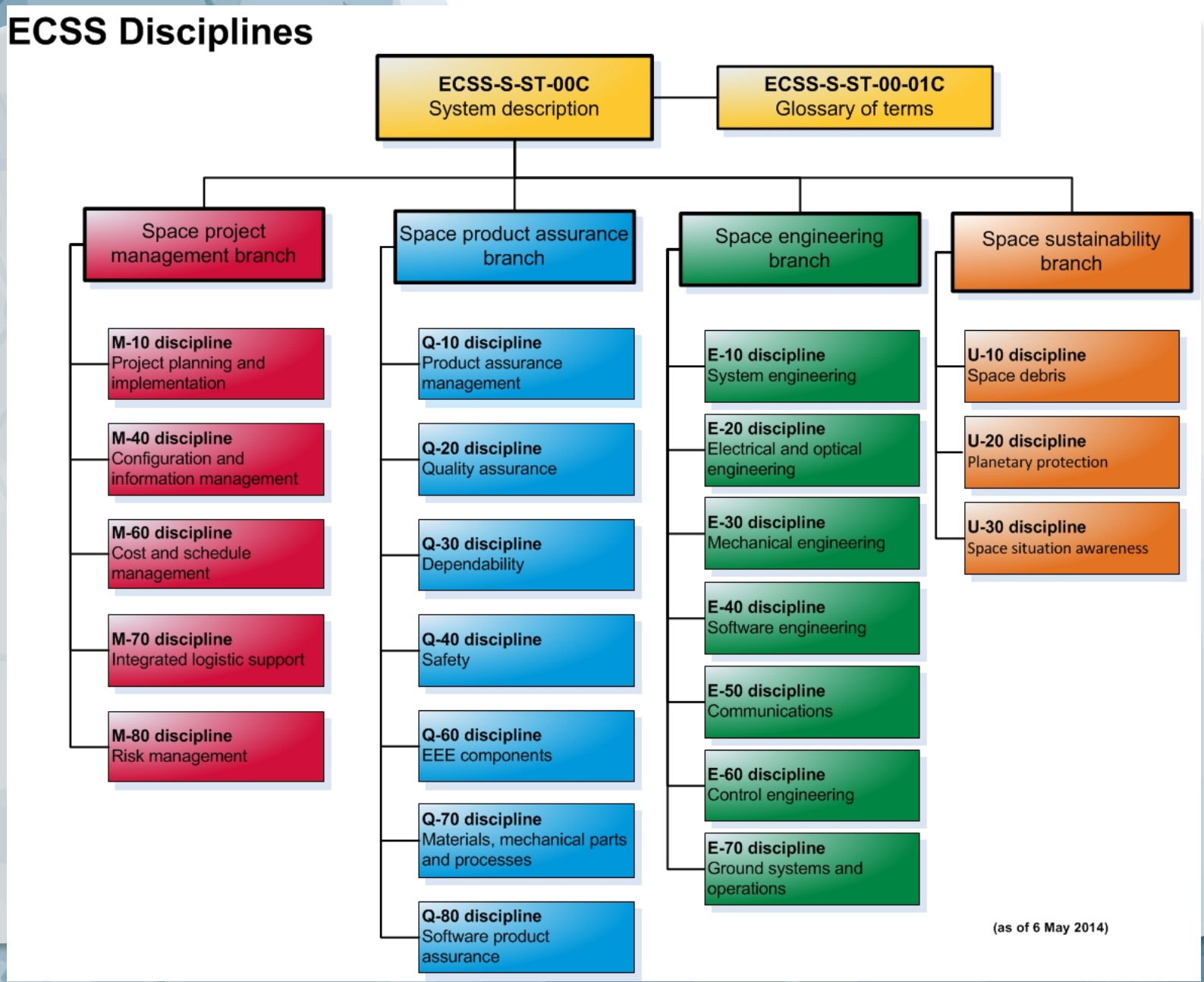
Requirements
based on ECSS
Functional
Technical
PA
etc.

Providing requirement specification is one of the most critical step of the mission for each level.

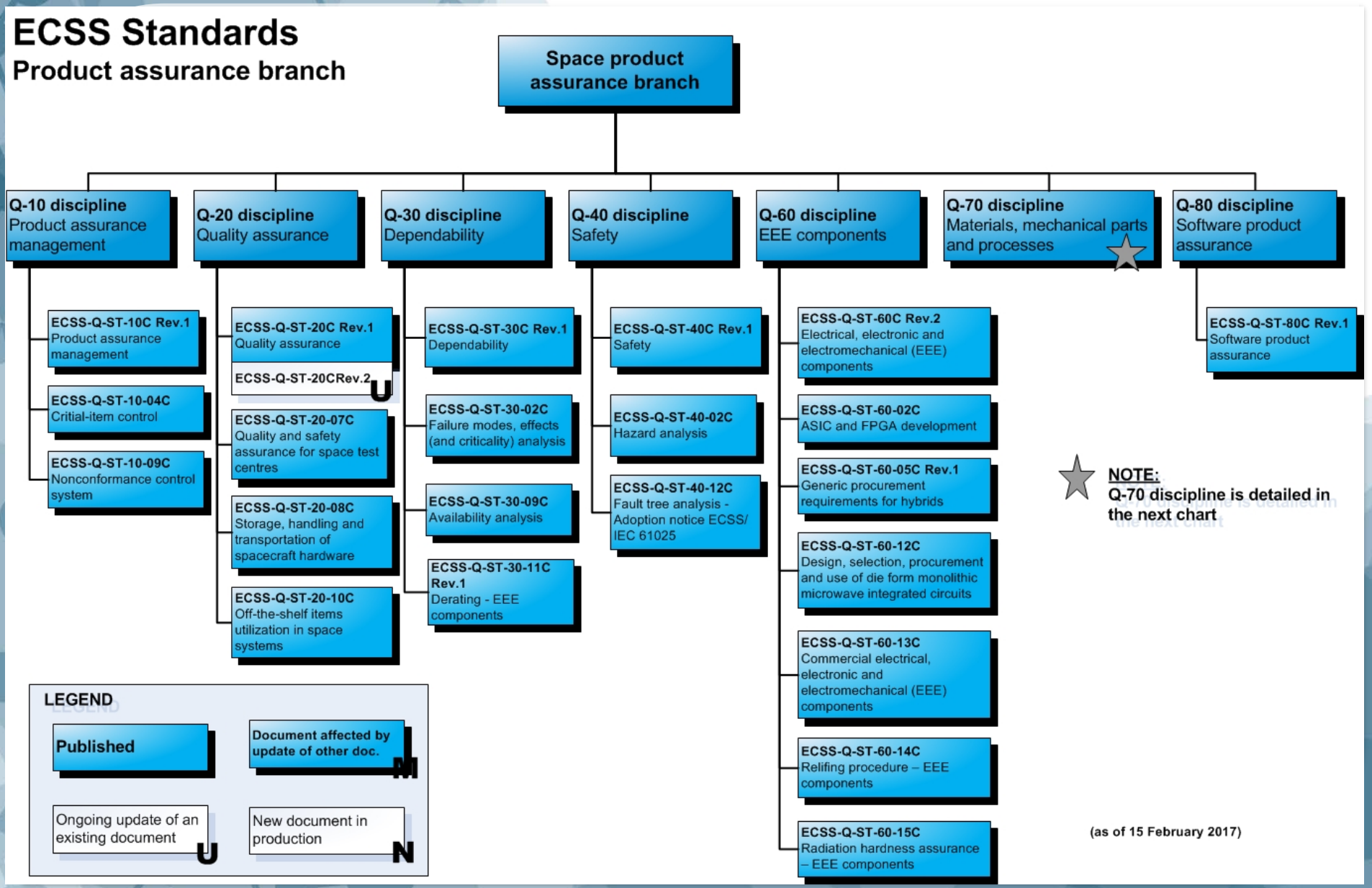
Standards

SME without quality management system	no requirements
SME with ISO9001	requirements on 20 pages
SME with AS/EN9100	requirements on ~30 pages
SME working according to ECSS	requirements on few thousand pages + referred EN / national standards

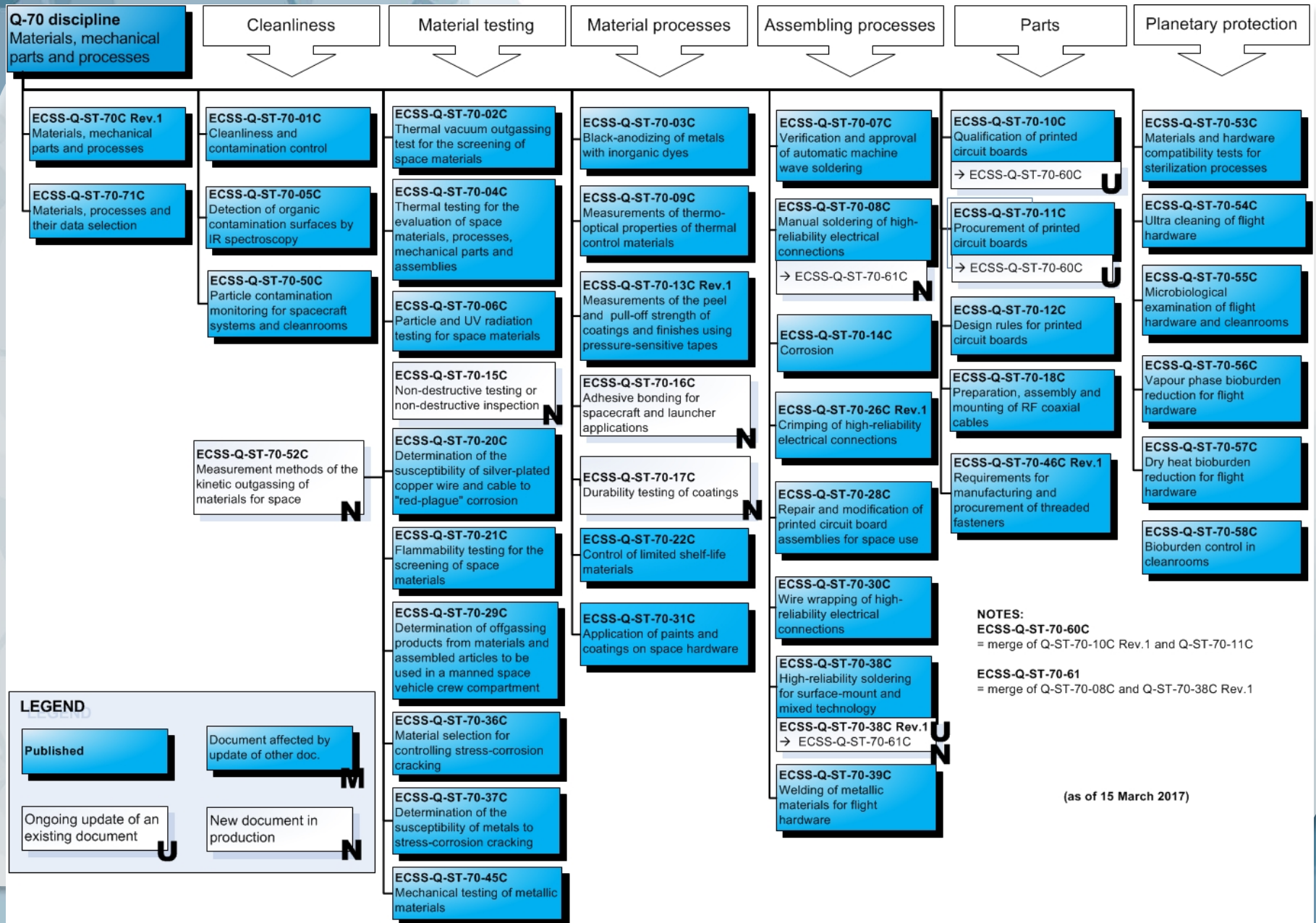
ECSS structure



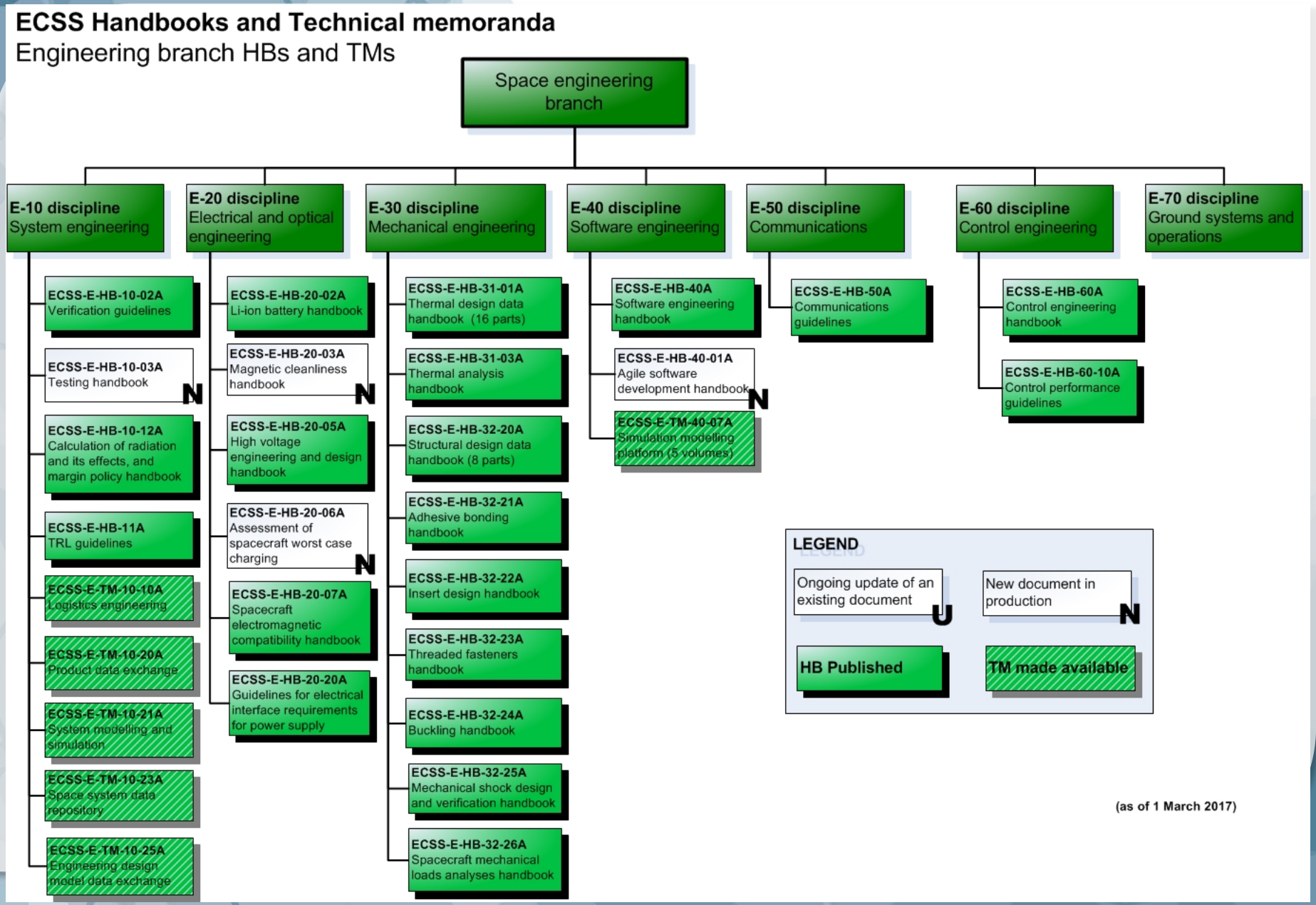
ECSS structure



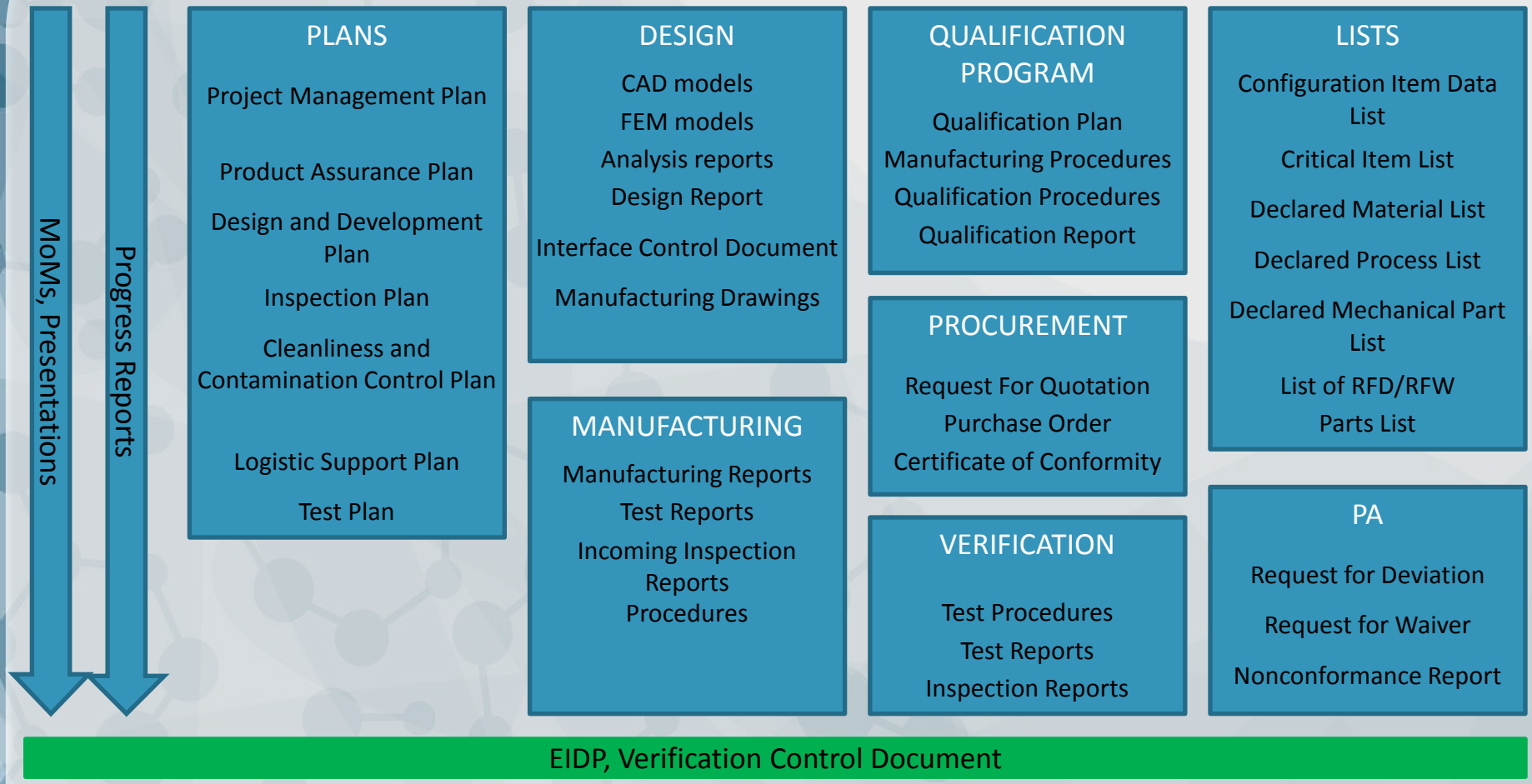
ECSS structure



ECSS SE HandBook structure



Most relevant documents



Documents Delivery List

DDL for	APP	Proposal	Kick-Off	MPCB	PDR	CDR	QR	MRR For options only	TRR	TR (TRB)	DR (DRB)	Periodic or as available
Statement of Compliance												
SoC to contract	R	X	U									
SoC to SOW (generic and specific)	R	X	U		U	U	U	U				
SoC to PA requirements	R	X	U		U	U	U	U				
SoC to Equipment specification	R	X	U		U	U	U	U				
Plans & Progress												
Management Plan	R	X	U		U	U						
Product Assurance Plan	A	X	U		U	U						
Cleanliness and contamination control plan	A				X	U						
Development & Test Plan including VCD	A	X	U		U	U	U		U	U		
Monthly Progress Report	R		X		X	X	X	X	X	X		X
Qualification Plan					X	U	U		U	U	U	
Design Build & Test												
Design report and justification (description, drawings, budgets…)	R	X	U	U	U	U	U	U				
Critical Item List and Long lead item list	R	X	U		U	U	U	U				
MAIT Flow Charts including MIPs and KIPs	A	X	U		U	U	U	U				
GSE design specification, description or equivalent	R	X	U		U	U	U	U	U			
Qualification and acceptance test procedures	R					X	U		U	U		
Qualification and acceptance test reports	R						X			X		
Test results	R						X			X		
Qualification Summary Report (QSR)	R						X	U	U			
Declared Material List (DML)*	A			X	U	U	U	U				
Declared Process List (DPL)*	A			X	U	U	U	U				
Configured Item Data List (CIDL)	R				X	X	X	X	X	X	X	
As Built Configuration List (ABCL)	R						X	U	U		U	
List of Request For Deviation (RFD)	R				X	U	U	U	U		U	
List of Request of waivers (RFW) and NCR	R						X	U	U	U	U	
Certificate of Conformity and cleanliness conformance	R											
Request For Deviation (RFD)	A										X	
Request of waivers (RFW)	A											X
												X
Interfaces & Models												
ICD's (OICD, MICD, TICD, EICD)	A				X	X		U	U		X	
CAD	I				X	X					X	X
Dynamic FE model	R				X	X		U			X	X
Thermo-elastic FE model	R				X	X		U			X	X
Thermal model												
Analyses												
Performance Analysis	R	X			X	X			U		X	
Mechanical and Stress Analysis	R	X			X	X			U		X	
Thermo-elastic Analysis	R	X			X	X			U		X	
Thermal analysis												
Radiation Analysis dedicated to coatings and/or glass type materials												
Optical Analysis												
Contamination Analysis	R				X	U					U	
Delivery & Operations												
Packaging, Transport, Handling and Storage Procedure (PHTS)	R					X	U				U	
Equipment User's and maintenance Manual	R					X	U				U	
Equipment Log Book	I										X	
End Item Data Package	A								X	X	X	
Export Control												
Export control list	R	X	U		U	U					U	
Export licenses	R										X	

Review system

1. step
Preparing the data package

2. step
Transfer the data package to customers 3 weeks before the meeting

3. step
Receiving Review Item Discrepancy (RIDs) 2 weeks before the meeting

4. step
Answer RIDs 1 week before the meeting

5. step
Meeting (presentation, discussion, open/close RIDs, action items, evaluate)

6. step
Prepare/transfer the delta review package 1 month after the meeting

7. step
Next progress meeting discuss the remaining open RIDs/AIs

Statistics of one real project

Raw materials

Aluminum
Procured: 2344 kg
Delivered: 36 kg (1,5%)

Screw
Normal: few EUR cents / piece
Space qualified: 8 – 100 EUR / piece

Paint
Normal: 3-5 EUR / kg
Space qualified white: 1 000 EUR / kg

Added value

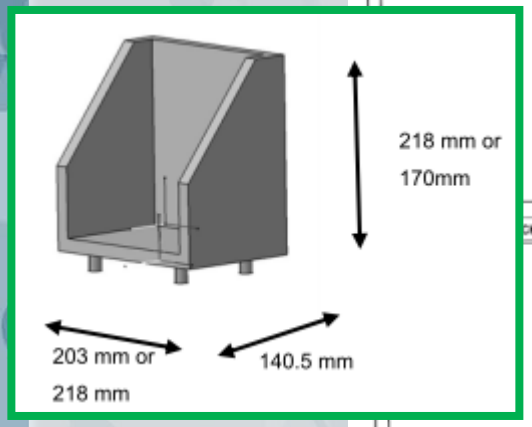
Price of raw material: 5 EUR / kg of Al
Price of flight hardware: 15 000 EUR / kg Al

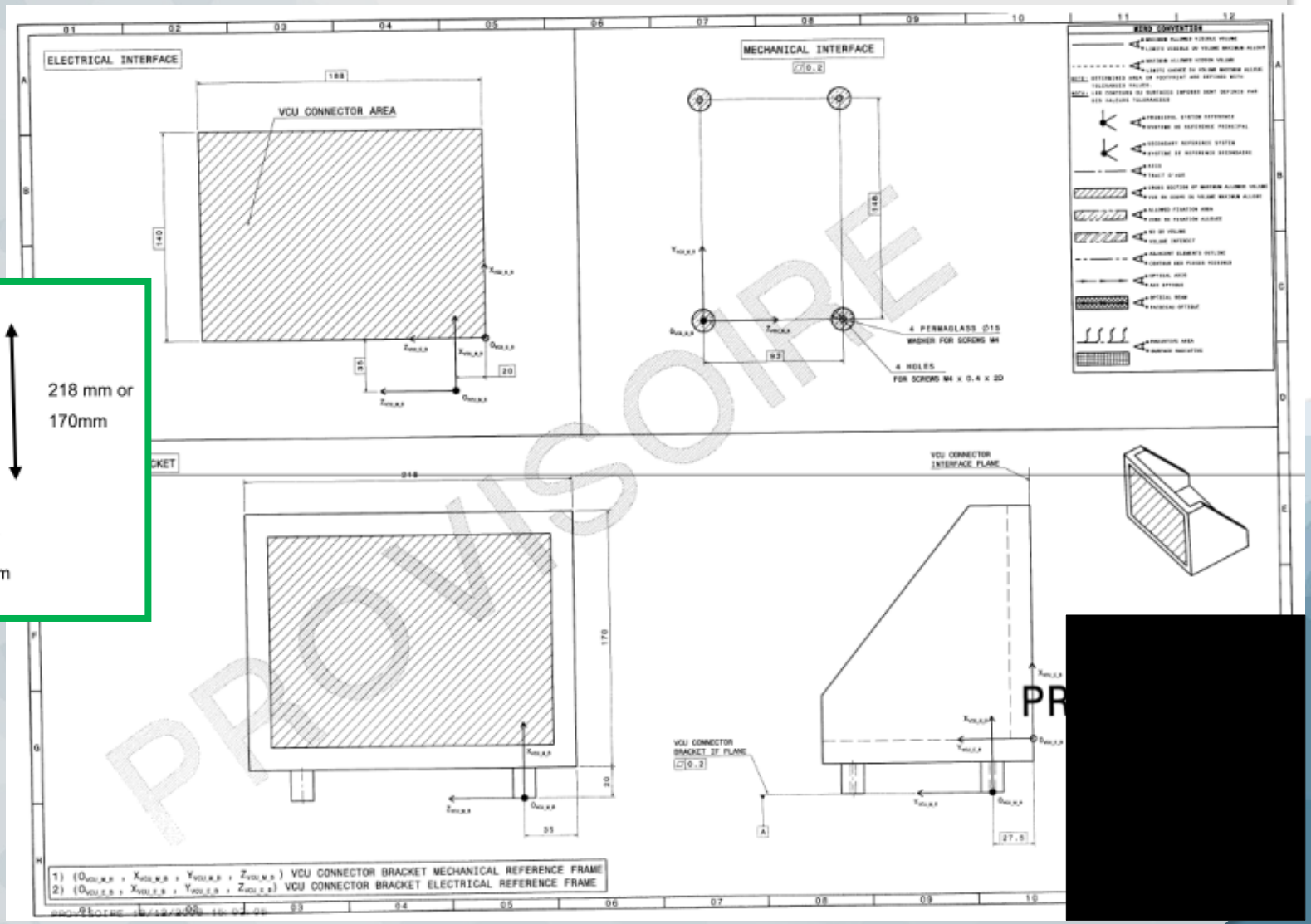
Documentation

3 000 documents with 60 000 pages total for 140 equipment containing 4 000 parts = 300 kg paper + presentations, drawings, models

Development of a satellite equipment

Allocated volume and interfaces





PROVISOIRE

Requirements (examples)

+ functional

(eg:. MTH-18: to provide easy integration of 18 electrical connectors with clearly identification)

+ design and manufacturing

(eg. MTH-49: wire thread inserts shall be used, MTH-67: out-gassing rates shall be CVCM < 0,01%)

+ performances

(eg. MTH-95: stiffness shall be higher than 150Hz, MTH-80: mass shall be max. 0,25kg)

+ operational

(eg. MTH-300: shall be compliant with all requirements in-orbit 7,25, on-ground lifetime 12 years)

+ interface

(eg. MTH-400: shall fit to allocated volume, MTH-410: be compliant with IRD)

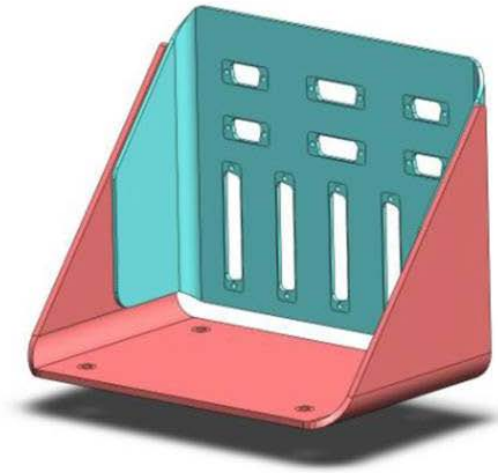
+ PA

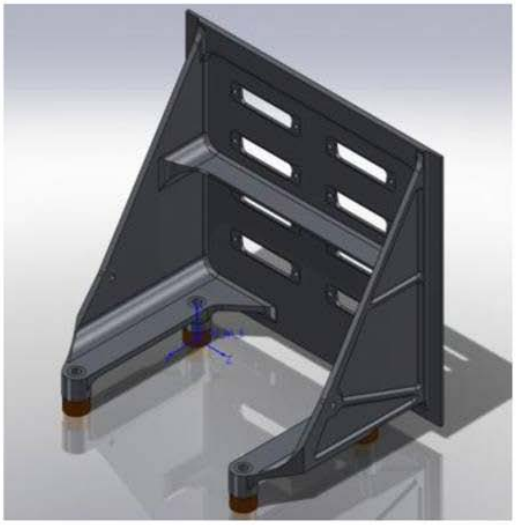
(eg. MTH-605: max. molecular contamination level $0{,}5 \times 10^{-7}$ g/cm^2)

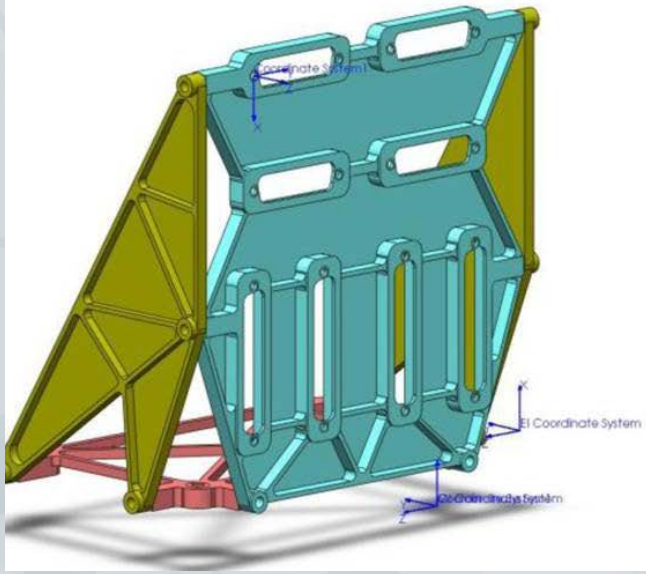
+ environmental

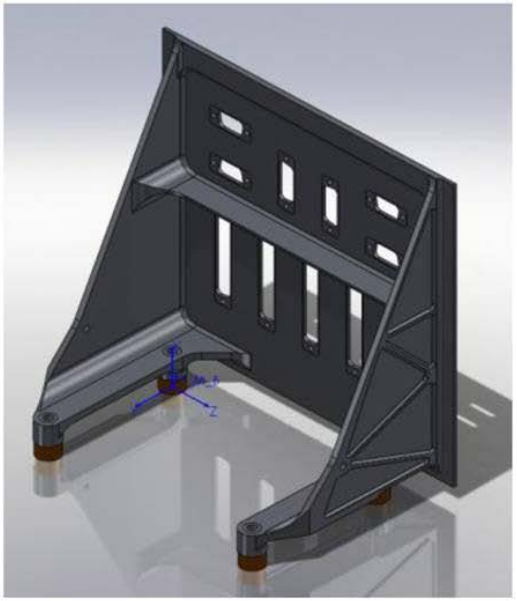
(eg. MTH-660: shall tolerate 30g quasi-static load, MTH-766: thermal resistance -50/+50 °C)

Conceptual designs









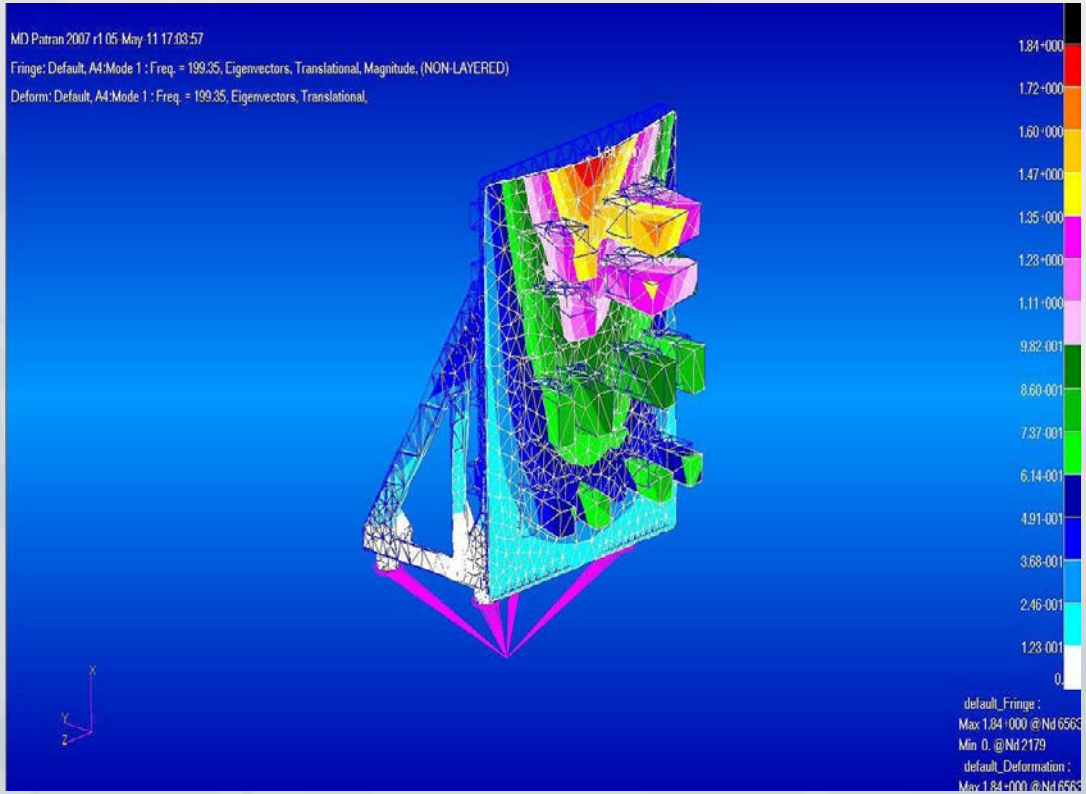
Analysis

Flight Hardware

- Quasi-static analysis
- Buckling analysis
- Normal modes analysis
- Sine analysis
- Random analysis
- Fatigue analysis
- Thermal analysis
- Thermo-elastic analysis

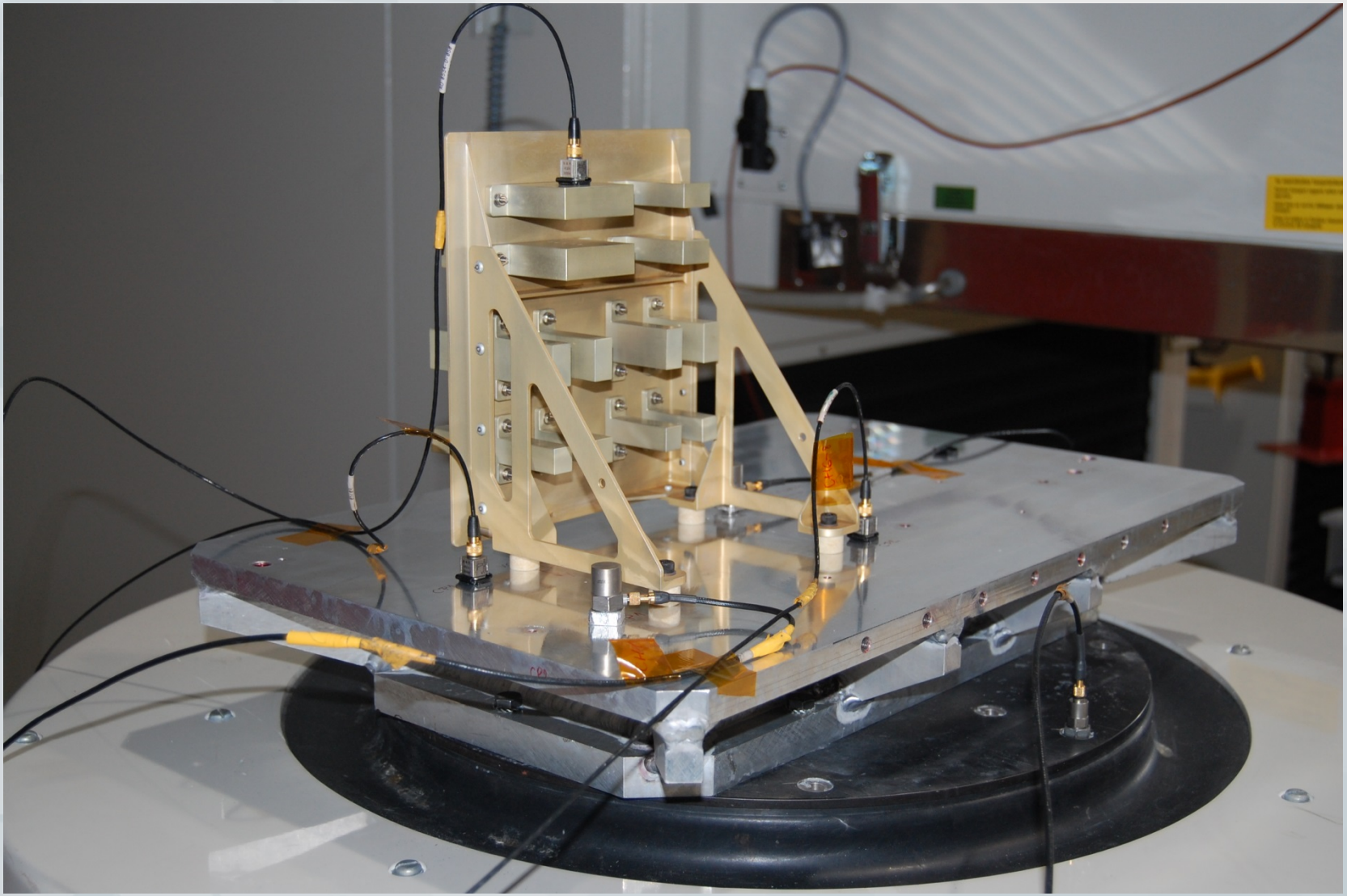
Bolted joints

- Preload
- Thermal effect on preload
- Tightening
- Fastener Failure
- Thread pull-out
- Slip resistance



Dimensional verification

Vibration test



Bake-out

Cleaning and packaging

Thank you!

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