The Telecommunications Long-Term Plan: 2006-2010

BR–256
October 2005

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Prepared by:	ESA Telecommunications Department
	ESA JCB (2005) 25, Rev. 1
Published by:	ESA Publications Division
	ESTEC, PO Box 299
	2200 AG Noordwijk
	The Netherlands
Editor:	Bruce Battrick
Layout:	Jules Perel
Copyright:	© 2005 ESA
ISSN No:	0250-1589
ISBN No.:	92-9092-442-X
Price:	10€

Printed in The Netherlands

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1

Introduction

Satellite telecommunications is by far the most important space sector for the European satellite manufacturing industry, representing more that 50% of satellite activities in Europe. This sector is mainly dominated by the worldwide commercial market, where the customers are private entities and the competitors are the large US manufacturers, in contrast to the other sectors such as science, Earth observation, human spaceflight, navigation, etc. In the last twenty years, European industry, benefiting from limited public support, has demonstrated its competence and its ability to export by capturing a significant part of the open market.

Through its volume and highly competitive environment, the presence of European industry in this market has in return a positive effect on the overall space activities. The commercial market provides opportunities for highly qualified employment, diversifies the field of activities offered to European space engineers, supports part of the fixed costs of the industrial infrastructure, and offers the institutional customers a benchmarking tool for measuring the technical efficiency and competitiveness of the European products.

The Executive has carried out an analysis of the situation in the Satellite Telecommunications sector for each of its major services (see ESA BR-253 and BR-254). The major conclusions of this analysis are that:

- The Telecommunications sector is a key pillar of the sustainability of the Space Industry in Europe.
- The satcom market, having undergone a major crisis, is expected to recover in the medium term.
- European Industry must improve its technological capabilities in order to enhance its competitiveness in the medium and long term.
- ESA's efforts in the commercial area must address both the improvement of the capabilities for existing services (FSS/DBS and MSS) and the development of new services (broadband access, broadcast to mobiles and institutional services).
- A major requirement for the development of new commercial satellites, applicable to practically all types of services, is the introduction of added flexibility in the configuration and utilisation of the payloads. This requirement also extends to the need for having platforms that are flexible enough to accommodate a wide range of payload configurations.
- From the system-architecture point of view, there is a marked trend towards the convergence of network technologies and services. This is reflected in the terrestrial networks (e.g. triple play including video, data and voice in a single package) and by the convergence of fixed and mobile services.
- The support provided by the USA to its industry in the development of advanced technologies under Department of Defense programmes will widen the gap in capabilities that already exists between American and European Industry.
- Institutional services, such as security-related services and data-relay systems, and their preparation, e.g. by the development of dual-use technologies, must be incorporated into the Telecommunications Programme.
- Several European States have deployed or are considering deploying operational defence communications systems. The military market is limited, representing less than one satellite per year, but the capability to deploy and operate

satcom systems is an asset of considerable strategic importance. New missions (ELINT, SIGINT) identified at European level as priorities for defence reinforce the importance of satcom competences in Europe. For all of these reasons, Europe needs to be present in this sector of high industrial, technological and strategic value.

- All aspects of the provision of the different commercial and institutional services must be addressed, including: user requirements, system architectures and applicable standards, payload equipment development, platform equipment development, ground segments and user terminals.

- The competitiveness of European telecommunications platforms must be maintained and enhanced. In addition to supporting equipment improvements for existing platforms, the TLTP must continue the support to the Large Platform initiative (AlphaBus) and must address the potential requirements for competitive small telecommunications platforms.

- Applications, in as much as they create demand for capacity and services, and because they address citizens' needs, must receive major dedicated support.

- ESA must support Satellite Telecommunications missions with the objectives of: allowing the demonstration and qualification of new technology, allowing the introduction and promotion of new services, and addressing the needs of Europe's institutions and citizens that are not met by commercial service provision.

- Three scenarios for the implementation of missions can be contemplated:
  (i) Agreement of partnerships with Industry, Operators and/or Institutions to demonstrate technology and introduce new services taking advantage of the AlphaBus qualification flight.
  (ii) Agreements leading to partnerships with Industry, Operators and/or Institutions to fly technology demonstrations as piggy-back payloads on commercial/operational satellites.
  (iii) Agreement of partnerships with Industry, Operators and/or Institutions based on the demonstration and qualifications of small telecommunications-satellite platforms.

In summary, a vigorous Telecommunications Programme is now more needed than ever.

ESA is a major source of public support for the space sector in Europe, even though it is neither a user of the space communication infrastructure, nor an operator providing services to users. The long-term competitiveness of European Industry is strongly dependent on the support provided by ESA's ARTES Telecommunications R&D Programme.

Considering the overall situation of the Satellite Tecommunications sector, the Executive proposes the extension of the existing Telecommunications Programme to cover the period 2006 to 2010 under the programmatic framework provided by the ARTES Declaration.

This publication describes the content, financial envelope and implementation procedures for the Telecommunications Long-Term Plan (TLTP) for the 2006-2010 time frame.

2

Programme Context

Structure

ESA's Telecommunications Programme addresses the requirements of the different actors in the satellite-telecommunications value chain, namely the space-segment suppliers, the equipment suppliers, the ground-segment developers and integrators, the application developers and, last but not least, the users. It must be adapted to the different degrees of maturity of Industry in the various countries and it must be framed within the rules applicable to the competitive provision of equipment, systems and services.

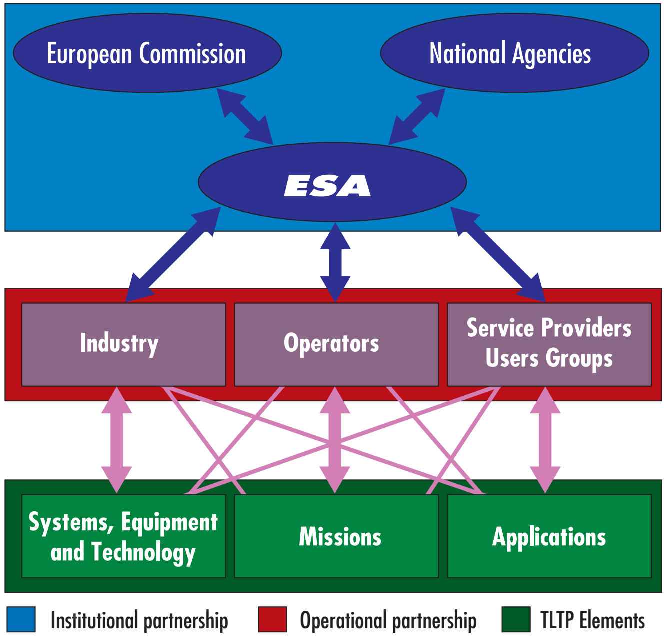
The Telecommunications Long-Term Plan (TLTP) adopted at the Ministerial Council held in Edinburgh has a matrix structure with two dimensions: on the one hand there is a thematic dimension along eight project lines, and on the other a programmatic implementation dimension associated with five ARTES Programme elements (ARTES 1, 3, 4, 5 and 8). The thematic dimension responds to the different segments/trends in the sector and defines the content and priorities proposed for implementation, whereas the programmatic dimension proposes the tools adapted to the specific content of the activities and to the roles of the various actors.

ESA must provide, in all the identified fields, the long-term strategic vision, the technologically driven initiatives and the infrastructure that will allow the implementation or deployment of specific systems. At the same time, ESA's programme should provide the framework for commercially-driven initiatives proposed by Industry, Operators and Users.

The TLTP 2006-2010 retains this matrix structure and is based on the revision of the Programmatic Project Lines presented in the TLTP 2002-2006, introducing the necessary adjustments derived from the reassessment of the present situation and the achievements of the on-going plan. This approach provides a flexible framework that allows the various initiatives to be implemented within an agreed set of Programme rules. These initiatives may range from very small projects focusing on specific equipment or service development, to more ambitious missions involving the deployment of new satellite systems.

It has been demonstrated that it is not possible to plan in advance when a given system-deployment opportunity may arise, since it is often conditioned by the conjunction of interests of the participating entities: Industry, Operators and Users. It is therefore paramount to have in place the necessary programmatic and financial framework that permits an efficient response to those opportunities. This process has been widely used throughout the TLTP 2002-2006 and has resulted in the successful implementation of several different systems: SatMode, AmerHis, DSL in the Sky, BGAN development, INDIGO etc. The TLTP 2006-2010 must also furnish the programmatic tool that will permit the implementation of future initiatives, which may arise from the dialogue established with other Agencies, Institutions and Satellite Operators, once sufficient maturity is reached.

The way in which the ESA activities relate to the overall telecommunications market is reflected in the accompanying figure. They are defined along three main lines:



The ESA Telecommunications Programme in relation to its environment

(i) ESA's activities are based on helping Industry to enhance its competitiveness in the Telecommunications market. From this relationship stems the need to maintain a well-structured and well-supported programme to improve Industry's commercial and technological capabilities. The context for these improvements lies in the need for different equipment, subsystems and systems for each segment of the Satellite Telecommunications market: hence the Telecommunications Systems, Equipment and Technology component of the Telecommunications Programme.

(ii) ESA's activities relate directly to the needs of the Users, who may be commercial or institutional entities such as the European Union, government agencies, or other international organisations. The market forces normally address user needs, but satellite-based solutions are often beyond the scope and capabilities, or even awareness, of many of the potential beneficiaries of such systems. In other words, there are many applications of satellite communications that can benefit the user communities, but which first require demonstration and promotion. ESA therefore proposes to reinforce the Applications component of the Telecommunications Programme to satisfy the needs of society and further develop the demand for satellite communications capacity, equipment and services.

(iii) Systems, Equipment, Technology and Applications can be developed over existing, commercially available satellite capacity. There are, however, well-defined situations in which the need for new satellite missions goes beyond the current availability of commercial systems, namely:

- To demonstrate and qualify new equipment and technologies.
- To demonstrate and promote new systems and services.
- To provide the infrastructure that allows the satisfaction of needs not otherwise served by the commercial market.

The majority of the past and future missions considered by ESA combine all three of these elements to a greater or lesser degree. In this respect ESA, in fulfilling its responsibilities, must include as a key component of the Telecommunications Programme the capability to generate new Satellite Telecommunications missions.

Over and above these three major components of the TLTP, there is the necessity to evaluate strategically the trends in the Satellite Telecommunications sector from every possible perspective. This 'Preparatory' Programme component includes following up the market's evolution, the analysis of new technology, the evolution of terrestrial services, scenarios and feasibility analysis for new satellite-system concepts, and especially support to standardisation.

In summary, the Telecommunications Long-Term Plan for the period 2006-2010 will be developed along the following four lines:

1. Preparatory
2. Systems, Equipment and Technology
3. Applications
4. Missions.

These programmatic components for the implementation of TLTP 2006-2010 are described in detail in the following sections.

Relationship with Other Institutional Programmes

The ESA Telecommunications Programme will be developed in coordination with other public entities, notably the National Agencies and especially the European Union. In the framework of the European Strategy on Space, Satellite Telecommunications is a key component of the Exploitation initiatives. ESA's TLTP will be coordinated with, and complemented and supported by European Union programmes:

- R&D activities, mainly in the context of the EU's 7th Framework Programme (ICT and Security and Space themes), will complement ESA's TLTP in a coordinated manner. The coordination mechanisms foresee the definition of agreed objectives, the scope of the activities initiated by each institution, mechanisms for communication and transparency, support to each other's actions, and collaborative projects.

- Specific projects, leading to the development of infrastructures or capabilities that will coincide with EU policy (e.g. Digital Divide, Security), will be supported in their inception by the presently proposed TLTP, although they may later require a specific programmatic framework.

ESA's cooperation with National Agencies will continue so as to further develop synergies between national and European projects. The models of EMS with ASI, AlphaBus with CNES, and AmerHis with CDTI, have demonstrated their usefulness in 'Europeanising' or developing opportunities around national initiatives. This concept of partnership will be continued during TLTP 2006-2010.

3

Programme Description

Preparatory Activities

The Preparatory activities of the Telecommunications Programme provide the strategic perspective and the initial analysis of potentially fertile satcom concepts, as well as a framework for the activities to support each of the Programme lines.

The Preparatory line thereby constitutes an indispensable tool for the implementation of the Telecommunications Programme and will need to be continued in the 2006-2010 time frame. The major strategic areas of appraisal will continue to be:

- Support to Telecommunications Strategy
- Next-Generation Systems
- Satellite Integration into Terrestrial Systems
- User Segment and Terminals.

In particular:
- Analysis of penetration of broadband access systems in Europe.
- Strategies for the introduction of HDTV services in Europe.
- Defence and security requirements on civil/dedicated satellite systems.
- Evolution and implications of digital-processing technologies.
- Evolution and implications of next-generation MMIC technologies (from GaAS to InP to improve the cost/performance ratio of SSPAs).
- DRA and telecommunications: What can we do and what would we need?
- Revision of DRS: optics requirements and technologies review.
- Industrial capacities and requirements for satcom competitiveness.

Systems, Equipment and Technology

GENERAL

The main goal of the Telecommunications Programme is to maintain the competitiveness of European Industry. This is achieved by developing system concepts, specific equipment and technologies as required by the different satellite services. The equipment and the technologies are therefore developed within the context of the satellite systems in which they are intended to be employed.

The Systems, Equipment and Technology component of the TLTP embraces all of the developments related to the different types of Telecommunications Satellite Services i.e. Fixed Satellite Services, Broadcast Satellite Services, Broadband Access, Mobile Satellite Services (MSS: Interactive and Broadcast), and to the different functional and physical elements that are incorporated in a satellite system: system, subsystem, equipment, and technological developments. In addition to the purely commercial services, there are other telecommunications services that have specific requirements from both the system and technological points of view: i.e. institutional services required by government and non-government organisations, such as systems involving the use of satellites for security purposes and/or those associated with data-relay systems of various types.

To address the different needs of the industry, the Systems, Equipment and Technology component of TLTP 2006-2010 comprises the following thematic lines:

- Service/systems-driven: These lines cover all activities that

have as their objective the realisation of end-to-end services, which may or may not involve the integration of available or new space segments and ground terminals; namely:
  - Fixed/Broadcast Satellite Services
  - Broadband Multimedia Services
  - Mobile Satellite Services
  - Broadcast to Mobile Services
  - Institutional (security/ public infrastructure) Services.

- Product-driven: These lines refer to activities where the objective is the development of a product, whether it be a piece of satellite hardware, a user terminal or other hardware or software products for a generic market. They include:
  - Satellite Communications Equipment
  - User Terminals.

FIXED AND BROADCAST SATELLITE SERVICES

Rationale

This market segment represents the vast majority of the value of present and future satellite systems. It is mainly based on the use of C- and Ku-band transparent transponders with continental or regional coverage (and more recently on the use of Ka-band for local TV distribution in the USA and for some point-to-point services).

Approximately 55% of FSS/BSS transponders are dedicated to video services, either for distribution, contribution or direct broadcasting. The bulk of the remaining utilisation is dedicated to network services, either voice or non-IP data trunking systems, which are in general stagnating, or to IP trunking which is growing by more than 10% per year.

Today this market sector represents 90% of space-capacity sales, and more than 98% of the turnover associated with downstream services. It has experienced a crisis caused mainly by the overprovision of capacity over some geographical regions, which took place in the late nineties. Its outlook is moderately optimistic.

Broadcast Satellite Services are expected to continue their expansion into geographical regions not yet exploited. The major system architecture and the reference standards are consolidating worldwide around the European-led DVB family, and specially DVB-S, and DVB-S2. The major growth factor is expected to result from the emergence of HDTV services. The combined use of improved source-coding algorithms, i.e MPEG 4, and physical layer standards, i.e. DVB-S2, will greatly increase the system's power and spectral efficiency. It is expected that around six HDTV channels will be accommodated on standard 36 MHz transponders, instead of the ten Standard Definition TV channels today, thereby resulting in a substantial increase in the demand for capacity. Other services (e.g. Interactive TV) and other forms of broadcasting (e.g. standard definition) will be favoured by the major reduction in transmission costs.

It is expected that, at least in Europe, HDTV services will be offered by the existing platform operators as premium services. The introduction of additional HDTV channels on existing TV platforms implies the need to increment capacity at already filled orbital positions. This strategy has led in the USA to the design of Ka-band satellites for HDTV and local TV broadcasting, and must therefore be considered when evaluating the technology trends implied by such a hybrid approach. In particular, fading countermeasures for broadcasting applications at Ka-band need to be developed at both the satellite-payload and physical-layer level.

IP-trunking systems will continue their growth, using dedicated medium- to high-capacity Single Channel per Carrier (SCPC) systems, and usually point-to-point connectivity between network-oriented (i.e. relatively large) stations. The transponder utilisation is usually multi-carrier, which calls for efficient onboard linearisers, but there is also growing demand for high-speed point-to-point links requiring single-carrier operation and ground pre-distortion/equalisation.

Trunking and back-hauling systems are also expected to play a key role in the introduction of new terrestrial services to remote areas, as would be the case with GSM, UMTS or WiFi/WiMax systems. Also fixed satellite-based solutions will enable the deployment of new terrestrial broadcast services (DVB-T/DAB/DVB H) or feed cells for S-DMB systems. In some cases, the configuration of meshed networks with fixed assignment of DAMA (FDMA or TDMA) may be needed.

The major requirement for IP-trunking systems is to ensure connectivity, efficiency and functionality: IP v6 integration, performance-enhancement protocols, IP security, multi-casting, IP quality, etc. must be further developed.

Satellite operators are demanding improved transponder performance and especially additional flexibility. It is therefore a fundamental requirement to step up the payload architecture and the technology that is associated with the major elements of conventional satellite payloads: antennas with improved performance, multiple coverage and flexibility, down- and up-converters associated with flexible frequency plans, RF/IF switches and specially improved HPAs. The Telecommunications Programme must address the system aspects and can incorporate equipment developed under the Telecommunications technology and equipment lines as required.

Content

The FSS/DBS line of the TLTP 2006-2010 needs to support the following developments:

SYSTEMS

- Reinforce the competitiveness of European Industry in the provision of new state-of-the-art C- and Ku-band FSS systems and payloads. This will be based on an analysis of the strategies of Satellite Operators, Broadcasters and Service Providers in the deployment of new capacity and services. This concept will be framed by the overall objective of improving the efficiency of utilisation of the payload, guaranteeing backwards compatibility of the different services, and integration of the system/network architecture with present and future standard terrestrial networks.

- Support to the development of services and systems for Standard TV, HDTV, interactive broadcasting, and trunking systems. The system approach will be based on support for ESA/European-driven standards, i.e. DVB-S, DVB-S2 and where applicable DVB-RCS. For Interactive TV, the developments based on SATMODE will be supported. Specific areas will include additional services by means of satellite return-link capabilities for DTH systems (i.e. enhanced Internet access, development of a standard API, and additional features, e.g. security).

- Additional support to all aspects of the integration of Trunking systems oriented towards the convergence of networks connecting ISPs, or UMTS/ WiFi/WiMax nodes into IP networks (IP v4 and IP v6). The achievement of improved efficiency both at the physical layer (i.e. developing high-speed adaptive coding and modulation systems, modulator pre-distortion and equalization techniques) and at higher layers (performance enhancement, cache techniques, etc.) is also included. Also, added functionality like multicasting, IP security and IP quality must be addressed.

PAYLOAD

- The FSS/BSS programme line will address the technology review of all key equipment: Tx/Rx antennas (shaped reflectors, flexible spot-beam antennas, beam-forming feed networks and digital beam-forming networks, DRAs), LNAs, improved I/P demux: filters, modular flexible and compact/integrated down-converters, time and frequency generating units, input reconfigurability switching either analogue at RF or IF or digital (transparent or regenerative) exploiting advanced deep sub-micron digital technologies.

- Payloads in general, but especially broadcast payloads are rated in terms of the performance of the output stage, i.e. channel amplifiers, HPAs and high-power-output multiplexers, in combination with antenna performance and coverage. The development of improved technology for HPAs, (e.g. flexible TWTAs, multi-port amplifiers, parallel TWTAs, and mini-TWTAs), output multiplexers and output flexibility switches, will be specially addressed.

- In addition, the FSS/BSS programme line will address the engineering approach leading to the definition of generic satellite architectures that will incorporate modular design, efficient implementation, industrialisation and testing of advanced payloads.

GROUND SEGMENT

- The Programme line must continue to support the development of user equipment for TV services: although many of these activities are driven by purely commercial opportunities, some developments geared to the reduction of cost and to dual Ku/Ka-band and Rx of outdoor units, introduction of next-generation set-top boxes, iTV low-cost easy-to-install interactive terminals, etc., will continue to require attention.

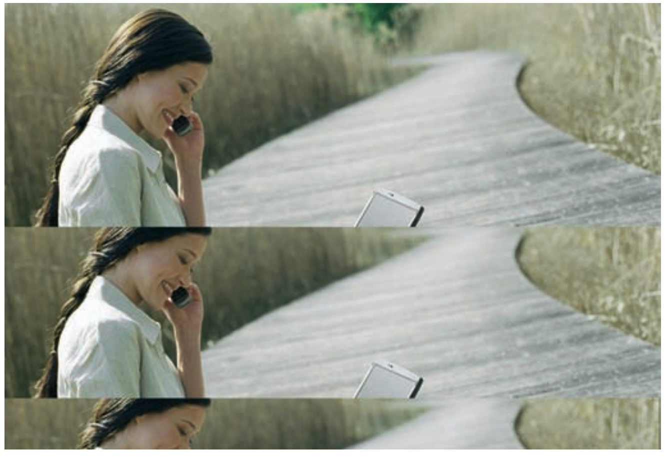
- The Programme will also address the development of satellite terminals dedicated to the provision of professional services in the FSS and DBS markets, as well as SNG systems, especially for HDTV, trunking and back-hauling systems.

BROADBAND MULTIMEDIA SERVICES

Rationale

Satellite broadband systems, and in particular the provision of broadband Internet access to residential and corporate users, have developed much more slowly than was expected in 2001. The general telecommunications crisis has affected the readiness of operators and investors to fund the launch of the many broadband Ka systems that were planned in the 1990's.

Today, the vast majority of satellite Internet access takes place over regular FSS Ku-band transponders, which are not optimised for the delivery of high-speed data to individual terminals. The result is that the space-segment costs are high, the economies of scale have not developed, and therefore the cost of the terminals is also high. The net result is that today less than 200 transponders are dedicated to Internet access globally, and most of them are offering narrow-band services, a far cry from Industry expectations a few years ago.



While the crisis in the Telecommunications sector in the period 2001-2005 damped projections of the growth in demand for broadband systems, several systems are now about to go into service. The recent deployment of Anik-F2, which has enabled the start of operations of Wild Blue and Telesat, the forthcoming IPStar system (successfully launched by Ariane flight 167 on 11 August 2005), the all-Ka-band ITT on AMC 17, and the planned Spaceway 3 by Hughes Network Systems, indicates that this segment of the market is gaining new life.

Broadband access is definitely one of the most important opportunities for satellite communications systems to generate a new cycle of growth, and its development therefore remains a strategic objective of the satellite Industry and ESA. European Industry must maintain the capabilities that have been developed so far, and wherever possible promote the deployment of these systems in partnership with Operators and other Agencies.

The efforts dedicated so far to Multimedia Systems under ESA's ARTES Programme have provided European Industry with the capability to offer a wide range of Ka-band multi-spotbeam satellites with or without regeneration. This effort has been complemented with the consolidation of the DVB-RCS Standard and the adoption of DVB-S2 for the forward link. The combined use of these standards and Ka multi-spotbeam satellites could reduce the cost of data delivery to individual terminals by a factor 10.

In line with the above considerations, the Executive's intention for the Broadband Multimedia Systems line is to pursue two avenues:

1. *Maintain and enhance the capabilities of European Industry through the continuation and reinforcement of the Broadband Multimedia developments at system, equipment and technology level:* This programme line will be based on improvement of the reference payload, and the system architectures will be based on DVB-S2/DVB RCS with enhanced fade-mitigation techniques. It will address the achievement of improved system efficiency by developing mechanisms to permit flexible capacity assignment to each spot beam and the improvement of Radio Resource Management (RRM) systems. RRM subsystem design is particularly challenging in conjunction with adaptive physical-layer techniques such as ACM and DRA. It will also review the need to provide meshed connectivity on DVB-based systems. The overall system aspects will be based on well-identified user and system requirements. This component of the programme will also address the technological evolution required by future flexible wideband payloads introducing advanced transparent processors and optical switching concepts.

2. *Promote the implementation, deployment and operation of a system able to achieve the intended reduction in service costs, especially for the space segment:* This initiative is meant to provide a demonstration of competitiveness and sustainability, and should ideally be implemented in partnership with the Satellite Operators and Service Providers.

The provision of broadband Internet access to rural communities to bridge the so-called 'Digital Divide' constitutes an interesting opportunity to demonstrate the benefits brought about by Ka-band multi-spotbeam satellite-based infrastructures. Numerous studies have demonstrated that satellite-based solutions are complementary means of providing universal Internet-access coverage to the European territories. The risk involved in the deployment of satellite solutions has precluded private stakeholders from embarking on large initiatives in Europe so far. It is therefore in this context that ESA has proposed a pan-European initiative for the implementation of a Digital Divide Satellite Solution.

Given that the required level of political agreement has not yet been reached, a full-scale Digital Divide mission is not included for implementation at this stage in TLTP 2006-2010. The TLTP will, however, support the continuation of the technology activities and preparatory studies that may be required for the future initiation of such a programme. In parallel, ESA will pursue the analysis of the socio-economic benefits of the project and provide its support to related initiatives, which may be initiated later either at national or international level.

Content

The Broadband and Multimedia line of the TLTP will address the following issues:

SYSTEMS

- The architecture and the system requirements for future Ka-band multi-spotbeam systems will be revised in the light of the evolution in demand. The reference system concept will be based on DVB-S2/DVB RCS broadband interactive with adaptive modulation and coding for either Ku or Ka multi-spotbeam systems. Additional activities will be related to resource management (critical in the ACM environment), optimisation of the architecture to cope with uneven throughput distribution, and the scalability of the system. The potential use of a DVB-S2-based beam-hopping air interface to provide maximum flexibility to lightly loaded spots will also be addressed.

- The programme will also support to the progressive and scalable deployment of systems that allow the provision of sustainable broadband Internet access to rural communities via either existing or new, optimised satellite capacity.

- The preparation of the system aspects and the technology required by advanced multi-spotbeam transparent flexible payloads will also be included in the programme development.

Bridging the Digital Divide

- Modern broadband interactive satellite systems require the availability of design and optimisation tools at system and subsystem level, taking into account the most advanced communication-network architectures and techniques, the payload architectures, and the complex interactions between the different system levels. It is also necessary to refine and expand propagation-channel modelling to account for fading, correlation and user mobility effects (e.g. trains), which are highly relevant for system performance analysis. These tools will support the system design, in-depth performance analysis and validation, and cost-reduction efforts for both the space and ground segments.

PAYLOAD

- It will be based on the improvement of existing designs for multi-spotbeam antenna systems. Antenna feed architectures with 50 to100 spotbeams using a combination of array-fed reflectors or direct radiating arrays. System sizes that can evolve to large capacity (greater than 20 Gbit/sec) with efficient power utilisation and spectrum reuse. MPA and HPA output stages will be enhanced to cope with the increased flexibility and efficiency demanded. Inclusion of advanced functionalities within the digital processor to enhance system performance: digital RF sensing techniques for fine pointing and new beam-forming/processing techniques to reduce the level of interference.

- The payload architecture will address full transponder flexibility by including regenerative and non-regenerative switching and dynamic allocation of resources to user and gateway spots, exploiting advanced deep-submicron digital technologies. For the implementation of wideband transparent processors, advanced DSP and improved performance ADC/DACs will also be required. Alternative technologies such as optical routing systems will also be investigated.

GROUND SEGMENT

- Further to the on-going development of DVB-based solutions for broadband systems, the Broadband Multimedia line will support additional improvements leading to reductions in the cost of both the user terminals and the service itself. Also, DVB-S2/DVB-RCS meshed and mobile configurations will be supported. The developments will be complemented with improved gateways (interference mitigation, robust synchronisation, enhanced MAC, RRM, etc.) and, to the extent needed, with network-management and network-control systems. A dedicated R&D line to support ground-segment development in line with system evolution and new requirements is envisaged. This R&D line will also be beneficial in defining new standards or possible future evolutions of existing standards.

MOBILE SATELLITE SERVICES

Rationale

Mobile-related communications represent an important portion of the global commercial telecommunications market. It is in mobile communications that the combination of sound system design with technological innovation has been demonstrated to be crucial to the success of new systems and services. It is therefore a segment of the market that requires the full support of the ESA Programme.

Following its successful launch on 11 March 2005, Inmarsat-4 is a reality and the technological preparation provided by ESA has been crucial to the role that European industry is playing in this programme. ESA is currently further supporting the definition of the BGAN services that will be provided over the Inmarsat system. The competitive edge achieved through these programmes must be maintained.

New mobile-system initiatives should be framed in the context of market-driven demand, and agreed with the potential Operator. Particular interest is attached to systems promoting the utilisation of mobile-service frequency bands that may require integration with other MSSs. Furthermore, the regulatory decisions by the FCC granting MSS Operators use of the mobile satellite frequencies via a complementary 'ancillary terrestrial component' call for the revision of the system architectures and business case, to evaluate the opportunities resulting from the deployment of such systems. In summary, ESA should continue the support being provided to system-driven, industry-led initiatives in the development of mobile-system concepts, and specific related equipment and subsystems.

Mobility has also become a fundamental requirement for a number of commercial and public services. The most obvious cases are the provision of communication systems to public-transport systems: planes, trains, etc. A number of Ku-based mobile communication systems are currently being proposed, and their eventual implementation should be incorporated into the programme. Specific system designs and equipment development based especially around Ku-band mobile user terminals will be needed.

Another important mobile communications system is dedicated to providing communications to aircraft cockpits for Air Traffic Control (ATC) and or air traffic operations. In this respect, the cooperation with Eurocontrol on the definition, standardisation and implementation of aeronautical communication systems calls for additional effort in the 2006-2010 period.

The TLTP 2006-2010 should therefore incorporate the specific space-segment and ground-segment requirements for such mobile systems and thereafter support the acquisition of the necessary industrial capabilities.

Content

The Mobility line of the TLTP 2006-2010 must include:

SYSTEMS

- The design, development and eventual deployment of new interactive mobile communication systems, to be carried out in partnership with Industry and MSS commercial Operators. Several architectures will be considered, including the extension of the reference provided by Inmarsat-4, i.e. improved-performance, large-capacity, large-frequency-reuse systems with active interference mitigation for voice and data (and video) services. Integration with terrestrial networks will be considered, as well as the complementing of coverage/performance with an ancillary terrestrial component. Regional system architectures will also be addressed. Further system analysis will take into consideration the evolution of terrestrial systems (B3G/4G) and its impact on the design of new air interfaces such as adaptive coding and modulation, MC-OFDM, MIMO. Efficient support to resource management and assignment of capacity to spots will also be included in the programme.

- Modern Mobile Satellite Systems require the availability of system design and optimisation tools at system and subsystem level, taking into account the most advanced communication-network architectures and techniques (including the ancillary terrestrial component for both broadcast and interactive services), payload architectures, and the complex interactions between the different system levels. There is a need to refine and complete wideband channel modelling for the various applications (including outdoor). These tools will allow efficient support for the system design, in-depth performance analysis and validation and cost reduction for both the space and ground segments.

- The Mobile line will also cover the design and deployment of mobile communication systems required by specific applications: e.g. Ku-band mobile systems, for terrestrial maritime and aeronautical applications, such as DVB mobile aeronautical communication systems.

PAYLOAD

- Development of mobile payload technology based on very large deployable reflectors (10-24 metres) and complex array feeds. System-driven antenna/payload design and optimisation. Improved front-end designs efficiently supporting large numbers of inter-connections/beams. Efficient SSPAs at L/S-bands. Next-generation digital processors. Direct-radiating arrays with dynamic pointing systems.

GROUND SEGMENT

- Development of mobile terminals in line with the evolution of system and air-interface definition for hand-held, land-mobile, maritime and aeronautical services, in all relevant frequency bands, and for individual and collective configurations. Development of radio-access networks, network-management and gateway systems. Development of the complementary terrestrial infrastructure (i.e. ancillary terrestrial component).

BROADCAST TO MOBILE SYSTEMS

Rationale

Broadcasting services to mobile terminals (e.g. DARS) are growing faster today in relative terms than any other service. The commercial success in the USA of XM Radio (5 million subscribers by mid-2005) and Sirius (nearly 2 million subscribers in the same period) has attracted the attention of investors and operators and is considered one of the most important developments in satellite communications over the last five years.

Also, the WorldSpace system provides a related radio service to Asia and Africa on two satellites (AsiaStar and AfriStar, respectively). Their broadcasts are freely available and therefore the service is financed by advertising. The rationale for the service is the absence of terrestrial radio broadcasting over substantial regions of the planet. In addition to the basic open service, WorldSpace has recently initiated a set of subscription services that, in just a few months, have attracted 55 000 customers.

In Korea and Japan, the MBSAT system has just started to provide TV, radio and data services via two distinct platforms addressing the two linguistic markets. These services are also subscription-based, and the user terminals are mainly hand-held devices. At present, there are no service-penetration figures available for either the Korean or Japanese platforms.

Both the system/air interface and payload technology behind XM Radio and WorldSpace are European in origin. There is, however, as yet no consolidated European initiative to provide similar services, although preliminary systems-preparation work has been carried out within ESA's Telecommunications Programme and the European Union's 6th Framework Programme (SDMB/MAESTRO projects).

The success of DARS services in the USA and their evolution towards multimedia, and especially TV broadcasting, is likely to generate important business opportunities in other markets, including Europe. In this context, it is considered crucial that European Industry maintains its technical SDMB system capabilities with a view to providing a European solution or being able to compete/complement future commercial broadcast systems.

Content

The Broadcast to Mobiles line of the TLTP 2006-2010 will support the development of:

SYSTEMS

- Development of Mobile Broadcast systems: Broadcast system architecture. System optimisation: trade-off between capacity, service availability and penetration, terrestrial repeater coverage, user-terminal performance: identification of compatibility/competitivity with terrestrial air interfaces.

PAYLOADS

- Contoured-beam antennas for different regional/linguistic target markets. Large antenna rigid reflectors (i.e. 6-7 metres). High-power-handling antennas. Very-high-power output stages, optimisation of HPA assembly. Flexibility in assignment of resources to different beams.

GROUND SEGMENT

- Development of compact, low-cost, dual-mode multi-standard terrestrial/satellite hand-held terminals, fixed and vehicle-mounted user terminals. Development of production/transmission facilities. Development of terrestrial repeaters. Promotion of the deployment of Mobile Broadcast systems in partnership with Satellite Operators.

INSTITUTIONAL SERVICES

Rationale

The use of satellite systems by Governments and Institutions has been an increasingly important segment of the satellite telecommunications market over the last few years.

Often the requirements for capacity and services of an institutional nature can be satisfied by the commercial Satellite Operators and Service Providers. In this case, the systems that are used are normally adaptations or variations of regular commercial satellite equipment, e.g Ku-band trunking links, VSATs or mobile services on any of the regular mobile satellite systems, while there may be specific requirements in terms of performance, security, connectivity or quality of service.

In particular, the utilisation of satellite capacity by defence institutions has grown dramatically. The capacity requirements during the war in Iraq have been 800 times greater than those during the Gulf War in the early 1990s. Also, other institutions such as NGOs have become major users of satellite capacity. It is reckoned that this user group collectively represents the second major source of revenue for Inmarsat.

Beyond this commercial impact, the use of telecommunications satellites by public institutions has, on the one hand, a structuring effect in the field of technology, and on the other constitutes a strategic element that has to be reflected in the European Space Policy and programmes. Current efforts in the field of advanced satellite-telecommunications technology, supported by the Department of Defense in the United States, have an impact on the overall technology level of the industry and create a 'technology gap', which threatens the position of European space industry.

In this context, the ESA TLTP aims to address the developments needed to ensure the competence of European sources for the institution-related satellite communications systems and services that may be required in the future. ESA's technical activities must cope with the requirements of the security community and prepare the necessary developments that will allow Industry to maintain the necessary technological capabilities. More specifically, it is considered that the requirements of the security community will call for:

- Security of the communications: involving encryption systems, advanced physical-layer techniques, interference-resilient/anti-jamming systems, mechanisms for selective reception: nulling antennas, regenerative systems, digital beam-forming, etc.

- Security of the network infrastructure: System protection, radiation hardening, network survivability, etc.

The development of security/defence-specific systems, equipment or technologies will be coordinated with the relevant institutions and Industry.

There is a particular set of institutional requirements associated with the provision of Data-Relay Services either to space agencies or to security and defence institutions. They are provided at both optical and RFfrequencies by systems for which European Industry has already demonstrated its capabilities, including the successful Artemis demonstrations and regular operations. However, the requirements of today's potential new users, and the degree of innovation/integration/improvement that would be possible with updated technology, requires reassessment of the system requirements and revaluation of the feasibility of next-generation Data-Relay Services, in concert with an in-depth analysis of the various utilisation scenarios.

Content

The Institutional line of the TLTP 2006-2010 will address the development of:

SYSTEMS

- Security systems definition: The development of specific systems and technology that may be required by institutional users on dedicated (commercial or non-commercial) satellite systems. In particular, the competence of the European Industry in security and defence systems will be sustained and improved.

- From the systems point of view, the programme should address the system requirements in terms of coverage, capacity throughput, scalability and re-configurability. Further specific requirements call for the integration of satellite-based systems with defence/security encryption structures, very stringent Quality of Service, and pre-emption required by the security chain of command, network survivability and re-configurability and the support to the legacy infrastructure with the new hybrid architectures. Both fixed (e.g. Ku, Ka, X-band) and mobile satellite services (UHF, L/S-bands) will be considered.

- DRS system definition involving the consolidation of system requirements: Capabilities, mission scenarios, throughput, number of targets, performance, global system architecture(s), system architecture (interfaces with ESA, civilian and military systems), payload definition and configuration, optical, S/K-band, feeder link, platform requirements, etc.

PAYLOAD

- Specific technologies involving X-band, SHF and EHF payloads will be addressed. The major areas of interest will include multi-spotbeam large-capacity systems, with or without OBP, jamming-resistant systems, nulling antennas, and radiation-hardened technology.

- Next-generation optical data-relay terminals: Including telescopes, lasers, pointing systems and digital processing of data for the different mission requirements for data-relay satellites and target customers. S/Ka-band DRS terminals.

GROUND SEGMENT

- Dedicated terminals for fixed, deployable and mobile scenarios in civil and government frequency bands associated with the reference systems will be developed. The development of standard terminals for optical and RF ISL will also be included in the programme.

SATCOM EQUIPMENT AND TECHNOLOGY

Rationale

The continuous development and improvement of technology is fundamental to the existence of a competitive industry. European Industry's competitiveness in Satellite Telecommunications is totally dependent on continuous innovation in terms of satcom equipment and its potential adoption in space systems. The existence of public support channelled through the space agencies is vital for the sector.

The corresponding activities may relate to new technologies that require proof of concept or closer-to-market equipment development involving qualification or prototype implementation. For some products or equipment, their evolving maturity of development will lead to their incorporation into specific service lines.

There is a continuous push for cheaper, lighter and smaller equipment with improved performance and reliability. This push is present in all satellite-technology areas, resulting in a need to upgrade all types of equipment, both payload- and platform-related, at regular intervals. Moreover, the US International Trade and Arms Regulations (ITAR) restrict access to some key technologies, which also results in a need for a re-design of equipment to replace the items affected with European technologies.

Payload technologies, while usually associated with specific services and systems, can also be developed in a generic manner by equipment suppliers striving to improve their competitiveness in the provision of particular types of equipment, independent of the overall system concept for which it is employed, e.g. TWTs, SSPAs, LNAs, FGUs, D/Cs. Even antenna systems, which are so closely related to the overall system requirements, are in some cases initiated as a generic technology. Platform technology has to be addressed both from the system integrator's point of view, and also that of the developers of the technologies and equipment associated with each of the subsystems. In parallel with the AlphaBus programme, ESA will continue to provide the necessary support for equipment and technology improvements in existing platform lines and will also support the introduction of new product lines corresponding to validated commercial or public needs.

Today, European Industry is able to supply competitive medium- and high-power platforms to the World market. Thanks to the AlphaBus programme, the high-end platform market will also now be covered by European suppliers. There is, however, a market segment that needs smaller platforms in order to provide cost-effective initial/scalable deployment of capacity in new markets or for new services. The TLTP must therefore also support the technological preparation of subsystems for those small platforms.

Further development of equipment for ground stations is equally under constant pressure from the competition. There is therefore a need to improve the competitiveness of European suppliers of professional ground-segment equipment.

As explained above, the developments under the Satcom Equipment and Technology line of the TLTP 2006-2010 correspond to generic technologies and components (i.e. non-system/service specific). These technology developments will be product-oriented. Fully funded activities will be required to result in a tested development model, while co-funded activities will result in products ready for market. Where appropriate, development will comprise all activities starting with feasibility and breadboarding, and ending with qualification and industrialisation of the product. Such an all-in development may be supported by a mix of funding, starting with full funding of the feasibility-study and breadboarding effort, followed by co-funding of the qualification and industrialisation.

Content

The Satcom Equipment and Technology line of the TLTP 2006-2010 will support the development and upgrading of equipment in all of the following areas:

PLATFORM

- Equipment and Technology: The programme will support systems analysis and developments associated with existing and future telecommunications satellite platforms. In particular, it will cover the system aspects associated with the development of small platform(s).

- Power Subsystem: The development of improved power subsystems has as its main drivers the need to provide higher power, improved efficiency and reliability, and a reduction in subsystem cost. These requirements will be addressed by the development of improved solar cells involving multi-junctions and an efficiency greater than 30%. Also, thinner cells and alternative solar-array technology, i.e. thin films, concentrators and high-voltage cells, will be developed. New substrates and mechanisms will need to be considered, as well as improved solar-array-drive and power-transfer solutions. High-temperature operation and improved lithium-ion batteries, such us polymer, will also be included in the programme.

Solar arrays

- Thermal Subsystem: The main requirement here is the need to handle higher levels of power dissipation. This will be addressed by developing deployable radiators, mechanisms and loop heat-pipes. Heat spreaders with active components and pumped fluid loops (two-phase systems), improved Sun shields, and controlled-emittance surfaces will also be developed.

- Propulsion Subsystem: The main requirements affecting the propulsion subsystem are the improvement of orbital lifetime, the elimination of ITAR dependence, the improvement of system reliability and the reduction of cost. The technologies being considered include the introduction of high-power electric propulsion for orbit-raising and orbit-adjusting manoeuvres and the adoption of electric propulsion for full north-south station-keeping. This will involve reviewing new electric-propulsion concepts, such as gridded ion-engine and Hall-effect plasma thrusters, as well as improvement of the power-conversion process, possibly including direct-drive solutions. Advanced chemical-propulsion engines (10 N, 500 N, AEF, propellants), and advanced propellant-gauging techniques should also be supported. In all cases, for both chemical and electrical propulsion systems, the elimination of dependence on non-European suppliers will be addressed.

- AOCS Subsystem: The major requirements for the AOCS subsystem are increased autonomy, reduction of cost and improved reliability. The technologies that are required call for new low-cost gyroscopes (MEMS technology transfer, HRG, FOG), new momentum-management devices, and improved Sun sensors that are more robust to radiation. The data-handling system calls for improved computers with additional processing capacity, and data storage. In particular, a dedicated effort is required to manage the detection of failure modes, the replacement of software and improvement of the overall process of software upgrading and verification.

- Mechanical Subsystems: The overall objectives for these subsystems are reduction of their mass, the ability to incorporate more and more complex deployable antennas, and the improvement of pointing accuracy. These needs will be addressed by the development of simpler and lighter deployment mechanisms, including more thermally stable stiff materials, development of new limbs and joints, and the inclusion of active pointing mechanisms and sensors.

PAYLOAD

- Equipment and Technology: Generic satellite equipment such as antennas, LNAs, frequency converters, processors, routers, channel amplifiers, power amplifiers (SSPAS, TWTs), filters, and multiplexers.

USER SEGMENT

- Developments: Generic ground-terminal equipment such as antennas (for user terminals and for professional fixed and transportable uplinks), LNBs, SSPAs, high-power amplifiers (TWTs, klystrons), frequency-generating units, frequency converters, modulators, demodulators, coding equipment, protocol software, management systems, etc.

USER SEGMENT

Rationale

The User Segment line addresses the necessity to support European Industry to enhance its competitiveness in the provision of satellite terminals. The economic value of the User Terminal segment of the business is for many services greater than that of the plain provision of satellite capacity, and it is therefore paramount to foster the development of a competitive set of European terminal manufacturers for the different types of services.

In this respect, User Terminals are a particular type of ground-segment product corresponding to systems and services that involve volume production for residential, corporate or institutional services. User Terminals are associated with service definition and normally involve standardisation of the air interface associated with these services. The development of terminals for any given service is closely related to the relevant system definition. However, the terminals themselves constitute a separate product, which requires specific capabilities, a dedicated industrial set-up, and (other than typically proprietary USA systems) are normally commercialised in an open provision environment.

The strategy that European Industry has pursued and ESA has supported is based on the expansion and opening up of the terminal market with the aim of achieving low costs through the introduction of economies of scale resulting from the adoption of open standards. A substantial amount of effort has been dedicated to the consolidation of the DVB-S, DVB-RCS and more recently DVB-S2 systems. According to Northern Sky Research, "with close to 70 hubs and over 16,750 DVB-RCS sites online as of late-2004, it is clear that DVB-RCS-based platforms are no longer a niche in the broader broadband satellite landscape". ESA can take a great deal of credit for this achievement.

More recently, ESA has also supported other standards for Interactive TV through the SATMODE project. Similarly, the Broadband Global Area Network (BGAN) development associated with the introduction of high-performance mobile satellite services, also supported by ESA, will be opened by Inmarsat as part of the agreement associated with this support.

Operators and service providers are finally recognising the value of the open-standards approach, and in particular a consolidation around the DVB family is taking place. Most worldwide requests for proposals are explicitly requiring DVB-RCS and excluding any proprietary technologies, and proprietary system manufacturers have therefore developed or are developing DVB-RCS versions of their products. This is due in part to the important efforts of the ESA-created SatLabs Group, which consolidates the views of all actors in the value chain around the same table, and provides valuable input to ESA regarding major initiatives/technologies to be developed.

SatLabs Group: www.satlabs.org

Content

The User Segment line will support:

- The development of low-cost solutions for integrated reception through individual and collective systems of combined HDTV and standard DTV in the Ku and Ka-bands.

- The development of a competitive European Industry in the terminals field by promoting standardised interactive systems, i.e. DVB-S2/DVB-RCS. In particular, the User Segment developments will address the need to reduce the cost of terminals for both IDU and ODU, and the simplification of installation procedures.

- This line will all also include the development of improved Radio Resource Management systems, which allow more efficient use of available resources. The development of protocol aspects like cross-layer techniques for reliable multicast, unicast and real-time services, provision of security and the integration of the satellite sub-network on terrestrial network management systems. Gateways of different sizes (large, light) will be developed, including full IP inter-working, point-to-point protocol termination, ISP contexts, IP security, multi-destination support, multi-protocol labelling, etc.

- As far as iTV services are concerned, there should be additional support to ensure the availability of very low cost, easy to install (multi-band) terminals. Additional system improvements involving the development of a standard API and the inclusion of security features will be developed. Gateways with different volume targets and capacity to grow will be also included in this programme line.

- The development of mobile terminals (e.g. BGAN next-generation) and associated ground subsystems for interactive services in either the L- or Ku/Ka-bands. Development of Radio Access Networks and the integration of terrestrial networks/components for mobile systems. Development of Ku-band-based collective mobile systems: trains, airplanes, ships, and services.

- The development of terminals for Mobile Broadcast systems. Development of complementary infrastructure: terrestrial repeaters.

MeCa antenna aboard ship

SUMMARY

Table 1 provides a summary of the identified Telecommunications Technology priorities for the 2006-2010 time frame.

SATCOM SERVICES	SYSTEMS (Architecture & Standards)	PAYLOADS (Subsystems & Equipment)	GROUND SEGMENT & USER TERMINALS	PLATFORMS
FSS+DBS (Mainly Ku-, C-band Systems) Purpose: Increase competitiveness and penetration of services. Increase demand for satellite capacity and satellite-based services. Reduce the cost of transmission. Reduce the cost of all service elements	• Traditional TV systems: Contribution, Transport Distribution and Broadcast • DVB-S based HDTV. • Interactive TV (Satmode) • Other: Network Operator Trunking Links; ISP connection to backbone. • User Network Architectures, mainly DVB-RCS based: Star, meshed (DAMA).	• Transparent transponders • HPAs, LNAs, D-U/Cs, switches, O/P Mux., MPAs, antenna flexibility on Frequency assignment Capacity assignment: output flexibility • Multiple-spot coverage. • Multi-frequency payloads	• TV: Evolution towards HDTV. Support to broadcast but also to contribution stations • FSS: Feeder systems. SCPC. SCPT. Backhaul systems • DVB-RCS for interactive access to Internet on existing satellites • iTV Terminals: MHP	Existing platforms + larger + smaller (scalable). All subsystems to be addressed: • power • thermal • AOCS, • propulsion, • mechanical etc.
FSS for INTERACTIVE BROAD BAND (Mainly Ka-band) Purpose: Bring satellite-based Broadband Internet access systems to cost/performance competing level with ADSL. Develop HDTV Ka-band systems	• Multi-spot systems: User beams vs G/W Beams: star and mesh topologies • With and without regeneration, i.e. DVB-S2 based • Also HDTV local broadcast + high-capacity point-to-point links	• Ka-band input stage flexibility • Flexible D/Cs, FGUs • Complex time and frequency switching (analogue and digital) • Output flexibility. HPAs, MPAs, beam hopping • Improved antenna design(s)	• System architectures based on DVB S2/RCS for either Ka/Ka or Ku/Ka bands • NCC/NMC: RRM, MAC, networking, terrestrial I/Fs • Gateways • User terminals: Improved functionality, COST	Existing platforms initially, plus large platforms in the medium-term (Scalable: strategies, e.g. HYLAS)
MOBILE INTERACTIVE (Mainly L- and S-band) Purpose: Maintain and improve competitiveness of space and ground industry. Develop new business opportunities, e.g. regional systems.	• Reference architecture based on Inmarsat-IV; BGAN and other services • Other mobile architectures: regional beams, ATC, • Non L-band based system architectures	• Improved antenna capabilities • Integration of feed into front-end design. Improved front-end design. Lessons learnt from Inmarsat • Processors (SW+BF) • HPAs, SSPAs and MPAs • Flexibility	• Development of next-generation mobile terminals: beyond BGAN (aeronautical, maritime, land mobile) • Dual-use terminals • Special systems: 'Connection by Airbus'. ATM/ATO • Ku-band interactive terminals: trains…	Large Piggy-back missions
MOBILE BROADCAST (SDMB) Purpose: System and technological readiness of European Industry. Favour the development and implementation of this new and promising satellite service.	• Complex balance between system capacity, coverage, quality of performance, use of ground repeaters. Low user antenna gain. High sat. EIRP • Open or proprietary standard integration in existing terminals, i.e. UMTS	• Regional contour/ lingustic area coverage. S-band antenna • Very high power output stage • Flexibility • Onboard Mux, Skyplex	• Multi-platform user terminals • Vehicular use terms • Terrestrial repeaters • Production and distribution architecture	Large
INSTITUTIONAL SERVICES Purpose: Maintain and improve technological competence of European industries.	Various scenarios: • Fixed, mobile. • Network architecture, service requirements • ISLs, GEO - Aircraft, GEO – GEO, GEO - Deep space • Optical systems • Standards	• RF Ka, Q/V, X Band, SHF,EHF • RF High and Low power. • Antennas: Nulling Antennas • Processors Optical terminal: Telescope, tracking, digital processing etc.	• RF terminals X Band, SHF, • Feeder systems • Centers of command • User terminals on other satellites • User terminals on planes • Resource management..	Small or piggy-back on large platforms

Table 1. The Systems Equipment and Technology Component of the Telecommunications Programme

Applications

GENERAL

In an overall context characterised by limited growth, or even stagnation in the demand for satellite capacity from the institutional and commercial sectors, future growth is linked to the ability of the space actors to demonstrate to new categories of users the potential of using space solutions to satisfy their needs.

The role of the users of space infrastructure is therefore becoming more and more important for ESA's future perspectives. The special relationship with Space Industry, which has dominated the Agency's approach from the outset and which has served to build up the European space capability, now has to be complemented with a strong and structured relationship with Users based on the development and demonstration of new applications.

Based on the experience acquired in the past years, the TLTP will incorporate:

- Development of associated technology and the demonstration of 'Exploratory Applications': This component of the programme creates the framework that allows Users and Industry to identify potential avenues of application development.

- Deployment of pilot 'Solution Projects': This new component of the Applications programme aims to consolidate the requirements and the proposed solutions that meet the needs of diverse sets of homogeneous Users across Europe.

EXPLORATORY APPLICATIONS

Rational

The traditional 'Exploratory Applications' activities play a crucial role in the generation and validation of new opportunities and constitute the innovation engine for new applications (new ideas, new entrants, seed opportunities). Due to the relatively high technical and operational risks, and sometimes the lack of awareness of satellite systems within the target user groups, those activities will be kept within small-scale projects until the concepts are fully developed and validated.

Content

The ESA Telecommunications Programme has supported innovative applications in one way or another since its inception nearly 30 years ago, first in the form of various satellites Utilisation Programmes and more recently through the different ARTES Elements (e.g. ARTES-3 Line 1). The scope of this support has been very open, allowing the proponents to submit proposals within agreed terms of reference. These 'Exploratory' proposals constitute the seed that allows the verification of the technical, operational and commercial viability of the proposed applications.

The TLTP 2006-2010 will maintain the existing programmatic and financial provisions for the implementation of innovative applications, either on the initiative of ESA or Industry/Users.

SOLUTION PROJECTS

Rational

The development of User Groups allows more efficient development and consolidation of new applications. The harmonisation of the requirements originated by the different sets of users allows the development of economies of scale, interoperability and competition between equipment providers. These factors result in greater benefits for the User communities. The federation of Users, which has led in some cases to the creation of User operators or agencies, is of key importance for the future of the sector, because it opens up the possibility of moving from a technology-push to a demand-pull approach. This is a necessary development, because it serves to root the Agency's action in the expression of citizens' needs. A permanent and structured dialogue between these User communities and ESA is essential for facilitating the development and penetration of space-based services.

Content

The Application line of the TLTP will provide the financial and legal framework to execute, in partnership with the interested parties, a number of User Group orientated Solution Projects, with the objective of setting up fully functional systems, characterised by service requirements derived by the Users, that can be easily extended in terms of scale and penetration, paving the way for sustainable services.

The major candidate areas for the development of such Solutions Projects are the following:

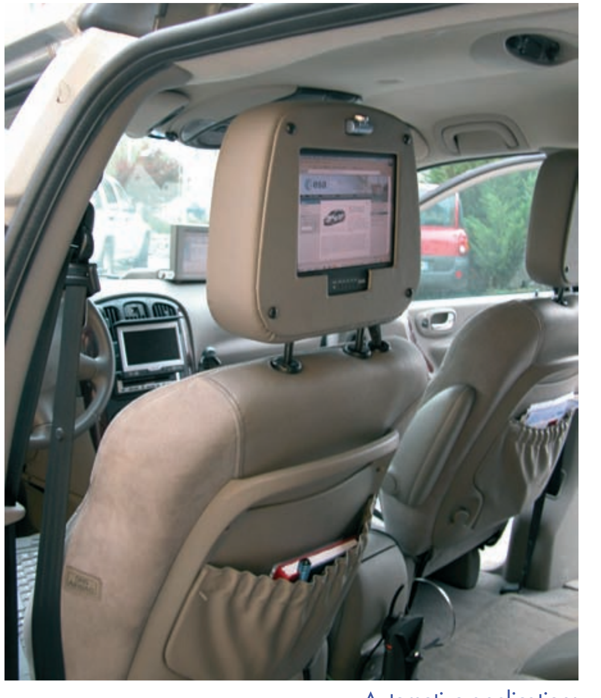
- Internet on Public Transport
- Telemedicine/eHealth
- Broadband Access to Consumer Applications
- Interactive TV Applications
- Civil-Protection Applications
- Location-Based Applications
- Safety/Security Monitoring and Control
- Support to Development and Capacity Building
- Automotive Applications.

If the emerging User community shows the necessary potential, the existing ARTES programme will have to be adapted in order to host ad-hoc programmatic actions capable of matching the user-driven nature of the application. Specific legal frameworks might have to be envisaged to reflect User participation in the different phases of the project, to guarantee compliance with competition/State-aid regulations for market-driven services, to regulate access to IPRs, and to establish synergies with complementary funding instruments such as EU grant, EIB/EBRD support, and private-sector investment/partnering.

To accomplish this task, ESA will have to complement the existing industry-driven actions with the following tailored steps: a User-federation task whereby, with the help of user working groups, symposia, questionnaires, web fora and other aggregation techniques, preliminarily identified user communities are brought together and helped to make their operational needs known through an established dialogue with ESA. In the next step, driven by the federated demands, ESA must put in place the necessary R&D, pilot projects and pre-operational programme actions to translate the emerging demand into pre-operational services. The ultimate goal will be to ensure service sustainability, and in this respect User financial involvement will be a prerequisite.

A specific legal framework will be required to regulate the participation of User communities in the management and funding of the different phases of the projects, to guarantee compliance with competition/state-aid regulations for the pre-

Telemedicine applications



Automotive applications

operational services, to regulate access to IPRs for Industry, ESA and Users, to verify the possibility of establishing synergies with regional/national/international development programmes with similar or complementary objectives and, last but not least, to provide a stable and appropriate funding scheme for the operational phase.

Table 2 provides a summary of the planned Solution Projects, identifying the key technological enablers, the nature of the demonstrations that may be supported by the ESA Applications Programme, and the key standardisation developments associated with each of them.

APPLICATIONS AREAS	SATCOM SOLUTIONS	KEY TECHNOLOGICAL ENABLERS	PILOT UTILISATION PROFILE	STANDARDISATION ACTIONS
Internet on Public Transport (Air, Land and Maritime)	FSS for Interactive BB FSS+DBS Mobile Interactive	Distributed Management and Control Agents. Integration with Terrestrial Wireless / Hybrid Comm. Links. Low-Cost New- Generation Steerable Antennas. New-Generation Communications Gateways. Personalised Multimedia Programming. Planar Electronic Steerable Antennas. Push/Caching of Multimedia Contents, QoS Management Tools	Pre-Operational System Deployment Medium to Large Scale Pilot	Interoperability Service-Provision Terminals
Telemedicine / eHealth	FSS for Interactive BB FSS+DBS Mobile Interactive	Body Area Network. Low-Cost/Easy-Installation Terminals. Low-Power-Consumption Miniaturised Terminals. Personal Localisation and Communications Terminals. Personalised Multimedia Programming. Personalised Software Agents. QoS Management Tools. Secure Communications, Conditional Access and DRM. Smartcards. Wearable Peripherals	Small Pilot with Friendly Users Pre-Operational System Deployment Medium to Large Scale Pilot Institutional Operational Service	Interoperability Service-Provision Security/Confidentiality Terminals
Broadband Access to Consumer Applications	FSS for Interactive BB FSS+DBS	Immersive 3D Virtual Environment. Integration with Terrestrial Wireless. Low-Cost/Easy-Installation Terminals. Low-Power-Consumption Miniaturised Terminals. New-Generation Communications Gateways. Push/Caching of Multimedia Contents. QoS Management Tools. Secure Communications and Digital Right Management	Small Pilot with Friendly Users Pre-Operational System Deployment Medium to Large Scale Pilot	Interoperability Service-Provision Terminals
Interactive TV Applications	FSS+DBS	Distributed Management and Control Agents. Immersive 3D Virtual Environment. Low-Cost/Easy-Installation Terminals. New-Generation Communications Gateways. Personalised Multimedia Programming. Push/Caching of Multimedia Contents. Conditional Access and Digital Right Management	Pre-Operational System Deployment Medium to Large Scale Pilot	Interoperability Terminals
Civil Protection	FSS for Interactive BB FSS+DBS Mobile Interactive	Distributed Management and Control Agents / Integration with Geographical Information System. Immersive 3D Virtual Environment. Integration with Terrestrial Wireless. Low-Cost New- Generation Steerable Antennas. Low-Power-Consumption Miniaturised Terminals. Personal Localisation and Communications Terminals. Wearable Peripherals	Small Pilot with Friendly Users Pre-Operational System Deployment Institutional Operational Service	Interoperability Terminals
Location-Based Applications	Mobile Broadcast Mobile Interactive	Distributed Management and Control Agents. Immersive 3D Virtual Environment. Low-Power-Consumption Miniaturised Terminals. Personal Localisation and Communications Terminals. Wearable Peripherals	Small Pilot with Friendly Users Pre-Operational System Deployment	Terminals
Safety/Security Monitoring and Control	FSS for Interactive BB Mobile Broadcast Mobile Interactive	Distributed Management and Control Agents. Low-Power-Consumption Miniaturised Terminals. Personal Localisation and Communications Terminals. Secure Communications. Smartcards. QoS Management Tools	Small Pilot with Friendly Users Pre-Operational System Deployment Institutional Operational Service	Terminals Security/Confidentiality
Support to Development and Capacity Building	FSS for Interactive BB FSS+DBS Mobile Broadcast	Integration with Terrestrial Wireless. Low-Cost/Easy-Installation Terminals. Push/Caching of Multimedia Contents	Pre-Operational System Deployment Medium to Large Scale Pilot Institutional Operational Service	Interoperability Service Provision
Automotive Applications	Mobile Broadcast Mobile Interactive	Integration with Terrestrial Wireless. Low-Power-Consumption Miniaturised Terminals. Personalised Multimedia Programming. Planar Electronic Steerable Antennas	Small Pilot with Friendly Users Pre-Operational System Deployment	Service Provision Terminals

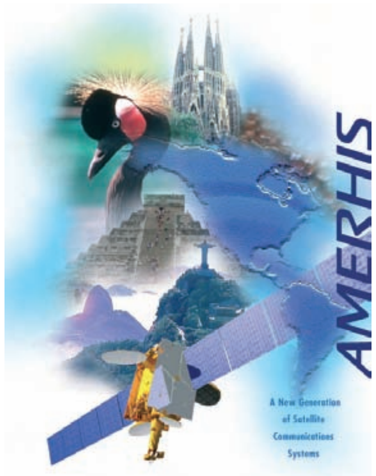
Table 2. Summary of Activities for Solution Project Applications

Missions

GENERAL

In the context of the TLTP, missions are defined as major projects developing end-to-end systems, including the development of the space component.

A fundamental part of ESA's role in Satellite Telecommunications is to provide the infrastructure to allow the in-orbit validation, qualification and demonstration of equipment, technology and services developed under the ESA programmes. In the past, this component has been realised either through dedicated satellites such as OTS, Marecs, Olympus and Artemis, or through the implementation of piggyback payloads on ESA or commercial satellites, such as IOC on Eureca, EMS on Italsat, Skyplex on Eutelsat satellites, and AmerHis on Hispasat's Amazonas satellite.



This in-orbit demonstration component constitutes a very important element of the overall satcom programme line: through its structuring effect on Industry and its ability to focus efforts on a well-defined objective with all the aspects and constraints of a real mission. At the same time, the deployment of technology by means of dedicated satellite missions allows the introduction and promotion of new services.

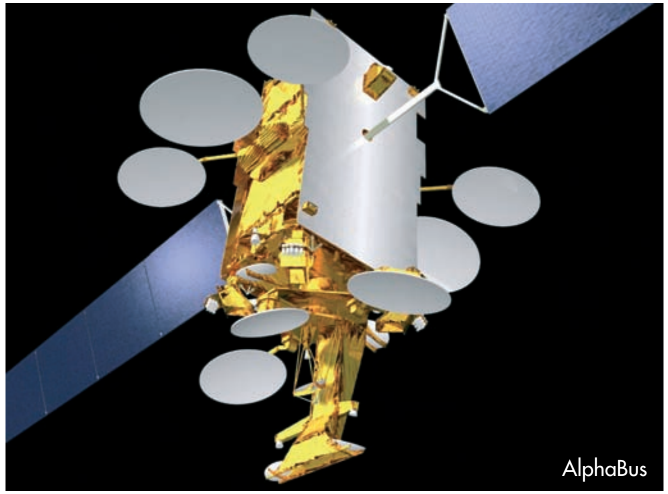
In addition, the development of an ambitious and well-identified mission serves as a flagship for the Telecommunications Programme, reinforcing the political attractiveness of the telecom sector.

Within the ESA Telecommunications Programme, two lines of activities will be pursued, namely a dedicated AlphaBus mission line and a line comprising several other opportunities including piggyback and small-satellite missions.

ALPHASAT

Rationale

Following the signature in June 2005 of the industrial contract for the main development programme (Phase-C/D), AlphaBus will be brought up to protoflight-model level in the context of the presently approved programme. Since the development of customer confidence in the AlphaBus product requires in-orbit qualification of the platform, conducting a first mission using the platform is essential to achieve the objectives of the AlphaBus effort. Furthermore, the availability of the AlphaBus proto-flight model, with its unique features in terms of mass and power, represents a unique opportunity for demonstrating new technologies, systems and services in orbit. Based on the past experiences with Olympus and Artemis, it is also of key importance, especially for such a high-capacity spacecraft, to


AlphaBus

define from the outset an operational use of the satellite consistent with the level of investment associated with mission implementation.

Content

The AlphaSat mission is foreseen to consist of two main components: a core (pre-)operational payload constituting the main justification for launching such a satellite and maintaining its operational phase, and a technology package benefiting from the flight opportunity offered by the maiden flight of AlphaBus.

The candidate (pre-)operational missions identified as constituting the core payload for AlphaBus are:

- an Institutional Security and Data-Relay Package:

  - Security and early warnings of emergencies are everyday issues of concern. Satellites offer a tool to alleviate these concerns by enabling communication independent of any kind of complex ground infrastructure. The satellites can be used when communication cables and radio links have been damaged. The satellites may have to operate under adverse conditions including intentional interference, implying that a number of technologies suitable for such conditions need to be developed. Dedicated systems addressing the needs of Institutional Users for both Fixed and Mobile Services in the civil (Ku, Ka, L and S) and military (X, UHF, EHF, SHF) bands will be considered.

- Current and future scenarios for the use of Artemis's data-relay payloads confirm the need for continuation of the data-relay services. The Envisat, EGNOS, ATV and Spot-4 missions depend on the use of Artemis and have made significant investments in anticipation of its continued availability. The lifetime of Artemis is finite, however, and the time has come to consider a mission to continue these data-relay services. The extension of present GEO-LEO data-relay system architectures to include other scenarios (GEO-GEO, GEO-aeronautical) also needs to be considered.

- Potential payloads provided by national agencies to demonstrate or qualify developments that have taken place within National Programmes.

- Commercial Payloads provided by Satellite Operators

- The capacity of AlphaBus allows the accommodation of a significant commercial payload in addition to the ESA-led payloads. There is sufficient mass, volume and power available on the platform to accommodate a commercial payload of today's size, together with one or two ESA technology-demonstration payloads. A combined technology payload and commercial payload has been studied in the framework of AlphaBus. Its accommodation is fully feasible provided such issues as frequency allocation and Operator partnerships are properly addressed.

- The selection of the core mission will be based on the results of an Announcement of Opportunity issued by ESA, and on consultations with potential public and private Stakeholders, Users, and Operators interested in the mission.

- Technology and Service Demonstration

The candidate technology items identified to be part of the Technology and Service Demonstrator are mainly the elements developed within the 'traditional' ARTES lines for which an in-orbit demonstration is a key element for their successful introduction on operational satellites, such as:

- L/S-band Payloads: Large antennas, complex reflector systems, new-generation processors, new ASIC technology (0.13 microns), software radio, channel amplifiers, SSPAs using the latest technology for RF power transistors. Potential provision of user-to-user communication and broadcast to Mobile User Services.

- Next-Generation FSS/DBS: Flexibility modules for C-, Ku- and Ka-band payloads, spotbeam antennas delivering up to a hundred beams, including flexible output and input sections, Ka-band LNA in Glob-Top, Potential provision of interactive multimedia and High Definition TV services. High-power TWTAs.

- Optical inter-satellite links or optical links to aircraft: ESA has supported the development of optical-link technology for several years and, following the SILEX development for Artemis, a new generation has been developed that requires in-orbit verification.

- Platform and payload technology items carried onboard as experiments: High-throughput electric thrusters, new solar cells, new gyroscope technologies, thermal technologies based on zero-g conditions (loop heat pipes, fluid loops), deployable radiators. These items will be tested in orbit to monitor and verify their correct operation, but they will not be part of the platform nor the payload providing services.

As a first step in the AlphaSat programme, 'ESA Payload Phase-A and B' studies will be undertaken to select and design the AlphaSat payloads.

Two studies, known as JADES 1 and 2, have already taken place to define a possible set of payloads for AlphaSat, but a clear baseline has not yet been established. The AlphaSat Payload Phase-A/B studies will therefore include a trade-off of various payloads and the selection of a baseline. This selection will take into consideration the interests of Industry, Operators and Delegations in achieving an in-orbit heritage for particular technologies and in acquiring knowledge about the market potential for specific new services.

The AlphaSat Phase-A/B will be initiated once the full payload, including commercial-opportunity payloads, ESA payloads, data-relay and security packages and payloads from other agencies, and their mission requirements have been established. AlphaSat Phase-A/B will thus address the complete mission, will lead to the mission design including the ground system, and will define the complete implementation and exploitation phases.

Upon completion of the AlphaSat Phase-A/B, Phase-C/D will be implemented, including the satellite's launch and in-orbit testing.

The operation of AlphaSat is foreseen to be the responsibility of the Operator providing a payload, or another agency with significant participation in the payload complement, except for the operation of the ESA payload, which will be under the Agency's own responsibility, at least for the initial operating period.

OPPORTUNITY MISSIONS

PIGGY-BACK MISSIONS

Rationale

On several occasions, Industry has expressed the need for establishing an in-orbit heritage for newly developed equipment. Today, satellite operators and insurers are extremely cautious about accepting equipment without such in-orbit heritage on new satellites. This is true not only for totally new equipment, but also for existing well-proven designs that have undergone updating to replace obsolete parts or parts subject to USA export restrictions with their European equivalents. Timing is an important factor in establishing flight heritage, the ideal solution being to fly newly developed or upgraded equipment immediately after the completion of its qualification campaign. From an ESA perspective, the implementation of a dedicated mission is difficult, due to its cost and the need to allocate a large part of usually scarce resources to expensive mission-specific items (platform, launcher, operations) that the user is not ready to pay for and do not fall within the Agency's usual funding rules.

Content

The Executive will therefore pursue its efforts to find a solution by approaching commercial operators and other agencies with advanced plans for launching a satellite, with the aim of obtaining an agreement on conditions for flying such newly developed equipment as piggyback experiments. The result is expected to be a fee to be paid to the satellite owner for including the newly developed equipment.

Moreover, the Executive will continue its dialogue with Operators and Industry to identify payloads for the demonstration of new or improved services. These payloads are also foreseen to be included as piggybacks on commercial satellites or, alternatively, on small platforms.

SMALL-SATELLITE MISSIONS

Rationale

In the context of probing the market with a new service or an existing service in an as yet untried geographical area, established Operators are searching for satellites with a limited capacity and, most importantly, low cost. Furthermore, upcoming or 'want to be' operators are also looking for small, low-cost satellites to facilitate their entry into the market.

The availability of platforms able to cover this need for limited-capacity satellites also has a strategic importance in as much as it permits the deployment of services or systems tailored to specific institutional requirements.

Currently, the GEO small-satellite market is almost exclusively covered by US suppliers (Boeing, Orbital) and by the emergence of new products from countries such as Russia, China, India and Israel. Several companies in Europe have undertaken developments that, with the necessary adaptation, could be considered precursors of such products.

Content

The Executive has been approached by several commercial entities to support the development of missions based on a small satellite, which indicates a real interest in such products. The missions range from in-orbit servicing of geostationary satellites, to multimedia systems, to the development of small platforms for the commercial market.

The Executive will continue to support these initiatives by assisting interested parties in developing and implementing both the satellites and the end-to-end systems. It will also investigate the need and requirements for small satellites for such potential market niches and for technology-demonstration purposes.

The initiation of a programme to develop such a platform will require considerable resources, which can only be envisaged if a clear support is expressed by Industry and the funding authorities. The development of a full mission associated with the qualification flight of the small platfom is also foreseen. It is envisaged that the implementation of such a small-satellite mission may require partnership with a satellite Operator or the Institutional User of the resulting system.

It is therefore proposed to open the programmatic framework for the implementation of a Small Geostationary Telecommunication Satellites initiative by the creation of a dedicated ARTES Programme Element. The scope and format of this initiative is expected to cover platform definition, pre-development, platform implementation including the associated satellite control centre, mission implementation including the associated ground segment, and launch and operation of the resulting system.

4

Implementation

The implementation of the various activities proposed benefits from the ARTES programmatic framework. Through its Elements 1, 3, 4 and 5, the adoption of yearly work plans, and its specific industrial-policy procedures, ARTES is well-adapted to the implementation of the various activities in a 'pay as you go' mode, and may easily be reoriented to cope with the evolution in needs or rapid changes in environment. The implementation of the activities described above will therefore exploit those 'traditional' elements according to their specific characteristics described in the ARTES Declaration and Implementing Rules.

In particular, commercially oriented developments will be framed within the ARTES-3 and ARTES-4 Programme Elements, giving a clear role to Industry in the initiation and co-funding of the activities, whereas the long-term technology and preparatory and support activities will be largely supported by ARTES-1 and 5. This traditional framework is also well-suited to Piggyback missions, as demonstrated with Skyplex and AmerHis.

For specific cases reaching critical mass and requiring dedicated management or a specific set of implementing rules, the creation of a new ARTES element may be necessary, as has been successfully demonstrated with ARTES-8. The ARTES Declaration already foresees implementation the AlphaSat mission in the framework of ARTES-8.

A dedicated framework will also be necessary for the implementation of large-scale projects in the field of applications and small-satellite missions. For those activities in particular, if a concrete partnership with a third party (institutional or private) does indeed materialise, a dedicated ARTES programme element will be created to reflect the specific interest of this partner and to address specific issues such as co-funding, security, etc. For funding purposes, an ARTES-11 Element has been included to take into account the small-satellite initiative if it materialises.

According to the ARTES Programme Declaration:

"ARTES is a continuous programme, carried out in successive periods. Each programmatic period will have an autonomous firm financial envelope, subscribed by Participating States, covering commitments to be taken during this period. Subscription by a Participating State to a given period shall not bind that State to subscribe to any following period".

This programmatic structure has resulted in a very complex financial management situation for Elements 1, 3, 4 and 5 (ARTES-8 being of a specific nature):

- Period 1 runs from 1993 until 2005 and Period 2 from 2002 until 2006, with an overlap of 4 years.

- Subscription to Period 1 was secured in phases for the different Elements, resulting in 9 envelopes and corresponding budgetary outputs under different economic conditions.

- Subscription to Period 2 added one envelope per Element, running in parallel with those of Period 1, resulting in a total of 13 budgetary outputs.

The Executive considers that the running in parallel of several financial envelopes associated with independent budgetary outputs for the same Element creates an unnecessarily heavy management task. The Programme Declaration allows the transfer of unused funds in one phase to the following one. This has already been done once for ARTES-5 and has been requested for ARTES-3, but it is not sufficient.

It is therefore proposed for ARTES Elements 1, 3, 4 and 5:

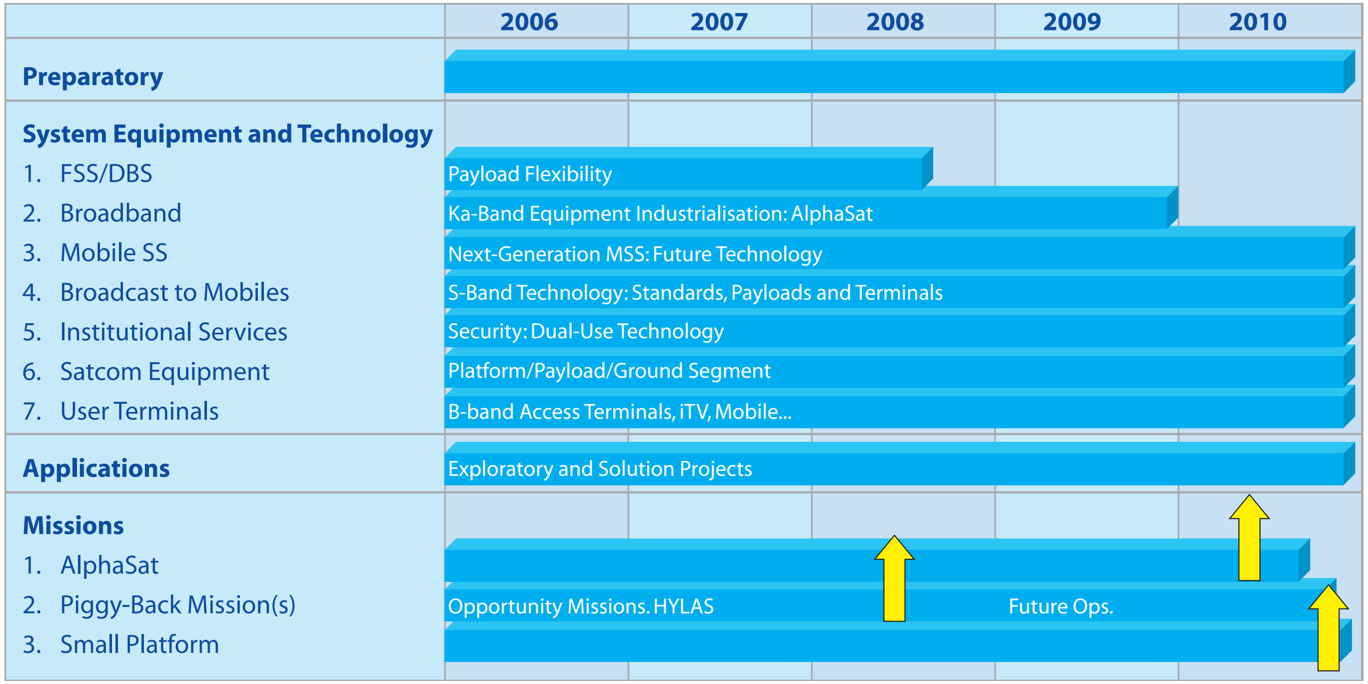
- To transfer the remaining funds from Period 1 to the Period 2 envelopes.

- To extend the ongoing Period 2 for 5 years up to 2010 by increasing the financial envelopes of the corresponding Elements at the Ministerial Council on the basis of this TLTP proposal, thereby ensuring continuity with the current LTP covering the period 2002-2006.

The Declaration will be prepared accordingly, it being understood that the Participating States will have "two years prior to the limit of the Programme (namely 2008 for the requested extension up to 2010) to decide upon the duration and conditions of the Programme for a further extension", and that "subscription by a Participating State to a given extension shall not bind that State to subscribe to any following extension".

The goal of the proposed mechanism is to have only one budgetary output per Element.

5



Schedule for the implementation of the TLTP 2006-2010

Schedule and Financial Perspectives

The financial perspective, as recapitulated in the accompanying table, is founded on the following hypotheses:

- Overall Level of Expenditure: Given a stabilisation of the ESA resources as confirmed by the majority of Delegations, the TLTP foresees in coherence with the overall ESA LTP a substantial increase in Member State expenditures for satcom activities. This increase responds to the intention of the Director General to focus ESA's efforts on the applications of space. It also constitutes an industrial-policy measure at a very difficult moment for the European Satellite Industry, thereby supporting this crucial asset in order to maintain a sound and competitive technical and industrial base in Europe.

- Balance of Activities: The financial proposal reflects a continuity in the effort allocated to preparatory technology and system activities at close to the current level of expenditure, and the implementation of complementary focused federating projects as already initiated with the full deployment of AlphaBus.

- The initiation of large-scale application development will be based on partnerships with Third Parties, thereby complementing ESA's own resources.

Table 3 summarises the TLTP financial requirements in terms of Commitment Appropriations (CA). The total amount needed is 1135 MEuro at 2006 economic conditions.

Table 4 gives the associated payment plan, showing presently approved funding still to be spent and the additional amounts required.

TLTP Components/ ARTES Element	A1	A3	A4	A5	A8	A11	Total
Preparatory	50						50
Systems + Equipment + Technology		175	200	150			525
Applications		30	20	50			100
Large Mission					300		300
Piggy-back Mission		30	30				60
Small Satellites						100	100
Total, MEuros	**50**	**235**	**250**	**200**	**300**	**100**	**1135**

Table 3. TLTP financial requirements

Programme	2006	2007	2008	2009	2010	2011	2012	2013	Total
Artemis Operations	3.1								3.1
ARTES-1	11.8	8.3							
ARTES-3	73.7	62.1	29.7						165.5
ARTES-4	37.9	36.4	10.9						85.2
ARTES-5	32.3	25.6	5.3						63.2
ARTES-8	63.3	68.3	23.4						155.0
Total Approved Programmes	**222.1**	**200.7**	**69.3**						**492.1**
Extension ARTES 2006-2010:									
ARTES-1		2.0	10.0	10.0	10.0	10.0	8.0		50.0
ARTES-3	2.0	7.0	25.0	40.0	55.0	70.0	36.0		235.0
ARTES-4	5.0	8.0	20.0	47.0	60.0	70.0	40.0		250.0
ARTES-5		5.0	35.0	40.0	40.0	60.0	20.0		200.0
ARTES-8	5.0	10.0	20.0	40.0	80.0	75.0	70.0		300.0
ARTES-11	2.0	5.0	20.0	25.0	28.9	19.1			100.0
Total To be Approved Next MC	**14.0**	**37.0**	**130.0**	**202.0**	**273.9**	**304.1**	**174.0**		**1,135.0**
Total Telecom ESA	**236.1**	**237.7**	**199.3**	**202.0**	**273.9**	**304.1**	**174.0**		**1,627.1**
EC Contributions		**20.0**	**40.0**	**45.0**	**50.0**	**50.0**	**50.0**		**255.0**
Total Telecom ESA + EC	**236.1**	**257.7**	**239.3**	**247.0**	**323.9**	**354.1**	**224.0**		**1,882.1**

Table 4. Payment plan for the TLTP (2006 e.c.)