Space structures

2. The structural subsystem in the frame of the spacecraft system. Configuration and functional relationships. Case studies

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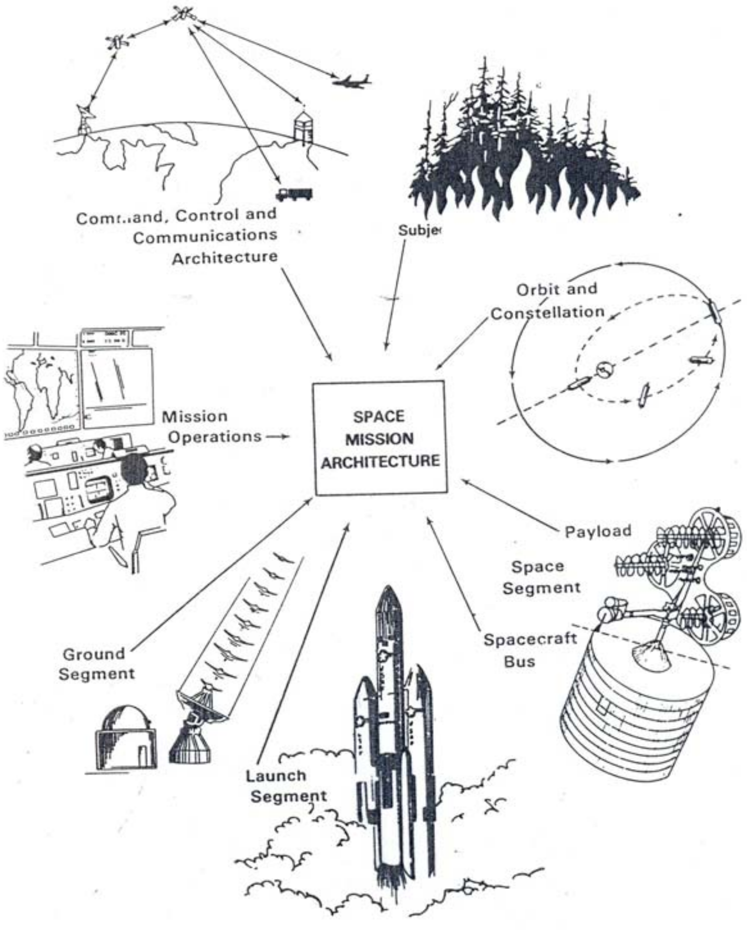
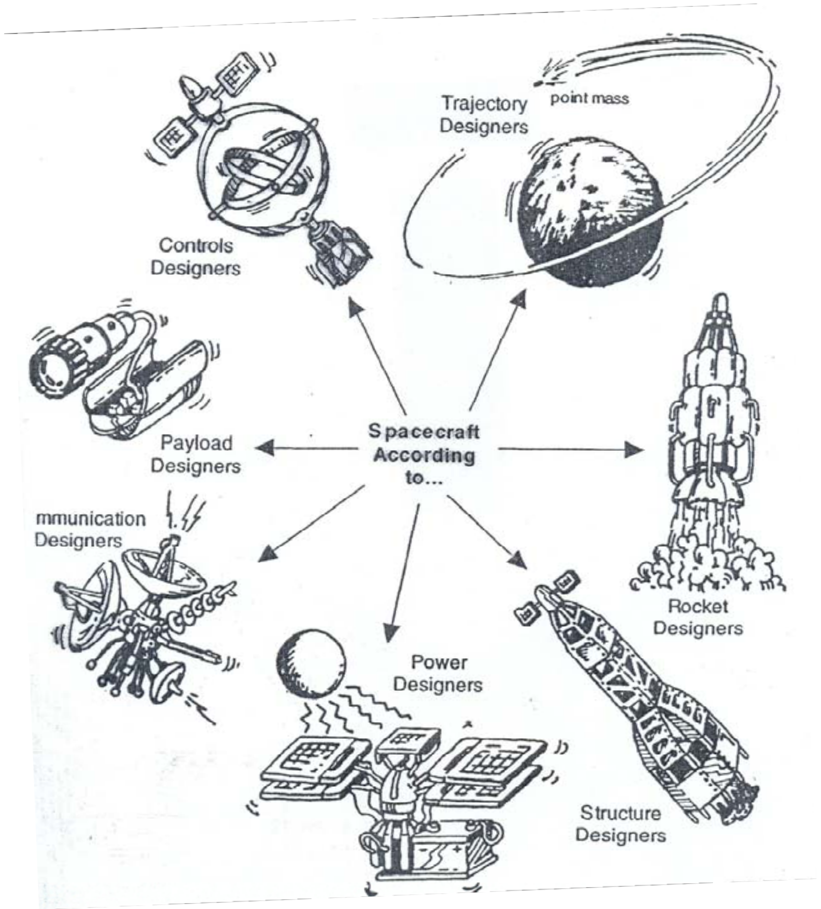
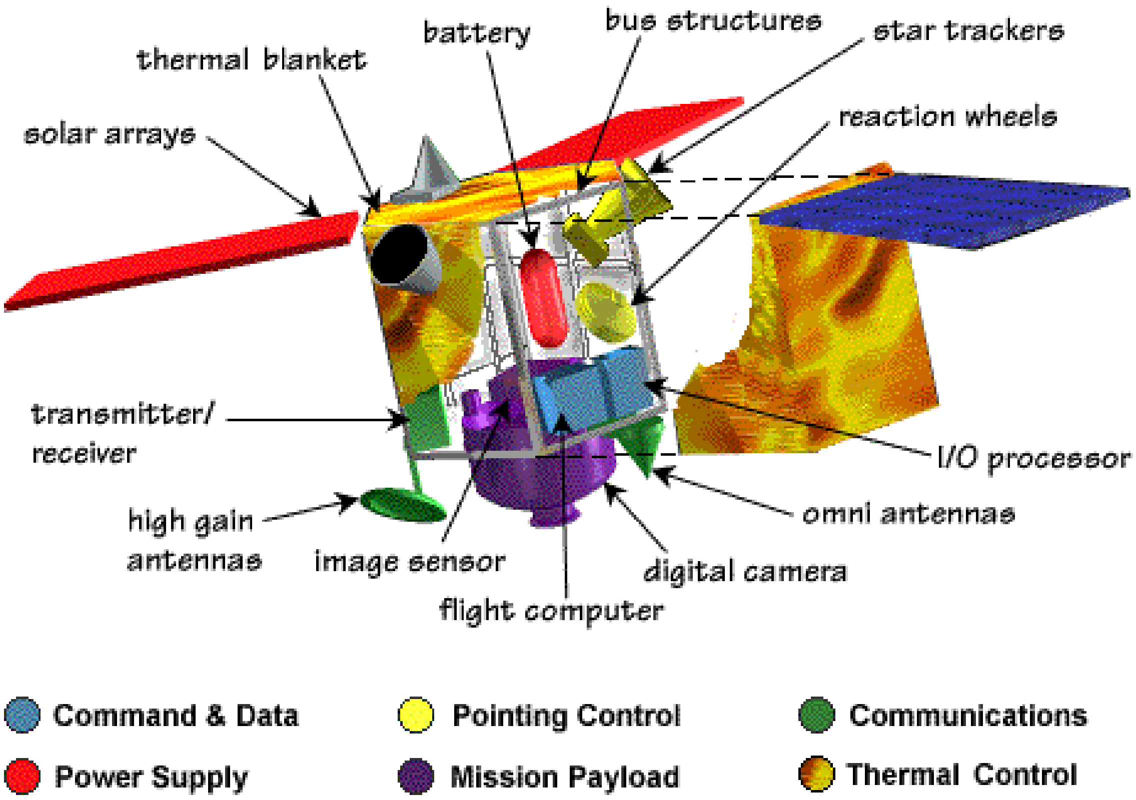
A SYSTEM (OR A SPECIALIST) VIEW ON A SPACE MISSION





Form Wetrz Larson, Space Mission Analyisis and Design

THE SUBSYSTEMS OF A SPACECRAFT



STRUCTURAL FUNCTIONS

Structure: set of mechanical components or assemblies designed to sustain loads or pressures, provide stiffness or stability or provide support or containement.

ECSS 30 2a 3.1.26 Definition

The structural system of a spacecraft has three main functions:

To provide the support of all the other subsystem and materialize the geometry of the spacecraft and its payloads;

To guarantee the necessary STRENGTH to survive all phases of the spacecraft life (in particular the most critical: e.g. the launch) without failures.

STRUCTURAL FUNCTIONS (2)

3. To keep the structural STIFFNESS in certain limits to guarantee the operational functionality of the overall system and avoid coupled resonant responses (e.g. between a satellite and its launcher).

Since the cost of mass is very critical in a space mission, the structural system should be optimized with respect to it both in terms of material and in terms of the optimal structural geometries.

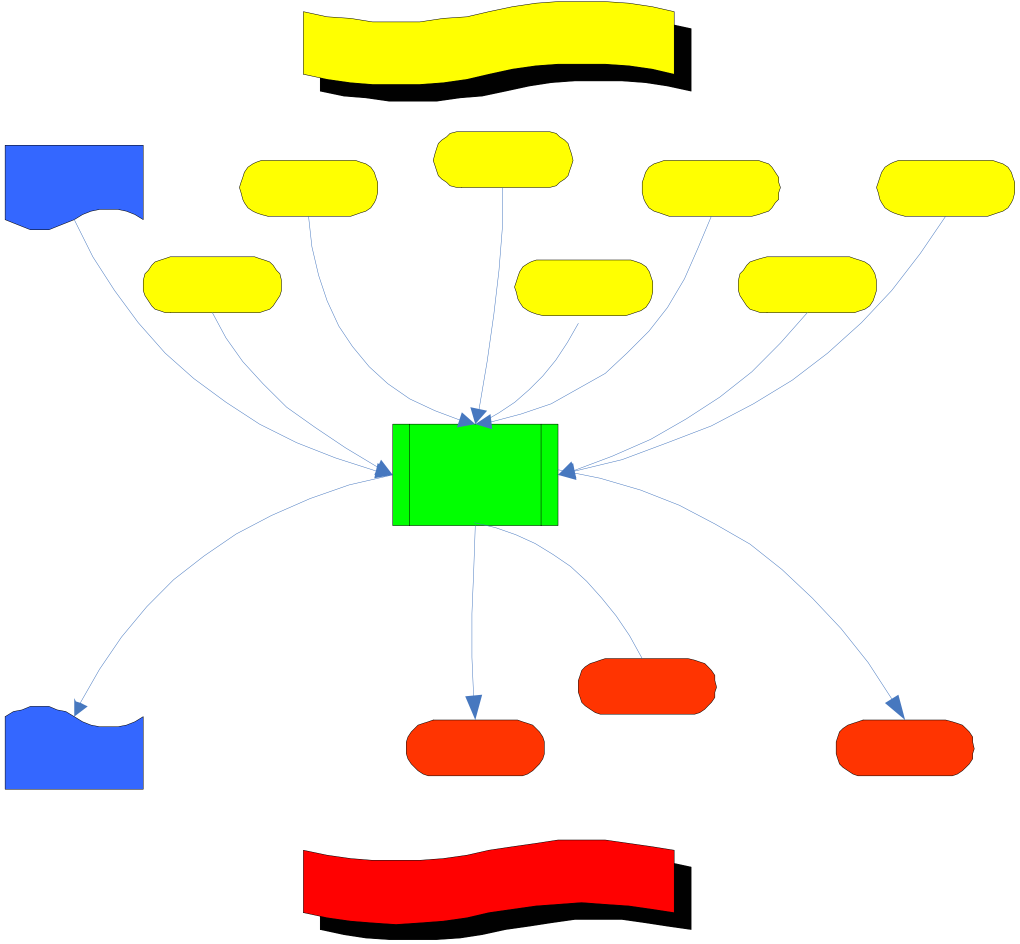
Structural problems affect also other subsytems (e.g. propulsion, attitude and orbital control, on board data handling, TTC) and the payload itself. In fact every component of a spacecraft needs to withstand the mission environment and a structural failure could occur in a component of the system and might be critical for the success of the mission.

STRUCTURAL REQUIREMENTS FOR DIFFERENT ASPECTS IN THE FRAME OF DIFFERENT MISSIONS

The mechanical engineering requirements for structural engineering are to be considered in all engineering aspects of structures: requirement definition and specification, design, development, verification, production, in-service and eventual disposal.

All general structural subsystem aspects of space products are to be considered and in particular: launch vehicles, transfer vehicles, re-entry vehicles, spacecraft, landing probes and rovers, sounding rockets, payloads and instruments, structural parts of all subsystems and of payloads.

FUNCTIONAL RELATIONSHIPS BETWEEN THE STRUCTURAL SUBSYSTEMS AND THE OTHER SUBSYSTEMS OF A SPACECRAFT



In this diagram the functional relationship among the structural subsys, the other subsys and the payload is represented in terms of the flow of information incoming and outgoing from the structural spacecraft design to all others. In the following pages a list of possible variables describing the system, the mission and the other subsystem is reported. The structural design is strongly linked with configuration design. In the following these two areas are considered equivalent.

THE MASS BUDGET: A SYSTEM DRIVER CRITICAL FOR THE STRUCTURAL SUBSYSTEM

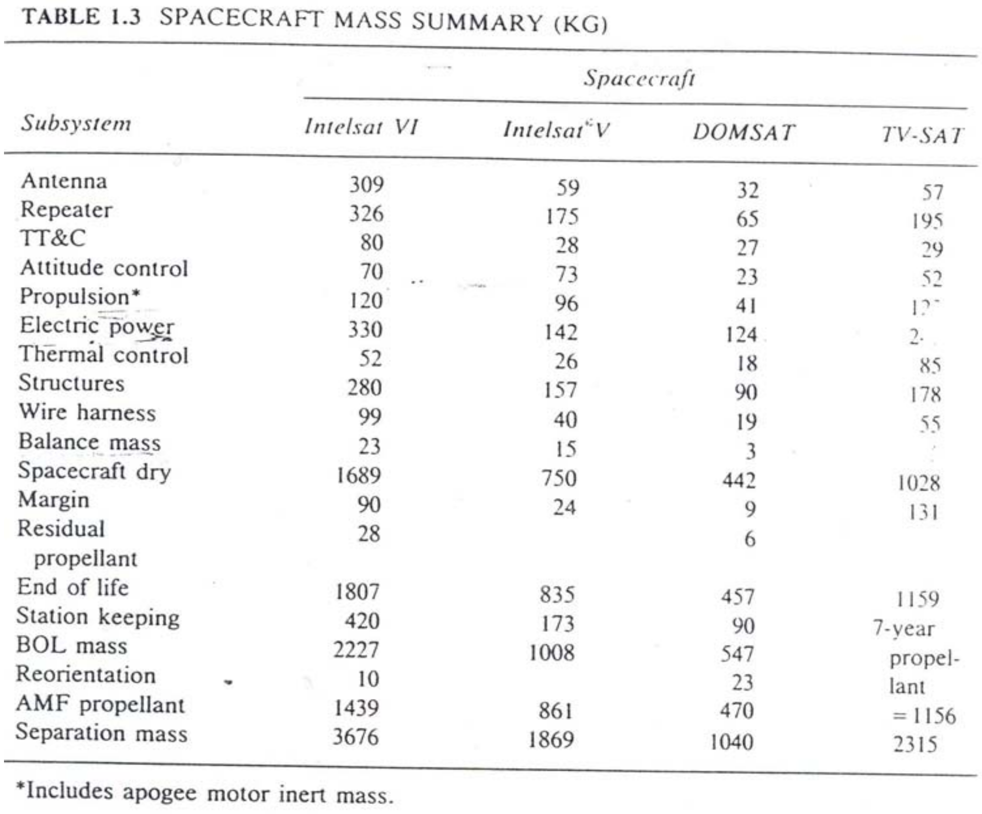


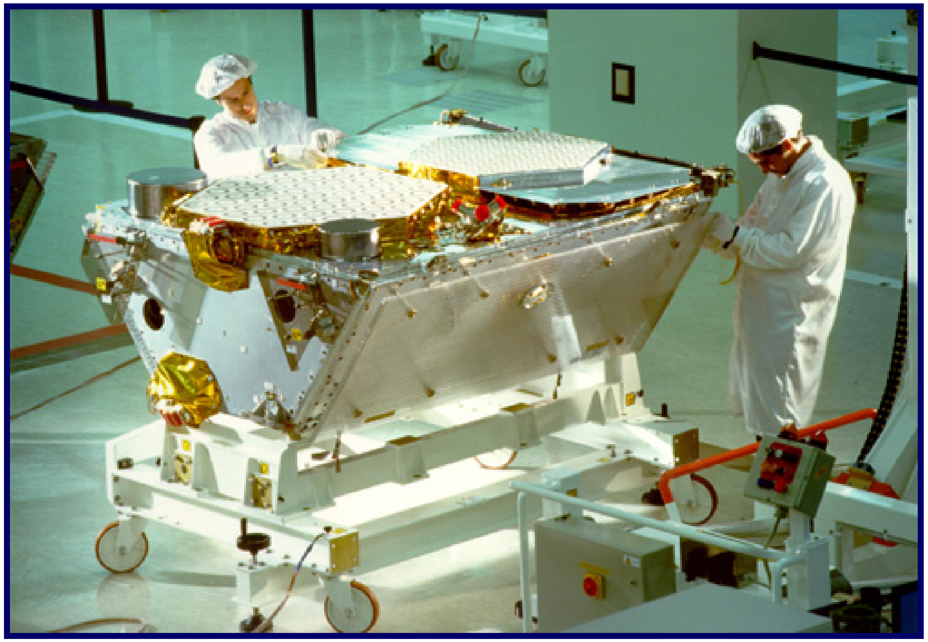
TABLE 1.3 SPACECRAFT MASS SUMMARY (KG)

	Spacecraft			
Subsystem	*Intelsat VI*	*Intelsat V*	*DOMSAT*	*TV-SAT*
Antenna	309	59	32	57
Repeater	326	175	65	195
TT&C	80	28	27	29
Attitude control	70	73	23	52
Propulsion*	120	96	41	12[illegible]
Electric power	330	142	124	2[illegible]
Thermal control	52	26	18	85
Structures	280	157	90	178
Wire harness	99	40	19	55
Balance mass	23	15	3	
Spacecraft dry	1689	750	442	1028
Margin	90	24	9	131
Residual propellant	28		6	
End of life	1807	835	457	1159
Station keeping	420	173	90	7-year propellant = 1156
BOL mass	2227	1008	547	
Reorientation	10		23	
AMF propellant	1439	861	470	
Separation mass	3676	1869	1040	2315

*Includes apogee motor inert mass.

Since in most cases the dimensioning loads for the structure of a payload are the ones due to the inertia forces, the distribution of the massive components of all the subsystems generates the forces acting on the satellite and their application points.

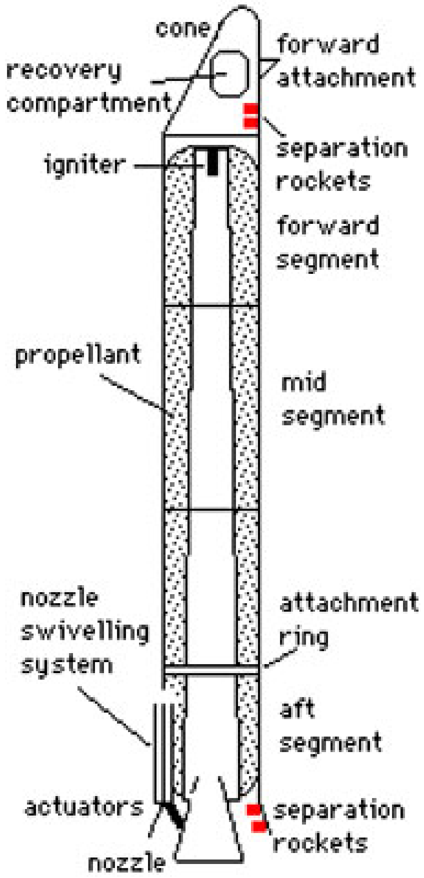
THE GEOMETRY OF A SPACECRAFT AND ITS STRUCTURAL SYSTEM



Globalstar: constellations of telecom satellites with multiple launch ; the single satellite could be positioned with different orientation with respect to the laucher by means of a dispenser. The structural concept is adapted to the idea of series production.

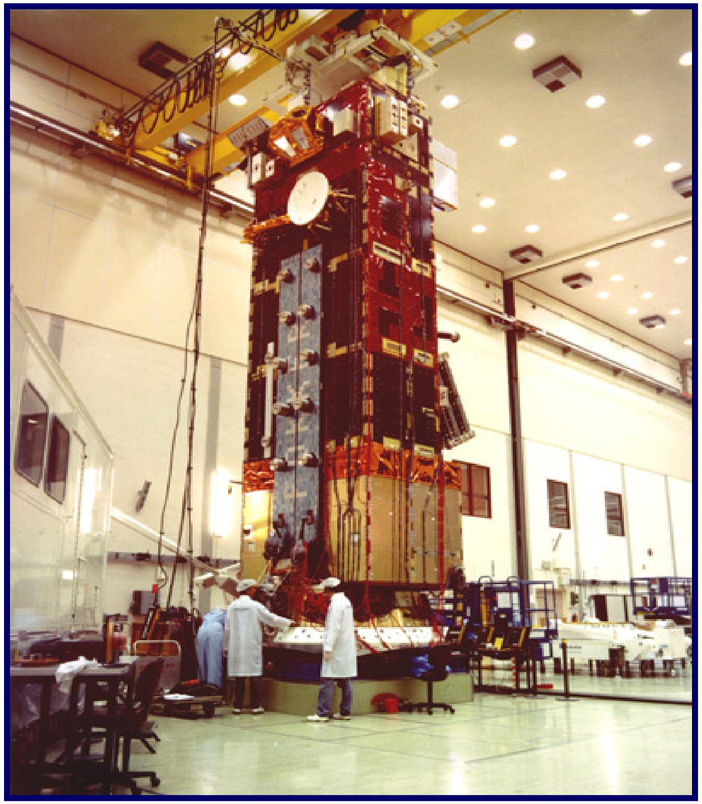
Cassini Huyghens: the high gain antenna and the landing probe are clearly visible.

THE GEOMETRY OF A LAUNCHER: ARIANE 5 ECA



In the pictures the overall system, the vehicle equipment bay, the solid booster section

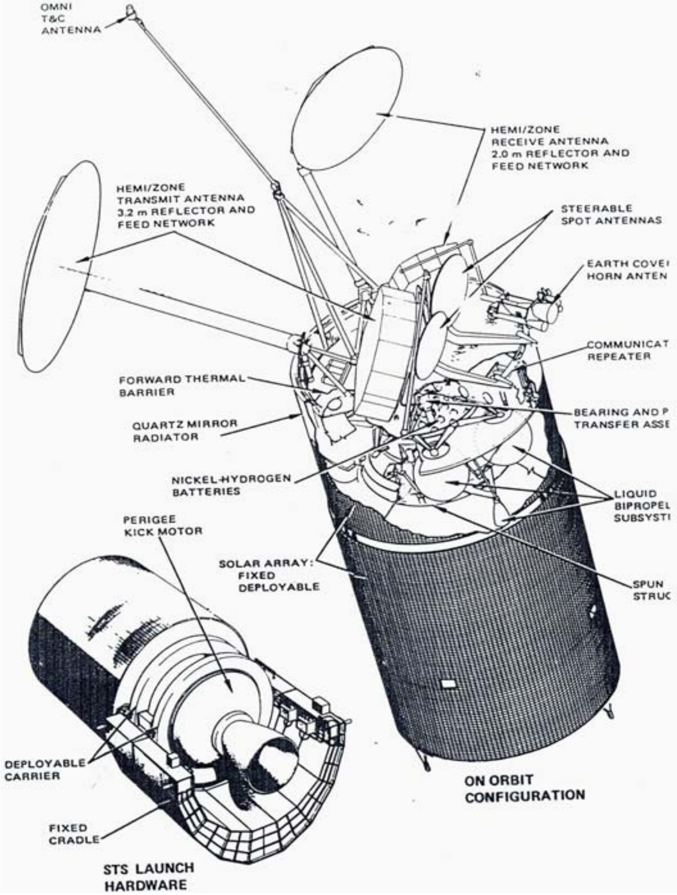
THE GEOMETRY OF A SPACECRAFT AND ITS STRUCTURAL SYSTEM



ENVISAT: a European Earth observation satellite for environment monitoirng

An artist view of a possible future space transportation system

INTELSAT VI: DOUBLE SPIN TLC SATELLITE



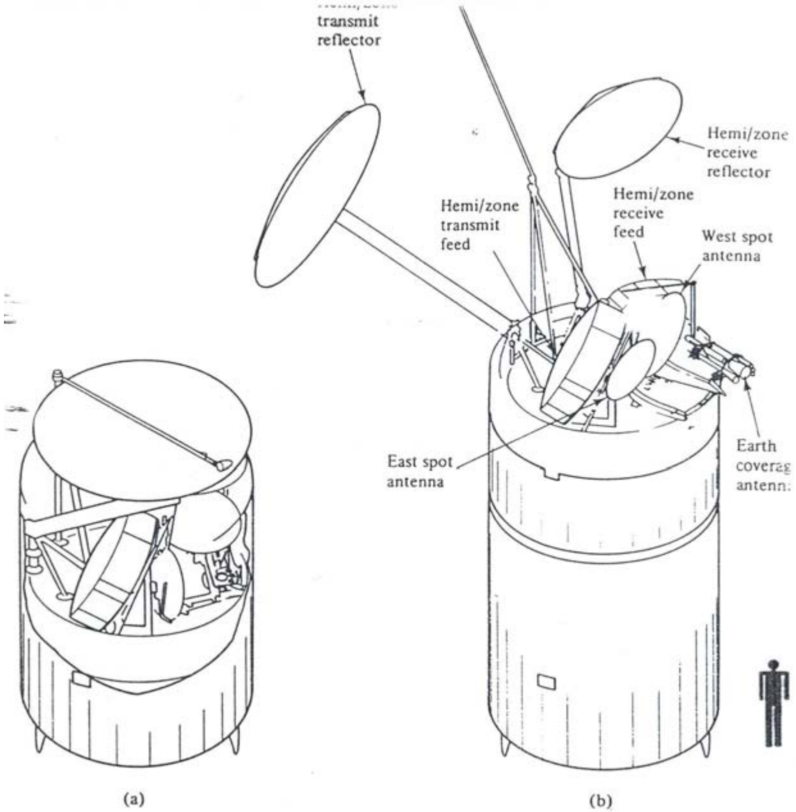
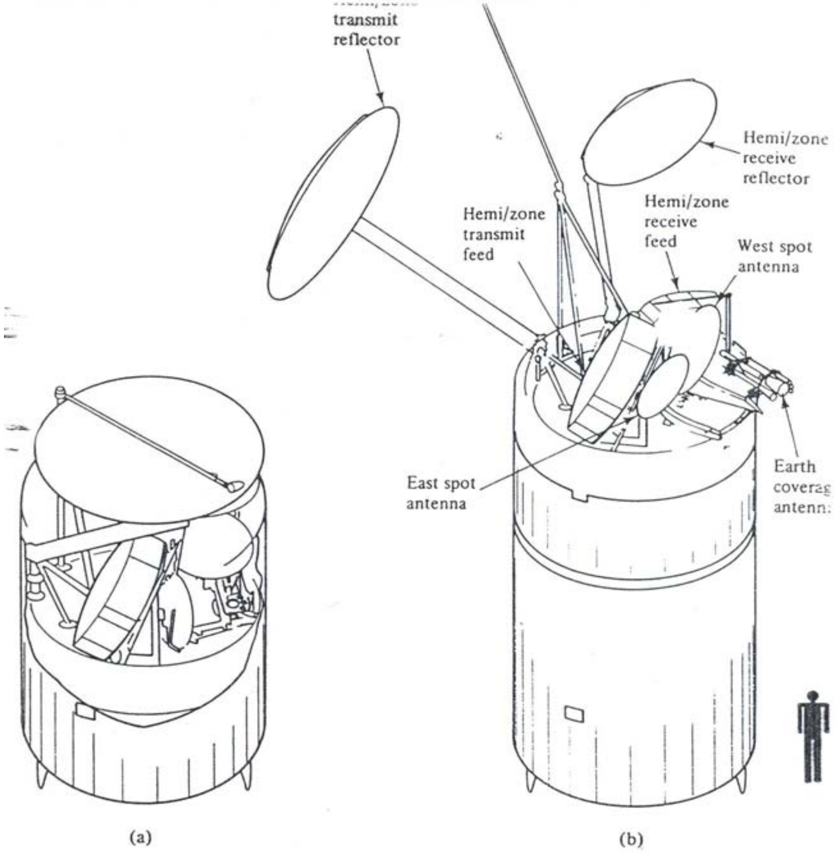


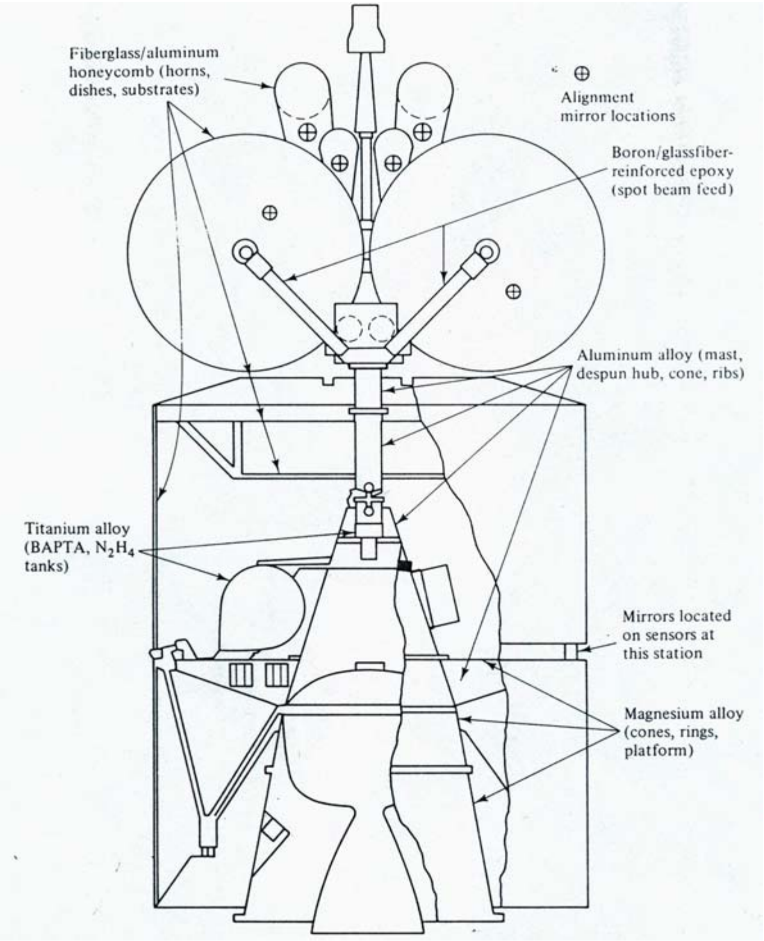
Figure 7.25 Intelsat VI antenna farm: (a) stowed; (b) deployed. (Courtesy of INTELSAT and HAC)

INTELSAT VI: DOUBLE SPIN TLC SATELLITE

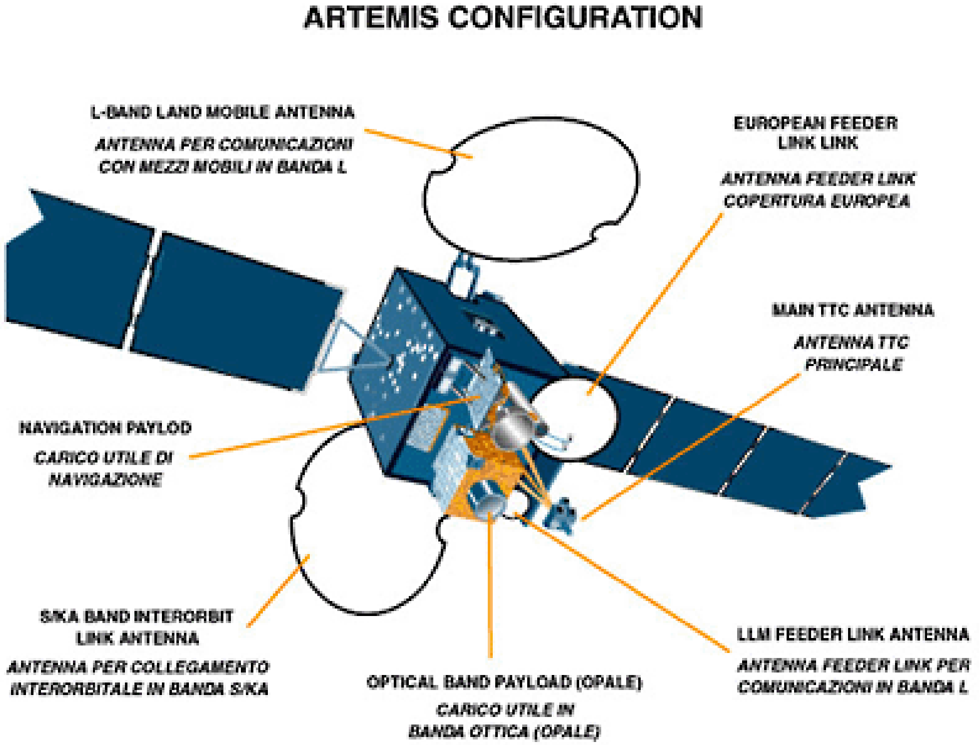


(a) (b)

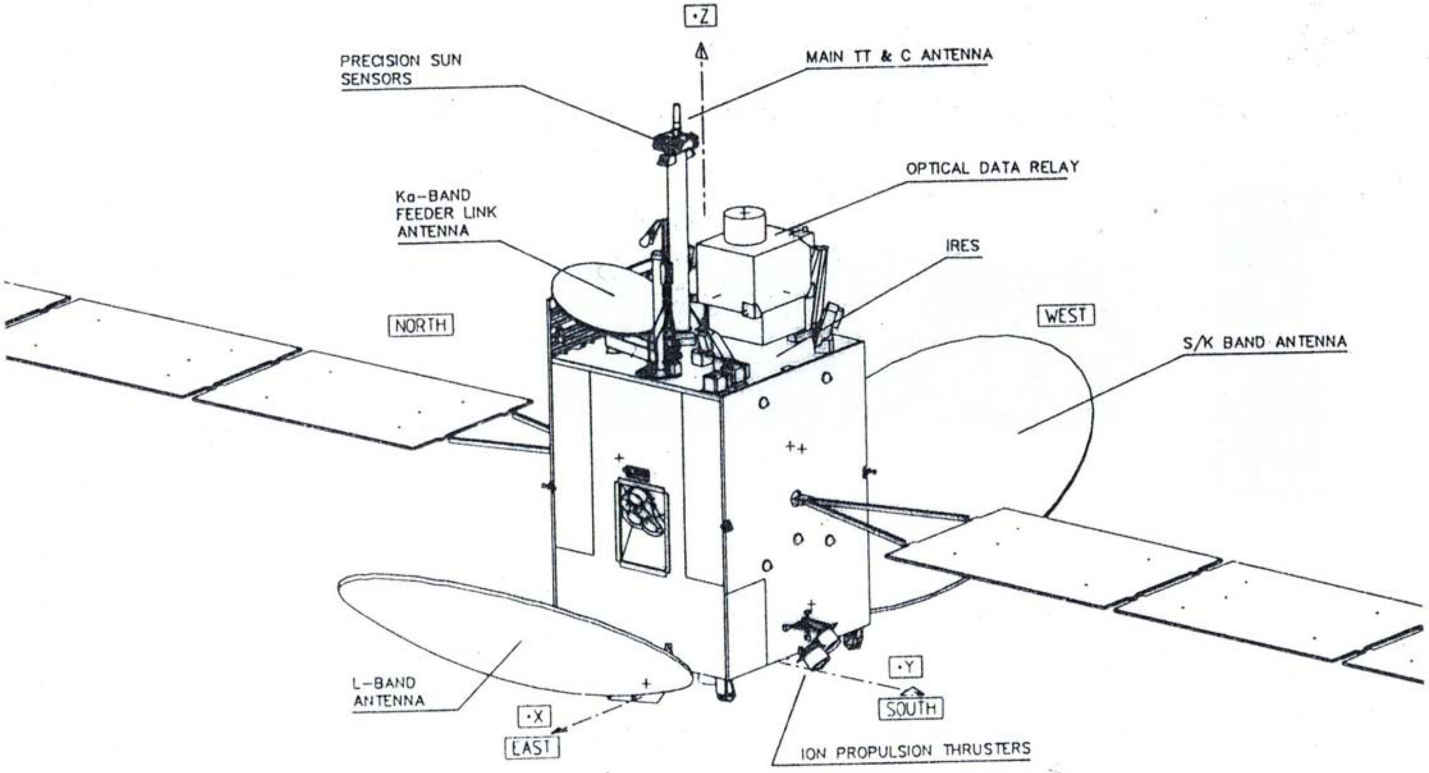
Figure 7.25 Intelsat VI antenna farm: (a) stowed; (b) deployed. (Courtesy of INTELSAT and HAC)



ARTEMIS: AN ADVANCED TLC SATELLITE

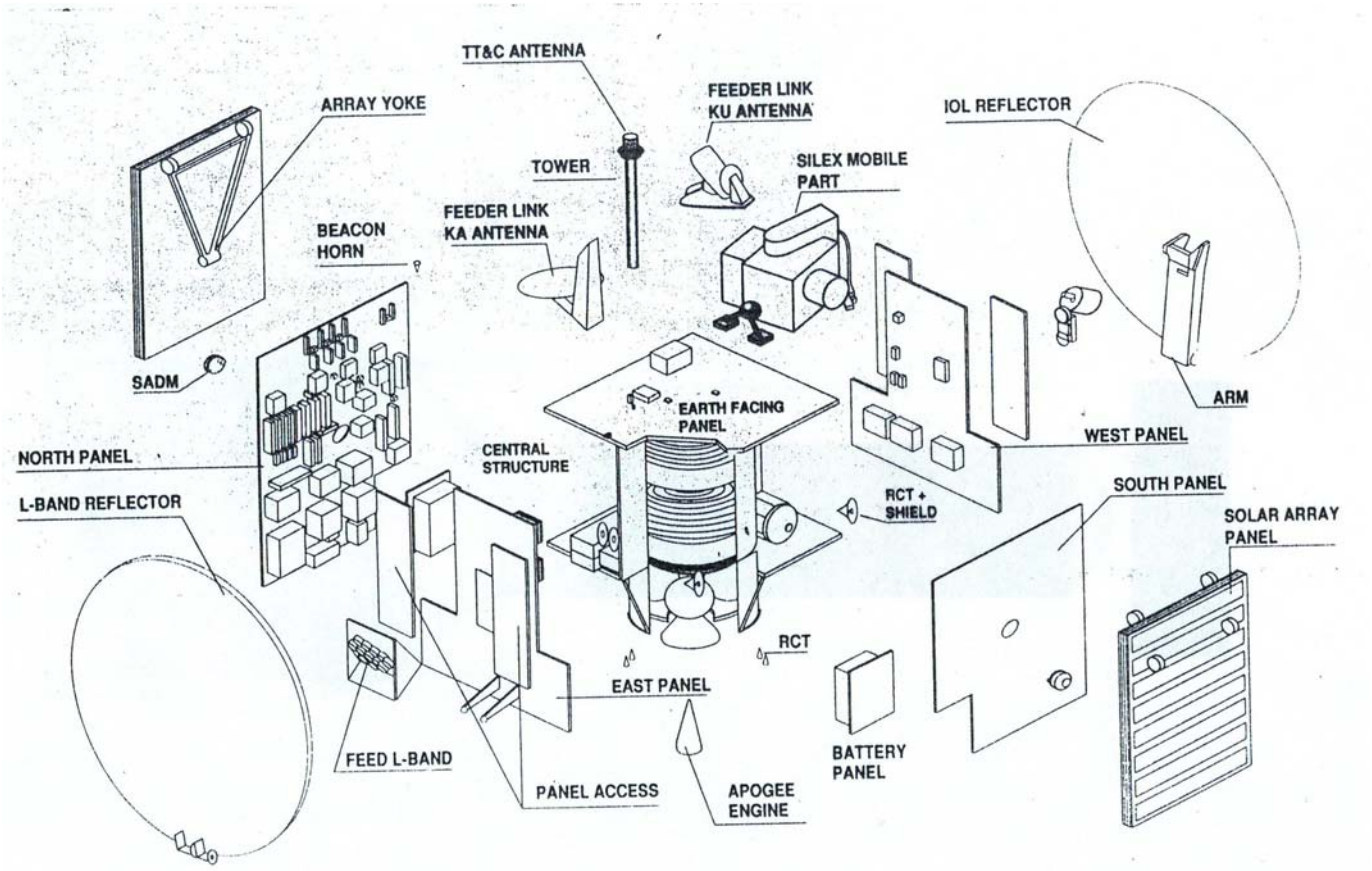


ARTEMIS: AN ADVANCED TLC SATELLITE (2)



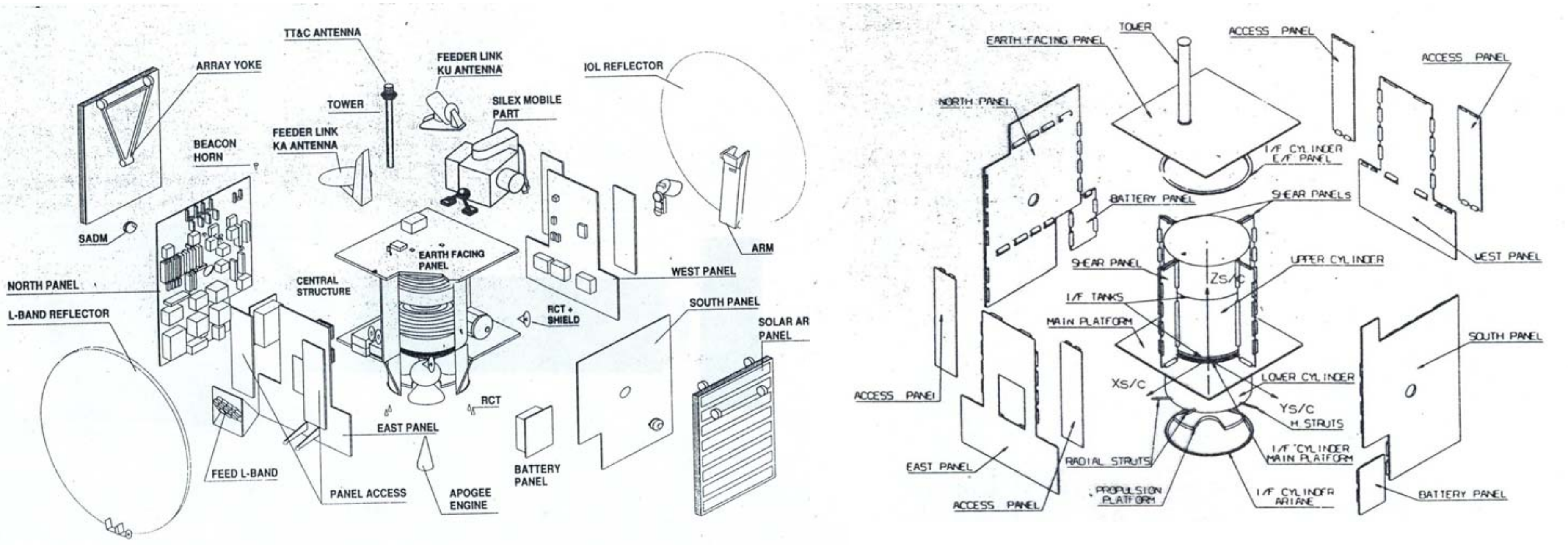
ARTEMIS: a TLC satellite, overall picture

ARTEMIS: AN ADVANCED TLC SATELLITE (3)



ARTEMIS: a TLC satellite, exploded view with main components

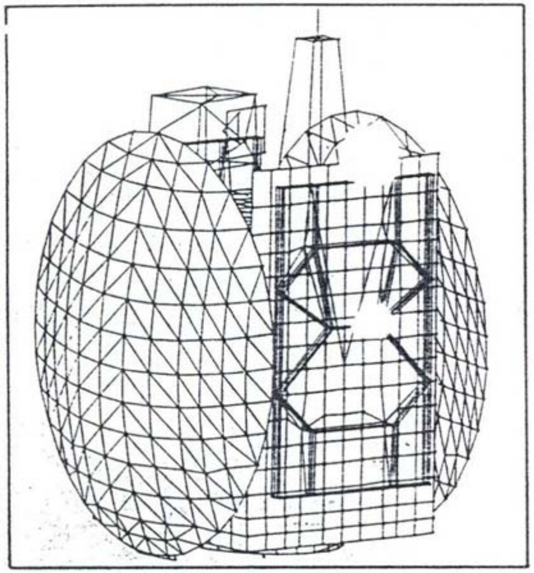
TYPICAL SHAPE OF STRUCTURAL SYSTEMS



ARTEMIS: the structural system materializes the geometry of the spacecraft and gives support to all other subsystems and to the payload.

The structural concept is based on the presence of a central cylinder that transmit the loads to the adapter and is connected to the lateral panel by means of four shear panels.

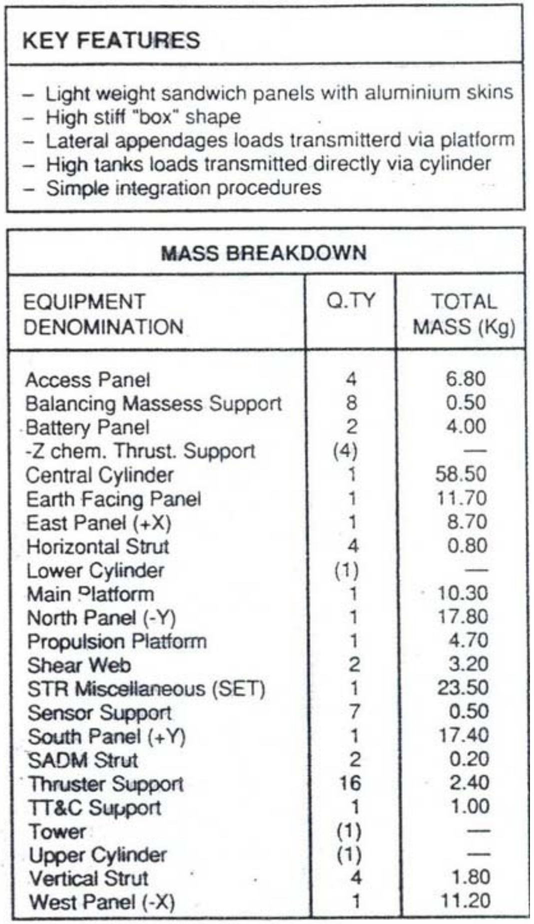
ARTEMIS: AN ADVANCED TLC SATELLITE (4)



Finite element mathematical model of the launch configuration (stowed) satellite, inclusing of appendages models.

KEY PERFORMANCE

- Launcher I/F: Ariane 1194 A
- Satellite mass: 2600 Kg
- Global Q.S.L.: 8.25 g (Axial); 2.70 g (Lateral)
- 1st axial frequency: 42 Hz
- 1st lateral frequency: 15 Hz
- Launcher: ariane V/APEX



KEY FEATURES

- Light weight sandwich panels with aluminium skins
- High stiff "box" shape
- Lateral appendages loads transmitterd via platform
- High tanks loads transmitted directly via cylinder
- Simple integration procedures

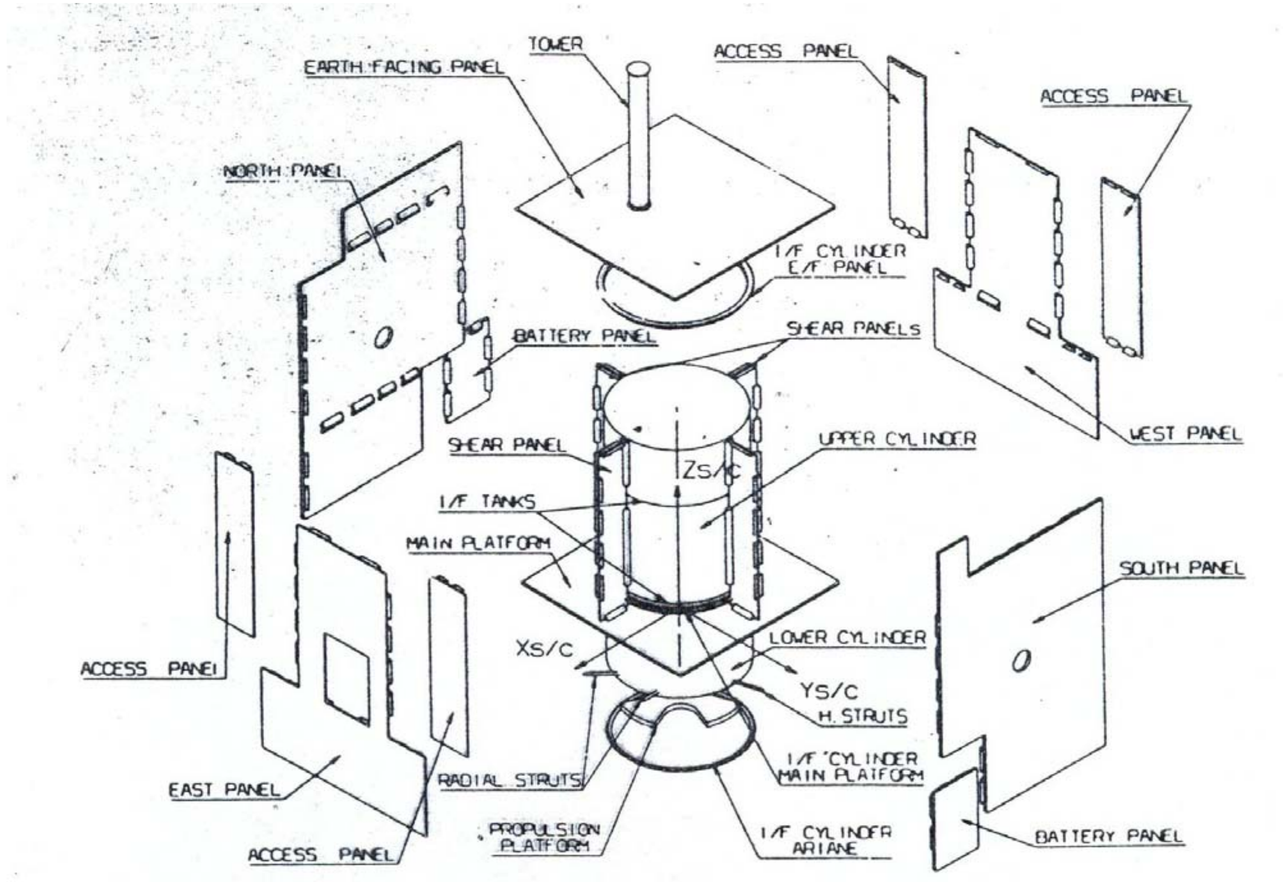
MASS BREAKDOWN

EQUIPMENT DENOMINATION	Q.TY	TOTAL MASS (Kg)
Access Panel	4	6.80
Balancing Massess Support	8	0.50
Battery Panel	2	4.00
-Z chem. Thrust. Support	(4)	—
Central Cylinder	1	58.50
Earth Facing Panel	1	11.70
East Panel (+X)	1	8.70
Horizontal Strut	4	0.80
Lower Cylinder	(1)	—
Main Platform	1	10.30
North Panel (-Y)	1	17.80
Propulsion Platform	1	4.70
Shear Web	2	3.20
STR Miscellaneous (SET)	1	23.50
Sensor Support	7	0.50
South Panel (+Y)	1	17.40
SADM Strut	2	0.20
Thruster Support	16	2.40
TT&C Support	1	1.00
Tower	(1)	—
Upper Cylinder	(1)	—
Vertical Strut	4	1.80
West Panel (-X)	1	11.20

Cortesy of Alenia Spazio

Artemis mass breakdown

TYPICAL STRUCTURAL ASSEMBLY



ARTEMIS: the structural system

PRIMARY STRUCTURES

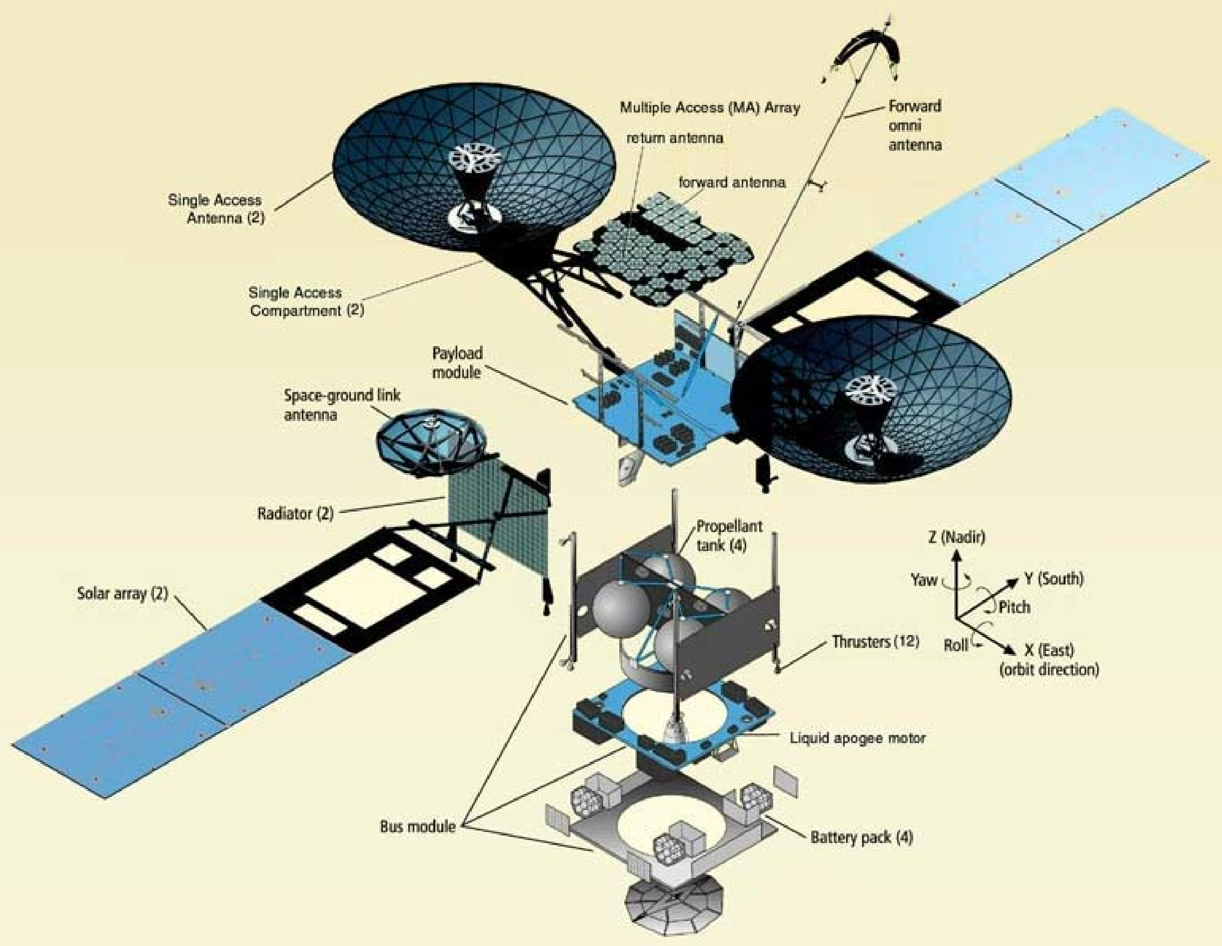
Typical cylindrical primary structure of a tlc satellite. The primary structure is responsible for carrying the maximum loads due to all the masses of the spacecraft.

The cylindrical structure has the optimal geometry for withstanding axial loading while hosting an internal volume free for hosting the propulsion reservoirs.

In this way the highest percentage possible of satellite mass has been displaced close the vertical axis of the launcher.

Moreover also launchers, both in the cases of liquid and solid rockets, have cylindrical structures.

SHAPE OF STRUCTURAL SYSTEMS: ALTERNATIVE GEOMETRY FOR TLC SATELLITE



TDRS: in this American tlc satellite the central cylinder is substituted by a structure made by a combination of a central panel and trusses connecting it to the propellant tanks (where an high percentage of the mass budget is allocated). A different assembly logic is self-evident. A easier access is provided to the internal part of the system. The structure is less optimized in strictly structural terms but offers other advantages.

SMART 1: SMALL LOW COST SATELLITE

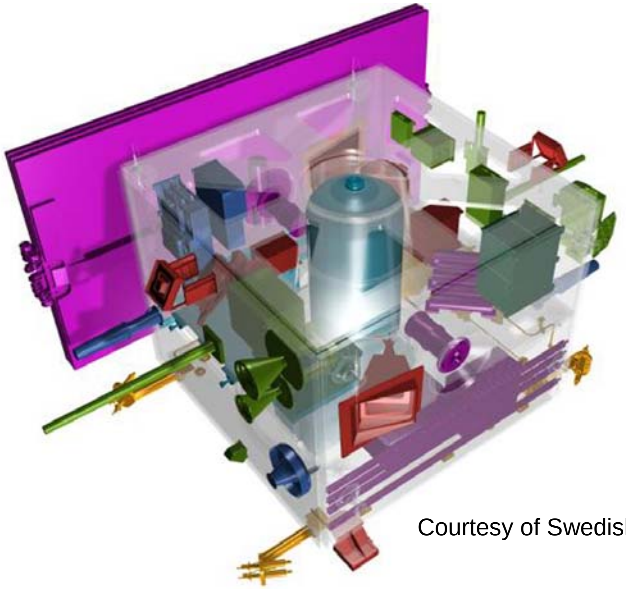
SMART-1 (Small Mission for Advanced Research and Technology) has been the first low cost experimental missions by ESA and the first European satellite orbiting the moon. Electric propulsion was used as the main propulsion system of the spacecraft.

Technical characteristics:

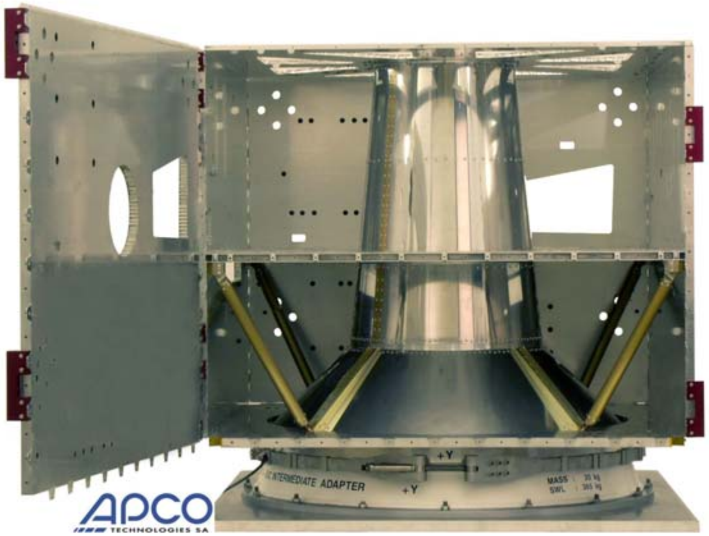
- Platform: 3-axis stabilised
- Launch mass: 367 kg
- Scientific payload mass: 19 kg
- One 68 mN electric thruster (PPS-1350, SNECMA)
- Xenon propellant mass: 85 kg to provide 3500 m/s deltaV

Courtesy of Swedish space corporation

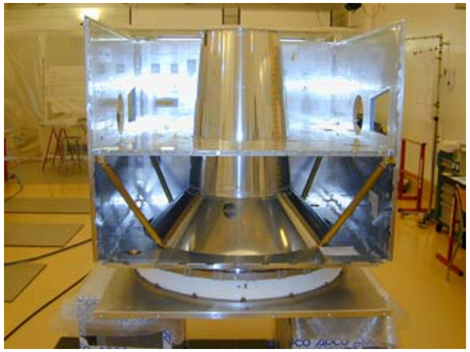
SMART 1: SMALL LOW COST SATELLITE (2)



Courtesy of Swedish space corporation



SMART 1 is a low cost experimental mission the satellite structure has been realized in aluminum as illustrated in the right photos. The various components of the satellite systems are also visible in the picture above. Special panel himge and attachment allows easy access inside the structure.



PAYLOAD STRUCTURES: ANTENNAS

The structures of space antennas are very critical for the performance of the TLC payload and are characterized by stringent requirements in terms of shape stability and dynamic response.

Courtesy of Alenia Spazio

CONCLUDING REMARKS

Functions of the structural subsystem

Structural requirements coming from other subsystems and from payload

Configuration and mass budget

Example of configuration and structures of different space vehicles