MINISTAR
A Small Spacecraft for GEO Missions

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ABSTRACT

This paper provides the information of the conceptual design of MINISTAR and presents the major features of this small spacecraft, able to support geostationary missions for satellite communications.

MINISTAR is a sun pointing satellite, with despun antenna provided with momentum wheels to achieve gyroscopic stiffness along the pitch axis, maintained orthogonal to the geosynchronous orbit.
Thrusters supply the attitude stabilization for yaw and roll axes and station keeping manoeuvres.
An unified propulsion system is adopted, with helium pressurized bipropellant. The system makes use of monomethyhl hydrazine as propellant and nitrogen tetroxide as oxidizer.

Large autonomy, is provided by the on-board system management.
The communications' payload power/mass ranges from 200 W/50 Kg to 600 W/100 Kg allowing payloads with volume of 0.13 m^3 and a maximum antenna diameter of 1.8 m.

MINISTAR can be launched as co-passenger by ARIANE or TITAN.

INTRODUCTION

MINISTAR is a small interstage satellite capable to fly at marginal cost on expendable launch vehicles on ARIANE and TITAN launch families.

ARIANE IV offers different launch opportunities by variation of solid and liquid strap on boosters.
In most applications, the primary spacecraft does not exactly fit the launcher capability, so that additional mass may be available for secondary payload. The required additional volume can be obtained using the difference in length between short and/or long fairings and between short and long SPELDA.

For TITAN III the application of similar concepts is possible by using an extension module which supports the launch of two MINISTAR satellites with relevant perigee kick-motor.

Major guidelines and project features are:

- Simplicity,
- Flexibility of design,
- Simplicity of interfaces between system elements,
- System's component elements designed around established philosophy based upon industrial high grade and volume production techniques.

The MINISTAR design approach aims to develop cost reductions in selected areas of the satellite project, as:

- sub system design,
- management efforts.

The low mass of the MINISTAR will allow reduction of launching costs.

Moreover, with simple and low cost spacecraft the risk of launch could be taken directly by the users, so launch insurance expenses might be avoided.

MINISTAR design is based on:

- New implementations:
  . structure concept;
  . system management processor for telemetry, commands, attitude logic, power control, etc;
  . solar array configuration.

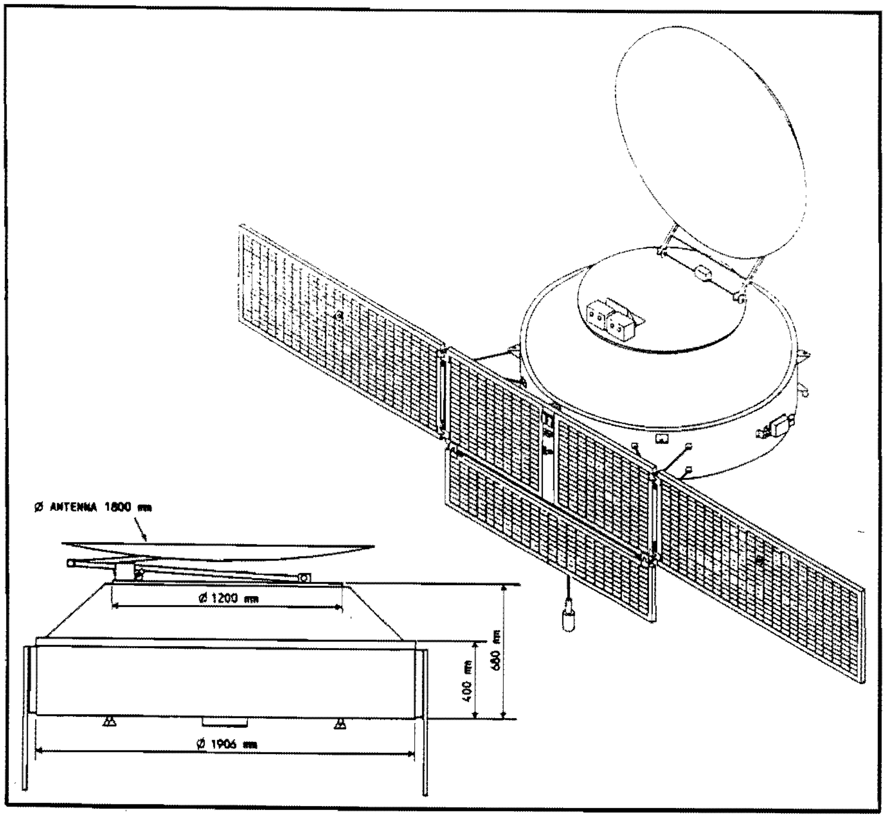
- Current technologies:
  . propulsion, reaction control, power generation, thermal control, TT&C.

MINISTAR CONFIGURATION

MINISTAR is a sun pointing geostationary satellite; it is divided into two main parts, a service module and a payload module.

The payload module is composed by the rotating platform connected through the Bapta to the structure supporting in the lower part the payload subsystem. In the upper part of the platform are mounted the feeds and the antenna system.

The service module houses and includes all subsystems necessary to support the payload operations.



MINISTAR CONFIGURATION

The shape of the satellite body is a cylinder with an upper conical part. The cylinder base diameter is 1906 mm to interface with the standard 3rd stage separation of ARIANE.

At the height of 400 mm from the base, the cylinder tapers to a diameter of 1200 mm to be housed inside the spacecraft adaptor. Within this 1096 to 1200 mm conical taper, the despun part of the spacecraft is located. The total height is 680 mm, excluding the deployable payload antenna. The driving concept of MINISTAR is a satellite configuration which represents the intermediate module of a stack launching configuration when other spacecrafts, typically two for ARIANE, simultaneously share the same launch as primary co-passengers.

The principal characteristics of the MINISTAR design are:

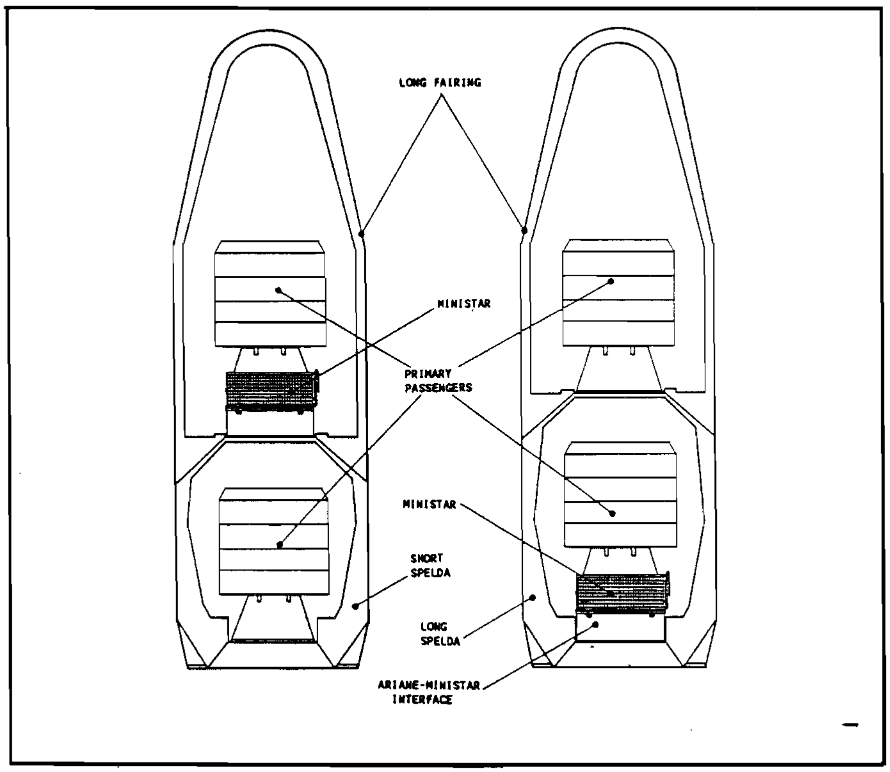
. **Communication payload power/mass:** from 200 W/50 Kg to 600 W/100 Kg.
. **Available volume for payload:** 0.13 m^3.
. **Payload dissipation:** 70% of DC input power.
. **Maximum antenna diameter:** 1.8 m.
. **Launch vehicle:** ARIANE IV, TITAN III.
. **Lifetime:** from 7 to 10 years.
. **In orbit storage:** 3 years.
. **Antenna pointing accuracy:** $\pm$ 0.1 degrees.

. **Orbit maintenance:**
  . N/S-E/W station keeping tolerances ± 0.1 degrees.
  . Orbit correction up to 50 m/s per year.
. **Operations:** Large autonomy, provided by the on-board system management.

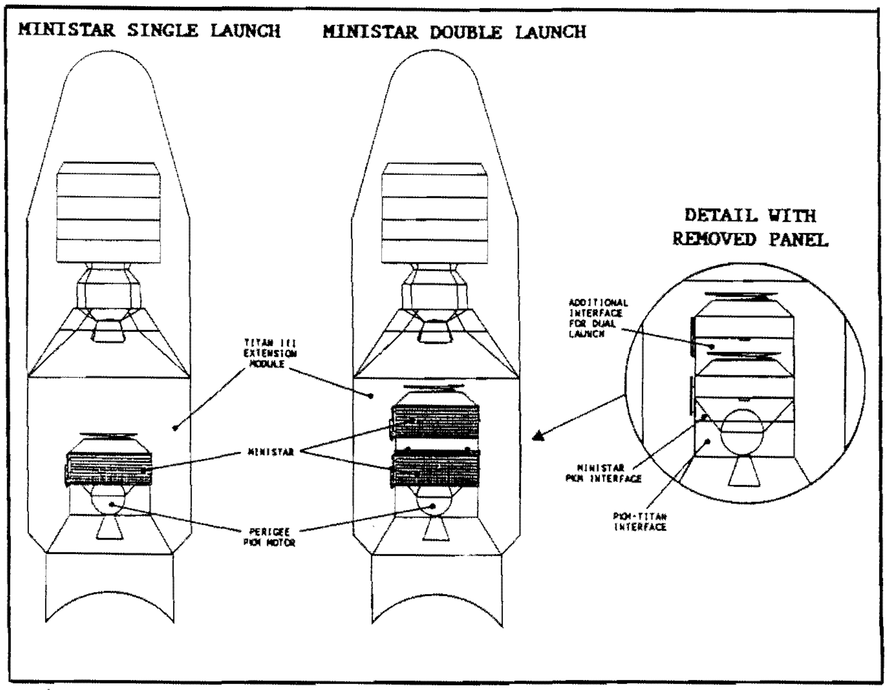
LAUNCH VEHICLE INTERFACES

The interfaces with the launcher have a crucial role in the design approach. Compatibility with the ARIANE IV and TITAN III launchers is assured.

The design makes reference to ARIANE, but fulfills the interface requirements of TITAN.
In launch configuration MINISTAR has to support the upper passenger. At the same time, it needs two interfaces to be separated from the adaptor of the upper passenger and from the launcher.
Thus, the supporting structure is composed by a cylinder divided into two parts: the first part is fixed to the third stage of the launcher or to Spelda structure in ARIANE flight. When the separation occurs this part remains with the launcher. The second part is the main structure of MINISTAR. The following figures present the major interfaces with above launchers.



MINISTAR IN UPPER AND LOWER POSITIONS FOR ARIANE IV LAUNCH

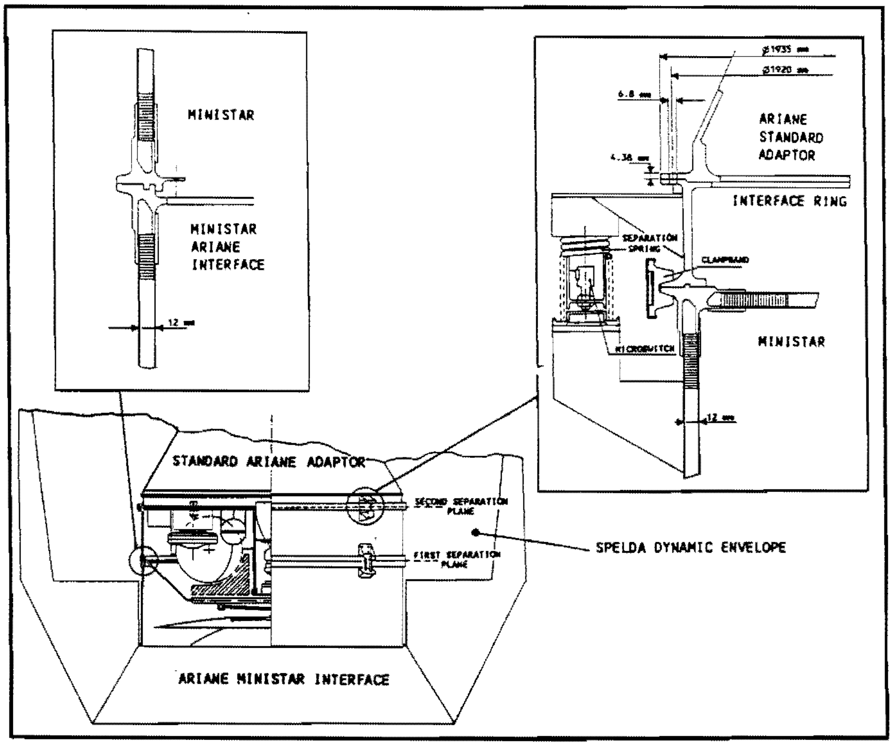


MINISTAR ACCOMMODATION ON TITAN III WITH EXTENSION MODULE

The first separation plane is located between the two structures. The second separation plane is positioned at the end of the cylindrical structure and it allows the separation from the adaptor of the main co-passenger.

The interface between the MINISTAR and the adaptor of the ARIANE main passenger consists of an aluminum ring 8 cm tall, provided with two attach flanges. The upper flange reproduces exactly the attach fitting of ARIANE third stage and at this extremity the adaptor is bolted. The lower flange is designed as junction of MINISTAR and is provided with a web for clamp-band fixing.
In the external part of the interface ring, in correspondence of internal inner panels, four webs for mounting the separation springs are fixed.

The interface between the MINISTAR and the LAUNCHER is a cylindrical aluminum honeycomb structure 60 cm tall and is provided with two aluminum attach flanges at the extremes. The upper flange is a junction for the MINISTAR using four separation springs. The lower flange reproduces the standard ARIANE adaptor junction.



MINISTAR MECHANICAL INTERFACES

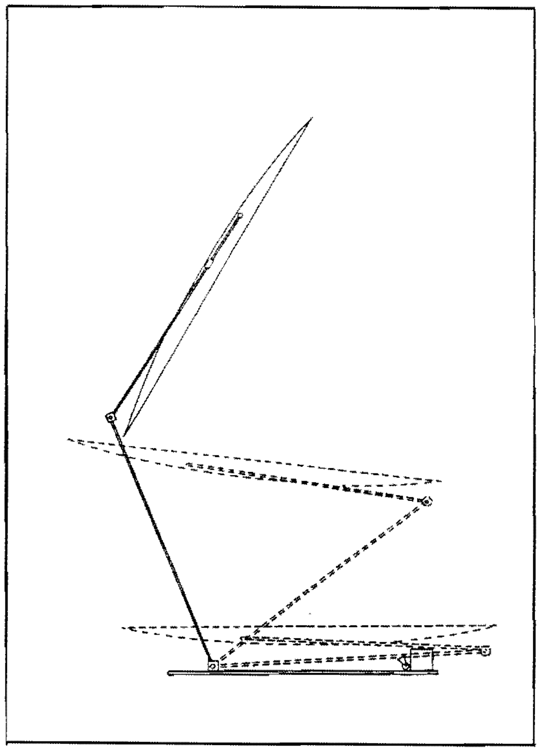
Antenna Accommodation and Deployment

The communications' antenna is fixed on the despun platform, which is mounted on the spacecraft through the bearing and power transfer assembly (Bapta). At the launch, the antenna is positioned inside the cylindrical body structure fixed at the launcher.

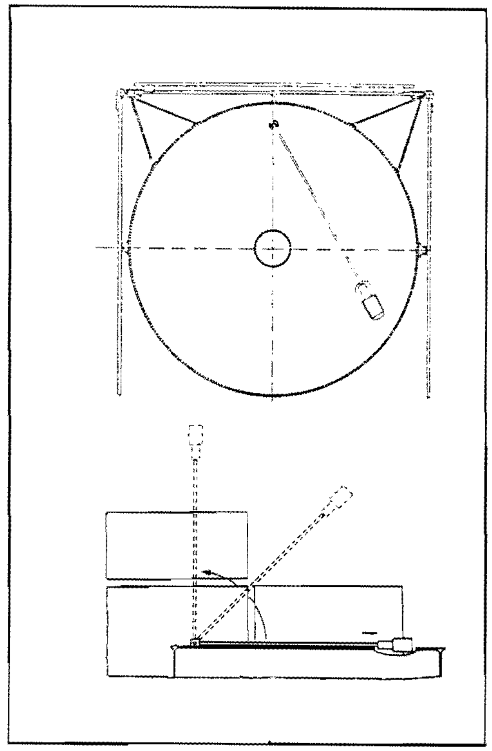
In the stowed configuration, it is oriented in such a way that the convex surface produces a cavity to surround the ARIANE third stage tank.

The antenna is supported by a structure of four mechanical beams, which allow the deployment. Two beams are fixed at the back of the antenna and are joined with other two beams by a rotation mechanism providing with one degree of freedom. The antenna supports are connected with two hinges at the despun platform. The rotation is achieved by a mechanism mounting a bar joined at the beams on the rotating platform.

The TT&C antenna field of view shall not be obscured during the reorientation manoeuvres in the transfer phase.



COMMUNICATION ANTENNA IN STOWED AND DEPLOYED POSITION



TT&C ANTENNA IN STOWED AND DEPLOYED POSITION

Solar Panel Accommodation and Deployment

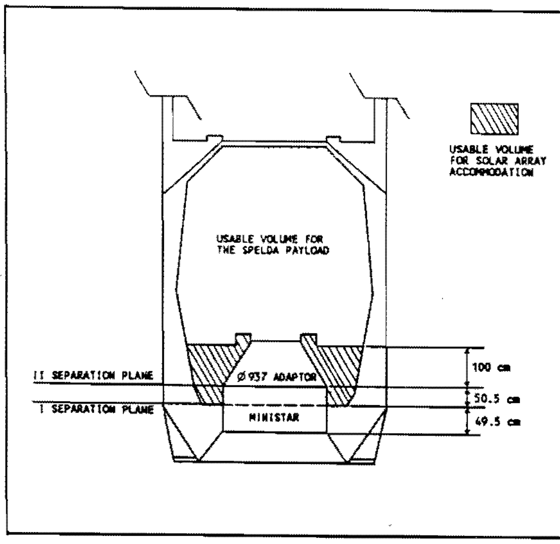
Two different power levels, 200 and 600 watts, are required as minimum and maximum options. Solar panels covered by silicon cells and having an area of 5.7 square meters for the minimum option. Solar panels covered by GaAs cells and having an area of 8.12 square meters are adopted for the maximum option.

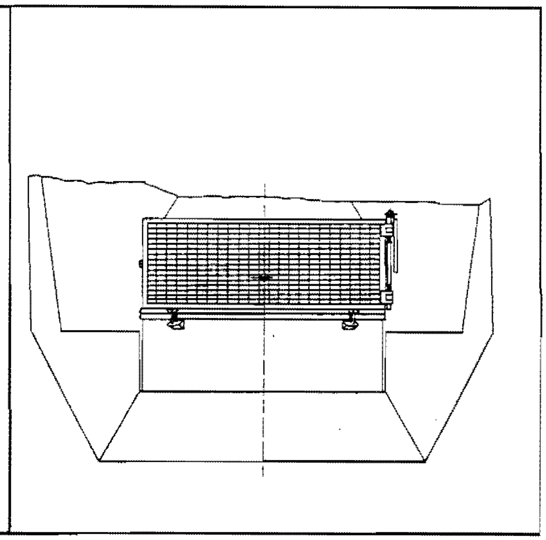
In order to simplify the spacecraft design, no rotation of the solar panel with respect to the spacecraft is foreseen. Through the use of sun sensors this flat plane is maintained perpendicular to the plane of the earth orbit around the sun, always pointing towards the sun direction. The power reduction due to the relative motion of the sun light above and below the earth's equator due to the 23.5 deg inclination of the earth's spin axis to it's orbit plane is balanced by an extra 9% of solar cells. In this way the need for any movement of the solar panels with respect to the spacecraft is avoided.

. SOLAR PANEL AREA:

200 W PAYLOAD = 5.4 SQUARE METERS MINIMUM OPTION, WITH SILICON CELLS
600 W PAYLOAD = 8.12 SQUARE METERS MAXIMUM OPTION, WITH GaAs CELLS

. ONE MAIN CENTRAL PANEL
. FOUR EDGE PANELS, TWO FOR EACH SIDE OF CENTRAL PANEL
. EDGE PANELS FOLDED DURING LAUNCH
. SOLAR PANEL RIGIDLY ATTACHED TO SPACECRAFT BODY
. COMPENSATION OF ± 23.5 DEG. SOLAR INCIDENCE: DELTA ARRAY = 9%





USABLE VOLUME FOR SOLAR ARRAYS ACCOMMODATION

SOLAR ARRAYS IN STOWED POSITION DURING LAUNCH

The central panel is fixed to the main structure using a bolted junction positioned at the center of the panel and four structures (two for each edge) which connect the panels to the spacecraft. During the launch, the solar panels are stowed around the spacecraft. On the final orbit, the outer solar panels are deployed using six interpanel hinges. The outer panels are independent and interchangeable, allowing an easy assembly and disassembly. The interpanel hinges are spring-actuated and a latching mechanism rigidly restraints the solar panels after the deployment. Passing from small Spelda to long Spelda in ARIANE or from short fairings to long fairings in TITAN a larger volume becomes available for MINISTAR, giving to the main passenger the same volume that would be available without piggying-back MINISTAR. Taking into account the dimensions of MINISTAR and standard ARIANE adaptor, the remaining dynamic envelope can be used for panel stowage.

. **Structure:** MINISTAR is designed for the dual compatibility with ARIANE and TITAN.
In the launch configuration MINISTAR has to support the upper passenger. At same time, it needs two interfaces to be separated from the adaptor of the upper passenger and from the launcher.
Thus, the supporting structure is composed by a cylinder divided into two parts: the first part is fixed to the third stage of the launcher or to the Spelda structure of ARIANE. When the separation occurs this part remains with the launcher. The second part constitutes the main structure of MINISTAR.
The first separation plane is located between the two structures. The

second separation plane is positioned at the end of the cylindrical structure and allows the separation of the main co-passenger from the adaptor.

. **Power:** all subsystems redundant units are switch-connected on two power buses. Each bus is fully regulated and the bus voltage is fixed to 28 ± 0.5 V. The solar arrays consist of rigid panels with deployment mechanism. The battery will be a nickel-hydrogen or N_iC_d for payloads capacities lower than 30 Ah.

. **System Management Processor:** The satellite functions and operation coordination are performed by two small on- board processors which can be programmed for each mission and for each configuration. The first is the attitude control processor (ACP) acting as the central controller for attitude control and station keeping functions. The second is the telemetry command processor and the system management processor (TCP/ SMP), performing TT&C functions, managing periodic control of other satellite subsystems and activating particular sequences as separation and apogee motor firing.

. **TT&C:** common frequencies for TT&C and payload with a rate between 200 and 500 bps.
In stationary conditions, the payload antenna system, is used. In the emergency and launch conditions, the TT&C will operate through the omnidirectional antenna.

. **Attitude:** MINISTAR is a sun pointing satellite, with a Bapta for antenna despinning.
The control is obtained for all three axis by using a two axis digital sun sensor, one earth sensor and an attitude control processor.
A momentum wheel provides gyroscopic stiffness along the pitch axis, which is maintained normal to the geosynchronous orbit.
Thrusters supply the attitude stabilization for yaw and roll axis and station keeping maneuver.

. **Propulsion:** the unified bi-propellant propulsion system is helium pressurized. It makes use of monomethyhl hydrazine as fuel and nitrogen tetroxide as oxidizer, with:
- one 400 N motor for the transfer phase,
- two sets of 6 reaction thrusters for station keeping.

. **Thermal:** passive thermal control. Electric heathers can be included. Payload dissipation 70% of DC input power.

. **Launch window:** MINISTAR does not imply specific constraints when launched as co-passenger by ARIANE or TITAN.

SYSTEM BUDGETS

MINISTAR Power Summary

	MINIMUM PAYLOAD	MAXIMUM PAYLOAD
PAYLOAD	200 W	600 W
PROPULSION	12 W	12 W
SYSTEM MANAGEMENT PROCES.	20 W	20 W
TELEMETRY AND COMMAND	20 W	25 W
ATTITUDE CONTROL	19 W	30 W
THERMAL	5 W	8 W
HARNESS LOSS	3 W	5 W
BATTERY CHARGE	38 W	85 W
MARGIN	20 W	30 W
TOTAL BUS + PAYLOAD	337 W	815 W

MINISTAR Mass Summary - Ariane IV

	MINIMUM PAYLOAD	MAXIMUM PAYLOAD
PAYLOAD	50 Kg	100 Kg
ELECTRIC POWER	44 Kg	69 Kg
STRUCTURE	56 Kg	65 Kg
PROPULSION	16 Kg	16 Kg
SYSTEM MANAGEMENT PROCES.	18 Kg	18 Kg
TELEMETRY AND COMMAND	10 Kg	12 Kg
ATTITUDE CONTROL	17 Kg	25 Kg
THERMAL	5 Kg	8 Kg
MASS MARGIN	10 Kg	20 Kg
DRY SPACECRAFT	226 Kg	333 Kg
PROPELLANT	33 Kg	49 Kg
APOGEE MOTOR EXPENDABLE	173 Kg	255 Kg
TOTAL SPACECRAFT	432 Kg	637 Kg
INTERFACES	12 Kg	12 Kg
TOTAL LAUNCH MASS	444 Kg	649 Kg

MINISTAR Mass Summary - TITAN III

	MINIMUM PAYLOAD		MAXIMUM PAYLOAD	
DRY SPACECRAFT	226 Kg		333 Kg	
PROPELLANT	33 Kg		49 Kg	
APOGEE MOTOR EXPENDABLE	189 Kg		278 Kg	
TOTAL SPACECRAFT	448 Kg		660 Kg	
SINGLE LAUNCH INTERFACES	19 Kg		19 Kg	
DOUBLE LAUNCH INTERFACES		29 Kg		29 Kg
PERIGEE KICK MOTOR	976 Kg	1650 Kg	1288 Kg	2274 Kg
TOTAL SINGLE LAUNCH	1443 Kg		1967 Kg	
TOTAL DOUBLE LAUNCH		2575 Kg		3623 Kg

MINISTAR Reliability	
STRUCTURE	0.998428
POWER	0.863376
AOC	0.961408
PYRO	0.972357
PROPULSION	0.947681
TT&C	0.985736
SYSTEM MANAGEMENT PROCESSOR	0.988243
THERMAL CONTROL	0.994235
OVERALL PLATFORM RELIABILITY	0.739651

COST OBJECTIVE

The innovative satellite concept is based upon the following guidelines:

- proven design concepts are assumed for all the elements as practicable,
- new design area shall be very limited,
- adaptation of existing designs to accept available components can be one of the major design efforts.

The design shall not be addressed to benefit of the technology improvements for pure design enhancements but for cost reductions.

The potential reduction on non-recurring and recurring costs applicable to the new design approach has been analyzed and the following overall results have been obtained.

NON-RECURRING TO RECURRING RATIO		NON-RECURR. COSTS	RECURRING COSTS	SAVING FACTOR
POLICY "A"	60/40	0.6X0.433	0.4X0.523	0.4690
POLICY "B"	70/30	0.7X0.433	0.3X0.523	0.4600
POLICY "C"	80/20	0.8X0.433	0.2X0.523	0.4510

Overall saving of 0.433 and 0.523 are expected for non-recurring and recurring costs.

Considering a basic reference cost for standard spacecraft production of about 200 K$ per Kg, it derives that according to the above saving factors, for a program of 3 flight units, the expected max average cost is reduced to about 50 K$/Kg.

	COST PER KILOGRAM IN THOUSANDS $					
	NRC	RC FOR 1 FU	RC FOR 2 FU	RC FOR 3 FU	MAXIMUM AVERAGE COST	MINIMUM AVERAGE COST
1 FU PROGRAM	51.96	41.84	-	-	93.80	90.200
2 FU PROGRAM	51.96	41.84	29.28	-	61.36	52.42
3 FU PROGRAM	51.96	41.84	29.28	25.10	49.39	39.13

If the total program comprises 3 batches, each one of 3 spacecrafts, although an additional N.R.C. has to be to taken into account for design enhancements, for each following batch, a further reduction due to mass production will lead to an expected cost of about 30 KAU per Kg (1 AU = 1.25 $, 1990 reference value).

	COST PER KILOGRAM IN THOUSAND $						
	NRC	SHARED NRC PER FU	AVERAGE RC PER FU	MAXIMUM AVERAGE COST	NOTES	MINIMUM AVERAGE COST	NOTES
1st BATCH OF 3 FU	51.96	17.32	32.07	49.39		39.12	
2nd BATCH OF 3 FU	59.75	9.95	21.61	31.56	+15% NRC FOR 2nd BATCH	22.92	+5% NRC FOR 2nd BATCH
3rd BATCH OF 3 FU	68.71	7.63	20.92	28.55	+15% NRC FOR 3rd BATCH	18.94	+5% NRC FOR 3rd BATCH
AVERAGE COST PER Kg OF A PRODUCTION OF 3 BATCHES				36.50 K$		26.99 K$	

Developments

The development program of Ministar, is articulated in two main phases:

- technological development
- manufacturing, assembly integration tests.

The first phase deals with detailed design and prototypes preparation of the subsystems to be newly implemented.

Such phase is planned to be started by fall '90 with prototypes delivery by mid '92.

The second phase relevant to the preparation of equipments based on standard technology is planned for the period '91-'92 at the end of which the newly developed prototypes should be ready for integration and validation.

A parallel activity relevant to the design and development of the Low Earth orbit version of Ministar, named LEOSTAR is scheduled to start by september of 1990.

LEOSTAR, is a small gravity gradient stabilized satellite compatible with Pegasus, SCOUT and Ariane-Piggy-Back with payload capacity of 50 Kg and 200 watt.

The total mass of LEOSTAR at launch shall be of the order of 400 Kg.

The initial version of LEOSTAR is tailored to satisfy the mission objectives of a store and forward communications missions "LEOCOM", intended to provide a world wide low cost service to connect, in a closed circuit mode, dispersed and isolated areas with major centers and industrial developers.

The payload architecture shall be capable in order to provide selected services among the following potential list:

i) Alphanumeric Message Service
This service allows both the transmission and the reception of messages (alphanumeric data) at low transmission rates. Users have personal computers or a key-board to digit their messages and a small monitor-printer which allows the display of the transmitted or received messages.

ii) Positioning Determination
This service gives the possibility of determining satellites and user's actual positions.

iii) Computer Data Transmission
Bulk data exchange with the central station.

iv) Freeze Frame TV
Image transmission, equivalent to the bulk data service.

v) FAX
Equivalent to low rate message transmission.

LEOCOM developing concept is based on the following basic requirements:

- the communications system shall provide full duplex 9.6 Kbps voice and data at UHF frequencies with a reasonable grade of service;
- price objectives for the user terminals of the order of 500$;
- orbit altitude around 1000 Km with satellites suitably distributed on quasi polar and/or 63 inclined orbits;

- no-intersatellite links are foreseen, crosslinks will operate through a ground based network traffic system;

- interconnection of network traffic system might be performed through a geostationary overlay package.

For the purpose of establishing the system architecture a traffic simulator is presently under development.

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