TITLE: **_Future Satellite Concepts, Architectures, Technologies and Service Capabilities_**

- EXECUTIVE SUMMARY -

CONTRACT REPORT
The work described in this report was done under ESA contract. Responsibility for the contents resides in the author or organization that prepared it.

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ESA STUDY CONTRACT REPORT

No ESA Study Contract Report will be accepted unless this sheet is inserted at the beginning of each volume of the Report

ESA CONTRACT NO.:	SUBJECT:		NAME OF CONTRACTOR:
11539/95/NL/JG(SC)	**Future Satellite Concepts, Architectures, Technologies and Service Capabilities EXECUTIVE SUMMARY**		**ALENIA AEROSPAZIO**
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ABSTRACT:
The traditional world space sector has been heavily affected by the political and economic changes of the last few years; government-financed space missions are being replaced by several commercial opportunities and the space industry is having to look for new methods and technologies that permit the sharing of the benefits.
In order to cope with this new situation, the space activity in Europe has not to be considered only as a research and development sector but has more and more to become an area of economic and regulatory importance, as far as world-wide economic competition becomes a dominant issue in the international affairs.
Due to this and other reasons, ESA started a number of studies with the aim to assess a strategy for the future of space activities in Europe, and this study has to be considered in the frame of this context.
To get the European space products ready to play an important role in the world, it is necessary to improve their commercial attractiveness, what means improving the European Industry competitiveness by increasing its capability to provide services based on space infrastructures and systems having a competitive BENEFIT/COST ratio; the general objective of this study is to give suggestions on how to increase this ratio by means of new promising concepts, advanced technologies and architectures to get available and mature enough in the future, where "future" means, in this context, far beyond the planned or foreseen space-based infrastructures and then the period 2010-2015.
To better understand the needs of the future space Industry, two services have been developed into end-to-end concepts in order to face with all aspects of a space-based service, from the user front-end to the S/C equipment.
The study has been divided into 3 phases:

1. market and services analysis, to understand which sectors could be commercially attractive in 2010
2. end-to-end concepts of the 2 selected services, with implementation of suitable emerging technologies, concepts and architectures
3. implementation plan of the two services (costs, market sectors and size, revenues, IRR....)

In order to consider all possible aspects the two services have been selected in such a way as to have

- the first service (Earth Observation) based on a LEO constellation: effort has been done to try to reduce mass and size, and then the COST, keeping the same performances of current satellites
- the second service (Telecommunications) based on one or more GEO satellite: effort has been done to try to increase the performances, and then the BENEFITS, keeping the size and mass of the biggest planned satellites.

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LIST OF ACRONYMS

AIT	Assembly Integration & Testing
ATM	Asynchronous Transfer Mode
BAQ	Block Adaptive Quantizer
B-ISDN	Broadband Integrated Services Digital Network
CCD	Charge Coupled Device
CDMA	Code Division Multiple Access
CFRP	Carbon Fibre Reinforced Plastic
DAM	Data Acquisition Module
DCT	Discrete Cosine Transform
DSMA	{D}-Sequence Multiple Access
DTH	Direct To Home
EEE	Electrical Electronic Electromechanical
EHF	Extremely High Frequency
EIRP	Equivalent Isotropic Radiated Power
EO	Earth Observation
FM/TDMA	Frequency Modulation/Time Division Multiple Access
GIS	Geographical Information System
G/T	Gain to system noise Temperature ratio
IRR	Internal Rate of Return
ISDN	Integrated Services Digital Network
ISL	Inter-Satellite Link
JPEG	Joint Photographic Pictures Experts Group
LAN	Local Area Network
LEO	Low Earth Orbit
LNA	Low Noise Amplifier
MCM	Multi-Chip Modules
MEMS	Micro ElectroMechanical Systems
MGSE	Mechanical Ground Support Equipment
MGTQ	MaGnetic TorQuer
MMIC	Monolithic Microwave Integrated Circuit
MMM	Mission Management Module
MPEG	Moving Picture Experts Group
M-PSK	Multi-Phase Shift Keying
MSS	Mobile Satellite System
MTI	Moving Target Indicator
NPV	Net Present Value
OBP	On-Board Processing
ROI	Return Of Investment
RX	Receiver
SAR	Synthetic Aperture Radar
SNR	Signal to Noise Ratio
SSPA	Solid State Power Amplifier
TCP/IP	Transmission Control Protocol / INTERNET Protocol
TLC	TeLeCommunications
TRx	Transponder
TWTA	Travel Wave Tube Assembly
USO	Ultra Stable Oscillator
w.r.t.	with respect to

1. MARKET AND SERVICES ANALYSIS

The market and service analysis have been used to select the two services for further technical, programmatic and economic assessment; the principal objective of this phase was to assess a range of markets for new future satellite-based services. The focus is on those new markets which have the potential for mass and synergistic market appeal; in this document only the most important results concerning Telecommunication and Earth Observation services are illustrated, as they are the most interesting from a commercial point of view.

FUTURE SATELLITE TELECOMMUNICATIONS SERVICES

The high-level assessment of satellite communications performed in the frame of this study has suggested that there are two approaches to defining future satellite services:

a) Factor of 5-10 reduction in the user price
b) Converge current services into new "leapfrog" broadband services

FUTURE SATELLITE EARTH OBSERVATION SERVICES

The value of EO data products will increase if they are as current as possible; *data products which are only a few hours old will be of greater value to a larger number of customers than identical products which are several weeks old.*
Two market areas where a wide variety of "old" through to "current" spatial data are required is in **Geographical Information Systems** (GIS) and **In-car and other mobile navigation systems**. Significant market growth could also be expected in areas including **Agriculture and Forest**, **Iceberg**, **Oil Spillage**, **Scientific/environmental Research**, **All Weather/time mapping**, **Disaster Management**, **Pollution Control**, **Education**, **Leisure and Commerce**, **Media**.
All these business sectors need for a high revisit frequency as this enables the highest possible revenue.

RECOMMENDATIONS

The selection of the two services to be defined in End-to-End concepts has been done taking into account the following guidelines:

- Very ambitious and general objectives; it is important to say that both the study team and the customer are perfectly aware of the fact that in certain cases the cost effectiveness of this approach is not maximised, but it has been followed in order to stress the needs for new technologies, architectures and concepts.
- To cover all aspects of a system design, the two services to be developed into End-to-End concepts have been selected in such a way as to have a first service based on a LEO constellation and a second one on big GEO satellites.

Taking into account the previous recommendations, the two services that have been selected to be defined in End-to-End concepts are:

1. **Earth Observation service**
   with near real-time and global access (revisit frequency ensured everywhere in the world) with very good performances and all-weather/time capability; it will based on LEO satellites with several kind of products and sensors. The general mission high level requirements are:
   - All weather/day-night observation capability
   - High spatial resolution for (1) optical ~ 0.5 m, and (2) SAR ~ 1 m
   - Multispectral capability
   - Global access time of 6 hours
2. **Telecommunication Multipurpose service**
   based on big GEO satellites, supporting mobile, fixed/semi-fixed terminals with several Media products; the mission will consist of full duplex services to low-cost user terminals providing:
   - Low data rates of up to 128 kbps accessible by "Palmtop" terminals
   - Medium data rates of up to 512 kbps accessible by "Laptop" terminals
   - High data rates of up to 1.2 Gbps accessible by "Fixed" terminals.

2. TECHNOLOGIES SURVEY

The results of a survey on the technological fields involved in the two services are illustrated in this section; the long term performances and characteristics have been used to size the future satellite systems described in sections 4 and 5.
Improving the ratio between BENEFIT and COST of a service, at satellite level, means....

....*increasing the BENEFIT*, improving the on-board performances; the technologies have to be improved in sectors that are able to improve the efficiency and in those that can improve the power generation and storage capabilities

....*reducing the COST*, reducing equipment size, mass and complexity; the technologies have to be improved in those fields that can impact the number, size and specific weight of the equipment.

2.1 SPACE EQUIPMENT

The most interesting on-board technology areas are described in the following paragraphs. Power and propulsion as well as thermal control are described a part because they involve well specific areas, while other determinant general technologies that involve several fields (e.g. spacecraft and payload equipment) are summarised in one only table.

PROPULSION AND POWER

Electrical Propulsion, for LEO-based missions, is subordinated to the performances of the power systems (this is why propulsion and power are under the same heading), that are very important for increasing the service capabilities of future satellites.
Future space solar generators are expected to improve performances in terms of cell efficiency, cell degradation, as well as mass and area specific power. Several technologies are under development: **Thin GaAs/Ge Solar Cells** (27% mass saving), **Multi-Junction GaAs Solar Cells**, **Indium Phosphide Solar Cells**, from USA (up to twice as much as EOL power density as GaAs/Ge in high radioactive environment), **Concentrators GaAs/GaSb Solar Cells**, from USA (specific power up to 4 times the current performances of 25 W/Kg), **Blue/Red Reflective Cover Glasses**, from USA (increase solar cells efficiency of 3%), **Concentrator Solar Array**, from USA (30 % more power), **Advanced Lightweight Solar Array**, from USA (cells on flexible Kapton substrate and inflatable Torus solar array, can achieve more than 140 W/Kg including deployment mechanism), **Nickel-Metal-Hydride Battery Cells**, from USA (specific energy 50% and energy density 100% more than NiH_2), **NaS Battery Cells**, from USA (140 Wh/Kg and 280 Wh/l at prototype level; projections to 2010: energy density up to 300 Wh/Kg), **Peak-Power Tracking Power Control** (solar array reduction more than 10%), **Direct Energy Transfer**, from USA (weight reduction, via replacing H/W with S/W).
European Industry is in line with current performances. Concerning solar cells and solar array, there should be the know-how in Germanium processing to achieve competitive performances; activities are planned in the frame of the ESA Basic TRP and GSTP with target of 22-24% efficiency for multi-junction cells, but nothing else seems to be in progress or planned, while in USA there are several initiatives. Concerning advanced batteries, qualification activities are in progress but nothing has been done in Europe. In the frame of power control electronics, nothing has been apparently planned in Europe but current European technology seems to be better than American one.
Long term goals to be considered for 2010 could be: 300 W/m^2 and 300 W/Kg for solar cells (by NASA); 200 Wh/Kg - 280 Wh/l - 40% depth of discharge after 30000 cycles for battery cells (NaS technology); mass and volume reduction in power electronics up to 65 % and 80 % respectively through the use of solid state components.

THERMAL CONTROL

Increasing the Benefits/Cost ratio also means increasing the Power/Size ratio, then a mandatory technological field that has to be improved is the thermal control system. The following technologies are emerging.
Two-phase Mechanically Pumped Loops, **Capillary Pumped Loops** (either in Europe and in USA several studies and experiments are planned), **Advanced Radiators** (studies are in progress also in Europe to develop low cost, low weight, high thermal conductivity components, with capability in changing radiating area), **Heat Pumps** (to transfer energy from low temperature to higher temperature), **Integrated Spacecraft Thermal Bus** (it is a module that is able to work at temperature level much higher than the rest of the satellite).

DETERMINANT GENERIC TECHNOLOGIES

The table summarises the main characteristics and the level of priority of the most promising emerging technologies.

(*): A = Mandatory B = Very Important (horizontal impact) but not mandatory C = Important (vertical impact)

TECHNOLOGY	UTILIZATION	TYPE / IMPROVEMENT FACTOR	MATURITY STATUS	ENVISAGED QUALIF. DATE	Prior. (*)
MICROWAVE AND TELECOMMUNICATIONS EQUIPMENT (Europ. Industry have product. capabil. in the items below; e.g. Alenia produces GaAs MMIC in MESFET and HEMT techn. up to 60 GHz)					
HIGH POWER AMPLIFIERS	TWTA; MPM (Multi Power Module); SSPA, better than TWTA at freq. suitable for SAR	Greater efficiency (from 40 to 65% in 2010); mass/vol. reduct.; high rel.; less power consumpt.; more traffic capab.	TWTA sp. qual. (also at Ka/EHF, but with low efficiency)	MPM/TWTA(high eff.): within 2005	A
LNA	Low Noise Amplifiers	Less than 1 dB noise figure at Ka / EHF	Sp. qualif. until Ku band	close to 2005	B
HIGH TEMP. SUPER-CONDUCT.	IMUX, Input Filters, Filters, local oscill., Reson. cavity, Beam Form. Networks, switch., up-converters...	Chan. capac. Increment or P/L mass/vol. reduct. (up to 30%, incl cyos.); diamagn.; no-resist.; very high Q-factor	USA exp.: (HTSSE-I & II, MIDAS); ACTS, Intelsat, Globalstar programs	Complete Sp. Qualif.: 2005	B
3D-VLSI, 3D-MCM, MMIC, MHCM	MMIC for beam form. netw.; MHCM for freq. conv.; MCM for modul. and cod; MCM for OBP	Mass/vol. Reduct.(up to 10x); high reliab.; wire-less; high perform. (fast response, S/W & H/W improvem., ...)	MMIC & MHCM are space qualified	3D-VLSI and 3D-MCM: sp. qual. by 2010	A
OPTICAL FIBER	Beam Forming Networks; Switch. & Channels; OBP; Inter Sat. Link	No electromagn. Interfer.; Low losses Low Costs; Huge Bandwidth (100 Gbps)	Utilisation in space projects (Artemis, Iridium, Telede.)	Complete Sp. Qualif.: 2005	B
RAIN-FADING COMPENSAT.	To avoid signal disturbance at high freq. (Ka and EHF bands)	Increment of system link budget margin and reduction of power demand	Not yet implemented. Active and passive techn.	≈2000 if work starts now	A
MULTI-BEAM ANT. GAIN	Multi-Beam Antenna with more than 100 beams at Ka-EHF bands	Improv. of on-board antenna gain. Link budgets margin increment (more users)	Today: up to 10 beams 2005: more than 100 b.	close to 2005	B
ON-BOARD PROCESSORS AND DATA COMPRESSION (European potential individual capab.: Alcatel, Alenia, ANT, DLR, MMS, Thesis, Telespazio)					
ON BOARD PROCESSOR	To cope with huge data flow, big channels number, traffic reconfig., routing, time/space/time stages.....	Near-real-time full interconnect. and reconfigur., instantaneous transponder satur., possibility of inter-satellite links.	High qualif. status of dig. Proc. technol. (DBS, ACTS, Artemis programs)	close to 2000	B
DATA COMPR. TECHNIQUES	Data, Audio, Images Compress.	Reduct. of data transm. rate, increment of sat. traf.. Comp. ratio up to 200 by 2010	Commercial (JPEG/MPEG)	≈2005 (hi. perf. alg. (BAQ, ...)	A
PARALLEL SUPER-COMP.	To perf. real-tim. adv. sign. proc. func. (wide bandw. sign. compos.)	Very fast input/output capability	Quadrics (Alenia)	APE-1000, under devel.	B
MECHANICAL SYSTEMS (Alenia and MBB are develop. lightweight. reflect., CSEM are invest. in MEMS and Smart str., Aerospatiale and Proel in EBC... No activity in Europe on large apertures for telescopes and antennas SAR and TLC)					
ULTRA-LIGHT ANTENNA REFLECTOR	Ant. struct. obtained by integr. of composite tri-axial woven composite carbon fiber/resin lines	Reduction of antenna mass. The goal is 1 Kg/m^2; 4 Kg/m^2 foreseen for ant. mech.	Hughes HS-601 DBS. Alenia is beginning tests	USA: now Europe: close to 2000	C
ELECTRON BEAM CUR. (EBC)	Minimiz. of stresses and residual deform., small pollution product., 10-100 times cur. time reduct.	Improv. of pointing perform.; possibility to cure high thickness and complex metal included; small cost	France and Italian Industries have began research	close to 2010	C
SMART & MEMS	Microelectronics and smart structures for antenna reflectors deformations and pointing control	Improved antenna pointing perf.; (q_{3dB} very small at Ka/EHF); mass/vol. reduct.	Artemis: Smart materials are envisaged for SILEX optical P/L	Smart: ≈2000 MEMS: within 2010	A
LARGE APERTURES	Telescopes, SAR antennas, TLC ant.	Weight reduct. (x10); 0.02-mm acc. with stiff refl. / depl mech.	1-mm accur. (NASA) with inflatable	NASA New Millennium Pr.	B
OPTICAL EQUIPMENT					
ADVANCED CRYO-COOL.	For CCDs temperature control and thermal dissipation	Elimination of vibration; miniaturisation (3x mass, 3x pow. w.r.t. current cr. cool.)	miniature 80K stirling cool. under developm.	Under developm.	B
ADV. FOCAL PLANE EQMT.	To improve sensitivity of detectors	10x mass / 10x pow. Reduction sensitivity improvement	CMOS-APS act. pixel techn. under develop.	Under developm.	A

2.2 GROUND AND USER EQUIPMENT

TELECOMMUNICATION TECHNOLOGIES

Technological developments are expected in **terminal characteristics** (multiple mode terminals, handheld personal communicator devices, two-way messaging devices) and **communications with other computers** (antennas, low power transmitters, battery technologies). The technologies in the following fields are expected to have a major impact onto the future development of semi-fixed and mobile satellite communications.

Terrestrial Networks (future data rates will be expressed in Gbits/s); **Modulation and Access Schemes** (e.g. DSMA, which has the same effect as CDMA); **Wireless Data Services** (standards are being developed for North American and European mobile data systems but high frequency technology is not commonly available); **Security** (data encryption provides one part of the complex solution to the data security problem);
Fibre-Optic Networks And Information Superhighways future development has a potential to greatly impact future satellite concepts: **High-Speed Infrastructures** (some experimental projects have been undertaken in Europe and North America); **ISDN, ATM, Network Integration** (for the satellite system to play a co-operative role with the terrestrial systems, techniques and protocols will have to be defined in common up to a level technically feasible; the work is pending).
Other enabling technological advances fall in the domain of interest of mobile users of any type of telecommunications services rather than being satellite specific. These include **miniaturisation of terminals, handwriting/speech/vision recognition, pen-based interfaces, LCD and plasma technology, embedded technology** (for intelligent rooms), **existing vertical applications, integrated voice and e-mail, next-generation operating systems for communications products, Next-Generation Operating Systems** (OS) for communications products, **Nomadic Computing** (ability of people to move easily from place to place, while retaining access to the same, potentially rich set of services while they are moving, at intermediate stops, and at their destinations).

TECHNOLOGIES FOR EARTH OBSERVATION

Specific future services or missions require faster response for all stages from Order Entry to Product Delivery. Some technologies which are likely to impact any future mission follow.
Basic Hardware Technologies: In the time frame of 1995 to 2005 changes in the following field are anticipated: Processing Power (3 times speed up; SPECfp92 = 500), Processing Power Cost (from $25/MFLOPS to $125/MFLOPS), Memory and Disk Capacity (8 and 4 time respectively increase), Archive Storage Cost (fairly constant at $15K/TB for large archives of 1 Pbytes), LAN Capacity (ATM -51Mbps→9.9Gbps-, Fibre channel -266Mbps→1Gbps-), WAN Capacity.
Commercial Satellite/Smallsat Ground Segment Technologies: to develop directly competitive missions either it would be needed to develop the technologies for high-resolution imagery or to license the technologies from other countries. An alternative is to define a service that does not directly compete with the other high-resolution programs, but uses the data in a complementary manner. **Catalogue/Archive Technologies:** ESA, governments and organisations operate their own catalogue systems for remote sensing data sets. Programs to establish links between data bases or at least consistent methods for user access to information across these data bases will be necessary if users are to efficiently access all the potential data sources; that requires new technologies of *multi-database management systems, metadata catalogues and metadata standards, distributed object based computing, object based geographic information standards, qualitative reasoning systems*. Technological development is already in progress in a number of areas such as *EOSDIS program* (NASA), *CEOS* (Europe), *CEONet* (Canada), *MUIS* (ESA). ESA is already actively working in these areas and they control the missions which generate much of the archived data.
In order to support quick delivery of products to users, large data archives must include automated handling of archive media to transfer data from near-line archive to on-line storage. Such technology is now available in tape robotics units with capacities up to 150 terabytes and access time of less than 1 minute. Commercial providers of these systems will continue to add features for inventory maintenance, automatic backup, tape media renewal and fast access.
While the cost of archive media is reasonable the communication costs to move the data between sites will be very significant. Technologies to develop data compression strategies with user-acceptable quality factors having compression ratios of 5:1, 10:1, or 50:1 would significantly reduce data handling and communication costs.
Order Entry and Acquisition Planning: Improving user access for order entry and planning will require development of technologies impacting *Order entry* (Internet services to query catalogues, browse products, place orders and receive products), *Order Planning* (order is submitted for a type of product. Order planning may chose from multiple data archives, satellite/ sensor platforms and production facilities and distribution methods to prepare and deliver the desired product).

3. ENGINEERING PROCESSES

In this section possible concepts and approaches that should be applied in the development of space-based infrastructures are proposed; cost saving figures are indicated (where possible) for the various identified items and they have been considered when evaluating the cost of the two systems described in sections 5 and 6.
The possible ways to optimise development activities include **Integrated Product Team (IPT) approach** (multidisciplinary teams of about 10 people optimise the design, manufacturing, and supportability processes with the main goal of improving quality while reducing life cycle time and costs), **Simultaneous and Interactive Design** (all three fundamental design elements -Mission, Satellite, Operations-, currently sequential, are considered simultaneously), **Integrated Development Approach** (reuse of tools and methods across the different project phases), **Rapid Prototyping** (early and quick implementation of a rough incomplete model, to be updated in line with the design and the tests results; attempts are already on the way like the "Flight System Testbed", NASA/JPL, and the Universal TestBed, ESA), **Design to Cost** (to reduce or adapt those requirements which do not compromise the final benefit but introduce useless costs), **Robust Design Approach** (high margins allow system tests reduction), **Remote Testing capabilities** (reduction of the team involved in External Environmental Test Facilities and Launch Site), **Verification Documentation** (to avoid redundancy of Spec's and procedures), **Risk Management Approach** (to manage the risk instead of reducing it), **Ship and Shoot** (integration, test and pre-encapsulation performed in Europe).
From the all the approaches defined herein, it derives that their implementation will provide an ***overall cost saving of about 35 to 45%.***

In order to get a service commercial viable, the time from the starting of funding to deployment of infrastructure must be as short as possible, so that a **High Rate Production** must be applied if talking of constellations; the Island approach followed for GLOBALSTAR AIT, based on a clean room where all test and integration facilities are implemented, allows to perform AIT activities on several satellites in the same time. The Island AIT concept also allows to apply the sample test concept and enhance productivity by learning.

4. FUTURE E. O. SERVICE

The end-to-end Earth Observation Service described in this section starts from the requirements (derived from the recommendations of section 1) up to the economical results. A comparison between current and future satellite based system is performed to highlight the need to implement emerging technologies (among those described in section 2) and concepts (section 3) in order to get the service viable from an economical point of view.

4.1 REQUIREMENTS AND GENERAL ARCHITECTURE

The market and service analysis has shown that an interesting market growth is possible (in the areas shown in section 1) if revisit time is in the region of 6 hours.
The mission and services requirements for a future (2010) EO system are summarised in Table 4.1-1.

Global Access Time (GAT)	< 6.30 hours
All weather/day-night capability	need SAR
High Spatial Resolution (HSR) images	<0.5 m optical <1 m SAR
Pointing accuracy	w.c. 3.8 10E-3°
Images geolocalisation	5 m
Programmable swath dimension	>10 Km for HSR
3-D images in both optical and MW bands	stereo + SAR Interferometry (possible with 2 antennas in the same satellite)
MTI capability	option
Multispectral capability	0.45-0.52μm (blue); 0.52-0.60μm (green); 0.63-0.69μm (red); 0.76-0.90μm (NIR); 1.55-1.75μm -Mid-IR
Service life time / Availability	15-20 years / > 95 %
Direct access to satellite by users	X band
Direct ground Rx	full raw data (1.5 Gbps), processed data (2Mb/s)
Low implementation and operation cost	commercial rules applicable

TABLE 4.1-1 SERVICE REQUIREMENTS AND FEATURES

The system architecture is based on the following ideas:
- use of small satellites in constellation (global access, high revisit frequency)
- implementation of both optical (multispectral capability) and SAR (all weather-time) sensors
- single payload satellites (minimisation of S/C complexity and orbit optimisation)
- decreasing of the optical satellite orbit altitude (payload complexity reduction)

The orbital configuration is:
- *6 SAR satellites in Sun-Synchronous Near-Noon orbit, 410 Km*
- *6 SAR satellites in Sun-Synchronous Down-Dusk orbit, 410 Km*
- *6 Optical satellites in SS-NN orbit 280 Km.*

5 satellites per plane would be sufficient, but one more satellite is needed to achieve 95% availability.
Both sides of SAR nadir trace are accessed. Optical sats have +/- 35° sensor tilt capability.
The ground segment is based on a central Mission Planning and Control Centre (constellation control and user requests plan). The satellite transmit the data to the 15 Acquisition Stations distributed along the World. They receive the data automatically at 1.5 Gbps and retransmit (data or elaborated products) to the users via TLC sats or ground based services. A single user will receive the data via a cheap, standard portable multimedia terminal everywhere in the globe.
The data acquisition and processing is composed with three main paths:
- raw data, transmitted via the high-rate link (~ 1.5 Gbit/s, Ka-band)
- compressed raw data, stored in the on-board mass memory for off-line transmission
- raw data on-board processed for image generation (transmitted via a low-rate link).

A sketch of the global infrastructure is in figure 4.1-1.

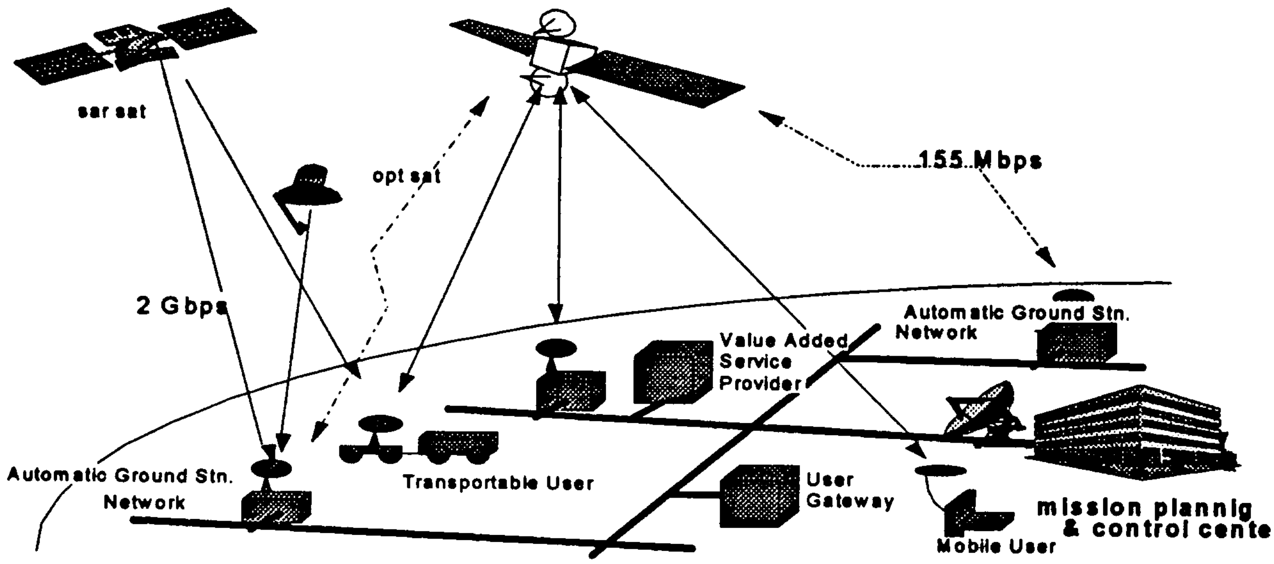


FIGURE 4.1-1 OVERALL SYSTEM ARCHITECTURE

4.2 SPACE SEGMENT

<u>MICROWAVE PAYLOAD</u>

The payload concept is based on a modular design (several functions performed via suitable combination of the same basic blocks). Advanced concepts are introduced such as *electronic steerable antenna, concatenated coding (e.g. Salomon + convolution), M-PSK or QAM signal modulation (up to 256 PSK)* to reduce mass and power. High frequency has been selected in order to have reduced mass and volume, larger depth of focus, reduced speckle, reduced range migration, possibility of single-pass Interferometry. The main characteristics of the SAR instrument are in the table that follows.

FREQUENCY BAND:	*Ku (13.8 GHz, 2.1 cm)*	PULSE LENGTH:	*10 us*
OFF-NADIR ANGLE:	*15° - 55°*	PRF:	*8000 Hz*
RESOLUTION (RANGEXAZIMUTH):	*1x1 m2*	ANTENNA TYPE:	*Rectangular, active phased array*
SWATH WIDTH:	*10 km at middle range (35° off-nadir)*	ANTENNA SIZE:	*2x1 m^2*
SNR:	*> 15 dB*	ANTENNA BANDWIDTH:	*350 - 550 MHz*
NEs°:	*< -22 dB*	ANTENNA PEAK GAIN:	*45 dBi*
BPS:	*8 (4I+4Q)*	ANTENNA POLARISATION:	*single/dual linear*
PULSE BANDWTH:	*from 183Mhz(55°) to 580Mhz(15°)*	ANTENNA NUMBER OF T/R MODULES:	*360*
ELEVATION / AZIMUTH BEAMWIDTH:	*1.05° / 0.53°*	ANTENNA ELEVATION STEERING:	*20°*
POWER:	*1 kw*	ANTENNA PEAK POWER:	*4 kw*

The use of the most advanced technologies described in section 2.1 and in particular ultra-lightweight panel and foldable/inflatable structures associated with smarts structures and MEMS, miniaturised digital devices, optical transmission, 3D MCMs, advanced processors associated with suitable compression algorithms, leads to an instrument design with the following main characteristics:

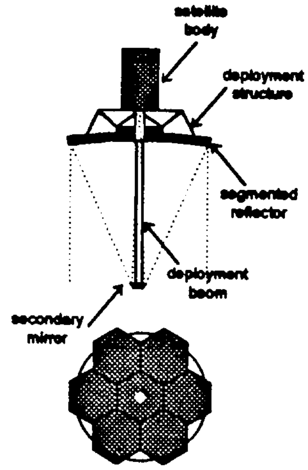
Weight **60 Kg**
Power Cons. **425 Watt** *(average in the orbit)*

OPTICAL PAYLOAD

The optical sensor is required to operate in 3 viewing modes (nadir, along track stereo, cross-track) with a high duty cycle (daylight), high spatial resolution (0.5 m) images. The optical payload characteristics follow.

Sensor mode	Panchromatic	Multispectral	Notes
Spatial Resolution (nadir)	0,5 meter	3 meter	0.9 m telescope diam. (0.75m+20%)
Radiometric Resol. (SNR)	> 1000	> 1000	Exceptional quality of image
Swath width / scene size	10x10 Km / 100 Km^2	12x12 Km / 144 Km^2	limit from data communication and storage capability
Stereo mode	Along-Track	-	-
Total Data-Rate	7,2 Gbits/s, stereo mode 3,2 Gbits/s per image	0,6 Gbits/sec	-

The future optical sensor design is based on a main mirror composed of a mosaic of deployable segments. Each segment is built with ultra-lightweight graphite and embedded with smart materials to compensate for distortions (see figure).



Cassegrain deployed telescope concept

The budgets obtained after application of performances of section 2.1 are:

Weight **30 Kg**
Power cons. **60 Watts**

SPACECRAFT AND SATELLITES SUMMARY

The design allowed by the current most advanced technologies is compared with long-term goals foreseen for the years around 2010, shown in section 2.1. The spacecraft has been supposed to be the same for the optical and the SAR satellites; the worst condition between them has been considered to size the various subsystems. Avionics functions of future system will be performed by the following equipment:
Smart Core (SC), based on high performance microprocessors (for AOCS, OBDH, power controlling), flash memory, attitude sensors electronics; cheap **Cameras** working as Star Trackers (algorithms running in high performances microprocessor inside the Central Core, that allows for Gyroless system); **Magneto-torquers and Magnetometer** (reduced controlling torque due to the reduced sats. weight); **GPS Receiver** (increased autonomy and reliability with reduced system complexity -coherent TRx is not needed, USO is replaced by crystal oscillator, set of AOCS sensors is reduced-). Expensive items such as high performances Star Trackers, Earth Sensors, Gyros, are not needed.
Considering future performances and technologies (section 2.1) the following table has been obtained.

	CURRENT [KG]	FUTURE (SAR) [KG]
PAYLOAD	800 (RADARSAT)	60
POWER SYSTEM	155	30
PROPULSION	130 (chemical)	25 (electrical)
AVIONICS	120	30
THERMAL CONTROL	40	15
HARNESS, BAL. MASS (≈5%)	75	12
STRUCTURE	180	20
MARGIN	150	38
TOTAL	*1650*	*230*

SERVICE AVAILABILITY

The service availability has been computed for various space segment configurations in terms of number of satellites on-orbit and on-ground, ready to be launched.

The following conclusions, regarding the service that we have analysed, have been drown out:

- the MIL-Grade based system can achieve more or less the same availability than the Hi-Rel based system ***if one more satellite is added to each orbital plane***, but for this cluster configuration the total cost remains the same if the same availability level is taken as a reference
- the availability figures relevant to the Commercial parts are very low. This is because the official failure rate figures are very conservative, while experimental results specify that commercial parts failure rates are approaching MIL-Grade quality level.

DESIGN

All concepts described in section 3 can be applied for what is concerning the design, such as integrated product team, integrated development approach, rapid prototyping, robust design.

An important concept that has to be applied is the "P/L bolted on" approach, which allows for the construction of 20 (18 + 2 spares) identical platforms for the three kinds of satellite (Optical, SAR Near-Noon Orbit, SAR Down-Dusk Orbit).

MODEL PHILOSOPHY

The following models will be developed:

- Breadboard at equipment level, Engineering Model at Platform Level
- 1 Protoflight Model (PFM) for SAR satellites (to be used as spare after the test campaign)
- 1 PFM for Optical satellites, to be used as spare after the test campaign
- 12 Flight Models of SAR satellite, 6 Flight Models of Optical satellite.

ASSEMBLY, INTEGRATION AND TESTING APPROACH

A dedicated facility for Island AIT approach (see section 3) will be used to reduce development time.

SCHEDULE

The development will follow the schedule described here below:

- 24 months for design and breadbording activity (rapid prototyping, see section 4)
- 60 working days (average) of AIT per satellite; an average stationement of 10 working days in each island allows for a manufacturing of 6 satellites at once, and a total AIT time of 230 working days (less than 1 year). This timing is allowed by the "bolted-on approach".

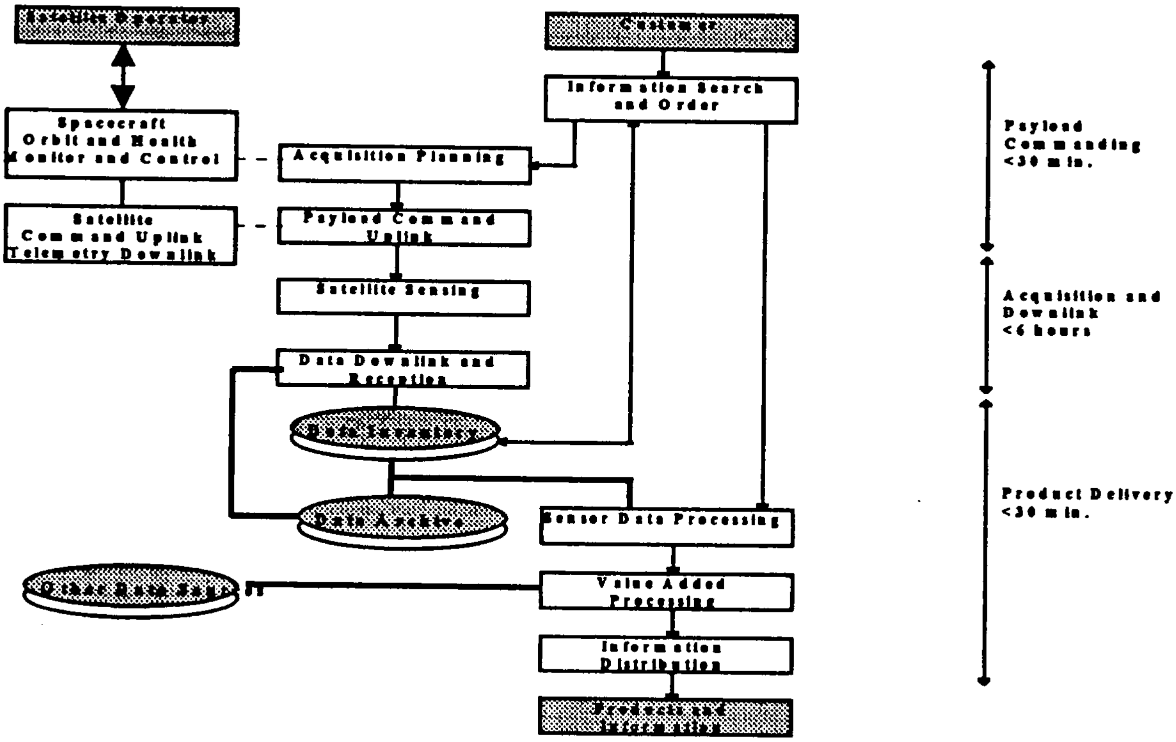
LAUNCH STRATEGY

The launch for the future EO satellites can be done through 6 triple launches (2 per orbital plane), through a recoverable KYSTLER-like launcher (1 launch every 1.5 months, starting 4 months after the AIT kick-off). Availability of launchers has to be foreseen, e.g. via contracts with different launcher authorities.

4.3 GROUND AND USER SEGMENT

The ground segment should be designed to support this total user transaction time by introducing a ground segment delay in the order of 1/2 hour to process order, uplink command, downlink and receive data, process image product and distribute to user, the Ground Segment should also automate much of the satellite constellation monitoring and control in order to reduce operational staff costs. The operations of the service are supposed to last 15 years.

FUNCTIONAL ARCHITECTURE



Some of the functional steps will be grouped and operated at a designated facility while others may be distributed through a number of sites. Automatic ground stations may be distributed around the world and interconnected to User Access Gateways and Value Added Service Providers. A Communication Satellite may also be used for sending orders and receiving products. The ground segment architecture is included in the General Architecture illustrated in figure 4.1-1, section 4.1.

PRODUCTS REQUEST, ACQUISITION AND DELIVERY

Customers of EO may be expected to use mobile, transportable or fixed terminal equipment that will impact the format and types of products available to that user. Key technologies for mobile or portable user access terminals: high resolution image product displays, improved terrestrial and satellite communications and data rates up to 500 Kbps.
The **Information Search and Order System** provides the primary interface between the users and the EO Ground and Space Segments.
When an acquisition user order is entered, automated tools will construct satellite sensor commands for uplink to the appropriate EO satellite; significant development is required in this area for **automated acquisition planning** and this may include use of Artificial Intelligence systems. Satellite sensor commands must be relayed from the acquisition planning facility to the appropriate ground station for uplink. Each ground station must be capable of automatically **tracking satellites and uplinking payload commands**.
Ground stations will receive **downlink payload data** either in real-time during the sensing operation or delayed and transmitted from on-board memory within one orbit period. Distributed ground stations will have limited processing capability locally and then will ship the data to the archive and catalogue facility.

SENSOR DATA PROCESSING, ADDED VALUE AND DISTRIBUTION

Each new sensor will require development of raw data processing algorithms. These are likely to be modelled on existing sensor types but extended to handle the required high spatial resolution. One area of technological development is in the precise, automatic geolocation of the imagery products.
There will be a number of different value added processors to support all business sectors and application areas.

The products will be distributed to end users by terrestrial and satellite communication networks to the user terminals; the advanced technologies necessary are primarily related to communications rather than Earth observation but EO image data compression technologies will be required.

4.4 CUMULATIVE COSTS AND REVENUES

The analysis has demonstrated that there should be a total potential *addressable* market of between 4,000 and 13,000 MECU by the year 2010; if 50% (conservative assumption) is captured by non-space resources and the remaining is shared by 3 competitors, revenues, by 2010, are in the range of **600 million ECU/year** (worst case) and **2,000 million ECU/year** (best case). Figure 4.4-1 shows the cumulative cost for current- and future-sized infrastructure (the second with 95 % availability -6 satellites per orbital plane, 1 spare on ground per orbital plane- and 50 % availability -5 satellites per orbital plane, no-spare on ground-) as well as cumulative revenues for the worst and best case; table 4.4-1 shows the related IRR and NPV.

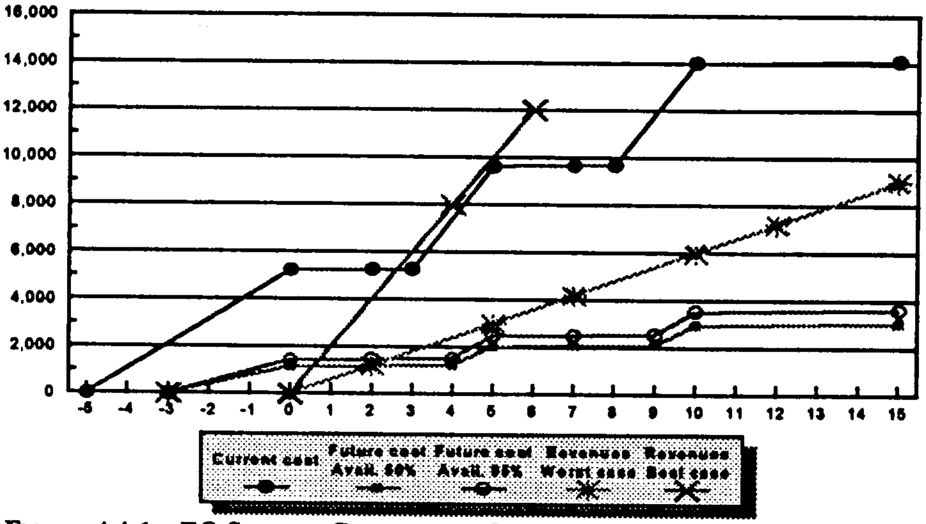


FIGURE 4.4-1 EO SERVICE CUMULATIVE COST AND REVENUES (MECU VS YEAR)

10 % cost of money has been considered for NPV	*CURRENT SIZING*		*FUTURE SIZING*	
	WORST CASE	BEST CASE	WORST CASE	BEST CASE
NPV 5TH YEAR (MECU)	-4300	-1050	20	4000
NPV 10TH YEAR (MECU)	-4560	780	780	7200
NPV 15TH YEAR (MECU) / IRR	-4000 / -	2600 / 17%	1400 / 25%	9400 / 71%

TABLE 4.4-1 EARTH OBSERVATION SERVICE NPV AND IRR

The chart in Figure 4.4-1 and the table 4.4-1 show that:

- difference is not significant, in economical terms, between 50 % and 95 % availability, so that the last one can be considered as a baseline
- the EO infrastructure sized on the basis of the <u>current parameters</u> and methods is not commercially viable, as a positive NPV is achieved only after 7 years from the beginning of the operations in the best case, and is not achieved at all in the worst case
- <u>future satellites infrastructure</u> allows for IRR ranging from 25 % to 71 %.

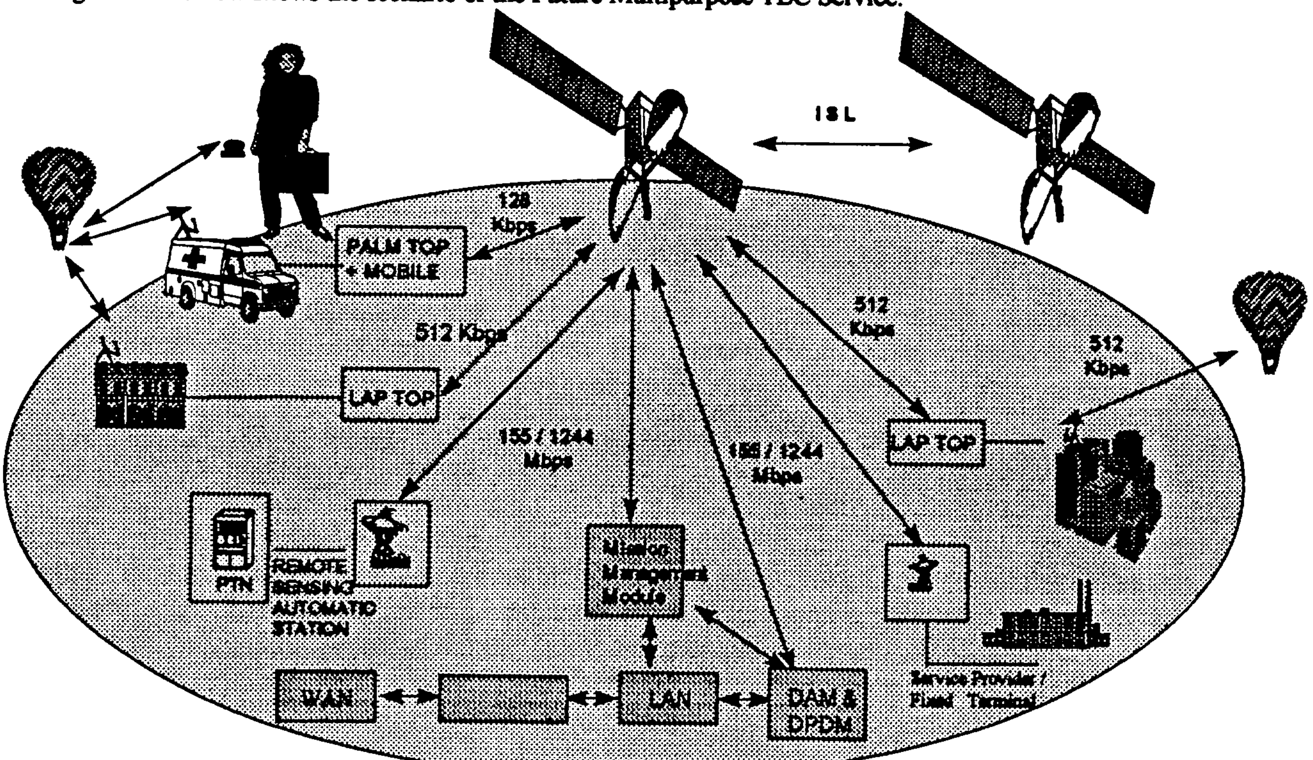
In conclusion, the analysis has demonstrated that what is not commercial viable with current technologies and methods, appears to be commercially interesting if emerging methods are applied and, principally, advanced promising technologies (able to increase the BENEFIT/COST ratio) are available.

5. MULTIPURPOSE TLC SERVICE

The end-to-end Telecommunications Service is described in this section, starting from the requirements (derived from section 1 recommendations) up to the economical results. A comparison between current and future satellite based system is performed to highlight the necessity to implement emerging technologies and concepts in order to get the service viable from an economical point of view.

5.1 REQUIREMENTS AND GENERAL ARCHITECTURE

The service shall support both mobile (palmtop / laptop) and fixed (desktop) user terminals. There shall be fully integration with terrestrial networks. The Lifetime shall be 10 years. Applications shall range from basic voice telephony and data to multimedia interactive applications, including: Internet-like services, video-conferencing, Tele-working, archive browsing and data/information retrieval, Tele-medicine, Tele-education and training.
Due to the high improvements in data compression techniques, the required data rates <u>for a fixed product</u> will in general sensibly decrease w.r.t. current needs. On the other hand, while today the Internet user data rate ranges from 16 to 128 Kbps (ISDN), 512 Kbps can be considered for 2010. To solve the today's problems due to end to end delivery, few fixed 1.2 Gbps user terminals are needed.
The Communications requirements are: 3 levels of **data rate** (low, medium and high), **BER** = 10^{-6}-10^{-9} (depending on the coding) for 99.5% (up to 99.9%) of time, **Low Cost terminals** and space segments (minimised infrastructures), **Low Cost Portable Terminals** (comparable with projected ground-based services terminals) with less than 1 W RF power and antenna diameter less than 40 cm, **Wide service area** (global or continental), **Compatibility** with foreseen terrestrial communications standards and protocols (e.g. MPEG video standards, TCP-IP and ATM / B-ISDN network standards).
The figure here below shows the scenario of the Future Multipurpose TLC Service.



The Future Satellite telecommunications service infrastructure is composed with:

- a *space segment* (6 7-tons-class sats deployed in such a way as to grant the global coverage and to support the traffic demand)
- a *ground segment* to provide satellite control, payload control and network operation control; gateway stations to serve major communications centres
- *user segment*: terminals of various type and costs to support different needs and services.

The main characteristics of the Multipurpose Satellite TLC system design are:

- ORBIT: GEO
- FREQUENCY: EHF (to cope with the high traffic demand for low-medium rate), and Ka (to support large bandwidth), in line with the applicable planned system (SECOMS)
- ACCESS & MODULATION: FM/TDMA or CDMA to obtain more frequency reuse.

Water vapour is particularly detrimental to Ka / EHF bands; a suitable approach has to be adopted to cope with rain fading (Adaptive modulation switching techniques, or Hybrid transmitter capable of switching to a lower and less rain susceptible frequency band, or Adaptive power control scheme).

5.2 SPACE SEGMENT

7-tons class satellites mass is the second one on the basis of the results of the trade-off that has demonstrated that in terms of number of user channels, $1\ satellite_{7000Kg\text{-}class} = 3\ satellites_{3500Kg\text{-}class}$.
The proposed system works in high frequency bands: **EHF band** for small data rates applications (e.g. 128 Kbps), for hand-portable **terminals**; **Ka band** for medium data rates (e.g. 512 Kbps), for medium portable/fixed terminals; **Ka band** for high data rates (e.g. 1.2 Gbps), for fixed user terminals. The following concepts have been implemented: multiple satellites connected through **Inter-Satellite Links** (ISLs); **High-Gain Spot Beams** (HGSB) generated on-board, allowing multi-spot coverage; on-board **fast digital processing** (OFDP); **FM/TDMA** access/distribution technique; **intelligent terminals** with limited EIRP (from 44.4 dBW/carrier -EHF- to 57.3 dBW/carrier -Ka-) and G/T (19.6 dB/°K for EHF, 20.5 dB/°K for Ka).

PAYLOAD

The payload consists of a regeneration section based on a switching matrix and an on-board traffic routing processor. The payload is composed of 4 distinctive sections: the **antennas subsystem**, the **reception section** (low noise amplification, frequency down conversion, decoding and demodulation), the **processing section** (routing, beam selection, power mode, synchronisation and rain fade compensation) and the **transmission section** (frequency up conversion, coding and modulation, RF power amplification stage). All technologies discussed in section 2.1 are implemented. The antenna subsystem is composed with **EHF antennas** (interleaved multibeams antennas for both Tx and Rx show high gain capabilities; pointing error must be an acceptable fraction of the beam size ~0.01°, better than current typical values), **Ka antennas** (multi-hopping beam configuration, with a 2 m main reflector diameter to increase the beam peak gain) and **Inter-Satellite Link antenna** (two axis parabolic gimballed reflector or Optic link antenna using diode pumped NdYAG with very large bandwidth, tenths of watts output power, very compact size). The antennas characteristics are summarised in the following table.

	EHF MULTI-FIXED BEAMS ANTENNA		KA MULTI-HOPPING-BEAMS ANT.	
	TX ANTENNA	RX ANTENNA	TX ANTENNA	RX ANTENNA
ANTENNAS NUMBER	3	3	1	1
FREQUENCY	40 GHz	45 GHz	20 GHz	30 GHz
REFLECTOR SIZE	2 m	1 m	1.5 m	1 m
F/D	> 1.5	> 1.5	> 1.5	> 1.5
BEAMS PER ANTENNA	160	59	18	18
GAIN	>54 dBi	> 47 dBi	47.7 dBi	46.7 dBi
STEERING AREA	-	-	5 ° (half cone)	5° (half cone)

SATELLITE OVERALL DESCRIPTION

A Liquid Apogee Engine is used for injection into the geostationary orbit. A bipropellant chemical propulsion subsystem provides orbit raising, attitude control and East/West manoeuvres. Momentum wheels are employed to maintain attitude during on-station operations. Electric Propulsion is used for North/South manoeuvres. Avionics architecture described in section 4.3 and advanced performances power system (see section 2.1) have been implemented. A performances comparison has been performed between 7-tons current-sized sat. and 7-tons sat. implementing advanced technologies described in section 2.1; the result is

$$1\ sat_{2010} = 6\text{-}8\ satellites_{today}$$

The maximum power capability achievable today is in the region of 14 kW, while long term goals identified in section 2 will allow in the 2010 to achieve 70 kW for the same satellite class (7 tons).
The table here below shows the maximum number of simultaneous users (number of channels) for each satellite.

	PALM TOP	LAP TOP	DESKTOP
MAXIMUM CHANNELS	1 Million	0.5 Million	450

SERVICE AVAILABILITY
The failure of 1 satellite does not interrupt the service but reduces the capability to support the traffic; 1 satellite spare on ground (ready for launch) will recover the full service capability.

DESIGN
All concepts described in section 3 can be applied (integrated product team, integrated development approach, rapid prototyping, robust design).

MODEL PHILOSOPHY
The following models will be developed:
- Breadboard at equipment level, Engineering Model at satellite Level
- 1 Protoflight Model (PFM); the satellite can be used as spare after the test campaign
- 6 Flight Models.

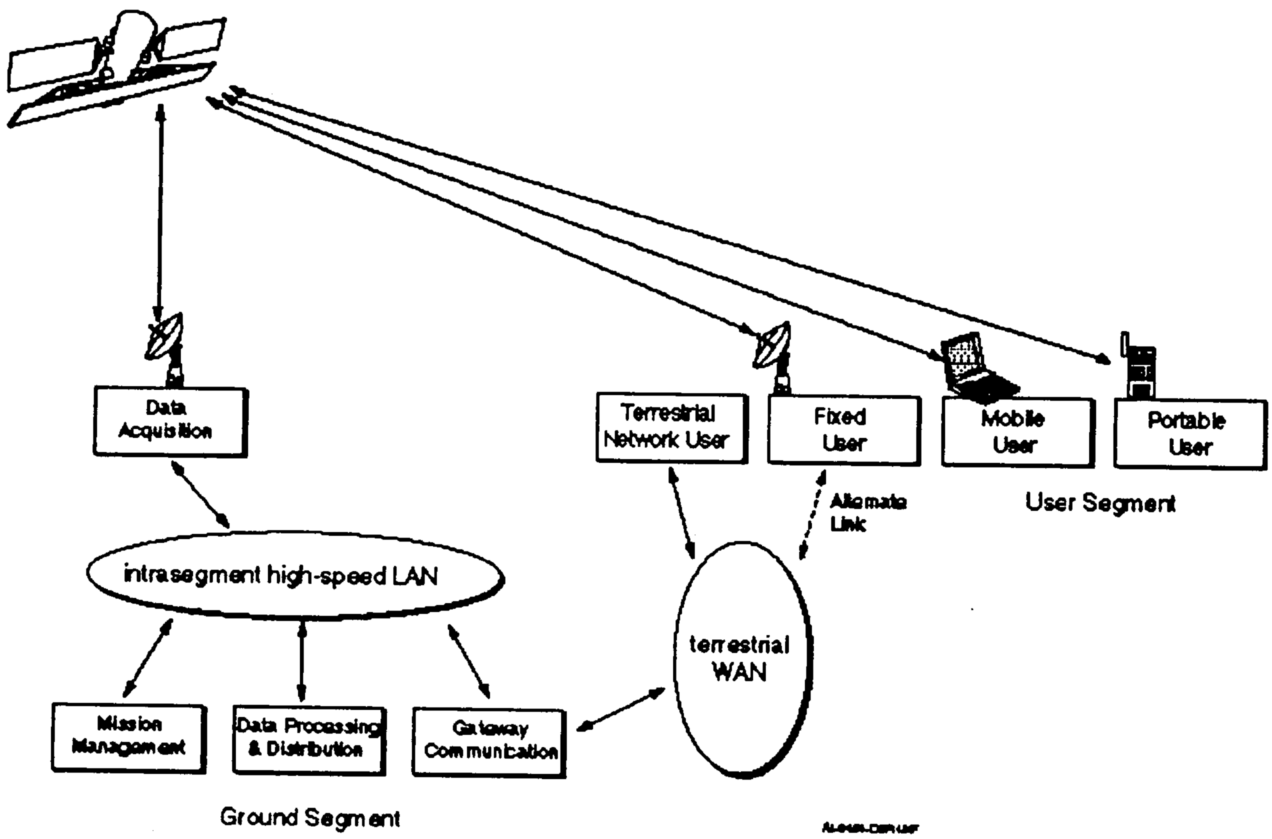
ASSEMBLY, INTEGRATION AND TESTING APPROACH
Problems could arise related to the dimension of the facility, that should be able to integrate 2 satellites at a time in order to reduce the development time.

SCHEDULE
The development will follow the schedule described here below:
- 24 months for design, included breadbording activity (rapid prototyping)
- 90 days (average) of AIT per satellite (obtainable through standardisation at the maximum extent), 2 satellites at a time, for a total of 270 working days (~1 year).

LAUNCH
Dedicated launches through an ARIANE-5 class expendable launch vehicle

5.3 GROUND AND USER SEGMENT

The following figure presents the block diagram of the major subsystems in the ground/user segment and their functional and network interconnectivity. Highly interactive services are not allowed because of delay problems associated with GEO systems. Operations are supposed to last 10 years.



The architectural model is horizontally integrated; due to the proliferation of services, it allows a modular approach and higher level of flexibility w.r.t. vertical architectures. A three-level architecture is proposed:

1. networked applications (e.g. e-mail, database access, video conferencing....)
2. services (e.g. Audio and video telephony, file system management....)
3. bitways (ATM)

In the frame of an universal network, satellite TLC services will have to satisfy the following requirements:

- develop an infrastructure that will allow for the transparent extension of terrestrial TLC services and applications
- develop new applications that will require satellite services.

The prerequisite for both requirements is the provision of the seamless interface of the space-based service with the future terrestrial network such as B-ISDN, IN (Intelligent Networks), Integrated Network Management, Nomadic Computing, PCS (Personal Communications Services). The requirement of seamless integration with the B-ISDN infrastructures requires technology compatible with the User and Network I/F (UNI) and Network to Node I/F (NNI), that provide the interoperation of bearer resources, signalling and network management functions. Standardisation activity must be pursued within adequate panels and bodies to define and develop UNI and NNI for hybrid satellite-terrestrial networks, also trying to solve interoperability problems related to delay and noise (and limited bandwidth).

GROUND SEGMENT

The following ground segment modules have been considered:

- Mission Management Module (MMM), 1 station per satellite, for mission operations control.
- Gateway Communications Module (GCM), for gateway to terrestrial networks
- Data Acquisition Module (DAM), 1 station per sat., to acquire data directly from satellites
- Data Processing and Distribution Module (DPDM), 1 station per satellite, for product generation, enhancement and distribution.

USER SEGMENT

Next user terminals for the future multipurpose TLC satellite services could be as follows:

	PALMTOP	LAPTOP	DESKTOP
Tx data rate	128 kbps	512 kbps	0.155-1.2 Gbps
Rx data rate	128 kbps	512 kbps	0.155-1.2 Gbps
Antenna type	Flat	Flat	Flat
Antenna size	23x23x3 cm	35x35x7 cm	450x450x50 cm
Weight	<0.5 kg	2 kg	10 kg
Use	Individual	Individual	Service provider
Price (guideline only)	100 ECU	200 ECU	1000 ECU

The user segment requirements are broken down into 3 separate requirements tables:

- near-real-time services (asymmetrical where uplink is of low bandwidth) - *M1W*
- interactive services without full motion video and no-real time services - *M2W*
- all TLC service types, but specifically geared towards interactive service types and VCR Quality Video Distribution - *FSF2W*

The user segment may receive requested data and service directly via satellite or via terrestrial network where satellite link is not available.

5.4 CUMULATIVE COSTS AND REVENUES

The revenues have been estimated on the basis of the assumptions shown in the table that follows; the maximum users per day per satellite is, practically, the maximum capability of the satellites (in terms of number of channels) at the end of the last years. For each service type

a. an utilisation price (ECU) and rate (hours/day) is assumed (***High case***)
b. price and rate of use are reduced by a factor of 2 (revenue per user reduced by 4) (***Low case***).

	PALMTOP	LAPTOP	DESKTOP
Terminal price [ECU]	100	200	1000
Subscription [ECU/month]	10	25	500
Daily customers end 1st full year	235000	120000	130
Daily customers end 10th full year	6 Million	3 Million	2600
Rates (high) [ECU/hour]	2	3	500
Rates (low) [ECU/hour]	1	1.5	250
Utilisation (high) [hour/day]	1	1	1
Utilisation (low) [hour/day]	0.5	0.5	0.5
Market penetration	2% of cellular telephony users	very small fraction of ISDN users	1 % of Europe E-1 users

In figure 5.4-1 the most important results, in terms of cumulative cost, revenues (low and high case) while in table 5.4-1 the NPV and IRR for current- and future-sized infrastructure are shown.

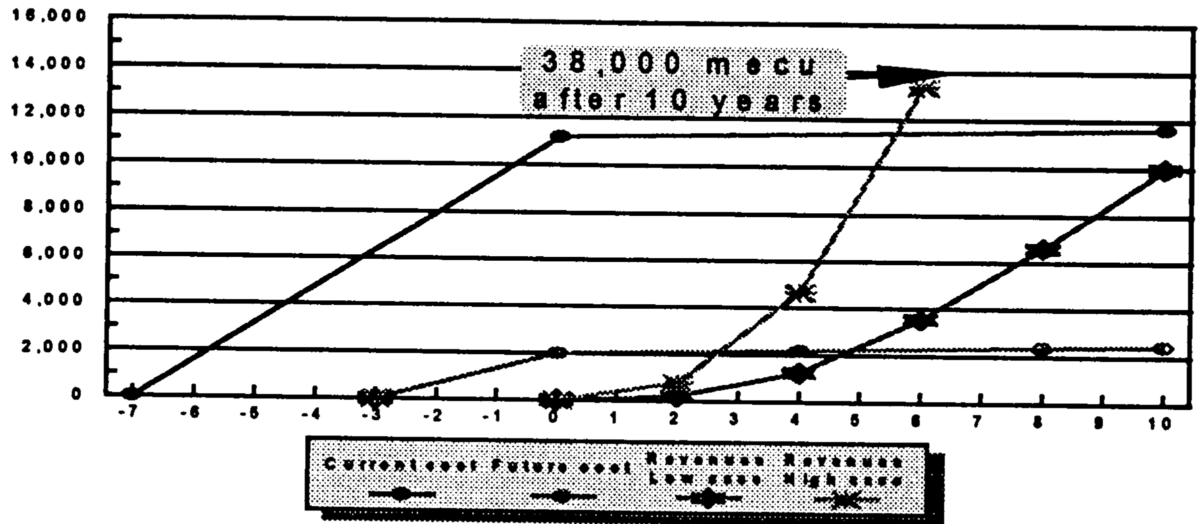


FIGURE 5.4-1 TLC SERVICE: CUMULATIVE COST AND REVENUES (MECU VS. YEAR)

10 % cost of money has been considered	CURRENT SIZING		FUTURE SIZING	
	LOW CASE	HIGH CASE	LOW CASE	HIGH CASE
NPV 5TH YEAR (MECU)	-7000	-4700	-550	2850
NPV 10TH YEAR (MECU) / IRR	-5300 / -	2150 / 13%	2000 / 22%	12900 / 50%

TABLE 5.4-1 TELECOMMUNICATIONS SERVICE NPV AND IRR

The results show that the TLC infrastructure sized on the basis of the current parameters and methods is not commercially viable; with current technologies and concepts, the only way to increase the NPV and reduce the time for break even point is to increase the rates, which means that the service will not be competitive w.r.t. ground based services. Future service appears to be potentially very profitable, with a very low market penetration; if from one hand this means that could be possible to be very profitable with rates comparable with projected ground-based services rates, on the other hand it seems that utilisation of satellites for global purposes is not possible unless several hundreds of 7-tons / 70-Kwatts satellites are launched; then, the satellites have to be seen as an integration of global information systems; a possible optimisation in the use of future big GEO satellites could be achieved in the frame of "fixed desktop services", for second level customers such as Internet-like service providers, or for private Intranets. In this case, if satellites resources are fully dedicated to this kind of customers (palmtop and laptop could be in any case serviced by other space based services, like LEO or MEO constellations, so reducing delay problems), a market penetration of more than 5 % will be likely to be achieved by the studied system.

While being complementary, satellites will also be able to compete directly with terrestrial services, especially for small organisations who need limited or occasional access to high-speed networks, and developing nations ripe for significant economic expansion. In both cases, there is a window of opportunity for satellite services to secure a significant market foothold before terrestrial services become available. Once affordable terrestrial services are in place, it will be difficult to displace them *unless* radically improved services are provided via satellite. The fixed "Gbps" service may well be able displace terrestrial services for certain users.

For the palmtop and laptop services, the main ground-based terrestrial competitor will likely be Local Multi-point Distribution System or LMDS; they operate in Ka-band with two-way (~ 10 Mbps) services distributed via cellular base stations. A competitor to the space-based palmtop and laptop services could be the proposed stratospheric airships system (Sky Station). In any case, neither LMDS nor airships seem to be able to provide a complete solution, leaving room for satellite services, because they have been demonstrated to be significantly more expensive than a space-based system where a single satellite could provide initial services for 10-20 % of the cost.

6. CONCLUSIONS

6.1 FUTURE SATELLITE

The whole study has been focused on the definition of the main impacts of innovative methodologies that could improve the competitiveness of European space based services, with particular emphasis on the space-segment, and then on the satellite aspects, which is currently the "weak point", in economical terms, of the global infrastructure any service is based on.
Two services have been selected and the various aspects have been analysed that can increase the BENEFIT/COST ratio. The two services, completely different each other, have shown that they are potentially profitable in 2010, but several emerging concepts, architectures, technologies (identified and discussed in the frame of the study) able to increase the BENEFIT/COST ratio have to be implemented.

6.1.1 ....CONCEPTS,

Some concepts follow that have been identified to be able *to reduce the cost* of the services space-segment.
Design approach
It should be based on a Robust Design philosophy (high design margin, in order to reduce analysis and testing, so improving cost and schedule)
Integration approach
The commercial quality of a service is strongly related to the time from the beginning of the expenditure and the achievement of positive cash flow figures; integration time has to be reduced and suitable approach (e.g. Island concept) should be applied when talking about satellite constellations
Quality-standard level of EEE parts
Commercial parts are very interesting from cost, leading time and performances points of view. Official handbooks provide quality factors that penalise excessively them, as their actual failure rate is approaching the MIL-Grade ones. Suitable EEE components strategy and official handbooks updating should be planned.

6.1.2 ....ARCHITECTURES,

One main consideration relevant to the global infrastructure architecture of the future-satellite-based services can be done in order to be able *to reduce the user rates and subscriptions* and then to increase the competitiveness of the services:

- a strong integration among the various players (space organisations, ground organisations, value added producers, and so on) should be achieved

In fact, what currently gets difficult the competitiveness of space based services is the very high gearing ratio between *price* of a product and *total cost* to deliver the product; the difference between these parameters is mainly constituted by the various overheads that have to be applied between the production and the delivery of a space based product.

6.1.3 ....TECHNOLOGIES

The advances in technologies are mandatory to get the European space industry ready for the 2010 market bid; in fact the advances in technology have also an important impact on concepts and architectures. Technologies that should be improved in order *to increase the PERFORMANCES/MASS ratio* and then the BENEFIT/COST ratio of the future satellite based services have been illustrated in section 2. Several of them are already under development, or have been planned in Europe, in the frame of the ESA technology research and development programs. Other important ones are not yet been started.

6.2 ....AND SERVICE CAPABILITIES

An interesting BENEFIT/COST ratio is potentially able to increase the service capabilities of future services, but the suitability of space-based products to various applications should be demonstrated and advertised. Pilot projects, not necessarily space-based, aimed at diffusing this kind of culture, should start well in advance w.r.t. the deployment of the infrastructure in order to target the users, provide data for preliminary feedback, initiate the user interest and define the details of the user requirements.
Pilot project could be the diffusion of E.O. images obtainable by new generation sensors, provided by aeroplanes, in order to demonstrate the applications, ask potential user for possible improvements and needs, and close the loop for the requirements and market size evaluation before starting the development of the space-based infrastructure.
The potentiality of multimedia networks is well known, because of the large diffusion of INTERNET, and explosion of the number of users is foreseen in the next 5-10 years. What has to be demonstrated and advertised is the possibility to obtain the same products in a better and cheaper way via satellites. Some pilot projects have already been started by the European Union, and ALENIA AEROSPAZIO is responsible for two of them (ISIS and SECOMS). Already operative satellites (ITALSAT, EUTELSAT, and so on) could be used in order to test also some particular products such as teleworking and telemedicine. Some particular users (hospitals, big bank institutions and so on) could be identified and provided with these products, and their impressions could be monitored.
Finally, products could be introduced in several schools or university institutes for mass diffusion.

Pilot project could be considered programs aimed at demonstrating the technology feasibility and, at the same time, at demonstrating the quality of some products. Cheap access to space should be used; for example an approach based on launcher piggy backs and Small Satellites, as well as opportunities in the International Space Station (e.g. the EPA, Express Pallet Adapter) could be followed.

7. RECOMMENDATIONS

The following actions can be proposed, aimed at increasing the competitiveness of the European space Industry and its capability in service provision:

a) Reduce analysis and test activities requirements, through Robust Design philosophy

b) Update the EEE components official handbooks for what concerns the commercial parts

c) Most of the performances described in section 2 on technologies, are relevant to laboratory results applicable not only to space equipment; activity should be performed to qualify for space or follow a suitable procurement strategy associated with a suitable risk management approach

d) Large apertures (for optical telescopes, SAR and TLC antennas) are needed for future EO and TLC satellites; technologies should be developed in the frame of Inflatable items as well as High precision deployment mechanism and active control systems, that are able to achieve suitable optical accuracy

e) While current European power systems performances are in line with USA ones, in the future USA technology could improve a lot w.r.t. European one, mainly in the frame of batteries performances; it is important to say that improving power systems also means getting possible the implementation of other technologies in other fields, such as Electrical Propulsion

f) For the satellite system to play a co-operative role with the terrestrial systems (Network Integration), techniques and protocols will have to be defined in common up to a level technically feasible; this work is still pending

g) Pilot projects should start in order to:
- target the users of space-based services, provide data for preliminary feedback, initiate the user interest and define the details of the user requirements
- demonstrate the technology feasibility and, at the same time, at demonstrating the quality of some products.

All results, conclusions and recommendations coming from this study, do not have to be seen as the solutions to solve or reduce all problems, but only as suggestions on topics to be deeply investigated in the next future.