The Integral Satcom Initiative

ISI Strategic Research Agenda

Version 1.1

31 January 2006

DOCUMENT HISTORY:

The first complete version of the ISI Strategic Research Agenda was issued on 19 December 2005 to all ISI members.

This Version 1.1 takes account of comments made by:

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1. INTRODUCTION

1.1 The ISI Technology Platform brings together for the first time in a unified, industry-led forum all research and technology aspects related to satellite communications, including **mobile**, **broadband**, and **broadcasting** applications. The purpose is to foster and develop the entire industrial sector, maximise the value of European research and technology development, and contribute to EU and ESA policies.

1.2 ISI is an open platform, whose membership embraces all relevant and interested private and public stakeholders. ISI will collaborate and cooperate with the European Commission, the European Space Agency (ESA), the EU and ESA Member States and Associated States, the National Space Agencies, International Organizations, User fora, and other European Technology Platforms. ISI fosters international cooperation under a global perspective.

1.3 This document specifies the Strategic Research Agenda of the ISI Technology Platform. It addresses the overall development of satellite communications and satellite broadcasting in Europe over the next 20 years. In doing so, it shows that satellite communications and broadcasting has strategic relevance for Europe, and identifies medium and long term strategic objectives.

1.4 At the end of the Document the **ISI Vision Statement** is included as Annex A. This concise description of the ISI scope and purposes has been signed by highest-level representatives of all ISI participating entities. Also available is the **ISI Strategic Vision Document.** This specifies in much greater detail the context, vision and ambitions of ISI: it sets the scene for this Strategic Research Agenda.

1.5 ISI's **System Concepts** and **Priorities:** the Strategic Research Agenda for ISI is built upon understanding future user needs and necessities and how these are going to be satisfied by satellite communication systems. In practical terms, a classification of satcom users into five macro-categories has been adopted:

1. Citizens and Governments: the **CG** institutional market
2. Individual users and families in their Homes: the **IH** market
3. Individual users on the Move: the **IM** market
4. User Groups in villages and Remote areas: the **UGR** market
5. User Groups on the Move: the **UGM** market

For each of the above categories, ISI has defined some simplified **system concepts** which incorporate the specific R&D priorities outlined in this document:

CG market: the ISI system concept includes a European civil security system for public protection, emergency and disaster relief, with services for citizens and governments, integrated with GMES and Galileo, as well as High Altitude Platforms.

IH market: the ISI system concept includes high capacity direct-to-home satellite broadcasting systems for HDTV and 3DTV, as well as IPTV development.

IM market: the ISI system concept includes mobile broadcasting and datacasting systems, the 4G satellite component (complementary to terrestrial 4G), and systems for info-mobility integrated with Galileo and GMES.

UGR market: the ISI system concept includes direct broadband access provision for bridging the digital divide, and interworking with several terrestrial wireless access systems for seamless and dependable broadband connectivity

UGM market: the ISI system concept includes mobile broadband interconnections for the aeronautical, maritime, railway, and vehicular user platforms, integrated with Galileo, GMES, and Air Traffic Management systems.

2. EXECUTIVE SUMMARY

2.1 The role of satcom today

Satellites provide both direct access to, and the foundations of European and worldwide digital information networks. Satellites provide the platform for Direct-to-Home analogue and digital TV, as well as interactive and subscription TV services, mobile services to ships, aircraft and land-based users, and data distribution within business networks. Satellites are also a key element in the Internet backbone, and enable both broad and narrowband Internet access services from remote and rural locations. Satellite services provide an essential component of disaster relief activities worldwide, offering reliability, instant and long-term availability, over very wide areas. In addition to civil applications, the unique coverage advantages of satellite systems position them as key players for risk and crisis management for institutional, government and defence applications.

2.2 Future development of satcom services

Satellite services need continuous development to provide more power and bandwidth in space, in order to enable cheaper, smaller user terminals, as well as lower utilisation costs, and enhanced, higher data rate services. Unlike terrestrial networks - where extra capacity can be installed incrementally, following market demand - satellites have to be ordered far in advance of the market if they are to be deployed on time for new services. Moreover, new technology components have to be tested in real conditions before being adopted in operational satellite systems. Thus up-front R&D (including protoflights) must be included in any R&D plan if Europe wants to keep its leading position in an increasingly competitive international environment. Furthermore, continuous innovation will be necessary to ensure that the limited spectrum allocated to satellites is used effectively and efficiently. Increased flexibility is also required, so that satellite systems can support evolution of traffic types, and of satellite users' behaviour and geographical distribution. Future satellite platforms will need to be flexible enough to support an evolving range and mix of traffic types, targeting a wide range of applications and allowing reconfigurations to follow service demand and user behaviour, both in nature and in coverage.

There will be emphasis on developing solutions that ease the integration between satellite communications systems and terrestrial systems, thus making it far more appealing and ubiquitous for the user. This will necessitate the design and validation of fully open network architectures. Hybrid networks, in which satellite complements terrestrial technologies rather than competing with them, must be developed. Satellite can then be seamlessly integrated into hybrid systems, and its contribution will evolve in line with the progress of technology during the lifetime of the satellite. Ultimately, satellite should have the capability to serve as a universal overlay of any terrestrial network, fixed or mobile, as well as being able to deliver service where satellite has clear advantages (e.g. in remote and rural areas).

2.3 Convergence

Various convergence trends are developing that satellite communication has to follow in order to develop its proper place in telecom applications. Among them are:

- **a)** Convergence allows multiple services transported over IP to be offered on the same networks: triple play (TV, Internet, voice) on fixed networks and quadruple play which in addition allows switching between fixed and mobile telecom networks depending on the user location: outside versus at home or in office. In hybrid networks satellites shall offer the same types of convergence in order to be seamlessly integrated with terrestrial infrastructures.
- **b)** Broadcast and multicast services are evolving with the introduction of new formats and new ways of service consumption: HDTV, UHDV, 3DTV, Local programming, PVR (Personal Video Recorder), Pay per View, interactive TV, etc. Satellite telecom systems must evolve to support these new types of services.
- **c)** Telecom networks are becoming heterogeneous. Connections to the same services are available from a variety of networks wired or radio based. Satellite shall position itself as a piece of these heterogeneous global networks.
- **d)** Telecom networks are connected to networks in the home, facilitating access to the full range of services.

2.4 The ISI Strategic Research Agenda

The overall vision of ISI is to ensure that the satellite communication sector builds on the successes already achieved, and makes a major contribution to delivering the full range of advanced digital services to European users, wherever they are, whatever they are doing. The ISI Strategic Research Agenda focuses initially on the three fundamental areas of satellite communication: broadband, broadcast, and mobile. Each of these sectors has a dedicated section in this document. The increasing pace of convergence means that there are overlaps between these three sectors, and the boundaries are becoming ever more blurred. However distinguishing between them remains a valid and productive approach, not least because the respective user communities each have very specific, differing requirements and priorities.

In addition ISI is keen to demonstrate the valuable role of satellite communications as an enabling and value-adding technology, when complementing terrestrial networks, and when augmenting other related technologies such as navigation and earth observation. Further, the opportunities for dual use, civil/military solutions will increase dramatically over the next 20 years. Thus this document contains a dedicated section on each of these issues also.

A fundamental consideration underlying the ISI Strategic Research Agenda is that of long lead times, and the consequent need for early, anticipatory technology development. The development of satellite systems and services is a long-term process. From the creation of an initial satcom concept to the start of in-orbit satellite operation can take as much as 10 years, and a minimum of 4 to 5 years. Because of the lead-times, the need to achieve up to 15 years of consistent in-orbit operations without any maintenance, and the significant inherent technical and commercial risks, strong and thorough initial specification and R&D work are the vital pre-requisites of any successful satellite system.

A further under-pinning theme of this Strategic Research Agenda is to pioneer new applications which integrate satellite communications and broadcasting with other satellite techniques involving security, environmental monitoring, disaster and emergency relief, navigation/positioning, ad-hoc networking and air traffic control/air traffic management systems.

Taken together, Sections 3 to 8 of this Strategic Research Agenda offer a comprehensive assessment of the research needs and priorities of the satellite communications industry over the next 20 years. The material here is not just applicable within Europe, it has validity worldwide.

2.5 Key Research Themes of ISI

The key research themes of ISI are summarised in the 4 sub-paragraphs below.

2.5.1 Research Themes across all satcom services and applications:

a) **Spectrum availability with efficient spectrum use:** Ensuring that sufficient spectrum is available, that existing allocations are justified and protected, and that spectrum is allocated in the right bands (e.g. to permit interworking with terrestrial services). Developing techniques and system designs that improve radio transmission efficiency and spectrum utilisation (e.g. narrower spot beams, multi-user detection, robust and efficient video/audio compression technologies, innovative spectrum sharing technologies), to maximise the exploitation of the available spectrum. Avoiding interference, whether caused by or caused to satellite services.

b) **Higher frequency bands:** Investigating and proving technologies, covering both satellite payload and ground segment, for the utilisation of Ka-band (20/30 GHz) for integrated broadcast, broadband and mobile satellite services, and the utilisation of the 40/50 GHz frequency band for broadband satellite services, with particular emphasis on low-cost satellite access terminals.

c) **Flexible satellite missions:** Evolving satellite communications system architectures with flexibility to support a wide range of services. Developing satellite payload technologies and spacecraft platforms, including on-board processing and software radio techniques, which offer high degrees of flexibility to allow satellite mission adaptation to evolving requirements (e.g. coverage evolution, traffic distribution change, connectivity modification over the coverage).

d) **New satellite technologies, lower costs, faster deployment:** Designing satellite payload technologies and spacecraft platform technologies that lead to lower costs associated with building and launching satellites. Conceiving smaller, cheaper satellites, delivered more quickly, enabling the deployment of constellations, clusters and multi-mission systems, using hybrid orbits. Defining all-IP networks in the sky and associated technologies.

e) **Interworking with terrestrial networks:** Delivering full, seamless integration of satellite services with global (terrestrial) telecommunications infrastructures. Developing radio, access and networking techniques that allow satellite systems to play a role in access network, to provide overlay and connectivity services for ad-hoc networks, and to offer backbone connectivity between terrestrial systems. Defining the satellite component of systems beyond 3G, and 4G. Integrating satellite technologies into systems beyond 3G, and 4G, in close co-operation with network operators.

f) **Urban and in-building coverage:** Specifying high power satellites, in various constellations, capable of providing coverage in buildings and urban areas without gap-fillers. Working on auxiliary terrestrial components and terrestrial repeaters (particularly in urban areas) to improve coverage and enable new applications for both urban and rural areas. Researching gap-fillers relying on HAPs/Unmanned Aerial Vehicles.

g) **Dual use:** Developing ground and space technologies to allow satellite systems to play a role in future security oriented applications (civil security or military) and allow for the development of dual use of satellite capacity. Focusing on social and civilian defence as opposed to conventional military defence: for the ISI case, defence is understood as civilian defence from a military/civilian threat/risk. Exploiting the potential of advanced commercial technologies to meet governmental needs. Integrating commercial and governmental production to enable industry to "dual produce". Inserting commercial products, processes, and technologies into defence systems, wherever possible. Working in key areas such as secure communications and connectivity, resistance to jamming, and hardened systems

h) **Interworking with Galileo and GMES:** Achieving and demonstrating successful inter-working with other (non communications) systems, networks and technologies, notably Galileo and GMES. Demonstrating satellite communications as essential complementary elements to exploit Navigation and Earth Observation systems to their fullest, and providing integrated applications fully meeting user demands.

i) **High performance with low cost:** Finding high-performance and low-cost solutions in order to provide services with reasonable costs for the end user. Investigating relevant aspects such as:
   - Cost and performance of antennas; new antenna technologies.
   - Optimal use of transponder bandwidth.
   - Techniques to limit the transmission power hence the cost of small terminals.
   - Flexible QoS strategies at access and IP layer.
   - Active management of services to optimise bandwidth usage.

j) **Open standards:** Participating fully in relevant standardisation activities, adopting terrestrial standards where appropriate, and co-operating with terrestrial system operators on standards. Facilitating hybrid systems development by studying adaptation of terrestrial standards to satellite, as well as ensuring that new terrestrial standards incorporate a satellite dimension when necessary.

k) Regulation: Facilitating the removal of regulatory barriers to enable the commercial success of satcom projects. Contributing to the harmonisation of policy and procedures relating to frequency use and authorizations of satellite networks. Promoting technical solutions which assist in the liberalisation of regulatory and licensing conditions. Initiating the necessary work relevant to regulation early enough to ensure that the satellite contribution to new systems and services is recognised and integrated (e.g notably in the process of next generation terrestrial mobile systems (4G)).

2.5.2 Research Themes of particular relevance for Broadband applications and services:

a) Providing high capacities at reasonable cost to facilitate broadband offerings, fixed and mobile.

b) Designing flexible devices, applications and services that will provide partial, complementary or full interoperability with existing and future fixed and mobile wireless broadband terrestrial networks. Supporting the convergence of satellite and terrestrial networks assuring secure connectivity and end-to-end protected communication.

c) Developing mobile broadband access with service characteristics which match as closely as possible those of terrestrial systems. Designing broadband MSS solutions for mobile collective terminals in aeronautical, maritime, vehicular and railway domains, and broadcast systems supporting terrestrial mobility and vehicular/handheld reception.

d) Exploiting satellite communications capabilities to the maximum to provide universal coverage, by extending terrestrial broadband network infrastructures in sub-urban and business installations deployed in remote areas, which are equipped with broadband premises radio networks (e.g. WiFi/WiMax, UWB) but which lack connectivity to remote installations or terrestrial backbones. Embedding satellite solutions ubiquitously with other terrestrial technologies.

2.5.3 Research Themes of particular relevance for Broadcast applications and services:

a) Progressing the implementation of commercial HDTV broadcasting by making use of the evolution of compression technologies and the success of the home video. Developing all elements of the audio-visual delivery chain to ensure the technical and commercial success of HDTV in Europe, with satellite as the platform of choice.

b) Pursuing the availability of low-cost, user-friendly and programmable HDTV set-top-boxes; developing appropriate content offers, and designing an efficient network for content provision and delivery.

c) Demonstrating that direct satellite broadcasting represents a credible alternative to a purely terrestrial solution based on DVB-H for Mobile TV. In parallel, working on integration with terrestrial mobile digital systems (DVB-H, etc.).

d) Expanding the range and capabilities of Interactive TV services by building on the evolution from linear television (live streaming) towards non-linear television (on-demand, PVR, etc.) as well as the development of interactive valued-added services centred around audio-visual services.

e) Taking forward the new opportunities presented by IP Broadcasting technology. Applications will include:
   - Business TV, Point of sales TV, and other applications which rely on the simultaneous delivery of packaged content to numerous reception points where it will be played. The combination of the unique multicast ability of satellite and IP technologies inherited from the Internet will provide the optimal solution to deliver large quantities of content at fixed cost and optimised transfer time.
   - Live transmission using high compression standards such as H.264 that will allow near broadcast quality over a very narrow (thus cost contained) bandwidth (thus promoting the emergence of more and more MicroTV channels).

f) Exploiting the rapid take-up of digital services, PVRs, HD-ready sets, broadband access and new generation mobile devices, to lead broadcasting into a new era that spans broadcasting, telecommunications and IT sectors.

2.5.4 Research Themes of particular relevance for Mobile applications and services:

a) Developing multi-band MSS, incorporating on-the-move (e.g. L/S band technology) and transportable solutions and collective terminals (e.g. Ku/Ka band technology) sharing same infrastructure.

b) Designing reconfigurable low cost user terminals capable of working seamlessly between satellite and terrestrial systems.

c) Integrating satellite technologies into long-term (2020+) solutions for ATM/ATC systems.

d) Working on efficient broadcasting and multicasting technologies to develop MSS into mass markets, through the delivery of land-mobile broadcast and multicast services.

e) Researching satellite extensions for ad-hoc radios deployed in emergency events (e.g. Tetra 1 and 2, WLAN, WiFi) connecting field-workers with remote coordination centres database sites, etc.. Considerations will include the safety needs of on-field personnel in the front line, real time system reconfigurability to track on-field personnel, and the integration of communication and localisation systems for indoor and outdoor needs.

The following sections of this document elaborate in detail the research challenges which ISI will confront in addressing the themes and objectives listed above.

3. KEY STRATEGIC RESEARCH OBJECTIVES FOR SATELLITE BROADBAND

3.1 BACKGROUND

There has been a significant emphasis on developing satellite communications supporting broadband access and broadband related services and applications. A tremendous technology development has taken place, resulting in several satellite broadband systems based both on open and industry proprietary standards for satellite access terminals. There is clear and common understanding among the industry and operators that satellite broadband systems will be a natural part of the global telecommunications networks, where satellites serve both access networks and backbone networks. Hence, there will be a continuous evolution of satellite broadband in the sense that existing systems will emerge, and new systems will arise. Compared to the traditional broadcast satellite services and mobile satellite services, broadband satellite services still represent a fairly new area within the satellite business. Different from satellite broadcast and satellite mobile, satellite broadband systems must be implemented with significantly higher capacities in order to support the services and applications usually associated with broadband networks in the future. High capacity is also an important clue with regards to service cost levels offered to the customers. However, for satellite broadband to be an interesting solution for the customers, the cost and capacity offered must not fall too far behind that offered by terrestrial systems. Based on this consideration, the satellite broadband industry should aim for a reduction of the transportation costs per bit by a factor in the order of 5 to 10 during the next 5 years.

A significant part of the focus on satellite broadband has been devoted to access networks. However, provision of global wireless connectivity must pass through backbone systems, where both satellites and fibre are key technologies. Satellite backbone networks will be complementary solutions to fibre networks, particularly in geographical areas with poor or no deployed fibre networks, and when it is not beneficial to roll out fibre networks from a cost point of view. In order to achieve such an objective, the capacity of satellite links should be significantly increased.

Significantly high capacities in satellite broadband networks can be achieved in several ways. One approach is utilising frequency bands like Ka-band (20-30 GHz), V-band (40-75 GHz) and W-band (80-110 GHz), where the frequency spectrum that can be allocated to satellite broadband is high. By utilising multiple spot beam satellite designs, the overall capacity that the satellite can provide can be significantly increased through frequency re-use. Furthermore, high capacity satellite links can be achieved by taking in mind the new perspective of regenerative and self-configuring satellite networks. Moreover, advanced adaptive coding and modulation techniques, capable of offering improved power/spectral efficiencies with respect to more traditional signalling formats on the direct link, should be utilised in satellite backbone networks.

Convergence of broadband technologies and techniques is a key driver into the establishment of a common framework for the integration of broadband terrestrial and satellite communications systems and networks. Common grounds must be reached in several ambivalent areas and conflicting points from both terrestrial broadband wireless access community and satellite society. It is therefore essential to put the research and development focus in the definition of a common air interface, simple network interconnectivity and an efficient spectrum distribution among terrestrial and satellite networks. Removing technological barriers to satellite and earthly broadband systems is the principal action point of the ISI that will result to the development and validation of successful future broadband infrastructures.

In the following sections the strategic research elements considered as important to the future evolution of broadband satellite communications are addressed.

3.2 STRATEGIC RESEARCH ELEMENTS

The collection of strategic research elements is partitioned in four groups, which are system aspects, space segment aspects, ground segment aspects, and applications and services.

3.2.1 System and Network Aspects

It is of major importance that the strategic research elements for broadband satellite services have focus on system solution and technologies that lead to satellite broadband systems with very high capacities, and technologies that enhance the utilisation of satellite links.

The strategic research elements related to satellite broadband systems and network aspects are listed below.

- **a)** Explore new satellite system concepts utilising multiple beam satellites featuring sophisticated onboard processing and switching facilitating Quality of Service.
- **b)** Investigate radio resource management and scheduling algorithms with cross layer information coming from adaptive physical layer and QoS requirements from upper layers, to achieve optimum performance of mobile broadband multimedia satellite (MBMS) services.
- **c)** Investigate transport layer protocols (SCTP, TCP …) for suitability and optimal operation in broadband satellite systems.
- **d)** Investigate new bandwidth/spectrum efficient transmission schemes, featuring adaptive coding and modulation.
- **e)** Explore system design and modelling of the mobile satellite channels for the specific broadband applications.
- **f)** Explore new access scheme making possible meshed satellite system topologies, allowing efficient terminal-to-terminal communications.
- **g)** (covered in l) below)
- **h)** Elaborate a reconfigurable physical layer and radio platforms capable for multi-band and multi-user operation, by using for example mobile agents and/or mobile codes.
- **i)** Investigate mesh inter-satellite connectivity with advanced radio resource management algorithms to achieve a flexible satellite overlay network.
- **j)** Data Coding in Transport Layer, utilising erasure codes to ease the design of flow and congestion control mechanisms, particularly for one-to-one data delivery.
- **k)** Investigate utilisation of Ka-band (20-30 GHz), V-band (40-75 GHz) and W-band (80-110 GHz). Critical aspects concerning channel propagation and physical layer design should be properly studied and suggested for standardisation.
- **l)** (moved to e) above)
- **m)** Follow the general trend in telecommunications, explore and develop satellite access schemes tailored for carrying IP traffic with provision of mechanisms for adherence to QoS frameworks adopted in terrestrial networks.
- **n)** Mobile Satellite Services (MSS) are today usually provided at L-band (1.5/1.6 GHz).

However, further growth of future MSS requires systems operating at higher frequency bands like Ku-band (11/14 GHz) and Ka-band (20/30 GHz). This expansion of MSS must have a long-term perspective, since it requires that both regulatory issues and sever technological challenges being resolved. In order to bridge the gap between MSS systems operating at L-band today and future MSS systems operating at higher frequency bands, there will be significant need for hybrid L-band/Ku-band systems. As a shorter-term issue, some research effort will be put into analysing different hybrid system concepts utilising L-band, Ku-band and Ka-band for MSS, emphasising communication system architectures as well as end-user equipment solutions. This research should be performed in conjunction with research on the future MSS systems operating on higher frequencies only.

o) Channel Adaptive Transmission Techniques (CATT) represent a solution for communications on channels with highly varying channel characteristics, and will gain increasing importance also in future satellite communications systems. Adaptive Coding and Modulation (ACM) have recently been introduced in several contexts. ACM assumes shortage on power resources, rather than frequency spectrum, and is most adequate for satellite systems operating at frequency bands like Ku-band and Ka-band where frequency spectrum is a less critical resource. For mobile satellite services in L-band, both power and frequency spectrum are restricted and very critical resources, and it is questionable whether ACM will be an adequate solution. Furthermore, mobile satellite channel characteristics change rapidly, especially in maritime environments at low elevation angles, but also on land-mobile environments where the communications signals are subject to blockage, shadowing and multi-path transmissions. ACM has been introduced associated with fixed satellite services and broadcast satellite services, where the user equipment is fixed installations, and the channel characteristics are relatively slowly varying. As a consequence, the utilization of ACM on satellite mobile channels should be analysed, along with a significant emphasise on investigating alternative channel adaptive transmission techniques.

p) Investigate new multiplexing schemes that allow efficient use of multicast to significantly improve the spectrum efficiency of satellite broadband systems. This topic spans from technological development and regulatory initiatives to allow the use of wider channels to developing stream formats that allow simple extraction of IP packets on the customer side.

q) Interworking between satellite broadband networks and terrestrial wireless access networks (e.g. WiMAX networks). Hybrid satellite/terrestrial wireless access represents an interesting solution for providing broadband to fixed, nomadic and mobile users in a cost efficient way. Such solutions can be the best alternative in rural and remote areas and can be a competitor to xDSL-based solutions in more densely populated areas.

r) Investigate utilisation of *spatial diversity* in order to meet strict power and spectral efficiency requirements, with particular focus on *satellite diversity*, so that mobile terminals can rely on multiple replicas of the transmitted signals, originating from different satellites inside the user field of view. Solutions that provide diversity gain utilising both macro-diversity and micro diversity should be considered.

s) Study integration of traditional satellite systems with relays provided by LEO and HAPs/Unmanned Aerial Vehicle systems that also act as proxies.

t) New interference cancellation and precoding schemes for multibeam satellites using DVB-RCS and DVB-S2. Interbeam interference is a limiting factor of the frequency reuse in multibeam satellites. Such techniques will allow a more efficient spectrum usage by reducing the frequency reuse pattern and allowing the use of transmission modes with higher spectral efficiency.

3.2.2 Space Segment Aspects

One of the key elements in making broadband satellite services successful commercially is significantly lower space segment costs relative to what is available today (2005). The overall capacity per satellite has to be significantly increased, and the space segment related research elements should have significant emphasis on technologies facilitating this. Exploration of satellite communication payload technologies utilising Ka-band (20-30 GHz), V-band (40-75 GHz) and W-band (80-110 GHz) is another important area for future research. The emphasis should be on new payload technologies leading to reduced payload mass and volume, hence reducing the overall spacecraft and launch costs.

The space segment related strategic research areas are listed below.

a) Explore satellite communication payload technologies for operations on Ka-band (20-30 GHz), V-band (40-75 GHz) and W-band (80-110 GHz), covering:
  - **i)** Travelling wave tube amplifier technologies ;
  - **ii)** Solid state power amplifier designs;
  - **iii)** Antenna and RF front end designs (antenna feeds, multi-feed structures, low-noise amplifiers, down and up converters);
  - **iv)** Channel filters, and channel filter structures (IMUX, OMUX).

b) Develop techniques for linearization of satellite transponders operating close to saturation in order to support transmissions of amplitude modulated satellite signals.

c) Multiple spot beam antenna systems, utilising sophisticated beam-forming techniques, also featuring beam-hopping capabilities, in order to realise massive frequency reuse.

d) Explore regenerative satellite communications payloads featuring sophisticated onboard processing and switching, also facilitating QoS.

e) Develop new solar panel and battery technologies, hence producing more power necessary to increase that satellite payload capacity.

f) Develop thermal structures capable of handling higher power dissipations onboard the satellite.

g) Promote research on common network management protocols that will allow seamless integration of broadband satellite with other access network technologies (e.g. ADSL).

3.2.3 Ground Segment Aspects

The ground segment typically includes both satellite access terminals and gateway stations, where the gateway stations also may include network control centres. It is an indisputable clue that focus has to be on research addressing increased performance, high reliability, low costs, flexible, low-cost and easy-to-use satellite access terminals, and gateway stations capable of handling a very large number of users (100000+).

The strategic research elements related to the ground segment are listed below.

a) Explore satellite broadband access terminal designs that can rely on multiple replicas of the transmitted signals, originating from different satellites within the user field of view, in a cost-efficient manner.

b) Develop small size devices that can be integrated to existing mass-market equipments.

c) Explore satellite broadband access terminal architectures, including Software Defined Radio concepts, featuring:
   i) Efficient processing architectures that provide flexible and scalable modules, with enough processing power and inter communications means;
   ii) Efficient SW/HW partition to allow the support of multiple physical layers, as for example, support a range of satellite and terrestrial physical layers;
   iii) Architecture to support efficient re-configurability capacity;
   iv) Efficient architectures that minimise power consumption;
   v) Jointly design of digital and RF analogue modules;

d) Develop advanced antenna techniques that improve the satellite link budget and hence increase the overall capacity;

e) Use of array antennas for both transmission and reception;

f) Explore satellite broadband access terminal antenna and RF front-end technologies for operations on Ka-band (20-30 GHz), V-band (40-75 GHz) and W-band (80-110 GHz), with particular focus on low cost, multiple band operations, and easy deployment;

g) Investigate high-power amplifier designs for future satellite broadband access terminals, with particular focus on:
   i) Characterisation and modelling of transistors for high-power amplifiers with output power up to 15 Watt, operating at Ka-band (20-30 GHz), V-band (40-75 GHz) and W-band (80-110 GHz);
   ii) New power amplifier designs, facilitating high efficiency, like for example Class E, dynamic biasing, other possible schemes;
   iii) Utilising adaptive schemes and algorithms for joint linearization of transistor characteristics.

h) Explore cost-efficient satellite gateway systems capable of handling customer bases of 100,000+ users.

i) Investigate common designs and joint techniques for both satellite and terrestrial broadband devices in order to simplify the interoperability and convergence between satellite broadband networks and terrestrial broadband wireless access networks (i.e. WiMAX).

3.2.4 Applications and Services

Within the area of applications and services, the following research elements have been identified:

a) Develop new application and service areas, with associated techniques and technologies, related to multicast applications, interactive TV, broadband terrestrial wireless network hotspot uplinking/downlinking, military applications, safety and security applications.

b) Develop new techniques and technologies for reliable acquisition and distribution of information (use of retransmission techniques combined with modern Forward Error Correction (FEC) methods), integration of terrestrial repeaters.

c) Study unequal error protection schemes for minimum quality of service provisioning also in severe conditions.

d) Evaluate the possibility to implement video transcoding techniques either on board or at intermediate relays/gateways.

4. KEY STRATEGIC RESEARCH OBJECTIVES FOR SATELLITE BROADCASTING

4.1 BACKGROUND

The applications of satellites to broadcasting TV have been very favourable, leading to the fact that satellites are currently the most popular channel in the world to access digital TV, especially non-free services. Likewise, the broadcasting business is a fundamental part of the revenues of satellite platforms and one of the few satellite-related products that consumers are willing to pay for. The introduction of digital video broadcast technologies (DVB-S, DVB-S2, DBS) has led to a more efficient utilisation of satellite spectrum, meaning that many more channels and contents have become available to the consumers. Today, it is common that households have several TV sets and the customers require that the TV program can be chosen independently on the different TV sets. The current satellite broadcasting systems were designed with the single TV per customer scenario in mind, and relatively costly equipment is required on the customer side to realize the fully flexible multi TV-sets per customer scenario. Hence, this is an area were the satellite broadcasting industry must find good solutions. Furthermore, digital broadcast technology platforms enable the implementation of a new world of services accessible through TV, including interactive services. Although the interactive services offered through satellite will be similar to those of other mediums, a particular service offering approach will be necessary because of the distinctive characteristics of the satellite channel that lead to advantages as well as drawbacks. The central role of new interactive TV services must be, as always, the entertainment. However, the interactive and computational characteristics of the new receivers will permit the TV to facilitate the user's daily routines, especially regarding information exchange activities, and to fulfil a promising educational role. TV must remain one of the most important channels to access to the forthcoming Information Society as its penetration index; easiness to use and users' confidence are second to no other device. These characteristics make digital TV with interactivity an invaluable tool to reduce the digital divide, paving the way to a fully connected society.

Another important trend regarding satellite broadcasting is that a convergence between satellite broadcasting and satellite broadband services is taking place, since the boundaries between these two service categories are being blurred in the satellite broadband context. This is already the situation with regard to technology, where the technologies for satellite broadcasting are extended to cover bi-directional satellite services as well. The development of the open DVB-RCS and DVB-S2 standards has played an important role in this context, but also the vendors of proprietary satellite networks are adopting technological solutions that lean on broadcasting of information by means of multicasting and uni-casting. This trend will continue to evolve also in the future, but with extended emphasis on service architectures, where QoS, security, roaming, and integration with terrestrial telecommunications systems are crucial issues.

A third and very important trend is convergence between satellite broadcasting and mobile satellite communications. Satellite broadcasting of radio and TV to mobile users has been in operation in the US for some years, and similar services are to be introduced in Asia in 2005. The convergence between satellite broadcasting and mobile communications will take place serving maritime vessels, land-mobile vehicles and portables, and aircrafts. There are also some systems offering services combining satellite broadcasting (DVB-S) and Inmarsat

mobile communications, and combining satellite broadcasting (DVB-S) and LEO mobile satellite communications systems. Such hybrid systems will be more common in a short-term perspective, and will serve as important bridge solutions between the traditional narrow-band mobile communications of today, and the future advanced satellite mobile communications integrating broadband and broadcast satellite services.
In the following sections the strategic research elements considered as important to the future evolutions of satellite broadcasting are addressed.

4.2 STRATEGIC RESEARCH ELEMENTS

The collection of strategic research elements is partitioned in four groups, which are system aspects, space segment aspects, ground segment aspects, and applications and services.

4.2.1 System and Network Aspects

The strategic research elements related to system and network aspects are listed below:

- **a)** Quality of service mechanisms for multicast and broadcast systems.
- **b)** Efficient resource management for satellite digital multimedia broadcasting (S-DMB).
- **c)** Efficient Packet Scheduling mechanisms for QoS support in the presence of mixed traffic and fading satellite radio propagation channel.
- **d)** Cross layer design of radio resource management (RRM) techniques, with cross layer information coming from adaptive physical layer and QoS requirements from upper layers, to achieve optimum performance of mobile broadband multimedia satellite (MBMS) services.
- **e)** Feasibility study to implement an adaptation of HSDPA system in the satellite environment.
- **f)** Inter-working between Satellite and Terrestrial segments: Intersystem Handover of MBMS flows from satellite to terrestrial network and vise versa.
- **g)** Convergence of broadcast and cellular mobile networks enabling mobile broadcast service provision, with particular to pay attention to the integration of technologies like DVB-H, WiMax.
- **h)** Convergence of broadcast and mobile networks enabling mobile broadcast service provision, including convergence of satellite broadcast and satellite mobile networks, as well as terrestrial broadcast and cellular mobile networks and technologies.
- **i)** Investigate integration and inter-operability among different broadcast technologies, home networks and consumer electronics in order to get connected in-home environments that can use the information received in the broadcast signal.
- **j)** Investigate and develop new communication models among users based on broadcasting for this particular environment.
- **k)** Investigate security of networks and protection of privacy in these new heterogeneous environments.
- **l)** Investigate how the broadcasted multiplex formats can be tailored to allow cost efficient and simple distribution in peoples' homes. This includes use of multiplex methods and stream formats allowing simple extraction of single programs.
- **m)** New channel coding and modulation techniques for multi-resolution broadcasting. Such techniques allow a graceful degradation of the received signal quality when the channel conditions are adverse. Additionally, it is possible to broadcast to different types of receiving terminals (fixed terminals and mobile terminals) with different received signal quality, achieving high spectral efficiency.

4.2.2 Space Segment Aspects

The most convenient feature of satellite is their inherent capabilities for information broadcasting. Broadcast satellites typically have a few, but large beams, covering very large geographical areas. At the same time, the radiated power in the beam should be sufficiently high in order to allow small and low-cost satellite receivers.

Wide geographical beams with high radiation power will continue to be a highly desirable feature of broadcast satellites in the future. However, the new DVB-S2 standard introduces new modulation formats that lead to enhanced utilisation of the frequency spectrum allocated to broadcast satellites. This is particularly important for satellite broadcasting of HDTV, for which DVB-S2 is a powerful signal transmission technique. But, in order to benefit from the full effect of these new modulation formats, the satellites must have much higher radiated power than today. In addition, the new modulation formats require that the satellite transponders be linearised.

The strategic research elements associated with the space segment are listed below.

- **a)** Development of travelling wave tube amplifiers with powers beyond 250 W, in order to make it feasible to design broadcast satellites featuring wide beams with sufficiently high radiated power to take full advantage of the new DVB-S2 standard.
- **b)** Development of techniques for linearisation of satellite transponders operating close to saturation in order to support transmissions of amplitude modulated satellite signals.
- **c)** Development of new solar panel and battery technologies, capable of producing more power necessary to increase that satellite payload capacity.
- **d)** Development of thermal structures capable of handling higher power dissipations onboard the satellite.
- **e)** Development of new payload technologies leading to reduced payload mass and volume, hence reducing the overall spacecraft and launch costs.
- **f)** Consolidation of available research findings and critical comparison of alternatives for satellite constellations, elliptical and other non-geostationary orbits being within the scope of this comparison.

4.2.3 Ground Segment Aspects

New broadcast services will require end-user devices with features not available with the state-of-the art equipment, especially regarding user interaction capabilities because user interfaces and usability are critical factors determining the success of any service. Also, users will need to access to contents and services through more and more heterogeneous and mobile network infrastructures and from different terminal types. This complex scenario will influence on both the contents presentation and the contents and application development processes.

Related to these fields, the following research areas can be identified:

- **a)** Increase the average resources in the end-user devices to support CPU and memory intensive real-time tasks.
- **b)** Necessity of middleware standardization in user terminals, to get a horizontal market that promotes real competition. Specially, some complexity problems on current standards must be solved for their widespread adoption.
- **c)** Research on residential gateways based on OSGi framework for a broadcast environment. Residential gateways will be one of the key devices in the connected home area. They will allow convergence of applications, integration of appliances into

systems, an in-home communication infrastructure and the possibility of providing new services based on this infrastructure.

d) Development of authentication and electronic payment systems suitable for new services and its integration in the different types of user terminals.

e) Design of very simple navigation systems, able to be used by people who do not normally use explorers or other access methods, like electronic menus. These interfaces have also to provide adaptation capacity to user preferences and interests (personalization). For example, it is necessary to develop advanced EPGs with personalized search, filter and sort capabilities.

f) Enhance current user interfaces with advanced accessibility capabilities.

g) Explore context-awareness techniques to provide a flexible framework with efficient means of presenting, maintaining, sharing, protecting, reasoning and querying contents according to the device and network features and user needs. These techniques will allow making progress in the concept of access to any content, anytime and from anywhere.

4.2.4 Applications, Services and Content

For a suitable development and management of content and services, it is necessary to adapt the available technologies and tools. Whenever this is not possible, new ones should be developed. In particular, it is necessary to work on the following research areas:

a) Research and development of authoring tools for content and open services, including models which allow the aforementioned adaptation of content and services to the user context in every situation.

b) Study how Web Services technologies, automated code generation tools, XML-based data, interface and interaction description languages should be enhanced to permit integration of platforms, services, access networks and devices.

c) Design of simpler and more powerful technologies for application development and test, as well as validation of scenarios through simulations and demonstration activities.

d) Explore techniques for semi-automated composition of services, based on pre-existing sub-services. These techniques will permit, among other things, automatic on-the-fly generation of personalised services and user interfaces adapted to user needs at every moment and situation.

e) Research on content management techniques and tools, including their indexation, segmentation, storing, access and, especially, semantic processing. Also, in the field of personalization, it is necessary to improve the techniques for user and content modelling, as well as the related algorithms for matching and classifying.

f) Research on adaptive content matching to fix as well as mobile satellite broadcast and multicast system constraints. Focus areas include throughput variations in heterogeneous networks, and content matching to varying user equipment characteristics.

g) Development of a new service model for TV, allowing a dynamic configuration through contents aggregation from different platforms and sources, even in real time. Within this field, a key issue is the research on contents reuse techniques, so as a particular content may be reused in services with different objectives and destined to different user profiles. Normalization is crucial for achieving this contents reuse.

h) Research on personalization and recommendation models and techniques, because of the enormous amount of contents that will be available for users. These techniques will allow, for example, the generation of personalized Electronic Programme Guides (EPGs), the generation of ad hoc virtual channels, the contents search, the automatic recommendation of contents, products and services derived from the user's profile or from the sites recently visited. Semantic information should be considered especially interesting in order to improve these processes.

i) Design and development of new business models for proposed services together with both further work on scenarios and migration paths. Also, it is necessary to validate the scenarios through simulations and demonstration activities.

j) Exploitation of novel video source coding paradigms based on scalable and multiple description coding options to achieve a higher degree of service levels adapted to different terminals and open to transmission schemes exploiting (e.g.) unequal error protection for different parts of the flow

k) If the satellite platform is to be used to deliver TCP based services, study the effect of latency and up-downlink asymmetry.

5 KEY STRATEGIC RESEARCH OBJECTIVES FOR MOBILE SATELLITE SERVICES (MSS)

INTRODUCTION

In its extensive work on R&D issues relating to MSS, the ASMS Task Force has identified 9 Thematic Priorities (TPs) which focus on specific user application areas. They are addressed in summary form in this assessment of MSS research issues, in the following order:

5.1 Mobile Broadband access
5.2 S-DMB: Satellite-Digital Multimedia Broadcasting
5.3 2G and 3G service and coverage extension
5.4 Mobile broadcasting and multicasting
5.5 NAV-COM
5.6 Security and disaster relief
5.7 4G Evolution
5.8 Ad-hoc networks
5.9 SatCom for Air Traffic Management

Section 5.10 then summarises the key satellite technologies in MSS which require development effort. Some of these are also referred to in the earlier 9 sections.

5.1 ASMS THEMATIC PRIORITY: MOBILE BROADBAND ACCESS

The provision of broadband services to mobile users through satellite responds to the objective of being “Optimally connected Anywhere, Anytime”. The most relevant frequency bands for mobile broadband access are Ku and Ka bands. Ka band is open to mobile applications as primary allocation, and Ku band is since 2003 open to mobile applications as secondary allocation. The typical mobile market for broadband access in these bands is composed of collective mobile terminals installed in aircraft, trains, ships, buses, and other vehicles. The question of opening and adapting standards for fixed service (e.g. DVB-RCS/DVB-S2) to cover mobile markets will be an on-going issue.

The key R&D issues in this field are:

5.1.1 Antenna design

The availability of low-cost and low-profile conformal antennas is a key enabler for the successful commercial deployment of broadband mobile services.

5.1.2 Waveform adaptation to regulatory constraints (e.g. measures to avoid interference)

The access of mobile services to Ku band is authorised under condition of not interfering with fixed services. This results in high regulatory constraints on EIRP masks that are highly dimensioning especially when combined with the use of small antennas.

5.1.3 Synchronization issues (notably in the context of DVB-RCS re-use for mobile terminals)

The access synchronisation process in DVB-RCS is realised through different complementary procedures, including the knowledge of both satellite and terminal position, but also interactive measures and signalling exchanges between gateway and terminals. Adaptation to mobile environments represents a key issue.

5.1.4 Power Control

In particular as applied to the mobile propagation channel: a critical issue because of the antenna dynamic pointing and regulatory constraints.

5.1.5 Handover and mobility management

Different handover strategies can be proposed: they represent an important study area in terms of terminal reconfiguration capabilities, decision criteria, and algorithms.

5.1.6 Fade Mitigation Techniques

Especially in Ka band, smart Fade Mitigation Techniques (FMTs) have to be introduced for mobile Ka band propagation channels. In cases where fades are due to mobility (e.g. passing obstacles), then Ku-band is also heavily affected.

5.1.7 Resource Management

The use of smart FMTs suggests the design of Resource Management (RM) strategies based on a cross-layer design. Furthermore, the mobile environment and the support of handover require the definition of very flexible RM strategies, in particular for the return link.

5.1.8 Reliability

An increased level of protection is required to guarantee reliable data transfer over mobile satellite channels, possibly limiting the impact on the DVB-S2/RCS physical layer.

5.1.9 MAC Layer Design

Investigate a new medium access layer that takes into consideration the capabilities of an advanced, flexible physical layer as well as regenerative satellite technologies. The design paradigm should follow a cross-layer perspective, and it has implications in medium access protocols and resource management.

5.2 ASMS THEMATIC PRIORITY: SATELLITE DIGITAL MULTIMEDIA BROADCASTING (S-DMB)

The S-DMB system pursues horizontal and vertical convergence between mobile, wireless, and satellite applications and technologies, for the efficient and seamless provision of multimedia interactive mobile services broadcast to handheld devices. The S-DMB overlay network is a real beyond-3G extension of terrestrial networks, whereby interworking is not only a wanted feature, but an intrinsic and unavoidable asset. The design of the S-DMB system aims at identifying a set of enhancements to 3G networks that might be easily and transparently integrated into operational networks to improve service delivery and pave the way for further technical enhancements and increased business opportunities in mobile telecommunications. Furthermore, the large umbrella cell provided by S-DMB can effectively connect the islands created over wide, local, and personal areas by terrestrial means.

The key R&D issues are:

5.2.1 Terrestrial repeater architecture and operational concepts

One of the main concerns with mobile satellite systems is their limitation of link availability in mobile environments when a blockage of the radio link is experienced. Thus gap fillers are needed to avoid link obstruction and to achieve extended coverage.

5.2.2 Satellite accommodation

The specific issues for accommodation of an S-DMB payload on a satellite are related to the need to provide high EIRP levels in S-band. Hence the points to investigate concern mainly power/dissipation and large antennas.

5.2.3 Evolution towards higher data rates

S-DMB, as currently conceived, is based on the 3GPP W-CDMA FDD waveform. In order to be able to evolve towards more efficient waveforms offering higher data rates, the following R&D issues must be tackled:

a) Selection of more efficient terrestrial waveforms;
b) Adaptation of these waveforms to the satellite environment;
c) Standardisation of the above waveforms;
d) Compatibility with 1st stage infrastructure and migration scenarios.

5.2.4 Optimised routing between satellite and terrestrial 3G network implementing Multicast/Broadcast Multimedia Services (MBMS)

The system provides a point to multi-point bearer service via satellite or terrestrial network. The choice for routing between satellite or terrestrial network is triggered by optimised routing algorithms that can be based on parameters such as localisation, audience, QOS, data size, etc..

5.2.5 Security issues

The scope of security issues includes channel security, service and content protection as well as DRM.

5.2.6 Services and applications

The success of satellites in the TV broadcast market to fixed receivers has stimulated the extension of this functionality also towards mobile receivers. As far as S-DMB is concerned, recent market studies have shown that the killer application is likely to be the mobile TV service (live TV, Video on Demand). In this framework, interactivity and the possibility to address personalized content become essential aspects, as well as compatibility with DVB-H. Alert services (e.g. Emergency notifications) for PPDR applications are also possible.

5.2.7 Data filtering/metadata

When the system is used to push contents towards the mobile terminal, an important topic is the way to decide automatically if the content is to be demodulated, decoded and finally stored on the mobile.

5.2.8 Resource management in the hybrid terrestrial/satellite network

Advanced radio resource management (RRM) techniques can provide optimum use of the scarce spectrum resource and contribute to lowering the level of electromagnetic radiation in the environment. Of particular interest is the unidirectional nature of SDMB (i.e. lack of feedback from the terminals), which poses several challenges in the design of RRM algorithms.

5.2.9 Global roaming and seamless horizontal and vertical handover

5.2.10 Terminal reconfigurability

In the context of the terrestrial/satellite integrated network, the receive chain has to be matched periodically either to the terrestrial signal or to the satellite signal. Reconfigurability is needed in order to optimize the re-use of hardware to meet the challenge of producing S-DMB enabled handheld terminals with minimal impact on size, battery consumption, and cost.

5.3 ASMS THEMATIC PRIORITY: 2G AND 3G COVERAGE AND SERVICE EXTENSION

Many ESA- and EU-funded projects have analysed and verified the possibility of extending terrestrial UMTS services to the satellite segment for most attractive applications in terms of implementation and deployment complexity, cost and user need satisfaction. Most effort focused on the definition and the design of the system architecture and on the implementation of algorithms that allow the capacity utilisation to be optimised, while serving as many additional customers as possible. This optimisation process is based on three main pillars:

a) Cost effectiveness of the services most suitable for satellite UMTS application, with respect to the terrestrial deployment.
b) The achievable QoS for best user satisfaction.
c) Access schemes, that while ensuring contiguity with the technology of the terrestrial UMTS network, provide the best approach to the satellite UMTS environment.

The key R&D issues are:

5.3.1 2G and 3G service extension

The integration of IP core network with the UMTS access network for all classes of services, and the efficient and effective management of mobility within integrated terrestrial and satellite UMTS environments are the key issues for the extension of 2 and 3G services.

The optimised management of the available network resources is the core of the integrated terrestrial and satellite system, through the so-called Intelligent Segment Selection, as part of the Connection Admission Control procedures. Besides the demonstration of the feasibility and viability of these services over the integrated T- S-UMTS network, an important goal is to lay a foundation to standards for an innovative Satellite UMTS system complementary to the integrated Terrestrial UMTS.

5.3.2 Architectures

As current interest has focused on the establishment of more flexible architectures and on multi-homing scenarios in order to fully exploit the advantages of the expected co-existence of different access technologies, new concepts have to be developed in next generation mobile networks to achieve these aims.

5.3.3 Access Network optimisation

One of the main goals of UMTS is to make possible the provision of a wide range of voice, data and multimedia services in an extremely competitive and fast-moving environment. The objectives will be to:

a) offer an increasingly wide range of ever more innovative services;
b) guarantee an integrated personalized and homogeneous environment for the user, independently of the type of terminal or network used to access the service;
c) guarantee different sets of quality of service (QoS) requirements in that environment;
d) optimise the spectrum efficiency in the air interface by means of efficient radio resource management algorithms.

5.4 ASMS THEMATIC PRIORITY: MOBILE BROADCASTING AND MULTICASTING

One of the major strengths of satellites is their inherent capability to broadcast data to large audiences. The success of satellites in the TV broadcast market to fixed receivers is still one of the most commercially successful examples of the usage of communication satellites. An extension of this approach is broadcast to mobile receivers, especially ships, aircraft, trains and cars. The latter has been realised in the U.S. by XM-Radio and Sirius with great success.

In the future, further growth in this market is expected, and the integration of a return link for the collective terminal environments, like aircraft or trains, will open the possibility to merge the broadcast aspects with individual point-to-point communication needs into a common system.

To identify the main R&D directions in this framework, we distinguish between satellite broadcasting and multicasting in mobile environments.

5.4.1 Satellite broadcasting for moving collective terminals

The type of mobility characterizing the terminal determines a specific mobile broadcast environment, which presents different needs and criticalities. Thus, there are different requirements and R&D challenges in the broadcast area to be taken into account for each identifiable environment. A concise overview of the most relevant R&D topics is as follows:

a) Aircraft

- Integration of broadcast content (e.g., films), cached internet content, multicast and streaming services to passengers, delivering at the same time also normal internet services.
- Connection capabilities of the passengers to a server, preferably without any cable infrastructure.
- Extension of the large satellite coverage to comprise also the regions near the poles.

b) Ships

- Robust installation in particular in regard to antenna technologies and steering mechanisms (e.g., usage of the same outdoor unit for TV reception and downlink data services)
- Medium to low cost equipments, to be appealing also for vessels with small crews or leisure vehicles.
- Combination with distress and safety applications. In this framework, the requirements of the Global Maritime Distress and Safety System (GMDSS) for the return link would be advantageous, especially since only a low data rate return link would be necessary in association with broadcast and multicast services.

c) **Trains**
- Robustness at the service level to tunnels, trackside infrastructure, and other obstacles.

d) **Vehicles** (cars, trucks, etc.)
- Robustness against shadowing and fading.
- Cheap installation costs, without changing the look.
- Compact, low cost terminals.
- Use of cheap in-built sensors to solve the problem of antenna pointing.
- Availability of a large variety of entertainment services, coupled with user-specific content (games, songs, clips, etc.).

5.4.2 Mobile satellite multicasting

In contrast to the large available knowledge on separate broadcast and communication infrastructures, the inclusion of integrated or heterogeneous multicast / broadcast system architecture allows the achievement of a much more powerful system, but increases the complexity and poses new challenges to the infrastructure design, especially for mobile systems. In principle four approaches can be identified in this framework:

a) **Extension of the S-UMTS system architecture** to provide integrated Multicast component, aligned with the terrestrial UMTS system architecture (the Multicast part of ESA BGAN Extension Programme is an example of this approach).
b) **Extension of satellite broadcast TV by a satellite return link in Ku/Ka band** (e.g., Mobile DVB-RCS).
c) **Combination of a satellite broadcast system and a satellite communication** system (e.g., DVB-S and Inmarsat).
d) **Combination of a satellite broadcast system and a terrestrial return link**: this is treated in more detail in the S-DMB thematic priority, but also other combinations are possible, e.g. with GSM or WCDMA, or even with WLAN stations, which are only available at certain intervals.

5.5 ASMS THEMATIC PRIORITY: NAV-COM

There exists a very broad framework of applications that need fulfilling the requirements of transport, mobility and precise location, the information contents of which is function of the user position. These are the so-called Navigation-Related Services (NRS) and Location-Based Services (LBS), depending on whether directing to a target or precisely locating objects is predominant.

The key concept of NRS and LBS NAV/COM services is the thorough integration of navigation and communication components. This can be pursued with two possible orthogonal approaches:

a) A horizontal integration, where integration is obtained at the user terminal and application level, by combining capabilities provided by independent NAV and COM entities
b) A vertical integration, where integration is obtained at system level, by defining a system architecture, which synergistically combines both capabilities at all levels: ground segment, space segment, user terminal segment, application level.

The former approach is in the current state of the art of applications that combine GPS-based navigation capability (in the near future GALILEO) with either terrestrial or satellite cellular mobile communications. A new space system is indeed required with the latter approach that combines the Signal-In-Space capability of the space navigation system with the communication capability of S-UMTS.

Possible applications include geo-referenced services capable of collecting/disseminating position data or supporting navigation decision taking and making, related to the instantaneous user position, such as an intelligent management of mobile work force, asset tracking and tracing, emergency assistance and management, m-commerce, etc.

Common denominators of all sectors in terms of NAV/COM service requirements are:
Safety and low risk; Security; Reliability/Availability; Integrity and Continuity; Efficiency, Ease of use; Cost effectiveness and transparency; Data broadcast and data collection services

In addition to the above, the key R&D issues are:

- 5.5.1 Minimum NAV/COM integrated system performance requirements
- 5.5.2 Minimum navigation system requirements
- 5.5.3 Minimum communication system requirements
- 5.5.4 NAV/COM service models
- 5.5.5 NAV/COM data packet structures.

5.6 ASMS THEMATIC PRIORITY: SECURITY/DISASTER RELIEF

In recent years, it has become evident that additional international attention needs to be placed on the importance and the need for enhanced telecommunication for public agencies and organizations dealing with law and order, safety of life and property, emergency and disaster relief. In this context, the use of a satellite overlay network allows efficient implementation of public protection and disaster relief (PPDR) applications. An example in this direction is the Emergency call application (Enhanced 112 service in Europe). The broadcasting capability of the satellite overlying network offers the possibility to exploit Location Based Broadcasting Services to implement PPDR. Thanks to the automatic collection of the user location, safety services improve their efficiency in case of disaster (e.g., earthquakes, pollution), and the citizens can be promptly informed of the guidelines to be applied. By disposing of a direct return link through the satellite, the user can communicate with the public service provider in order to notify anomalies, and report on crises. And according to his/her location, the user can benefit of the appropriate navigation information to reach safety services, even in a completely new landscape drawn due catastrophic conditions.

The key R&D topics are:

5.6.1 Emergency call management

The R&D issues related to the emergency call application are mainly linked to the terminal impact, as well as to interworking capabilities with terrestrial networks, e.g., the determination and automatic collection of the user location.

5.6.2 Population management & Localized Broadcast Services

The use of a satellite to alert the population about a risk or an impending disaster is an interesting application, the timeliness of which is testified by very recent catastrophic events, like the tsunami of December 2004 that has heavily damaged the Indian Ocean regions.

5.6.3 Satellite return link

The disposal of a direct return link (RL) through satellite is a necessary requisite for an efficient public protection and disaster relief application. The design of a satellite return link has to cope with several issues, including a clear service definition.

5.6.4 Low cost terminal impact

When considering a satellite return link, the unavoidable question is related to the terminal impact. What are the conditions to offer emergency call possibilities in outdoor line-of-sight conditions to a range of mobile satellite terminals, including handsets with no form-factor impacts and very limited price increase?

5.6.5 Incorporating mobile and nomadic distress and safety services in evolving and future mobile satellite services.

5.6.6 Provisioning of end to end secure mobile satellite services, to fulfil dual use of the system by civil and defence customers.

5.7 ASMS THEMATIC PRIORITY: 4G EVOLUTION

2G networks can be viewed as a stepping stone to 3G networks, which offer multimedia services to mobile users at transmission rates ranging from some kbps to 2 Mbps. However, new requirements for flexible network access have emerged within the telecommunications community, spurred by the vision for optimal connectivity anywhere, anytime. In this respect, 4G systems (often dubbed as beyond 3G systems) are expected to fulfil this vision, providing high bit rates at low cost. Although the term is still vague, it is safe to see 4G as a system that brings in all existing and emerging fixed and mobile networks including broadcast.

For the medium term future in terrestrial networks the emphasis will be on the exploitation of the features that 3G offers beyond those of 2G. Hence the evolution will be service dominated. In the satellite areas, GEO MSS satellites are expected to dominate but with higher power, increased numbers of beams and processed bandwidth.

In this framework, key technologies will be:

- **a)** Larger deployable reflectors up to terms of meters in diameter.
- **b)** Higher power multi-beam antennas with adaptive beam shaping via DSP.
- **c)** Scalable digital processors enabling improved connectivity.
- **d)** On board regenerative switching.
- **e)** Lighter and reduced volume components with on board wireless connections.

Looking further ahead beyond 2010 and towards 2020 to the introduction of beyond-3G (B3G) or 4G networks, this is likely to be a smoother evolution rather than the “big bang” of introducing another standard - 4G. Services for new life styles in this era have been researched by WWRF, mITF and others, and there exists a reasonable comparability to their conclusions. Technology roadmaps derived from such scenarios lead to the following key issues:

- **f)** Reconfigurable and ad-hoc networking
- **g)** Software networks and cognitive radios
- **h)** Ambience and context awareness
- **i)** Personalised, trusted and secure services
- **j)** Mixed sensor/communications networks
- **k)** More efficient radio IP stacks
- **l)** Management of complexity
- **m)** Efficiency to reduce the 'cost per bit'

Notwithstanding the outstanding features of satellite systems, some challenging issues do require special treatment so that the aforementioned advantages of satellite systems will not be negated. The following R&D topics are of utmost importance:

5.7.1 Mobile IP

Future 4G infrastructures will comprise a set of various networks using IP as a common protocol, so that users are in control because they will be able to choose every application and environment. Unfortunately, the IP addressing system makes working far from home easier said than done. Mobile IP has been proposed for mobility support in IP networks, and satellite positioning systems can contribute to the real-time location tracking and optimal route selection. In this perspective, the proposal of a efficient network architecture, as well as the development of optimal routing protocols, based on the strengths and drawbacks of Mobile IPv4 and the newer Mobile IPv6, is are deemed necessary.

5.7.2 Location management

Mobility and location management constitutes one of the most important issues of 4G networks. Terminal mobility is a must in 4G networks, so as to allow mobile users to roam among different network segments. In particular, Mobile IP is essential to perform location management procedures.

5.7.3 QoS provisioning techniques.

IntServ and DiffServ represent two well known Internet QoS provisioning paradigms. However, they are not optimized for the Mobile IP environment since they have been developed for wired networks with a fixed topology. Therefore, new strategies/schemes should be developed that will integrate these QoS technologies in the Mobile IP environment efficiently.

5.7.4 Applications and services for 4G networks

The anticipated saturation of mobile telephony demand has led to the introduction of new multimedia services in the past few years, in order to spur the demand for these mobile services in current and future wireless networks. Five categories have attracted the interest of wireless infrastructure providers, which are:

- f) the Internet
- g) location information
- h) distribution
- i) remote sensing/control
- j) settlement (mobile e-commerce)

The aim will be to establish, define, specify and validate the possible MSS services in the 4G Mobile systems, including multimedia services, and direct to mobile broadcast and multicast services. This last kind of service is better know as Mobile TV, and satellite based Mobile TV should also be part of the platform. Associated business plans will need to be studied and validated.

5.7.5 Call Admission Control and seamless handover in 4G networks

In preparation for 4G, much research is focusing on enhancing handover techniques, such as incorporating satellite positioning services (i.e., GPS) to assist handover mechanisms in predicting when handover can be initiated or executed. The incorporation of location-positioning information to achieve seamless handover in 4G and improved accuracy in predicting when handover needs to be performed remains an area of research that can be further explored.

5.7.6 New wireless dedicated TCP/IP protocols

Most of the Transport Control protocols have been designed in a time when all networks were based on wired technology, and the TCP/IP suite of protocols fails when used in a wireless environment, mainly due to the increased losses that are not related to congestion factors. In this respect, new wireless dedicated transport protocols should be examined that will take into account the characteristics of heterogeneous networks.

5.7.7 Multimode User Terminals

The reuse of hardware is a must to meet the challenge of producing satellite service enabled handheld terminals with minimal impact on size, battery consumption, and cost. In the context of an integrated terrestrial/satellite network where the same terminal is employed both for terrestrial point-to-point communication and to receive satellite broadcast/multicast contents, power conserving protocols are extremely important to maximize battery exploitation, for terminals that effectively are almost never idle. The multimode user terminal is also an essential component in realising integrated terrestrial/satellite communications networks, allowing seamlessly roaming from one network to another. The Software Defined Radio (SDR) approach is reckoned as the most promising way of implementing multimode terminals (ITU WP8F - Question ITU-R 230-1/8, SDR Forum: www.sdrforum.org).

5.7.8 Convergence of satellite and terrestrial standards

4G networks will consist of inter-working networks. Satellite activity is covered mainly by the standards of ETSI (in particular S-UMTS, DVB-S and DVB-RCS) and ITU, while many standards for terrestrial systems have been proposed or are currently in use (GSM, GPRS, UMTS, WLAN standards, etc). The convergence of these recommendations and standards should be examined in detail.

5.7.9 Content scheduling techniques for multi-stage systems

A compelling approach of 4G networks involves the use of satellites for the provision of broadcast and multicast services (mobile broadcasting and multicasting thematic priority). In both push and pull multi-stage content delivery systems, the optimisation of content scheduling techniques and radio planning is deemed necessary for achieving better content access times and increased coverage with efficient capacity utilization.

5.7.10 QoS provision in 4G networks

QoS provision is a major challenge in 4G networks owing to the different characteristics of the heterogeneous wireless networks, such as channel characteristics, fault tolerance and network capacity. As services provided by future generation mobile networks will demand varying QoS for real-time and non-real time applications, offering efficient algorithms will be of paramount importance in 4G.

5.7.11 Spectrum

Explore various frequency bands (S, L, C…), and start regulatory processes, defining sharing rules with terrestrial 4G systems.

5.7.12 Architectures

Establish, specify and validate high level requirements for the architecture of the 4G MSS, especially focused on close integration inside 4G terrestrial networks.

5.7.13 Air Interfaces

Define, specify and validate potential Air Interfaces for 4G MSS, based on (and close to as far as possible) terrestrial Air Interfaces, and possible evolutions. Define impacts on User equipment, and refine their specifications (performances requirements).

5.7.14 Satellite Constellations

Study different satellite constellations or combination of various constellations like GEO, LEO, MEO. Propose and define candidate constellations, specify associated space segments.

5.7.15 Capacity

Establish and validate overall capacity in various scenarios.

5.8 ASMS THEMATIC PRIORITY: AD-HOC NETWORKS

A number of activities and commercial standards have been evolving since the mid to late 90's for ad hoc configurations.

Satellites can be used to interconnect an ad-hoc network with another ad-hoc network, or generally a LAN (wireless or wired). Among the mobile nodes, some specific nodes maintain communication links with the satellite nodes, acting as gateway stations. A specific case arises when the dynamic nature of ad-hoc networks result in a cluster of nodes, which may be isolated from other networks, especially when deployed in impervious areas where there is no existing terrestrial infrastructure. Furthermore, due to the stochastic movement of the nodes that form the ad-hoc network, it is likely that some partitions-groups might occur in the wireless network without connectivity among them. We can envisage a "range extension" network comprising geostationary/non-geostationary satellites. Extending the aforementioned scenario, except for connecting different ad-hoc networks, the satellite node may connect a new distant node to the ad-hoc network. This is the case of military applications where a manned infantry squad wants to exchange information with a remote base.

Satellites can also be used to connect an ad-hoc network to a Wide Area Network (WAN) or to a Metropolitan Area Network (MAN). The satellite node can be employed to connect the ad-hoc network with backbone networks as well, such as the Internet. Due to its intrinsic reliability and robustness with respect to both natural hazards and terrorist attacks, the satellite is the ideal system to ensure the provision of telecommunication services to rescue parties, whose members may form an ad-hoc network.

Ad-hoc networks are characterized by some particular features, such as frequent topology changes, common wireless medium, narrow bandwidth and limited energy of the mobile devices, which complicate the problem of routing in these networks. There have been many proposals of routing algorithms that face these difficulties and provide good performance. These are divided into many categories according to the type of information they take into account in order to construct routing tables and the way they obtain this information. Providing location information may be useful in implementing advanced routing techniques, able to support QoS. Geographical routing protocols use geographical-location information in order for every node to create its own routing table. Satellite Positioning Systems, like GPS and Galileo, could be an appropriate way for the nodes to know their own location, so as to share it with the other nodes in the network. This is a significant contribution to the routing problem, as these services are now low-cost, efficient and widely available.

Key R&D issues are:

5.8.1 Mobility and Location Management in ad-hoc networks
5.8.2 Routing protocols for ad-hoc networks
5.8.3 Position-based routing for ad-hoc connectivity

5.9 SATCOM FOR AIR TRAFFIC MANAGEMENT

The integration of a satellite segment within next generation (2020 and beyond) global Air Traffic Management systems with a higher degree of safety and reliability, is a key opportunity for SatCom. More details can be found in Section 6 of this document, devoted to Interworking & Interoperability.

5.10 KEY SATELLITE TECHNOLOGY ISSUES

The foregoing sections have looked at specific user application areas. The following summarises the key, supply-side technology issues seen from the perspective of the satellite system:

5.10.1 MSS system design and technology optimisation at L-band, as well as higher mobile satellite frequency bands, aiming to maximise satellite resource utilisation.

5.10.2 Next generation spacecraft / constellation concepts.

5.10.3 New concepts of mobile satellite terminals aiming to mitigate impact of the mobile environment such as fading, rain attenuation, and shadowing, while addressing practical terminal design issues, and terminal cost effectiveness.

5.10.4 Reconfigurable mobile satellite terminals.

5.10.5 Robust and scalable source coding techniques (voice, audio, video).

5.10.6 Harmonisation between mobile satellite air interface and emerging terrestrial wireless effectiveness.

5.10.7 Optimisation of spectrum utilisation in sharing between mobile satellite and terrestrial wireless networks.

5.10.8 Cheap, light, and robust tracking antennas.

5.10.9 High-power satellites to enable the use of omni-directional or low gain antennas in smaller vehicles.

5.10.10 Standardized protocols and cheap multi-user terminal layout, which allow different users to easily connect to the terminal with their own equipment (e.g., laptop, vehicle data infrastructure, I-Pod) without having to configure it.

5.10.11 Employment of intelligent cache (broadcast) strategies to reduce the link usage and increase robustness.

5.10.12 Possibility of integration with terrestrial infrastructures like WLAN, or even DVB-H, for land-based systems; integration is intended at least in the sense that the same service can be offered via different infrastructures, according to the application/content provider willingness, without having to re-setup the whole infrastructure.

5.10.13 Possibility to integrate space segment (satellites, HAPs), air segment (direct aircraft to ground and aircraft to aircraft links) and ground segment for global and reliable Air Traffic Management systems.

6. INTEROPERABILITY & INTERWORKING, (including network management and quality of service issues)

6.1 INTRODUCTION

As presented in ISI's Strategic Vision Document, the convergence moves in the telecom world set several trends that satellite has to follow in order to develop its place for future telecom applications. The main trends are:

- **a)** Multiple services are offered on the same networks building upon IP technology.
- **b)** Broadcast, multicast and unicast services are evolving with the introduction of new formats and new ways of service consumption.
- **c)** Service continuity is maintained everywhere between different heterogeneous networks: wired and wireless, fixed and mobile.
- **d)** Telecom networks are connected to the home networks.

Satellites shall participate in this convergence in order to be seamlessly integrated with the terrestrial networks, in terms of service offering and in particular in being a part of hybrid networks. It will have to be integrated in a transparent way to the final users, not requiring complex setup and deployment processes. This has a significant impact and implication on systems internetworking and interoperability.

6.1.1 Context

The ever increasing popularity of hybrid networks, i.e., networks that have both terrestrial wired and wireless links (including satellite), reveals that they will play a crucial role in future infrastructures for multimedia applications. Indeed, one of the most challenging issues is to provide a seamless service provision across different networks and, in particular, to evaluate end-to-end performance for wired/wireless customers, slow or fast moving. For instance, a network inside a quick moving vehicle, such as a train, can be connected to the terrestrial network via one or more satellite links; analogously, a WiMax network could deploy a satellite back-haul towards a wired high-speed backbone. In these scenarios broadband satellite links play a significant role because of their many advantages: global coverage, bandwidth flexibility, rapid deployment, reliability and broadcast/multicast capability.
On the other hand, Internet and its related protocol suite have definitely become the leading solution for wide area data internetworking and the study of their performance in networks combining wired and wireless links is crucial. Since IP is the reference at network level, DiffServ and IntServ architectures for IP QoS have to be investigated, with the goal of determining the best network utilization with the greatest number of satisfied customers. In essence, network models for quality of service must be developed and refined, to successfully accommodate multimedia service provisioning.

Overall, the analysis of all issues related to end-to-end quality of service, taking into account the interplay between both the Internet and transport layers and the underlying MAC/physical levels, is strategic in hybrid scenarios of wired (Gigabit Ethernet/optical networks) and terrestrial wireless (3G/4G/Wi-Fi/WiMax) connected to satellite links. Also, mobility has to be carefully considered, since an ever increasing number of users is asking not only for high-speed and ubiquitous connectivity, but also for "on-the move", seamless connections.

The Interworking procedures, running both at terminal and at network side, are in charge of accomplishing the inter-segment procedures (adaptation of QoS requirements to segment characteristics, inter-segment roaming, inter-segment handover...). In a heterogeneous network scenario, Interworking procedures aim at rendering the network technology dependent aspects (i.e., the layers below the IP layer) as transparent as possible from the service perspective, so that the use of different network technologies does not affect the QoS perceived by the users. Recent trials carried out in several parts of Europe have demonstrated the interest of efficient and optimized solutions for the interconnection of satellite and terrestrial systems, in particular for the extension of broadband services to a "total coverage". The intelligent and efficient management of traffic in these heterogeneous networks is of vital importance for the successful use of satellite systems.

6.1.2 Some scenarios

The satellite role in a hybrid network can be considered from two different points of view:

- **i)** From a geographical point of view, two scenarios are envisaged, depending on the application (which may end-up making such differentiation useless or irrelevant): satellite as gap-filler of terrestrial networks or terrestrial networks as gap-filler of satellite networks.
- **ii)** From a service-oriented point of view, satellite complement terrestrial-based networks for instance with broadcast of multimedia information and selective multicast on the satellite and unicast on terrestrial networks.

The following list is only given for illustration and is certainly not exhaustive as new services configurations will appear from the combination of user behaviours (and therefore demands) evolution and technology development:

- **a)** Service evolution towards new paradigms of communications (such as user-centric, context awareness, middleware to support applications of all kinds) aiming at the delivery of information and traffic flows to users, adapted to their current access situation, location, and preferences (or user's profile) in an heterogeneous network environment. This issue seems particularly interesting as a contact point with the activities of other Platforms, such as eMobility, and other EU initiatives, such as Galileo (for its interest in location-based services).
- **b)** Seamless support of end-to-end services and applications, ranging from low data rate to broadband, mobile, interactive services. This also requires synergy in network and resource management policies in satellite and terrestrial segments.
- **c)** Techniques for intelligent distribution of services across multiple access technologies and network layers. This is interesting, for example, in the view of the integration of emerging DVB platforms (DVB-RCS, DVB-T, DVB-H) in a generic multi-tier hierarchical system. This is also one scenario to offer mobile TV services, in which the satellite together with terrestrial transmitters distribute the most demanded programmes on the whole service area, whereas terrestrial mobile networks distribute in multicast and unicast additional contents.
- **d)** Integration of satellite and WiMax networks, use of satellite as backbone among WiMax Base stations and/or to extend WiMax fixed coverage as a gap filler to ensure full mobility
- **e)** Integration of a satellite segment within next generation (2020 and beyond) global Air Traffic Management systems, with higher degree of safety and reliability. The interworking of several communication links which are specially adapted to different environments, e.g. W-LAN based technology for airport communication and satellite-

based communication for remote or oceanic areas shall enable globally optimised coverage and network performance, transparently to the end user.

6.1.3 Structure of this Interworking and Inter-operability section

In order to structure the requested work analysis, it has been chosen to analyse the R&D tasks along with some of the ISO layered model (physical, access, network and applications) complemented with a section covering system architecture and terminal. This layered analysis is completed with a network and service management section, and sections dedicated to standards and spectrum allocation issues.

6.2 PHYSICAL LAYER

6.2.1 Link efficiency

a) To follow the ever increasing capabilities of terrestrial networks, take advantage of improved efficiency brought by new technologies and solutions
b) Increase the bandwidth efficiency thanks to powerful modulation and coding, including use of ACM techniques and DRA.
c) Develop advanced antenna techniques that improve the satellite link budget and hence increase the overall capacity.
d) Elaborate a reconfigurable physical layer and radio platforms capable for multi-band and multi-user operation.
e) Incorporate dynamic spectrum and radio resource management to achieve excellent quality of service for satellite overlay-backhaul and broadcast networks.

6.2.2 Integrated Terrestrial – Satellite and Heterogeneous Airborne Networking

a) Measure the impact of coexistence of different types of sub-networks (terrestrial, satellite and Airborne) in terms of spectrum needs and estimate the potential re-use of bands.
b) Develop hand-over mechanisms between various sub-networks.
c) Support multi-layered mobility that tries to take advantage of the micro and macro coverage areas by the heterogeneous networks.

6.2.3 Air interface harmonization

a) Harmonise mobile satellite air interface and emerging terrestrial wireless air interface in order to optimise satellite system resource, while ensuring user terminal cost effectiveness.

6.2.4 Software Defined Radio

This item is also considered in the system section as far it has consequences over multiple layers. It covers the capability to reconfigure both the satellites (flexibility) and the terminals. The resulting advantages are:

a) Provision of adaptable user terminal platform to support a broad range of satcom services covering p2p, multicast, and broadcast;
b) Provision of dynamic reconfiguration in response to available satcom networks, services and user needs.

6.3 ACCESS LAYER

Satellite networks' QoS performances can be optimized by pursuing an integrated approach to resource management; in particular, a tight cooperation between scheduling algorithms and dynamic capacity allocation procedures facilitate the achievement of (i) full-IP QoS management, (ii) minimization of access latency, (iii) maximization of network resources. Moreover, Admission Control (AC) algorithms are crucial to effectively differentiate the various services provided by the network: advanced service-aware AC algorithms are required to manage the blocking probabilities of the different services in various traffic conditions. Above all, for the sake of cost-effective satellite system solutions, a consensus must be reached to standardize the resource management procedures.

6.3.1 Radio Resource Management

a) Develop cross network optimization through a coordinated Radio Resource Management to optimize the resource allocation over the different networks.
b) Develop Dynamic Resource Allocation over Satellite Networks
c) Define novel Radio Resource Management (RRM) protocols that include Medium Access Control (MAC) and Usage Parameter Control (UPC) mechanisms for the QoS provision under fairness constraints.
d) Define efficient methods for Aggregation, multiplexing and bandwidth sharing of terrestrial traffic towards Satellite networks.
e) Evaluate the impact of MAC choices/rules on the TCP layer throughput.
f) Assess feasibility and trade-offs of cross-layer mechanisms (either top-down or bottom-up) able to operate in an heterogeneous networks. With the advent of all-IP wireless networks a great impact on traditional layered and OSI is being witnessed. Cross-layer design may be a preferred choice in all IP network architectures since in principle it allows a natural adaptation of current protocols to networks dynamics including physical layer adaptation. However, cross-layer information flow across terrestrial and satellite networks may require a number of additional constraints that may affect the overall cross-layer optimization and eventual benefit.

6.3.2 CAC Schemes

d) Design Call Admission Control, Scheduling and Medium Access Control algorithms for the support of multimedia traffic and for the efficient management of radio resources in hybrid networks.

6.4 NETWORK LAYER

6.4.1 Evolution towards all-IP integrated networks

IP is the basis for convergence of services and networks, satellite shall build upon this protocol to be integrated into heterogeneous networks. For this integration a number of satellite specific items shall be optimised:

a) Manage the response time problem inherent to satellite systems.
b) Optimise TCP/IP QoS-oriented Architectures and Protocols for Satellite and Space Networks
  i) PEP Performance Enhancing Proxies Analysis and Development
  ii) Transport Layer/Application Layer Enhanced and Adapted Protocols for Satellite Links

- **iii)** Cross-layer solutions
- **iv)** Development of Protocols and Solutions for Interplanetary Communication
- **v)** Delay Tolerant Networks

c) Study the evolution towards all-IP integrated networks and possible alternative Transport Layer Modelling.

d) Design transport Protocol design with reference to the TCP over multi-path and multi-layer networks (STCP).

6.4.2 Integration of satellite into heterogeneous terrestrial-satellite networks

a) Define hand-over and roaming procedures between various sub-networks.

b) Develop an advanced general network management platform that will accelerate terrestrial-satellite network operation. Users must be able to acquire access in any of the satellite or terrestrial network while optimizing the service costs in terms of necessary resources. This implies inter-network synchronization in terms of traffic, services, connection management and routing from network to application layer.

c) Develop technologies for content distribution and multi-modal presentation to users over heterogeneous networks. This can be an issue in heterogeneous DVB platforms.

d) Study the possible introduction of interworking units (IWU) between networks of different standards (2G, 3G, and 4G) and between satellite and terrestrial wired and wireless networks.

e) Multi-layered mobility support across heterogeneous networks. This requires a cross layer approach to provide for transparent mobility during both horizontal and vertical handoffs.

f) Evaluate the trade-off between scalability and service granularity in large scale networks. This is particularly relevant when the satellite network is used as an access technology to a fixed backbone in which a Diffserv approach is normally used to provide service quality.

g) Build upon location and situation aware protocols design for mobile and fixed satellite access.

6.4.3 Quality of Service (QoS)

In the existing communication networks there is a concept gaining special interest which is related with the capacity of the system to provide the adequate QoS. Such QoS level must be understood as the required one for providing certain service to the end user. Most of the work related with QoS is focused in improving the performance when using only one communication system, but usually when establishing a session there are involved several domains (mobile terrestrial domain, fixed IP network, service provider network, satellite, etc) in providing the link between the application server and the user or between two users. This means that a better coordination among such domains must be achieved in order to optimise the resource management in the different domains. Such objective can be assumed by Policy-based management strategies (one well known example is the Policy-based management in Diffserv IP domains) in the different sub-network domains and developing the suitable QoS architectures, the corresponding QoS management entities and the interfaces between them. Special interest could be the development of the adequate framework for managing the QoS between the terrestrial and the satellite mobile domains.

The aim of the study is the release of a solution allowing the following main objectives to be accomplished within the End-to-End QoS management framework:

a) Monitoring and interoperability analysis: to evaluate the status of the global network (satellite/terrestrial); to find the best interaction among several interfaces in different domains and to define the relations among them and the existing standard and products. Its definition is necessary for services requiring an interconnection among different operators, managing different network technologies.

b) Network design: to provide methodology guidelines as fundamental help to the design team optimising the work process and allowing several solutions to be profitably weighed up.

c) New services impact analysis: to estimate a priori the changes due to the introduction of new services. The use of a simulation tool is decisive because it allows several choices to be deeply investigated.

d) Network resources optimization: to define steps needed for re-distributing the network resources optimising performances in order to increase the operator revenue and user satisfaction.

e) IP Quality of Service and multimedia support in heterogeneous networks that make use of the satellite segment.

f) End to end QoS over heterogeneous networks will need cross layer techniques over different networks.

6.5 APPLICATIONS LAYER

The application layer must allow the creation of flexible applications that adapt to the varying networks. Some applications (e.g. those based on TCP) are traditionally self adaptive to this and inherently robust provided that some minimum level of transmission quality is guaranteed. This is not the case for video and multimedia in general. The integrated network will then include support of video coding with scalability options and placement of transcoders at the interface between network segments.

6.5.1 Interworking between heterogeneous networks

a) Adopt robust, highly efficient, and scalable source coding and trans-coding techniques (voice, audio, video)

b) Facilitate content rate adaptation to match the available bandwidth of the interworking satcom networks

c) Develop tools for applications validation such as:

- **i)** Tele-education
- **ii)** Remote access to instruments
- **iii)** Efficient Audio/Video Transmission over Satellite
- **iv)** Interfaces to remote access control and management

d) Assess feasibility and trade-offs of cross-layer mechanisms (either top-down or bottom-up) able to operate in an heterogeneous networks. With the advent of all-IP wireless networks a great impact on traditional layered and OSI is being witnessed. Cross-layer design may be a preferred choice in all IP network architectures since in principle it allows a natural adaptation of current protocols to networks dynamics including physical layer adaptation. However, cross-layer information flow across terrestrial and satellite networks may require a number of additional constraints that may affect the overall cross-layer optimization and eventual benefit.

6.5.2 Satellite-specific applications

a) Use of satellites to interconnect vehicle networks, fixed (Wi-Fi based) hot spots, MANET areas. This can be interesting to provide wide area connectivity to roaming users or group of users (travelling together on a transportation means), to support corporate office activities, etc.

b) Use of satellites to collect and distribute information from terrestrial sensor networks used for monitoring and control applications (in this case, the role of Unmanned Aerial Vehicles or HAPS can also be considered). This issue is particularly interesting in the view of the strong interest of European Community and International research programs dealing with platforms and solutions, also based on satellite segments, for monitoring and intervention in case of natural disaster and terrorist attack.

6.6 SYSTEMS ARCHITECTURE AND TERMINALS

6.6.1 Architecture

The convergence of the telecommunication network infrastructure is an objective that has to be reached by first converging the satellite system infrastructure. On-Board processing technology has proved to be a perfect answer to the requirement to provide real time mesh communications to end-users (AmerHis, the first DVB OBP, is a proof of that). OBP allows communication between satellite wireless networks with existing terrestrial networks, such as Internet, PSTN, RDSI or corporative private networks, with a single satellite hop and star access. Connection with other new networks as Wimax is possible, in this case satellite networks act as a backhaul towards a high speed backbone, and a fast and effective interconnection with home networks can be deployed too. Other issue to consider is on board processing participation in ad-hoc networks supplying direct interconnection between terminals which will access a meshed network. This is possible as far as on board processing offers different network architectures depending on the desired service platform thanks to additional intelligence it is provided with.

Regarding unicast communications, OBP cross connectivity benefits specially to real time applications as videoconference or VoIP, because direct connection between desired uplink and downlink beam can be established to communicate terminals in a single satellite hop, not double hop as usual, what allows us to reduce the bandwidth consumption and delay.

On board processing offers some improvements in IP multicast, such as dynamic multicast to complement terrestrial networks with. We will find more flexibility when choosing the beams where we want to address the multicast signal to, and the terminals in these beams will be provided with capabilities of dynamic reconfiguration to log on the multicast service and receive it without involving the gateway that transmits the signal from the multicast service provider.

However the costs introduced by these systems have to be controlled not to penalise the overall service offer. The transparent satellite systems are more competitive for other kind of services: non-real time traffic (mainly the Internet). A meshed adaptation on transparent satellite is also requested by some customers. In this respect it is very important to evolve

all systems above so that hybrid solutions can be deployed transparently to the users. This means that depending on the service the user can benefit from the on-board processing or use the transparent bent-pipe transponder. An integrated transparent-regenerative system must be explored to offer a real complement solution to terrestrial networks.
A second step would be to increase the flexibility of the payload considering the possibility of using software radio techniques for the satellite reconfiguration (e.g. capacity, multi-beam cross connectivity, etc). The capacity to modify an existing platform to accommodate new communication standards and services implies to modify the behaviour of the processing layer (analogue and digital processing) to adapt to the new circumstances. Moreover the need to correct some bugs introduced during the development flow, design time, makes necessary to define a development flow that takes into account the capacity to modify the systems during run time. Is in such directions where the Software Radio concept seems to show its strong level of flexibility what makes it suitable for the development of the satellite platforms for both the satellite system and the user terminal. Some of the most relevant research issues related with the development of satellite platforms under the Software Radio concept can be summarised by the following bullets:

a) Development of Hardware architectures, composed of an heterogeneous array of processors (including analogue and RF), suitable for accommodate the Software Radio concepts or what is similar, the capacity to reconfigure parts of the system to support several communication standards.
b) Development of an abstraction layer (Middleware, HAL, execution environment, etc.) capable to provide several services to the radio application at a very low cost in terms of energy consumption.
c) Development of a reconfigurable management architecture framework that includes the mechanism to analyse the reconfigurations needs, maintain the corresponding information database and promote the reconfiguration according the required service.

6.6.2 Systems

a) Integration and Interoperation of next generation Satellite Networks (DVB-S2, DVB-RCS) with home area networks, ad hoc networks, sensor networks, terrestrial networks, 3G networks, and, in the longer term, beyond 3G and 4G networks.
b) Integration of satellites with fixed and mobile terrestrial networks (UMTS, WiFi, WiMax, etc.) to provide full connectivity, QoS provisioning, transparent roaming, and full mobility.
c) Interoperability between Satellite and WiMax
  i) Use of Satellite as backbone among WiMax Base stations
  ii) Use of Satellite as gap filler to ensure full mobility
  iii) Use of satellite to extend WiMax fixed coverage.
d) Inter-Satellite Networking: develop mesh inter-satellite connectivity with advanced radio resource management algorithms and networking / routing to achieve a flexible satellite overlay network.
e) OBP IP traffic management offering a wide range of broadband and multimedia services. Considering the most critical part is reaching a proper end-to-end QoS along hybrid networks, OBP will support QoS techniques to satisfy IP Diffserv mechanism. This objective is possible using C2P (Connection Control Protocol) that in addition to its ARP (Address Resolution Protocol) functionalities, allows dynamic resource assignment thanks to traffic flow differentiation in several priority levels. With respect to this flow differentiation, transmission mode will be set in each terminal and dynamic

resource and bandwidth assignment will be carried out.

f) Development of on board processors with reconfiguration capabilities in view of new communication specifications, such as DVB-S2 that allows more efficient bandwidth communications and benefits multimedia services.

g) Integrated terrestrial-satellite-HAP solutions for deployment and operation of emergency Networks, and other network types.

h) Enhanced platforms based on the synergic interworking of Satellite and HAPS technologies

i) Coexistence strategies for satellite and HAPS systems.

j) Integration of satellites with cellular systems and HAPs in order to provide MBMS. Platforms for satellite-based MBMS have been studied; it can be interesting to integrate a further layer of HAPs in order to provide an alternative way for the forward and/or return channel in places where there is no direct satellite visibility or to reduce the negative consequences of congestion or ACK implosion.

k) Similar cost functions must also be studied on the network side for resource allocation purposes. Network topology must also be studied as the presence of "intermediate nodes" such as HAPS may impact the routing of the data to the user or, for example, suggest a 'routing in the sky' strategy among satellite networks.

l) Development of Real-Time Simulation and Emulation Tools to verify the system feasibility.

m) Cognitive Radio framework: Cognitive Radio must be understood as the framework to introduce intelligence to the system to adapt to the environment situation and the user circumstances. This concept achieves its maximum meaning when applied over a Software Radio platform/system. The flexibility provided by the Software Radio concept can be exploited by mechanism to automatically adapt some relevant parameter taking into account the variation in other ones. Some of the most relevant issues related with such topics include:

i) Develop a suitable monitoring framework not limited by any specific implementation capable to capture the desired parameter of the system evolution and provide it in real-time to the decision centre.

ii) Develop a suitable mechanism to modify the behaviour of some of parts of the system. Different levels of actuation are envisaged from changing a parameter to complete changes in a processing chain.

iii) Develop mechanisms to analyse the current situation and take decisions. An important part of this framework includes the capacity to learn from the adopted decisions and the posterior evolution of the system. Suitable learning technologies must be applied on such issue taking into account the characteristics of the communication system.

Such Cognitive Radio framework can be seen as the mechanism for an automatic Cross Layering framework when the flow of information goes from one layer to another. Software Radio and Cognitive Radio must be understood as tools for providing or improving interoperability among different systems by using the same platform (terminal or base station-satellite).

n) Optimal planning of regenerative space networks: The provision of global wireless connectivity must pass through "backbones in the sky", able to complement terrestrial fibre-based backbones. The development of "backbones in the sky" will require the use of multiple networked regenerative satellites able at directly exchanging information together without terrestrial hops. In such a way, a "space network" should be set up, with problems of efficient planning to be solved. The optimal planning of satellites positions is not the only issue to be faced in this context. In fact, the term “satellite network” has been replaced here by the term “space network”. This is because the most recent R&D efforts about space communications are going towards the integration of GEO and LEO satellite with high-altitude platforms (HAPs) in order to build multi-layered space networks. In such a framework, efficient planning strategies should be studied for the overall space network, considering the presence in the space segment both of different typologies of satellites and HAPs. The objective to be reached is to maximize both coverage and quality of service reached by the final users and, on the other hand, to minimize the number of regenerative repeaters (satellites and HAPs) employed in the space segment.

6.6.3 Terminals

Interworking, interoperability of networks necessitate the development of multimode and multi-radio wireless terminals. This need finds in the Software Radio concepts, introduced previously at system level, an enabler technology for such interesting challenge.
There is a strong need for ‘smart terminals’ capable to recognize the best serving system and eventually trigger handoff. This must be managed at the hardware level with Receive/Transmit chains not only controlled at the operating system level, but, in view of power and cost savings, capable to reconfigure themselves.
The adoption of terrestrial interface to satellite will facilitate the availability of terminals components and specially ASICs at lower cost:

a) To ensure a widespread adoption of hybrid satellite-terrestrial networks it is necessary to develop small size devices that can be integrated with existing mass-market equipments; OBP could help to decrease terminal costs as far as it increases link gain with on board signal regeneration with a consequently simplification of terminal structure.

b) To facilitate the adoption of wireless applications, a specific effort has to be done to reduce the energy consumption of wireless terminal devices.

6.7 NETWORK AND SERVICE MANAGEMENT

The intention is to provide a reliable, high quality return channel to the satellite capable of supporting two way video communications, video messaging and personal video broadcast. Solutions already exist such as DVB-RCS and Satmode, however new requirements and applications may request adaptation or new solutions.
To achieve this requires a thorough evaluation of the key parameters impacting on quality of each service, namely – bandwidth, packet loss, delay and jitter – alongside a study of the likely usage across a population to estimate the burstiness of the underlying video traffic. Implementation on a TV platform will also be a significant task, especially in understanding the user and interface requirements of such a system. It is expected that the behaviour of a TV User will generate traffic profiles quite different from “classical” PC centric behaviours.
To achieve the above objectives, we propose a stepped approach:

a) To identify which services are more suitable and viable when carried over new satellite technology. Starting from the example of wired networks (where Internet access, telephony and TV are the main services offered by “triple-play”).

b) To identify, analyse and solve any specific issues related to the provision of satellite based triple play and TV-Centric services. This may include,

- **i)** coping with satellite limitations;
- **ii)** defining a suitable architecture for the service platform(s);
- **iii)** investigating interactions with other networks

c) To prototype the needed components adaptation and interfaces, and proceed to Lab level Assembly, Integration and test of the platform.

d) To demonstrate the applications during a "pilot" phase that will permit to assess both the services and the underlying technology acceptance and performance.

6.7.1 Integrated Management View

In order to address this issue, the following areas of study are proposed:

a) Analysis and design of a generic Object Model for Service Management architecture which integrates telecom network elements, IP LANs, satellite mobile and broadband networks elements, IP networks and server farm infrastructures, web servers, content servers and applications (if provided by the supplier).

b) Specification and implementation of integrated fault management systems which reduce time taken to diagnose service level problems and thereby improve the efficiency of the service provider operator. In particular, the use of COTS products integrated with proprietary satellite network management systems is a key area of study as is the correlation of satellite network faults with problems in end to end services and applications

c) The suitability of the TMF (Tele-Management Forum) defined NGOSS (New Generation Operational Support System) business framework as a common standard needs study. Particularly an assessment needs to be performed of the ease of building interfaces to legacy equipment from NGOSS so that 'live' data is available in an 'open' industry standard and available to other Service Providers.

d) The integration of satellite network resource planning and management tools into more standard COTS automated Network Planning and Configuration systems requires study.

6.7.2 Management of End to End Customer Experience

In order to address this issue, the following areas of study are proposed:

a) Consolidation of low level performance information from the underlying networks including BER from the satellite links and satellite radio statistics into KPIs for overall services provided. This would include consideration of extracting entries from server/application log files ('log scraping') to obtain a more 'customer experience' level view.

b) Over-the-air network management techniques which allow user terminals to be managed over a radio interface hence measuring QoS and optimising the user QoS. A number of terrestrial cellular and fixed communications systems are considering providing dedicated Management Channels in the radio air interface specification. The viability of extending such technology to the satellite radio interface needs to be explored.

c) As user terminals in mobile and fixed satellite communications systems become more intelligent, 'light' software management agents can be deployed within them. These agents allow forwarding of alarms to a remote fixed management centre (over the air interface), collection of performance data to be transmitted transparently in quiet network periods. In addition, to optimise QoS of individual customers, OTA configuration of user terminals is an integral aim. A number of scenarios need to be studied for different satellite communications networks. The cost/benefit of deploying management probes/agents in user terminals for each case needs to be analysed.

d) Another large area to be studied in Network/Service Management is the use of dynamic satellite radio resource management/service planning using daily measured traffic profiles. The consideration of recently deployed satellites with intelligent payloads and configurable transponders should also be studied to understand how satellite radio resources would be efficiently managed between ground and space.

6.7.3 Exchange of information between Service Providers

In order to address this issue, the following areas of study are proposed:

a) Specification of Service Level Agreements (SLAs) are now becoming more common between service providers. The SLAs tend to provide the quantitive means to measure an agreement between two such providers. These SLAs can exist at many different levels (services, network etc.). An area of study is to look into specification of viable SLAs between satellite network providers, their customers and interworking agreement with partner network and service providers. The way in which the SLAs are managed including SLA violation detection and action taken in satellite networks when approaching threshold violation is also an area for study.

b) Use of NGOSS management architecture and associated SID (Shared Information and Data Model) as a standard framework for exposing information to other service providers. An area for study is the specification of contracts in NGOSS between service providers. For example, whatever management information has been agreed to be shared between service providers in a contract can be implemented. NGOSS will only allow the data contractually permitted to be accessed by a Service Provider from the SID. The study in this area would identify contracts between a satellite network provider and service providers/partner networks and assess the implementation of these contracts in the NGOSS framework in terms of generating realistic SLA rules and service credit logic.

c) The final area of study is in the interworking of management planes between not just different network/service providers but completely different communication technologies. In Mobile Satellite Systems, interworking of management planes for the two competing mobile satellite protocols DVB and UMTS is an important area to be studied.

6.8 STANDARDS

A key success factor for convergence in the satellite world is the adoption of open standards:

a) To facilitate the deployment of hybrid networks, the satellite component shall be included within standards proposals from their initial phases. With this approach, satellite terminals will benefit from large volumes of terrestrial networks, solving a key issue of today isolated satellite services

b) DVB-RCS and DVB-S2: The enhancements in those areas which are still under discussion (QoS, security, PEP, DVB-RCS2, Generic Streams) is extremely important to offer multi-vendor and interoperable solutions. DVB has already shown interest on the applicability of its specifications to mobile environments, including satellite services.

c) Multicast: support for the evolution of protocols and architectures to handle dynamic multicasting. These improvements will take advantage of the multi-beam and the multicast replication capabilities performed by a regenerative payload on board.

d) Mix of services (quadruple play) to handheld terminals exploiting the opportunities of a plethora of technologies based on DVB-H, DAB, DMB, etc..

6.9 SPECTRUM

a) Optimisation of spectrum utilisation using "intelligent" sharing between mobile satellite and terrestrial wireless networks.

b) Spectrum management and investigation of new frequency bands.

c) Identification of new frequency bands for HAPS systems providing fixed broadband services.

7. SECURITY, INCLUDING DUAL USE

7.1 SECURITY AND DUAL USE: INTRODUCTION AND DEFINITION

Space is a strategic asset. Europe has always maintained an important presence in space. In this sense, space as strategic and multiple-use technology is a key instrument for a comprehensive approach to security. Improving security is one of the most important contributions which space technologies and services can offer.

Because of the relevance of space and security for Europe, the development of dual-use technologies calls for a European approach to space security, linking, as far as practicable, the current national defence programmes with mainly civilian European programmes. The functions and means of security and defence uses of space overlap considerably. In fact, the European Commission seventh Framework Program calls for a new strategic objective based on Space and Security.

Dual Use Satellite systems could be defined as space systems where civilian and governmental applications can be carried out using the same resources. The dual use concept mainly responds to two different values: sharing costs, and similarity between civil and governmental applications.

Governmental requirements are currently satisfied, in many cases, through commercial satellite systems. These requirements are related to security corps such as police, civil protection, and peace-keeping agencies around the world. Such requirements today represent a high percentage of commercial satellite system growth.

The concept of "dual use" is certainly not new. Some commercial satellite systems have been carrying governmental and commercial traffic for specific networks for years. However the volume of traffic is growing exponentially and requirements and applications are expanding. These requirements impact on fixed, mobile, broadcast, store and forward satellite systems, and surveillance and navigation systems.

The development of dual-use systems is starting to be widely implemented by European and National communities, in particular because of the reaction against the real and perceived terrorism risks, and it is becoming a regular practice in many parts of the world. The current world environment (after 11S in New York, 11M in Madrid or 7J in London) has brought new requirements to be considered, related to Terrorism Attack, Homeland Security, Protection of Europe’s Borders, or Crisis Management. So, it is clear that satellite communications play a major role in assisting the police, emergency response services, armed forces and agencies by supporting humanitarian relief and responding more effectively to natural disasters or terrorist attacks.

In this sense, the Petersberg tasks show us the current commitments to these scenarios, overlapping military and civil security operations. These tasks were established in June 1992 at the Ministerial Council of the Western European Union (WEU). The WEU Member States declared their readiness to make available military units from the whole spectrum of their conventional armed forces for military tasks conducted under the authority of the WEU. The different types of military tasks which the WEU can undertake were defined: military units of WEU Member States may be employed for:

- humanitarian and rescue tasks;
- peace-keeping tasks;
- tasks of combat forces in crisis management, including peacemaking.

These tasks are today expressly included in Article 17 of the Treaty on European Union and form an integral part of the European Security and Defence Policy (ESPD).

Governmental service requirements for satellites will continue to represent a very substantial portion of all commercial satellite services and, in some cases, satellite systems have had to adapt to this situation in terms of capacity, availability, flexibility of geographic capability, and certain types of encryption and security requirements. For example, DVB (Digital Video Broadcasting) services, which represent a substantial share of the satellite system growth, although originally targeted and designed for the consumer market, have been later deployed to meet governmental requirements.

The demand for broadband and satellite business requirements is growing rapidly, together with the demand for security protection and the demand to protect intellectual property and commercial business information.

In short, the commercial satellite world will have to be able to protect information while maintaining its cost and throughput efficiencies, in order to respond to both commercial and governmental users market demand.

Figure 1 shows some typical applications within the satellite communication environment. They are grouped into three different areas, depending on the final users: civilian and commercial, governmental and military, or mixed (in this last case, they are called '*Dual Use*' applications). Some applications overlap, since initially they come from civilian or military areas and only recently they have been extended to other areas. From the ISI viewpoint, social and civilian defence as opposed to conventional military defence, is targeted. The potential applications for dual use in the military defence against military threats will not be the focus of ISI Research. Therefore, the dual use concept targeted by ISI relates to a more modern concept of defence and, in particular for the ISI case, defence is understood as civilian defence from a military/civilian threat/risk.

In the past, it was common to think of technologies as spinning off from military development to civilian markets. Today, many technologies have dual-use applications in both military and commercial products, such as polymer matrix composites for airframe structures, optoelectronics for advanced computers, flat-panel displays, and digital wireless communications. Currently, technologies are increasingly "spinning on" with commercial technologies being modified for military applications. While some technologies remain temporarily in exclusive or near-exclusive military use, many others have been originated in the commercial sector.

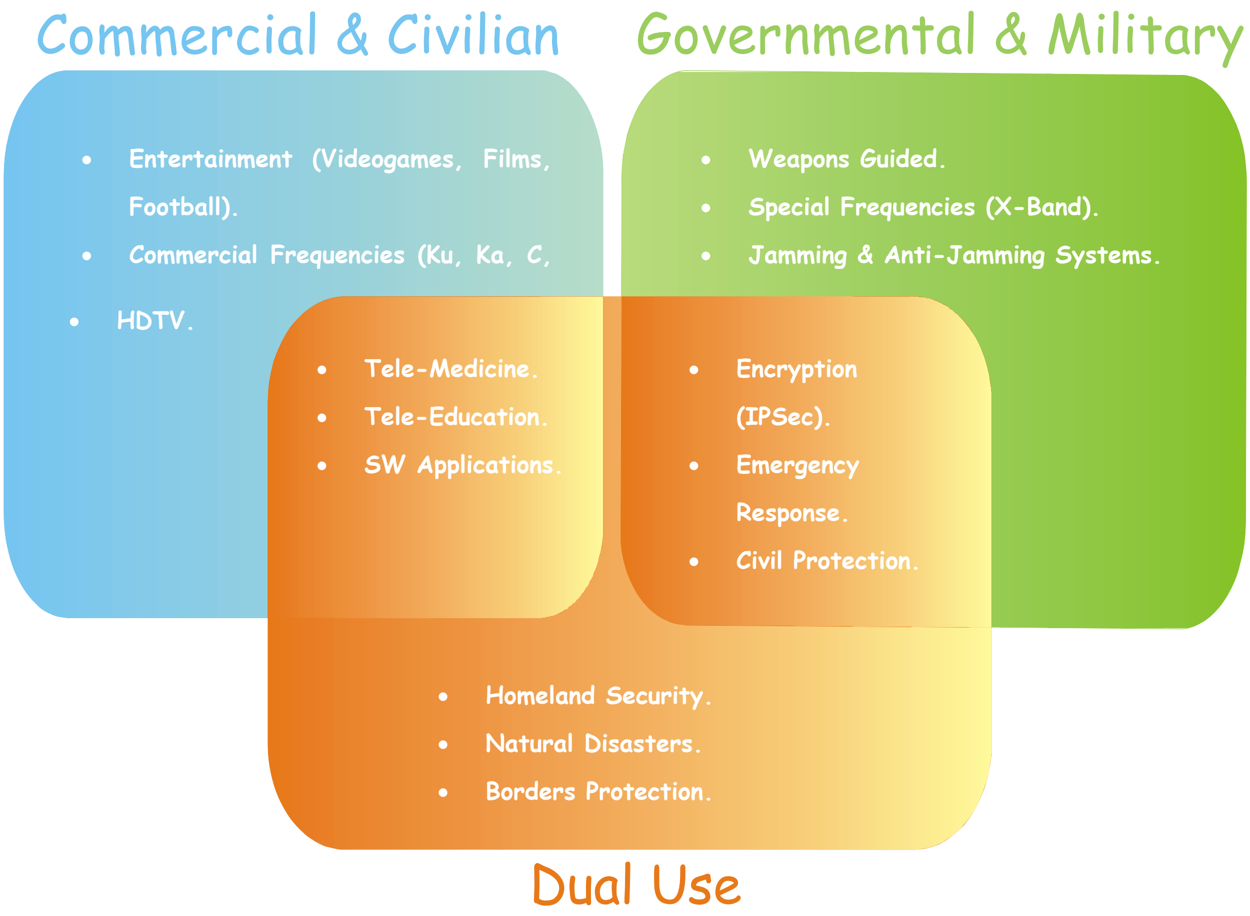

Figure 1. Typical Satellite Applications and Classification within "Commercial & Civilian", "Governmental & Military", and "Dual Use".

By using components, technologies and subsystems developed by commercial industry whenever possible, governmental and defence agencies should be able to achieve the following compatible objectives:

a) To shorten development times, by increasing the pace at which innovation is incorporated into new satellite defence systems.

b) To reduce costs for procuring leading technology to satisfy governmental needs. Commercial components, technologies and subsystems in many instances can meet functional needs at lower costs than technology military-driven and customized.

c) To integrate governmental and civilian sectors, which is an imperative goal, if societies have to be equipped to quickly gear up their capabilities.

d) To make more efficient use of the traditional stringent governmental requirements which provoke the availability of systems with low intensive use and which could be complementarily exploited in the civilian domain under certain operational conditions. It is clearly understood and assumed that governmental systems have to be designed and sized for identified worst case scenarios, which may not ever happen, or in just a few cases; during the lack of exploitation of these powerful systems, the civilian sector could make use and benefit from this enormous societal effort, willing to be equipped with powerful systems to face given circumstances. By this sharing of capabilities and infrastructures, the governmental sector may get revenue to compensate for the cost of the highly demanding requirements, while simultaneously, the civilian sector would enjoy the use of powerful systems under reasonable cost and operational conditions.

The dual-use strategy rests on three pillars:

- **i)** dual-use R&D to exploit the potential of advanced commercial technologies to meet governmental needs;
- **ii)** integration of commercial and governmental production to enable industry to "dual produce";
- **iii)** insertion of commercial products, processes, and technologies into defence systems, wherever possible. This strategy is designed to improve access to leading-edge technology, to reduce the cost of advanced governmental technologies, and to provide the ability to quickly enhance their capabilities to a higher level, if necessary.

7.2 EUROPEAN FRAMEWORK

Currently, the European-level R+D space framework is mainly addressing the civilian environment, without much focus on the defence requirements. Major defence or security programs have been developed on a National basis, and sometimes through bi-lateral cooperation. The development of dual-use systems calls for a European advance to space security, able to link National defence and European civilian approaches.

The Amsterdam Treaty spells out the objective "*to strengthen the security of the Union in all ways*" as one of the five fundamental objectives of the Common Foreign and Security Policy (CFSP). This Treaty incorporated the 'Petersberg Tasks' (humanitarian and rescue tasks, peace-keeping tasks, and tasks of combat forces in crisis management, including peacemaking) into the Treaty on European Union. This laid the Treaty basis for the operative development of the European Security and Defence Policy (ESDP).

The development of a European Security and Defence Policy (ESDP) is an ongoing project. It will play a significant role in determining the future of the Union. The central aim is to complete and thus to strengthen the European Union's external ability to act through the development of civilian and governmental capabilities for international conflict prevention and crisis management. If the EU member states work together successfully in these fields, this may help in forging a common identity and promoting integration.

Given the duality of modern technology, some of the Framework Programme's research activities have important security implications. This is the case, in particular, in the field of space, communication and information technology, where civil research projects can often lead to security-related applications.

However, this dual use potential is the result of a 'technology push' rather than of a 'requirement pull': it has not been actively sought, but has happened 'coincidentally' and is often politically sensitive.

Until now, it can be observed a dispersion of effort and a lack of coherence in research that hinders Europe in reaping the full benefits of its technological and industrial strength and creates enormous difficulties for interoperability between 'security users'. The need for more cooperation and coordination is increasingly recognized, and some initial steps to improve the situation have been taken. However, structural deficiencies still persist. The dividing line between defence and civil research funding, the absence of specific frameworks for security research at the European level, the limited cooperation between Member States, and the lack of coordination between National and European efforts make worse the lack of public research funding and present major obstacles to achieving cost-effective solutions.

In order to solve these problems, a European Security Research Programme (ESRP) is being promoted to be launched under the 7th Framework Programme. ESRP should take advantage of the duality of technologies and the growing overlap of security functions to bridge the gap between civil and defence research. In support of a comprehensive security approach, it should fund research activities targeted at the development of systems and products that are useful:

– in particular for the protection of Member State territory, sovereignty, domestic population and critical infrastructure against transnational threats, and

– for EU missions 'outside the Union for peace keeping, conflict prevention and strengthening international security in accordance with the principles of the United Nations Charter'.

An ESRP should maximize the benefits of multi-purpose aspects of technologies. In order to stimulate synergies, it should look at the 'crossroads' between civilian and defence applications and foster cross-sector transformation and integration of technologies. Its focus should be on interoperability and connectivity as key elements of trans-border and inter-service cooperation. A core of architectural design rules and standards should be worked out at an early stage.

An ESRP should complement civil Community programs on one hand, and security and defence research activities conducted at the national or intergovernmental level on the other. Effective coordination between an ESRP and other relevant research activities is crucial to ensure coherence of efforts. Moreover, an ESRP must take into account the specific aspects of the security market. This entails the creation of new funding instruments and technology transfer rules. At the same time, customers must be involved throughout the process to avoid disconnecting research and procurement.

In this way, ISI, as a global technological platform within satellite communication, must face up to these topics, considering security and dual use as one of their key activities and trying to resolve the difficulties between both communities (civilian and governmental). The aim is to bring together as many dual applications and activities as possible. In this sense, ISI and ESRP will have to cooperate.

Concerning standardization and security issues, ISI will also liaise with the European Telecommunications Standards Institute (ETSI). Within ETSI the technical committee on Satellite Earth Stations and Systems (SES) is responsible for all types of satellite communication services and applications (including mobile, broadcasting and broadband communications) and for all types of earth station equipments. In particular within the ETSI SES technical committee, the Broadband Satellite Multimedia (BSM) working group is facing some security aspects of satellite communications.

It is to be mentioned that the current draft definition of the FP7 includes Space and Security under the same strategic area, which implicitly connects space and security elements as components of a higher level framework.

7.3 DUAL USE AND SECURITY ELEMENTS FOR THE ISI STRATEGIC RESEARCH AGENDA

In the Security and dual use area it is necessary that commercial satellite systems respond to diverse requirements in terms of security of the networks, widely separated geographic locations, sudden peaks of traffic, and increasingly effective delivery of TCP/IP based traffic.

For that, commercial systems will need to be more protected and increasingly "secure", so they should be sure that satellite networks cannot be used to initiate terrorist activities or hacking attacks.

Despite the possible adaptations made by commercial satellite systems, it is clear that governmental satellites tend to be different and much more costly to build. It is because of the special requirements and the unique design features that make governmental satellites highly customized in their engineering and manufacture.

Commercial satellite systems are designed and built to meet commercial requirements and to be as cost effective and reliable as possible within the constraints of business efficiency. Thus there are limits to how effectively commercial satellite systems can meet governmental requirements.

Therefore, the major aim of new research in the dual-use concept should be to satisfy the requirements of both governmental and commercial satellite services. The difference between governmental and commercial should be only the level of security (e.g. stronger keys and algorithms). If such common systems and tools are adopted, then Duality of use can be achieved at a much reduced cost.

There are two scenarios that justify in particular the interest to develop Dual Use Systems:

- **i)** Systems with similar requirements (Daily Operations, Logistic, Communications, etc) which benefits for Dual Use are mainly driven by reduction of costs, enlarging economies of scale, etc..
- **ii)** Systems with different requirements and usually the defence ones with higher costs but lower usage ratios. In these cases, the civilian applications can make use of superior quality systems at reasonable costs, but then contributing to reduce the costs of high quality defence systems. This Dual Use is addressed because of the need to optimize costs for the conventional Defence Systems.

It is considered that this new perspective will open enormous opportunities to extend the effective and efficient use of the satellite systems.

7.3.1 Dual-use and Security within Broadband, Broadcast and Mobile Technologies.

Duality should take advantage of civilian and governmental technologies and the growing overlap of both functions to bridge the gaps between these research sectors. In this way, topics to be considered in the Strategic Research Agenda are:

a) To get a very high level of **secure connectivity**. Dual use capability should provide secure IP-based services on the whole world to make broadband IP transmission on satellite networks to work effectively. In this area, some issues to be considered are:

- TCP/IP QoS-oriented Architectures and Protocols for Satellite and Space Networks for Secure Communications.
  - Secure PEP (Performance Enhancing Proxies) Analysis and Development.
  - Transport Layer/Application Layer. Enhanced and Adapted Protocols for Satellite Links: evaluation of the impact on Security
  - Cross-layer solutions for safe communications.
  - Development of Protocols and Solutions for Interplanetary Communication.
  - Delay Tolerant Networks.

- Security for multicast and broadcast services over satellites:
  - Scalable key management for large groups and examining of impact of security on satellite network performance
  - Re-use of IPsec and related protocol for satellites
  - Security issues in satellite DVB network and examining the needs for satellite link layer security to provide access control and terminal authentication
  - Reliable and secure multicasting issues over satellites
  - Security policy provisioning, distribution and enforcement

- QoS over Global Information Infrastructures (and Impact on Security).
  - QoS Mapping over Heterogeneous Satellite Networks and Secure Protocols.
  - QoS Management of Multilayer Satellite Networks and relation with Secure Protocols.
  - Interworking Security Management of QoS Technologies over Heterogeneous Environments
  - Secure End-to-end QoS Provision.
  - QoS enabled secure multicast over satellite

- Impact of mobility on security and implications on end-to-end security.
- Development of Real-Time Simulation and Emulation Tools for Secure Protocols.
- Usage of TCP accelerators at each network node that uses the satellite link. Accelerator systems compatible with governmental and military security systems, such as those that are operational on a number of commercial systems carrying “dual use” traffic.
- Usage of block protocols with appropriate forward error correction.

- Security issues on the use of IPv6 over satellite: interworking and coexistence with IPv4, and interoperation with lower layer protocols and satellite technologies; this activity should take into particular account the work performed by ETSI in the last years within the Specialist Task Force 283 in support of the Broadband Satellite Multimedia (BSM) working group (ETSI/SES technical committee).
- Development of a novel authentication paradigm by combining digital signature and watermarking techniques. In such an attempt, classical signature-based authentication (based on private and public keys) is merged with digital watermarking (a technique largely used for copyright protection and fast search of images in databases). In particular, this methodology may exploit the advantages of both the authentication methods at once, by means of a multi-layer approach improving the security performance in comparison with a separate implementation of the two authentication methods. The advantage is twofold. The first is that the authenticity of the video stream can be verified, despite frame losses during transmission, provided that the watermark can be correctly extracted from the received frames,. The second advantage is that the sender can still prove its propriety of the data stream, even if the signature is deleted.

b) End-to-end **secure communications**, providing authentication, data confidentiality, access control, etc, though different networks.

- End-to-end security using IPsec: Practical and operational challenges.
- Secure web services and its possible for providing applications level end-to-end security.
- Virtual Private Networks at IP and at link layer, separation of flows: on-board routing and on-board switching, use of MPLS over satellite

c) Hardened systems: jamming protection, on-board processing.

- Regenerative techniques to block jammers and intruders making unauthorized use of satellite resources

d) Research on system architecture to guarantee security for heterogeneous networks (satellite and terrestrial).

- Security in heterogeneous networks can be achieved by adopting similar systems and tools such as IPsec and common AAA mechanisms such as DIAMETER RADIUS.
- Interaction (architecture interfaces and protocol mapping) between security systems and protocols used in IP broadband, broadcast and mobile technologies

e) To enhance the reliability, availability and efficiency of the systems with terrestrial telecommunication infrastructure.

- Examine the general threats in these systems such as network, software, human and hardware threats.

f) To expand current and future standards, such as DVB-S2 or DVB-RCS to others services and applications to meet governmental requirements.

- Such work should target both satellite link layer and using IPsec.

- DVB-RCS security should address secure multicast and re-keying.
- The use of cookies and smart cards in DVB-RCS should be examined.
- New systems such as Unidirectional Lightweight Encapsulation (ULE) security should be considered in DVB-S2 and DVB-RCS for services such asIPv6.
- Impact on existing Condition access system (CAS) / Simulcrypt (modifications may be required for high security requirements such as like for military services).
- Secure IP Encapsulation over DVB (ULE-SEC).
- Interaction between security provided over the satellite (DVB security) and end-to-end security.

g) Provisioning of end-to-end secure mobile satellite services, to fulfil dual use of the system by civil and defence customers:

- To include means for transparent support of p2p secured / encryption protocols that are mandated by defence agencies and Governments.
- To include means for transparent support of secured multicast and multicast routing protocols.
- To be efficient in consumption of satellite resources in order to be able to deliver Security across narrowband as well as broadband, mobile as well as fixed satellite systems.
- To be scalable in order to deliver secured communications to a broad range of SATCOM terminals, from low-end omni-directional, and hand-held terminals to high end directional mobile, transportable and fixed platforms.
- Secured communications need to coexist with non-secured traffic in order to fulfil dual use of SATCOM systems by civil and defence customers.

h) Security for re-configurability and upgradeability (communications and space missions):

- Single-satellite systems: re-configurability and upgradeability are key aspects on GEO missions for communications, it is therefore a key aspect to guarantee security. For example, if mobile agents (or better, mobile code) is to be used it is necessary to guarantee most of the basic security properties including interactions, communications, code and data.
- Multi-satellite systems: Multiple, highly autonomous, satellite systems are envisioned because they are capable of higher performance, lower cost, better fault tolerance, re-configurability and upgradeability. Security aspects should be also considered in this scenario and if mobile agents are used, agents should protect their code and data by carrying their own protection mechanisms.

7.3.2 Data Relay

Satellites can bring Beyond Line Of Sight capabilities to platforms such as Unmanned Aerial Vehicles and Earth observation satellites. With such a capability it is possible to control these platforms and the on-board sensors or payloads, while offering real time connectivity from any place in the world to central decision headquarters located in Europe.

Satellite telecommunication networks will therefore be instrumental in implementing the European Foreign Policy objectives, by gathering reliable information (fresh and independent) to assess the actual situation over any area. It will contribute to a real time monitoring of International Treaties (such as fisheries) and in the management of Crisis (Humanitarian Aid, Natural crisis like floods, etc.).

While Europe has implemented the Artemis data relay satellite carrying the SILEX experiment, it is necessary to transform this first technology trial into a truly operational service.

Dual use of this technology will therefore be facilitated by a forerunning service gathering the market and the needs for European institutional needs.

7.3.3 Applications for Dual Use.

Dual-use solutions can be used in many different applications that use satellite capacity. Some of them are:

- **a)** To provide backup communication capabilities and a rapidly deployable telecommunication infrastructure when terrestrial communication is interrupted in cases such as earthquakes or other natural (or unnatural) disasters.
- **b)** Hardened satellite systems to face up to intentional or unintentional threats. These threats may be ground-based, space-based, or interference-based.
- **c)** Highly responsive and reconfigurable links, to connect embassies, headquarters (crisis management centres, police HQ, ISTAR & C2), sensors and the forces deployed in operational areas anywhere in the world (including maritime areas) and ad-hoc operations management centres in Europe.
- **d)** Interoperability with member states, user communities, and defence NATO systems.
- **e)** To increase the capacity to absorb sudden peaks of traffic.
- **f)** World-wide coverage, connecting different widely separated geographic locations.
- **g)** High data rate communications (bi-directional and multidirectional, including videoconferencing and data-cast), between fixed users (decision and operations management centres, headquarters, harbours, airfields, information systems, logistics).
- **h)** Low to medium data rate secure communications between mobile or mobile - fixed terminals (aerial and maritime platforms, trains, ground vehicles).
- **i)** Wide-band secure communications from fixed to mobile users on a highly reliable basis but with real cost-effective solutions that are affordable to a wide range of user categories.
- **j)** Research in technologies to improve citizens' security, as communication infrastructures to support security forces missions, and at the same time to preserve citizens' privacy.
- **k)** ISI could tackle telecom PPDR systems, in the context of initiatives such as MESA, and providing a broadband evolution path to PPDR Technologies such as Tetra or Tetrapol.
- **l)** Deployment of SATCOM systems to cover Major Events such as Olympic Games, World Championship, exhibitions, Heads of State Meetings, etc..
- **m)** Provision of Virtual Private Network services over satellite both for governmental organizations and large private companies.

7.3.4 GMES and GALILEO.

In this area, Dual Use applications are multiple. GMES (Global Monitoring for Environment and Security) and GALILEO programs will play a key role in assisting emergency response services, natural disasters, terrorist attacks, borders control, early warning, homeland security, humanitarian missions, etc. It is clear that these programs could be called 'Dual Use Programs' because of their applications.

Mobile real-time positioning, as a part of Security, is an important role to be covered by Galileo System, as well as Time and Navigation applications. For that, it will be necessary to dispose high data rate interconnections between these sensors and decision-making centres, providing safer end-to-end communications to relay information from these centres to others.

Nowadays security is especially weak in telemetry links. This is a heritage of the years when the information transmitted through these links was assumed not to be safety critical. However, the situation is quite different at this moment since future space projects will place in orbit extremely valuable assets that will have to be protected from external access and that will transmit highly sensitive information (either in terms of national security or in terms of high added value and originality). This is the scenario faced currently by the development of future earth observation systems (GMES) and Galileo, and actions need to be taken in order to endow data/telemetry/telecontrol transmission with the required level of security. As an example of the current situation, there does not exist any security concept agreed at European (nor international) level for space/ground links and the existing ESA Packet Telecommand Decoder standard foresees only a very weak authentication scheme.

Typically, in earth observation systems, the high rate downlink is secured by encryption and message authentication. The encryption and authentication keys for the downlink are classically generated on ground and sent to the space platform via a command uplink, which needs then be highly secured. Therefore, secure communication for GMES shall incorporate as minimum means for self-authentication, key agreement, message authentication and en-/decryption of telemetry data. There exist algorithms that provide secure key exchange and authentication by using only a unidirectional link. Elliptic Curve (EC) based cryptography today is regarded as high secure implementation of the standard techniques, but deeper studies are necessary in order to analyse other alternatives. An EC based unidirectional scheme could provide the necessary level of security for a unidirectional link. The keys for encryption and authentication could in principle be generated on- board. By combining both EC based unidirectional key exchange/authentication and on- board key generation an autonomous secured downlink (working at rates higher than 100Mb/s) system can be designed, which is decoupled from the security requirements of the command uplink. However, further research is still required until a cryptographically reliable key on-board generator is ready to be implemented.

The discussion above is also applicable to the control link of the Galileo system. However, Galileo yet adds more complexity to the management of security. The reasons are twofold. First, there will be several tens of millions of users of Galileo simultaneously at any moment, using the systems for a equally large of safety-critical and non-safety critical applications; hence the integrity of the signal (i.e., the ability of the user to recognise that the signal is correct and not an intentional interferer) must be maintained at all time, otherwise a serious disruption of all applications can occur. It is mandatory that in the future Galileo includes in its signals the features required by users to check the integrity. Second, unlike GMES where the downlink transmission is addressed to control centres (which access all the information and later is re-distributed to the users via terrestrial networks), Galileo signals are intended for the individual users, each one having certain rights of access to the Galileo services. Therefore, the security means to be implemented in Galileo must allow service providers distinguish a potentially very large number of types of access and privileges. The second generation of Galileo starts to be considered. An important research effort is necessary to incorporate all these security aspects in the system design.

7.3.5 Interoperability and Interworking.

Civil and governmental securities are quite often very close one to each other and they can share technologies and resources. In order to stimulate synergies, security should look at the synergies between civil and defence applications and foster the transformation and integration of different technologies. In this field, its focus should be on interoperability and connectivity as key elements of trans-border and inter-service cooperation between civil and governmental systems and applications.

7.3.6 Cooperation with others players in FP7 and ESA.

Recently, ESA has undertaken to officially re-evaluate the legal meaning of its statute, concluding that the Convention does indeed not restrict ESA's capacity to launch and implement space programs for defence and security purposes or dual purposes or for national or international public bodies in charge of security and defence. Also, a security clearance system has been installed.

Thus, a new situation has been identified for the discussion on the future institutional structure for security and defence aspects of space. Instead of continuing to rely on national approaches or, possibly, setting up a special second European space agency just for security and defence, now an attractive option exists to take full advantage of the dual use nature of space by ESA. Any such an opportunity to avoid intra-European duplication should be welcome as a cost-reducing factor.

In this way, some programs, such as 'Alphasat', show the implementation of 'Dual Use' capabilities where governmental and civilian applications are considered within the same platform.

7.4 CONCLUSION AND RECOMMENDATIONS

Security and Space are strongly related. This is the view of ISI and it is also the perspective undertaken by the Seventh Framework Programme formulation. Research and Development of Dual-Use and Security solutions can be considered a key activity within the Integral Satcom Initiative, as these topics are taking a great relevance for the European Framework.

In this line, ISI also has an enormous possibility to contribute to other areas and programmes like the European Security Research Programme (ESRP), which will be also addressed in FP7. The ESRP, taking the ISI Platform as a support, should take advantage of the duality of technologies and the growing overlap of security functions to bridge the gap between civilian and defence research.

8. POSITIONING WITH RESPECT TO GALILEO & GMES

8.1 BACKGROUND

Satellite Telecommunication, Navigation and Observation Systems are the three fundamental space infrastructures that make possible the development of applications and the provision of integrated value-added services which fully meet the highly fragmented user demand.

The integration and synergic utilisation of the three space-based technologies is recognised to be of the utmost importance by the European policy and decision makers; furthermore, the full integration and inter-operability of the satellite based systems with the terrestrial networks and systems is essential to the success of the space-based applications and services.

In line with the above mentioned considerations, it is necessary for a Space-based Communication Technology Platform, like ISI, to position itself in the best possible way with respect to the present status and future evolution of the Satellite Navigation and Earth Observation Systems.

The main two European Initiatives in the field of navigations systems are EGNOS and Galileo. EGNOS has entered its initial operations phase and will be technically and operationally fully qualified by the end of 2006. In parallel, Galileo system developments are in progress and will lead to the in-orbit validation within 2008; this will allow the subsequent start-up of a full operational capability by the Galileo Concessionaire.

At global level, it is to be highlighted that the United States have started an impressive GPS modernisation programme, which will comprise, in the short term, the development of the Block IIF version, and will then lead to the 30 satellite GPS III system which will address the future needs of both military and civil users over the next 30 years. The GPS upgrading also comprises improved level of performance of the North American WAAS (Wide Area Augmentation System).

Through the development of EGNOS (the European GPS augmentation system) and Galileo, Europe's ambition is to match the pace of the United States in their upgrading of GPS and WAAS.

The success of the new upgraded Satellite Navigation systems will rely on the development of services and applications able to meet user demand; within this framework a key market and technology driver is the integration of Navigation and Communications Services: LBS (Location Based Services) and NRCS (Navigation-Related Communications Services) are deemed to be the most promising service categories in terms of market and business potential. In this field, the ISI Technology Platform can play an important role, provided that the requirements of LBS and NRCS are duly taken into account in the processes of objectives definition and architecture design of the ISI Platform.

Synergic and complementary to the development of the Galileo Programme is the evolution of the other fundamental European Space Initiative: GMES.

GMES will provide independent access to information for policy and decision makers in the strategic fields of environment and security. Furthermore, GMES represents the European contribution to GEOSS (the international Global Earth Observation System of Systems). The successful development of the GMES Programme will generate strategic, political, economic and cost-effectiveness benefits which accrue to the all of the GMES stakeholders: European, national and local Governments and Authorities, the European citizens, the European Industry and the European Scientific Community.

GMES will be able to change the historical situation, in which Europe has been dependent on partners like US for access to critical data during international crisis and emergency events, and will provide an important contribution to understanding climate change and its impacts. In addition to supporting the reduction of global deforestation and providing a more accurate estimate of crop failures in local regions, GMES will generate benefits through risk and civil protection applications in the areas of flooding, forest fires, landslides and industrial accidents.

GMES has been recently identified as a priority for Europe and is a fundamental part of the European Space policy as a European Union-led initiative, with ESA being in charge of implementing the GMES Space component. The European Commission has identified the first set of GMES pilot services for early operational implementation from 2008 onwards (the three "Fast Track Services"): Land Monitoring, Ocean Monitoring and Emergency Management.

A fundamental aspect which shall be underlined is that a Telecommunication Network Infrastructure will be vital for the effective provision of GMES services (examples are the GMES services devoted to the risk management, emergency and security applications, which will rely on the existence of a global, reliable and secure mobile and fixed telecommunication infrastructure to be based on both terrestrial and satellite systems). In this respect, the ISI Technology Platform will be able to play an important role, provided that it is properly designed taking into account the telecommunication requirements of the GMES User Community.

8.2 GENERAL CONCEPTS DRIVING ISI'S POSITIONING IN RELATION TO GALILEO AND GMES

a) Satellite Communications are essential elements to exploit Navigation and Earth Observation systems to their fullest.

b) Satellite Communications are not competing with the other two fundamental Satellite Technologies (NAV and EO systems); on the contrary, their complementary and synergic nature makes it possible for Satellite Systems to provide integrated applications fully meeting User demand.

c) The integration philosophy advantages are not limited to Satellite Technologies and Services: integration and interoperability of Satellite and Terrestrial systems are fundamental to the success of a high number of very promising applications.

d) ISI can play a very significant role in this integrated scenario, as a complement to Galileo and GMES to meet user expectations and as an initiative fully in line with the European Union strategic vision

8.3 ELEMENTS RELATED TO THE ISI POSITIONING WITH RESPECT TO GMES

8.3.1 Key Basic Concepts for ISI/GMES positioning

a) Through the Research action of the "Convergence and integration of satellite telecommunications with GMES" of the 6th Framework Programme, the European Commission has already established a preliminary basis to address the complementarity of GMES with Satcoms. However, the detailed definition of GMES needs is still at an early stage and not sufficient to measure all potential benefits of Satcoms capabilities. On the basis of the FP6 background experience ISI intends to foster the consolidation of basic concepts under investigation, then to go one step forward concept testing and make them truly operational for GMES stakeholders.

b) Integration at network level: a global satellite telecommunications network, inter-operable with terrestrial telecommunications systems and fully integrated in the GMES global architecture, is able to provide valuable operational support to all of GMES missions. ISI could play a significant role in this field.

c) Value added satellite telecommunications services can meet key user requirements in the majority of GMES thematic areas.

8.3.2 GMES Telecommunications needs

a) GMES User Communities are numerous and diversified. Even if it is not simple to get a clear picture of GMES users' telecommunication requirements and to identify from now all the GMES thematic areas where enhanced telecommunications functionalities will improve the quality of GMES services, it is already possible to list some areas where Satcoms are of paramount importance for GMES.
As a first example in case of emergency and crisis management, temporary communications links have to be rapidly deployed in order to enable rescue teams to coordinate and combine their effort from the very first hours of intervention. ISI will foster the validation and widespread adoption of the most appropriate standardised communications infrastructures to support management of pre- and post-crisis situations.
As a second example, GMES will benefit from, and is expected to also drive, upgrades of the most recent satellite telecommunication techniques for data collection (real time, global access) and distribution.

b) The former list is not exhaustive and will be consolidated once a picture of the GMES User needs is further defined. A translation of these needs into specific architectural and system requirements shall then be performed. The key principle promoted by ISI will be to foster the adoption of cost-effective, sustainable and user-friendly Satcoms solutions, enabling decision-makers to better anticipate and manage crisis situation issues related to GMES.

8.3.3 Satellite Telecommunications Solutions for GMES

a) Optimised Satcoms solutions shall be developed to meet those GMES Users Telecommunications requirements for which an added value, with respect to terrestrial networks, can be provided by satellite technology.

b) Emphasis shall be put on:

- **i)** Improvement of geographical service area, beyond coverage of existing terrestrial networks, in particular in developing countries, during crisis events as well as during the alert phase;
- **ii)** Improvement of reactivity, through faster data collection, with real time control of sensors or fresher data delivery, or for access to and remote control in-situ sensors;
- **iii)** Improvement of product quality, through the amount of data that can be collected and distributed thanks to higher available data rates;
- **iv)** Improvement of terminal and on-ground infrastructure deployment features (lightweight, robustness, autonomy, ease of operation) for immediate and reliable use by rescue teams and victims needing temporary telecom means during and after crisis events.

c) The satellite telecommunication platform for GMES will be based on modular sub-systems to perform these specific functionalities: data collection and distribution, emergency communications, positioning information communication, early-warning and alert communications.

d) New functionalities for transmission and networking protocols can also be envisaged for efficient and secure transmission of e.g. remotely sensed data to on-site teams.

8.3.4 GMES SAT-COM based Value Added Services

a) The functionalities of the GMES Satellite Telecommunications Platform will make it possible to develop a set of GMES SAT-COM based value added services providing the GMES users with real benefits, like fast deployment of rescue teams and secure connections for emergency and security operations.

b) GMES Thematic Areas for which development of SAT-COM based value added services can be beneficial include Marine Surveillance, Security, Natural Hazards, Environmental Monitoring.

8.3.5 Standards and Regulations for GMES Satellite Telecommunication

a) Any GMES SAT-COM technological solution development shall be made in compliance with existing and planned standards.

b) Possible need for additional ad-hoc standards shall be assessed.

c) Requirements for specific regulations/legislations at EU level to support GMES SAT-COM entry into operation shall be assessed.

8.3.6 Cost Benefit analysis

a) A detailed cost-benefit analysis referred to the possible utilisation of SAT-COM for GMES shall be assessed for each GMES Thematic Area.

b) Cost-benefit analysis needs to take into account the findings of the GMES Service Elements (GSE) projects.

8.4 ELEMENTS RELATED TO THE ISI POSITIONING WITH RESPECT TO GALILEO

8.4.1 Galileo and Satcom/ISI synergy

a) As stated in the European Commission "Aeronautics and Space" Work Programme, a significant number of applications and services can be developed for which the combined use of Galileo and Satcom has a strong added value. ISI could play a significant role in this field. Focus shall be on applications for which Satcom has a clear value added with respect to available terrestrial TLC, for example in terms of coverage area and rapid deployment capability.

8.4.2 NAV-COM Market

a) A large potential market exists for embedded nav/comms; GPS/GSM integrated systems have been forerunners in this field.

8.4.3 Integrated COM-NAV Applications

a) The application definition is the starting point of the analysis of the Satcom/ISI/Galileo positioning.

b) A broad and thorough analysis of the possible applications areas shall be performed, including the evaluation of respective target markets, key users, potential revenue and cash flow streams, possible technical, regulatory, economic barriers to the introduction of combined services.

c) Preliminary examples of applications with high growth potentiality include global tracking and tracing of mobile assets, fleet management, location based services, emergency, security, search and rescue and marine surveillance.

8.4.4 Possible methodology for the Navigation/Satcom/ISI positioning and integration analysis

a) For each identified application area, a definition and categorisation of the associated user requirements shall be performed, as a basis for the subsequent identification of the set of high-priority "Navigation related Communication Services" (NRCS: the family of communication services directly associated to the navigation services).

b) Next step will be a communication trade-off analysis (satellite versus terrestrial comm. systems) aiming at identifying the sub-set of NRCS to be developed through the integration of Galileo with Satcom systems (the other NRCS services being developed through the integration of Galileo with terrestrial communications systems).

c) Contribution of ISI to the development of the identified sub-set of NRCS based on Satcom systems shall than be assessed.

8.4.5 Low cost NAV-COM receivers

a) Development of low cost NAV-COM satellite receivers is of utmost importance to support large scale development and successful entry into the market of Galileo/Satcom based applications.

8.4.6 Technical typology of integration shall be selected for the priority application areas:

Three possibilities can be envisaged:

- **i)** Integration of communication function into the GNSS receiver (e.g. fleet management, position reporting);
- **ii)** Integration of navigation function into the communication receiver;
- **iii)** Integration at chipset level.

In any case, the user needs both functions (NAV and COM): it is up to the manufacturer to take two technologies/devices and make one value added service (at receiver level). The study of new architectures optimising the NAV and COM functions shall be analysed in order to keep the receiver within limited complexity.

8.4.7 Roaming/Interoperability

a) Roaming among different communications networks (Satcom systems, cellular networks, Wifi, etc.) is a capability requested by the users (depending on coverage, cost or other parameters the user may want to roam across a high number of networks). This aspect is a major point when dealing with international multi-modal transportation.

b) Accurate positioning of users can be exploited in the provision of telecommunication services in combination with signal power measurements to drive handovers from satellites to/from terrestrial networks.

8.4.8 Location Based Services (LBS)

a) All the market analyses performed in the frame of Galileo program (GALA WP1, GEMINUS, GALILEI Task H, PWC report) highlight that LBS will be the very first application for Galileo: this further demonstrates the importance of the NAV-COM integration concept and of the Galileo/ISI positioning evaluation, being LBS realised by the integration of a positioning capability into a mobile communications terminal.

8.4.9 Safety and Emergency Services

a) Combination of multimedia communications with high-accuracy positioning supported by broadband satellites and Galileo makes it possible to implement services for the safety of citizens as well as to manage emergencies. Wide area outdoor electronic-monitoring combining telecommunication and positioning capabilities can be used by police forces in order to monitor wide territories, prompt react to natural disasters and rescue people.

8.4.10 Standardisation

a) To make possible the large scale development of NAV-COM integrated applications and to generate a mass market (in particular for LBS applications) it is fundamental to perform standardisation efforts on the related cross-border technological areas.

b) One fundamental standardisation work to be carefully considered and followed by ISI is the one related to the Galileo introduction into the 3GPP mobile communications architecture (GPS is already considered at present; the future release of the standards could also insert Galileo specifications): work on this area has been performed within GALILEI project.

8.4.11 Regulation/Legislation

a) The impact of regulation on the possibility for integrated COM/NAV services to obtain a significant market share is heavy: examples are EU and US Emergency Call Handling Directives and Regulations (E112 and E911). In Europe the Regulation is too “soft”; a favourable regulation on E112 could lead to the success of LBS applications in Europe.

ANNEX A - ISI VISION STATEMENT

The Integral Satcom Initiative (ISI) is an industry-led action forum designed to bring together all aspects related to satellite communications. ISI addresses broadcasting, broadband, and mobile satellite communications, as well as their convergence, in integration within the global telecommunication network infrastructure. ISI supports all forms of space communication and space exploitation. ISI intends to be a Technology Platform included in the seventh Framework Programme (FP7) of the European Commission.

ISI is an open platform, whose membership embraces all relevant and interested private and public stakeholders. ISI intends to collaborate and cooperate with the European Commission, the European Space Agency (ESA), the EU and ESA Member States and Associated States, the National Space Agencies, International Organizations, User fora, and other European Technology Platforms. ISI fosters international cooperation under a global perspective.

ISI is determined to contribute significantly to several EU and ESA policies, in order to promote European industrial competitiveness, growth and employment in a sustainable way, in synergy with National priorities. Representative sectors of interest include ICT, Space, Security, Transport, Development, and Environment. Specific policy initiatives of interest include i2010, the European Space Policy, and in general all those initiatives which can benefit from the existence of an efficient satellite communications infrastructure, or which are aimed at the development of innovative satellite services and technologies.

Satellite communications constitute a strategic sector for Europe, with significant economic impact and high societal relevance. They are instrumental for European-wide and International broadcasting, mobile communications, broadband access, bridging the digital divide, safety, crisis management, disaster relief, and dual use applications. ISI works towards the convergence and integration of satellite and terrestrial networks, both fixed and mobile, considering all interworking and interoperability aspects. ISI supports the development of applications and services according to a user-centric approach, to enable all citizens to become full members of the knowledge-based society. ISI addresses the integration of satellite communications with navigation, Earth observation, and Air Traffic Management systems. Specific attention is devoted to Galileo and GMES. Data relay systems and the use of Unmanned Aerial Vehicles are in the scope of ISI, as well. ISI shall be instrumental in achieving and maintaining European leadership and competitiveness in all of the above fields, fostering the entire industrial sector, and maximising the value of related research and technology development. ISI embodies the critical mass required to pursue the above objectives considering short term priorities, medium-term evolutions, and long-term strategic directions.

ISI contributes to the harmonization of the European and International regulatory framework for satellite communications, helping in the removal of barriers. ISI works for the allocation of sufficient spectrum for all satellite communication applications and services. ISI favours the consideration of a regulatory framework for complementary ground components (CGC). ISI promotes open standards and international standardization approaches. ISI fosters wide adoption of common standards to enlarge markets, reduce costs and tariffs, facilitate interoperability and roaming, and ensure fair competition for the benefit of citizens, user communities and governments.

ANNEX B – GLOSSARY

2G	Second Generation Mobile Communication
3G	Third Generation Mobile Communication
3GPP	Third Generation Partnership Project
3DTV	Three Dimensional Television
4G	Fourth Generation Mobile Communication
AC	Admission Control
ACK	Acknowledgement code
ACM	Adaptive Coding and Modulation
ADC	Analogue-to-Digital Converter
ADSL	Asymmetric Digital Subscriber Line
AN	Access Network
AODV	Ad-hoc On-demand Distance Vector
AP	Access Point
ASIC	Application-Specific Integrated Circuit
ASMS-TF	Advanced Satellite Mobile Systems - Task Force
ATM	Air Traffic Management
ATC	Air Traffic Control
B3G	Beyond 3G
BPF	Band Pass Filter
BC/MC	Broadcast Multicast
BER	Bit Error Rate
BGAN	Broadband Global Area Network
BSM	Broadband Satellite Multimedia
BSS	Broadcast Satellite Service
BWA	Broadband Wireless Access
C2	Command & Control
CAC	Call Admission Control
CATT	Channel Adaptive Transmission Techniques
CATV	Community Antenna TV
CDMA	Code Division Multiple Access
CFSP	Common Foreign and Security Policy
CGN	Centralized Gateway Node
CN	Corresponding Node
CoA	Care of Address
CONUS	Continental US
COTS	Commercial Off The Shelf
CPT	Cellular Planning Tool
CPU	Central Processing Unit
CSC	Common Signalling Channel
CSCF	Call State Control Functions
DAB	Digital Audio Broadcasting
DARS	Digital Audio Radio Service

DBS	Digital Broadcast Satellite
DMB	Digital Multimedia Broadcasting
DRA	Dynamic Resource Allocation
DRM	Digital Rights Management
DSL	Digital Subscriber Line
DSP	Digital Signal Processing
DSR	Dynamic Source Routing
DVB	Digital Video Broadcasting
DVB-H	Digital Video Broadcasting - Handheld
DVB-RCS	Digital Video Broadcasting with Return Channel via Satellite
DVB-S	Digital Video Broadcasting via Satellite
DVB-S2	Digital Video Broadcasting via Satellite version 2
EC	European Commission
EC	Elliptic Curve
EIRP	Effective Isotropic Radiated Power
EGNOS	European Geostationary Navigation Overlay System
EO	Earth Observation
EPG	Electronic Programme Guide
ER	Edge Router
ESA	European Space Agency
ESPD	European Security and Defence Policy
ESRP	European Security Research Programme
ETSI	European Telecommunications Standards Institute
EU	European Union
FDD	Frequency Division Duplex
FEC	Forward Error Correction
FMT	Fading Mitigation Techniques
FP6	Framework Programme 6
FP7	Framework Programme 7
FSS	Fixed Satellite Service
FTTx	Fibre-To-The-x
GEDIR	Geographic Distance Routing
GEO	Geostationary Earth Orbit
GEOSS	Global Earth Observation System of Systems
GES	Gateway Earth Station
GGSN	Gateway GPRS Service Node
GIS	Geographic Information System
GMDSS	Global Maritime Distress and Safety System
GMES	Global Monitoring of Environment and Security
GNSS	Global Navigation Satellite System
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile Communications
GSN	GPRS Supporting Node

HA	Home Agent
HAL	Hardware Abstraction Layer
HAP	High Altitude Platform
HD	High Definition
HDTV	High Definition Television
HIPERLAN	HIgh-PErformance Radio Local Area Network
HPA	High Power Amplifier
HSDPA	High Speed Down-link Packet Access
HW	Hardware
ICO	Intermediate Circular Orbit
IETF	Internet Engineering Task Force
IMR	Intermediate Module Repeater
IMT-2000	International Mobile Telecommunication 2000
IP	Internet Protocol
ISI	The Integral Satcom Initiative
ISO	International Standards Organization
IST	Information Society Technologies
ISTAR	Intelligence, Surveillance Target Acquisition and Reconnaissance
IT	Information Technology
ITU	International Telecommunication Union
ITU-R	International Telecommunication Union - Radiocommunication sector
IWU	Interworking Unit(s)
KPI	Key Performance Indicator
LAN	Local Area Network
LAR	Location-Aided Routing
LBS	Location-Based Services
LDGM	Low Density Generator Matrix
LDPC	Low Density Parity Check
LEO	Low Earth Orbit
LNA	Low Noise Amplifier
MAC	Medium Access Control
MAN	Metropolitan Area Network
MANET	Mobile Ad-Hoc Networking
MBMS	Mobile Broadband Multimedia Satellite
MBSAT	Mobile Broadcasting Satellite
MDF	Main Distribution Frame
MEMS	Micro Electro Mechanical Systems
MEO	Medium Earth Orbit
MGIS	Mobile network Geographic Information System
MIMO	Multiple Input Multiple Output
mITF	mobile Information Technology Forum
MPLS	Multi Protocol Label Switching
MSIA	Membrane Surface Inflatable Antenna
MSS	Mobile Satellite Service

MSUA	Mesh Surface Unfurlable Antenna
MT	Mobile Terminal
NATO	North Atlantic Treaty Organisation
NAV-COM	Navigation - Communications
NC	Nearest Closer
NCC	Network Control Centre
NFP	Nearest Forward Progress
NGOSS	New Generation Operational Support System
NRCS	Navigation-Related Communications Services
NRS	Navigation-Related Services
OBP	On board processing
OFDM	Orthogonal Frequency Division Multiplexing
OSGi	Open Services Gateway Initiative
OSI	Open System Interconnection
OTA	Over The Air
PAN	Personal Area Network
PC	Personal Computer
PDA	Personal Digital Assistant
PEP	Performance Enhancing Proxies
PLMN	Public Land Mobile Network
PPDR	Public Protection Disaster Relief
PSTN	Public Switched Telephone Network
PVR	Personal Video Recorder
QoS	Quality of Service
R&D	Research and Development
RAB	Radio Access Bearer
RASN	Radio Access Support Node
RF	Radio Frequency
RL	Return Link
RM	Resource Management
RMU	Remote Mobile Users
RRM	Radio Resource Management
SDMA	Space Division Multiple Access
S-DMB	Satellite-Digital Multimedia Broadcasting
SDR	Software Defined Radio
SES	Satellite Earth Stations and systems
SGSN	Serving GPRS Support Node
SID	Shared Information and Data model
SIP	Session Initiation Protocol
SLA	Service Level Agreement
SOHO	Small office/ home office
SP	Service Provider

SR	Safety-Related
SRA	Strategic Research Agenda
SSDA	Solid Surface Deployable Antenna
S-UMTS	Satellite-UMTS
SW	Software
TCP	Transport Control Protocol
TDMA	Time Division Multiple Access
TMF	Tele-Management Forum
TORA	Temporally Ordered Routing Algorithm
TP	Thematic Priority
T-UMTS	Terrestrial-UMTS
TV	Television
U&DS	Up & Down Link Station
UHDV	Ultra High Definition Video
ULS	Up-Link Station
UMS	UMTS Mobility Server
UMTS	Universal Mobile Telecommunication System
UPC	Usage Parameter Control
UW	Unique Word
UWB	Ultra Wide Band
VoIP	Voice over IP
VPN	Virtual Private Network
VSAT	Very Small Aperture satellite Terminal
WAAS	Wide Area Augmentation System
WAN	Wide Area Network
WCDMA	Wideband-Code Division Multiple Access
WEU	Western European Union
WG1	Working Group 1 (of the ASMS Task Force)
WiFi	Wireless Fidelity
WiMAX	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Network
WPAN	Wireless Personal Area Network
WWRF	Wireless World Research Forum
xDSL	(Any) Digital Subscriber Line
XML	EXtensible Markup Language
ZRP	Zone Routing Protocol

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