Satellite System Engineering

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Lecture Outline

- Satellite System Engineering:
  - Concepts and Principles
  - Requirements
  - Timeline and Modes
  - Budgets and Margin
  - Options & Trade-offs, … …
- Satellite Subsystems
  - AOCS
  - Power System
  - Communication
  - OBDH
  - Mechanical Configuration, … …

Satellite System Engineering

-- Concepts & Principles

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System & Mission

- System
  << *A set of functional elements organized to satisfy user needs* >> (IEEE P1220)
- Mission
  << *Specific task, duty or function defined to be accomplished by a system* >> (EN 13701:2001)
- Requirement
  << *Need or expectation that is stated, generally implied or obligatory* >> [ISO 9000:2000]

System Engineering

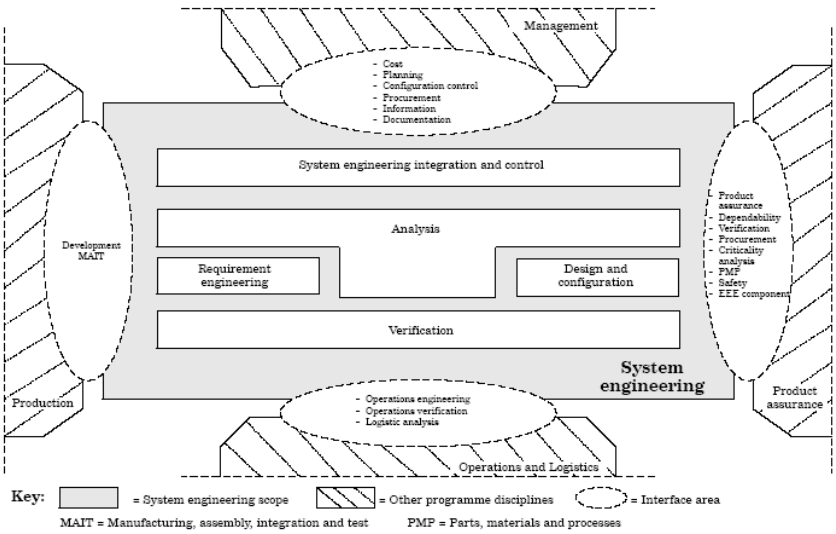
- Formal definition

  << *The interdisciplinary approach governing the total technical effort required to transform a requirement into a system solution* >> (ECSS E-ST-10C)

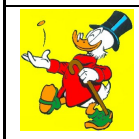
- Practical definition

  The "technical management" of a product design and development

Space Mission - System Engineering areas



Role Model

Character	Role	Requirements
 **User**	The ultimate receiver of the mission or service output	Specifies objectives, user needs and requirements of the mission or service
 **"Customer"/ Sponsor**	Procure and provide the output of mission or service either directly to the User or to an intermediate Service Provider	Specifies mission or service requirements
 **System Developer**	Develops and builds for the Customer the system that performs the mission or provides the service	Prepares system and lower-level technical specifications
 **Operator**	Operates the system on behalf of the user or the customer	Prepares operational specifications

Role Model - examples

System	User	Customer/ Sponsor	System Developer	Operator
Home swimming pool	Kids	Parents	Construction company	Parents/ House staff
Railway System	Passenger	Railway Company	Train and railway builders	Railway company
Interplanetary Probe	Scientists	ESA	Industrial Contractor(s)	ESA
ATV	ISS Astronauts	ESA	EADS	CNES

For simple systems often user=customer

For complex system the user may not have sufficient expertise/gain to procure the system

For very complex system there are even other layer(s) between User and Customer

Between the different roles there are normally formal arrangements

Space Missions

	Operational	*Research*
Use	Linked to provision of a service (e.g. comms, navigation, meteorology, military)	Linked to the achievement of a scientific or technological goal
Timeliness	Key requirement: Near real time data shall be guaranteed	Best effort
Availability	Only short gaps allowed	Requirement based on minimum loss of data
Performance	Based on Service Level Agreement (SLA) linked sometimes to business cases	Directly derived from the achievement of the objectives
Sustainability	Continuity required for many years (replacement, maintenance, obsolescence issues)	One-shot or incremental
Ground Infrastructure	Operational Network (complex and as critical as the Space Segment)	FTP and internet data dissemination, science centres

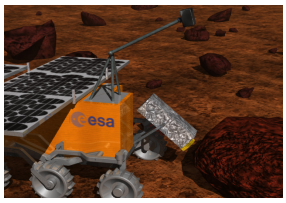
Space System

Space Segment

Spacecraft/Platform

The system composed of one or more elements that carries and provides all the required services to the payload

Payload



The set of instruments that achieve the (science) objectives of the mission

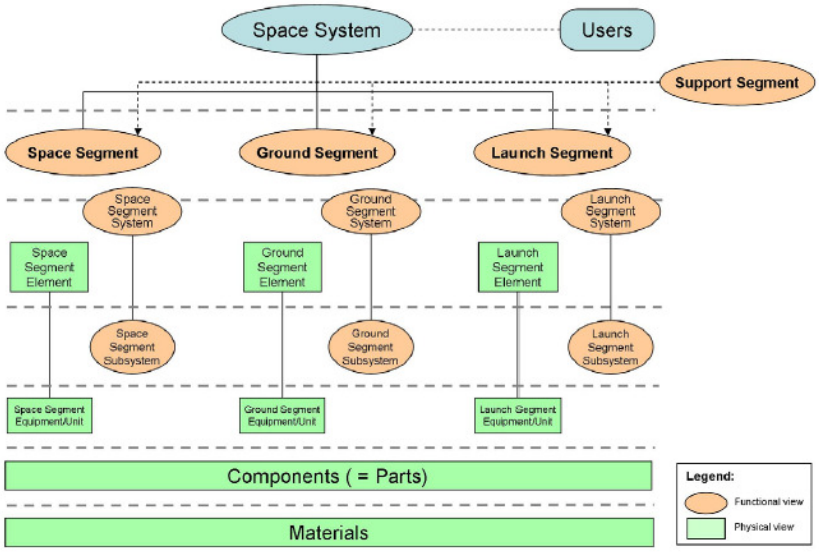
Ground Segment (incl. Operations)

The set of activities to operate the spacecraft and the payload from Earth

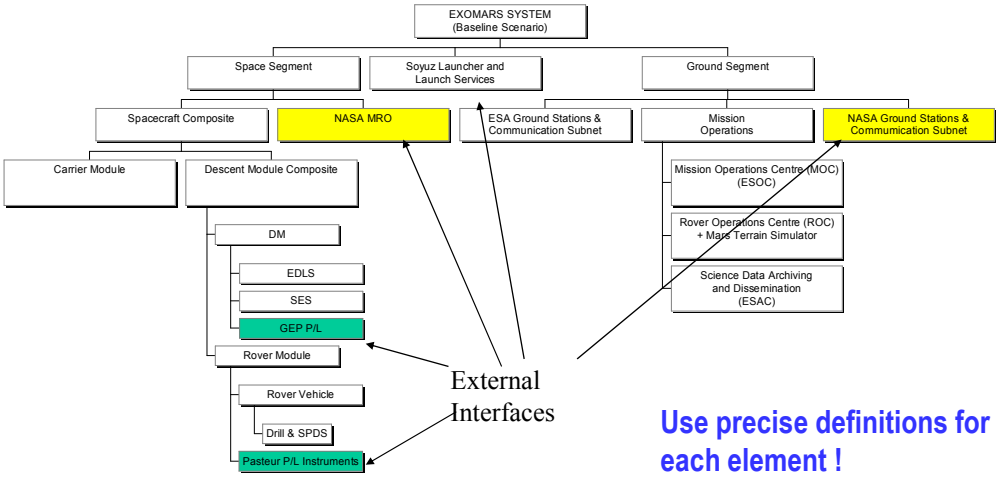
Launcher

The system design shall find the optimal combination of the elements above to achieve the given mission objectives

Space System breakdown (ECSS)



Product Tree



Use precise definitions for each element !

It defines what the System is made of and where the interfaces with external systems are.

Detailed mission/spacecraft breakdown

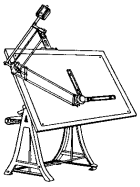
space segment
space segment system
space segment element
space segment subsystem
space segment equipment (=unit)
component (=part)
material

product or item					
examples					
Data Relay Satellite System	spacecraft (physical view)	power	electronic unit (e.g. DHU, PCSU, PDU, ICU)	ASIC	Alumiunium
Navigation Satellite System	satellite (physical view)	propulsion	thruster	hybrid	to be taken from Q60 & Q70
spacecraft (functional view)	payload	data handling	valve	integrated circuit	
satellite (functional view)	platform	thermal	battery	heat-pipe	
	instrument	structure	reflector	MLI	
	orbiter	AOCS	mechanism (when fully assembled)	structural panel	
	lander	Tm&Tc	vessel/tank	optical array	
	bay	optical	mirror/lenses/filters (assembly)	pyro components	
	module	RF	solar array (assembly)	PCB	
		communication	antenna (assembly)	mirror	
			focal plane assembly	solar cell	
			telescope (assembly)	insert	
			solar panel (equipped)	resistor	
			pressure vessels	diode	
			optical bench	transistor	
			RF filters	capacitor	
			LNA	thermistor	
			IMUX/OMUX	heater	
			OMT	propulsion fluidic	
			feeds		

System Development Life Cycle

1. Conceptual design and requirements definition

2. Design



3. Qualification (*verification that the system design fulfils the specified requirements with a margin)*

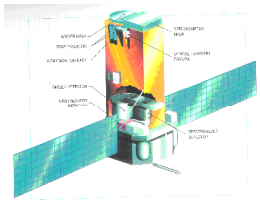
4. Production

5. Customer Acceptance (*check that the product is in agreement with the qualified design, is free from workmanship defects and acceptable for use)*

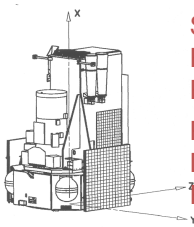
6. Utilisation/Operation

7.Disposal

Space Mission phases



Formulation of System Requirements

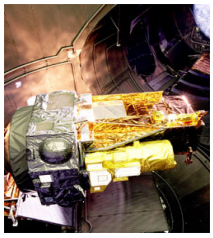


System Requirement Review

Preliminary Design Review

Phase 0: Conceptual design

Phases A&B: Detailed design



Critical Design Review

Qualification Review

Flight Acceptance Review

Phase C/D: Procurement, Integration and Testing

Phase E: Launch and operations

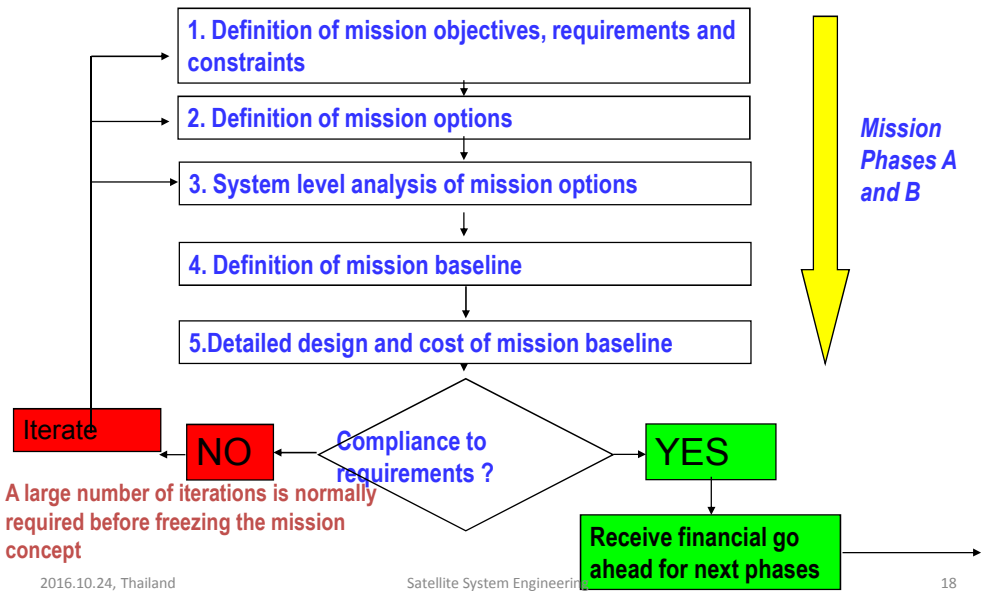
Space Mission phases - 2

Phase	Definition	Duration	Main Events
Phase 0	Identification of mission requirements	1-2 months	Issue of Mission Requirement Document
Phase A	Feasibility	1 year	Issue of Mission Assessment Report
Phase B	Preliminary Design	1 year	Freezing of System Requirements (System Requirement Review) Key design checkpoint (PDR)
Phase C	Detailed Design	6 months-1 year	Critical Design Review
Phase D	Qualification and Production	3-7 years	Models Testing, Qualification Review, Hardware building and Assembly, Flight Acceptance Review
Phase E	Launch and Utilisation	Many years	Launch, Spacecraft Commissioning, Nominal Operations, Contingencies
Phase F	Disposal	Few days	De-orbit

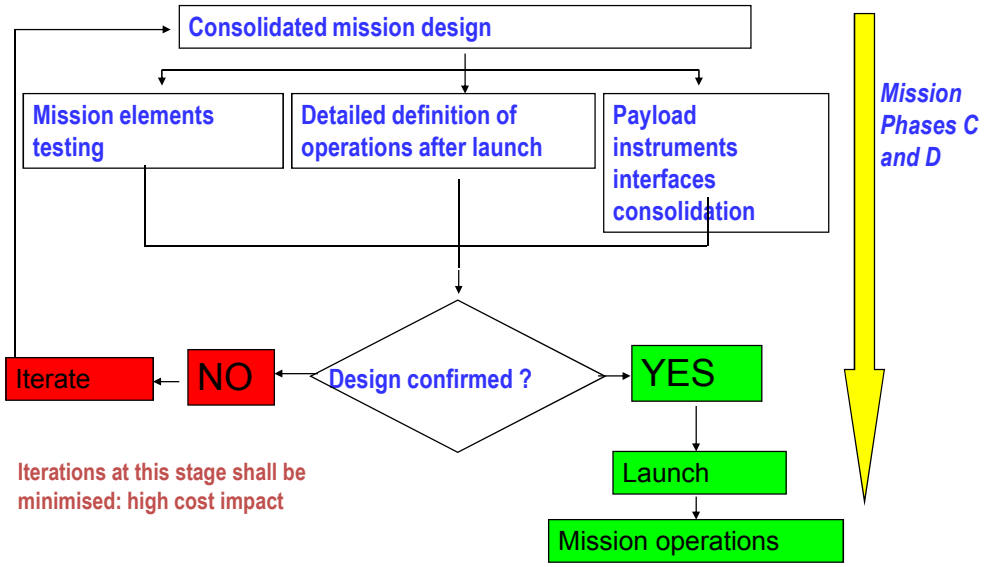
Disposal – the ESA policy

- All ESA Space Vehicle including Satellites, Launchers and Inhabited Vehicles shall be disposed of
- At the end of life they shall be out of "Protected regions" (LEO up to 2000 km and GEO +/-15 deg, +/- 200 km)
- Either moved to non-protected regions or re-entered into Earth atmosphere for break-up and burning
- Uncontrolled re-entry not allowed if casualty risk > 10^{-4} (the case of ATV and possibly Envisat)
- If drift to non-protected regions or re-entry do not happen naturally, additional propellant onboard needs to be accounted for

Space Mission: Steps & Iterations



Space Mission: Steps & Iterations - 2



System Engineer specific tasks - 1

Early phases of a project (Phase 0 to phase A):

1. Translation of customer requirements in mission/system technical requirements
2. Definition of mission/system options in compliance with the technical requirements
3. Interface to mission analysis (ESOC)
4. Options trade and definition of mission baseline
5. Overall design consistency
6. System harmonisation and optimisation (sensitivity analyses)
7. System budgets and design Margins management
8. Preliminary definition of interfaces (launcher, payload)

This course will concentrate on the system engineer's tasks in the early design phases

System Engineer specific tasks - 2

Detailed design phases of a project (Phase A to phase B/early C):

- Flow-down of requirements to subsystems
- Interface to mission analysis (ESOC)
- Overall design consistency and budgets
- Management of design margins
- System harmonisation and optimisation
- Definition of development process
- Support to operations definition
- Management of interfaces

System Engineer specific tasks - 3

Development phases of a project (Phase C to phase E):

- Traceability of requirements
- Support to AIV and Product Assurance in procurement, assembly and verification
- Overall design consistency and budgets
- Management of design margins
- Support to operations definition
- Management of interfaces