Contract no.: 257118

FISI Project - contract n°257118

D2.1.1 Research Roadmap for Universal Service and Future Internet – Draft

FISI project executive summary

The FISI project aims at supporting the Integral SatCom Initiative (European Technology Platform) in defining a strategic vision on innovation priorities to reinforce the competitiveness of the European SatCom industry and in promoting emerging SatCom architectures in response to EU policy objectives.

Abstract

This deliverable contains the draft Research Roadmap for Universal Service and Future Internet as defined by WP2 of the FISI project, devoted to identify and prioritize the necessary research topics for Universal Service and Future Internet based on technical gap analysis. It will also map these research activities onto FP7 and FP8 high level objectives as well as possibly in ESA TLTP and national space agencies work program.

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1 Introduction

This deliverable contains the draft Research Roadmap for Universal Service and Future Internet as defined by WP2 of the FISI project, devoted to identify and prioritize the necessary research topics for Universal Service and Future Internet based on technical gap analysis. It will also map these research activities onto FP7 and FP8 high level objectives as well as possibly in ESA TLTP and national space agencies work program.

Chapter 2 contains a review of the Net!Works and Photonics21 SRAs, aiming at the dentification of potential impacts, synergies and complementarities on the ISI Strategic Research Agenda with the aim to enhance SatCom solutions's features, performance and integration capabilities. Chapters 3 and 4 replicate this exercise for the ESA TLTP and for the national programmes of the countries corresponding to the WP2 partenrs (namely France, Germany, Italy and Spain) respectively.

Chapter 5 identifies the technological gaps that shall be addressed in order to secure a successful integration of SatCom based architectures into the targeted application scenarios (Universal Service and Future Internet).

Lastly, Chapter 6 provides a mapping of such roadmap onto FP7 and FP8 high level objectives in order to enable its effective implementation through R&D activities. Foreseen activities within ESA TLTP (Telecom Long Term Plan) shall be also taken into account to avoid duplication of work whilst fostering synergies instead.

2 Review of other ETP's SRA

2.1 Net!Works

Net!Works key messages are reported below (for more info see http://www.networks-etp.eu):

- *The desire of individuals to influence decision making by leaders has grown continuously in recent years. Never before has communications and IT technology provided individuals with such a range of opportunities to make their opinions heard. From Twitters to Web fora, the choice of communications options is growing every day. This change in the role of the individual in society is happening.*
- *ICT is essential for our continued economic growth and job creation in Europe!*
  - *Information and Communications Technology (ICT) is one of the industrial sectors set to grow in the coming decade generating lots of exciting new jobs and economic activity. Europe is excellently positioned to lead this growth based on the established leadership of European industry in communications technologies addressing societal challenges such as transport, energy, environmental and health applications. All of the new applications involve integrating the latest mobile and fixed communications networks and services directly into the application. This gives users the instant information and control they need to optimize their services to the specific needs of the individual as well as to the needs of society as a whole. We need to maintain R&D on ICT in Europe to have the experts needed to exploit the market opportunities for the new applications.*
  - *Communications networks will be a part of every application and is an absolutely key enabling technology across all sectors in the society and economy.*
- *Research on new networks and services has to start now to be ready to support the mass market use of new applications!*
  - *Already, the trend towards increasing use of communications technology to support all aspects of everyday life is clear. Predictions show that the current networks and services will reach the limits of the capabilities in coming years. The volume of users and transported information will rapidly increase demanding new levels of network performance while and society depends increasingly on reliable and secure services.*
  - *Major challenges lie ahead in overcoming the limitations of current networking technology. Physical limits are being approached in several key technologies while security and privacy issues have captured the attention of individuals and governments around the world. Innovation and multi-disciplinary research will be needed to develop flexible and adaptable solutions. We need to motivate our students to become technology researchers and invent the future, securing knowledge leadership for Europe! To secure and improve our leadership for the future, we need to take action now.*
  - *The collaborative projects, such as Integrated Projects, in the Cooperation area of the Framework Programme, have shown that excellent results can be achieved when industry, research centres and SMEs work together. We should build on this success!*

A Strategic Applications Research Agenda (SARA) has been delivered in July 2010. It aims at covering future communication requirements both from an application point of view and a technological point of view. While the application review is quite complementary respect to that developed within ISI, because it includes Health, Transport, Environment and the Future of Internet as applications, it is interesting to see that most of the technological challenges have synergies with those considered in the ISI SRA.

The following technological areas are considered:

- **Context and User Profiling**

  - It is highlighted how in the future communication areas the user point of view is crucial. The future communication technologies, services and applications needs to consider the user centric services for allowing more challenging services to each individual user. The most interesting research issues in the context and user profiling are addressed.
- **Security, Trust and Dependability**
  - The communication security from a broad point of view is considered with a particular focus on wireless communications.
- **Machine-to-Machine communications**
  - M2M communications are considered as one of the most challenging areas when considering communications among machines devices or objects without human intervention. Both industrial and research point of view are considered as well as the recent developments within the Standardization bodies.
- **Cognitive Radio Systems**
  - Radio scarcity and its opportunistic usage is a centric issue to be considered. Cognitive radio is considered with a particular attention toward the spectrum sensing issues and the standardization bodies' effort.
- **Broadband Mobile systems**
  - It is of fundamental importance also for satellite communication the development of a novel integrated and heterogeneous radio access network able to give to the user a broadband mobile access to the network. Research effort and priorities have been highlighted.
- **Optical radio technologies and Radio Over Fibre**
  - The terabit access technologies and hybrid wireless–wired architectures need to be taken into account. The research effort and its impact have been considered.
- **Mediation Bus**
  - The mediation bus could be defined as a distributed environment that achieves an optimized operation of Future Internet (FI) by performing mediation operations among the service and network/transport layer entities. This allows developing user centric applications within a future networking scenario.
- **Future Internet**
  - The aim toward a novel internet infrastructure aiming to cope the most novel requirements both in terms of user and network requirements is considered also within Net!Work platform by defining a novel architecture able to encompass all the future requirements.
- **Green Wireless**
  - Environment protection is an issue of paramount importance in lots of applications even outside communications. With this aim it is needed to develop environment friendly technologies for reducing the impact of the society on the environment.

2.2 Photonics21

Photonics21 vision for ICT is reported below for the sake of clarity (for more info, see http://www.photonics21.org/download/Photonics21_news/FinalEditionPhotonics21VisionDocument_InternetVersion.pdf):

1.0

Information and Communication

Vision

Photonics is now revolutionising the information and communication technologies (ICT), exploiting the full capabilities of solid-state lasers and ultra low-loss optical fibres. Transforming modern societies into knowledge-based societies relies on using efficient means for managing, processing, storing, recovering and communicating information digitally. Today we are experiencing an explosion of world wide web-based services, but this is only just the beginning, and a simple consequence of the penetration of relatively conventional photonic technology into commercial communication systems. Emerging new concepts and disruptive photonic technologies will, over the coming decades, be key-enablers for revolutionary advancements in the telecom and datacom fields across the world. They will enable:

- development of the future internet infrastructure with multi-terabit capacity, able to fully address traffic demands foreseen in the core & access networks, and thereby facilitate sophisticated services in all areas of human activities.
- penetration of photonics at the board- and chip-level for next-generation routers, processing systems, super-computers. This will lead to novel digital "machines" with unprecedented computing power and sophistication, able to "feel", "think" and "react" in real time, with the potential to profoundly impact our everyday lives.
- disruptive new photonics concepts, some already pursued today, that will dramatically reduce global energy consumption of our future telecommunications systems.

Figure 1: Photonics21 Vision for ICT.

Parts marked in yellow have a direct impact on ISI R&D priorities and shows also synergies and complementarities:

- the development of multi-terabit backbones shall be accompanied by suitable technological development for the last mile access in order to meet the digital agenda objectives, considering that FTTH will be limited to densly populated areas in order to ensure profitability. Most likely, this will achieved through a mixture of different access technologies, with satellite broadband access becoming as fundamental assett for unserved or underserved regions, both for last-mile access as well as for backhauling.
- Energy consumption reduction in telecommunication networks is an emerging topic. In the past, most of the effort has been devoted to optimising power consumption in mobile user terminals for the sake of the battery lifetime. This paradigm is today outdated, in favour of a broader approach aiming at optimising the overall energy consumption within the entire access and also core network. As solar-powered repeaters in the sky, with large coverage areas and unbeatable capability to distribute content to a large number of users with (almost) fixed cost per bit regardless where users

are located within the coverage area, communications satellite could contribute to reduce global energy consumption of future telecommunications networks.

3 Review of ESA TLTP

ESA's Telecommunications Long Term Programme (TLTP) has as objective the enhancement of the competitiveness of European Industry by promoting, among others, the use of satellites for advanced fixed, broadcasting, multimedia and mobile communications, data relay, search and rescue and aeronautical services and for pre-competitive services. The present TLTP (2009-2013), proposes the extension of the Telecommunications Programme for the reference period and defines a set of lines of action and corresponding budget allocations. These lines of action are based on the analysis of the trends for the different Satcom Market Segments and have been identified upon consultation with Industry, Operators and relevant Institutions. Further ESA has also evaluated the requirements of specific institutions (European Commission, Aviation Authorities, GMES community, Security Institutions etc.).

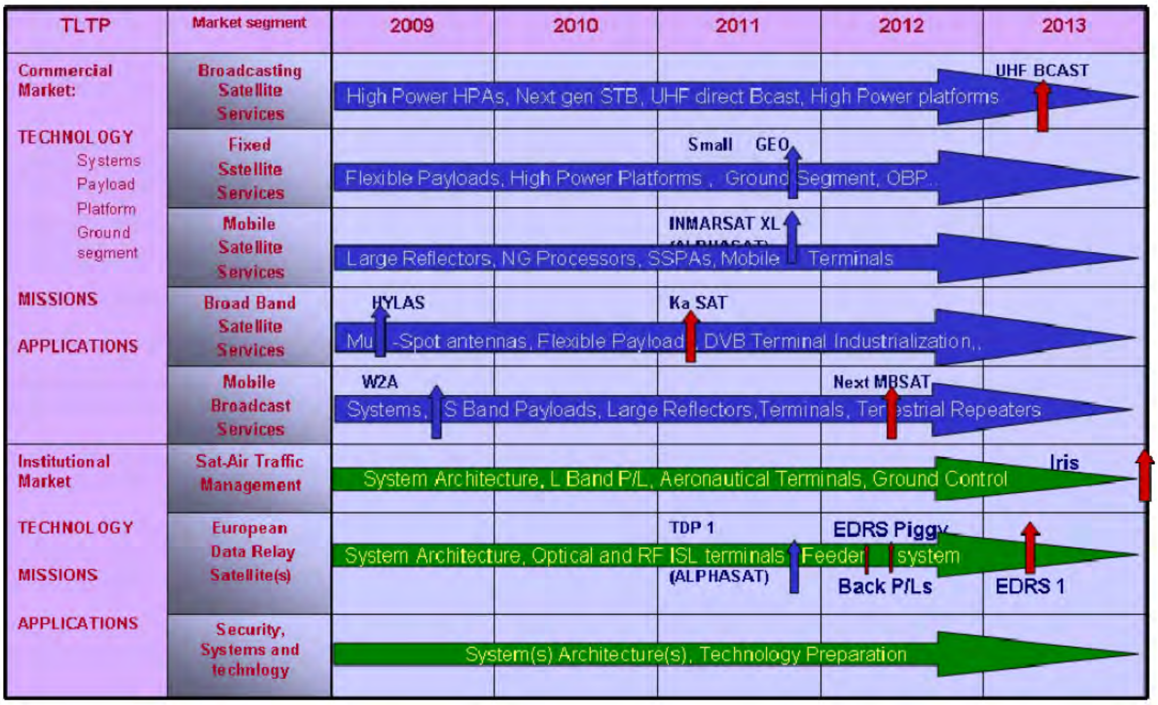

Figure 2: Summary of planned Actions of the TLTP (2009-2013). In Red potential new missions.

The realization of the initiatives proposed in the TLTP will be undertaken under the programmatic framework defined for Telecommunications, i.e. the ARTES Programme. The TLTP proposes the continuation and/or extension and/or adoption of the following programme elements:

1. **Preparatory: ARTES 1**. The TLTP proposes the continuation of the preparatory component of the Telecommunications programme. This is the instrument that allows the Executive to perform strategic analysis of the development of the market, technology and evolution of telecommunication services. It allows the realisation of feasibility analyses that are the seed for innovative system concepts. Further it provides an instrument for the support of standardization and promotional activities.

2. **Technology, Equipment and Systems: ARTES 3-4 and ARTES 5**. The TLTP proposes the continuation of the Technology, Equipment and Systems component of the Telecommunications programme. The scope of these activities covers all the developments required for the Fixed, Mobile, Broadcast, Broadband and Broadcast to Mobile Market sectors at system, equipment and technology development level. Commercially driven activities, geared towards the realization of products will be undertaken under the ARTES 3-4 Element. Long term R&D efforts of advanced technologies will be undertaken under the recently updated rules of ARTES 5. These cover activities proposed either by the Agency (Sub element 5.1) or by the Industry (Sub element 5.2)

3. **Telecommunications Applications: ARTES 3-4**. The TLTP proposes the continuation of the Telecommunications Applications component of the Telecommunications Programme. These activities

correspond to the development and realization of applications and service demonstrations of satellite based telecommunications applications. These will be undertaken in partnership with private entities (Industry, potential Users) and will be realised under the provisos of ARTES 3-4.

4. **Opportunity Mission(s): ARTES 3-4.** The TLTP proposes the realisation of new missions in partnership with Satellite Operators. These missions may involve either full satellites or piggy back payloads and represent a continuation of the model that has been used for systems such as HYLAS or AMERHIS. Although several opportunities may emerge the most mature appears to be the realisation of an S Band Mission(s) in partnership with the operator(s) that will be granted the S Band Licences currently being processed/proposed by the European Commission.
5. **Extension of ALPHASAT/ALPHABUS: ARTES 8.** Based on the identification of the trends for Platform and Services the Executive proposes the extension of the ARTES 8 programme Element with two purposes: 1/ Enhance the capacity of the platform to a power handling level up to 22 KW and Payload mass of up to 1400Kg. 2/ The extension of the range of services and terminals that will be provided by Inmarsat through Inmarsat XL, i.e. Alphasat.
6. **Extension of Small GEO: ARTES 11.** The TLTP proposes the extension of the Small GEO programme to optimize its competitiveness, by industrializing the production, improving its selling points by including advanced European technologies, and addressing the adaptation of the Small GEO Platform to potential Institutional customers.
7. **The Iris System: ARTES10.** The TLTP proposes the continuation of the Iris Programme with launch of Phase II.1. This includes the Phase B of the project and involves the design of the system which includes the definition of a new standard for the communication system, the space segment, the ground segment, and the aeronautical terminals. Further the relevant coordination with SESAR Joint Undertaking and international organisations, e.g. Eurocontrol, EUROCAE and ICAO, will be also performed under this phase. In 2011 the Phase II.2 of the Programme, which involves the full implementation of the Phase C/D of the "Subset" of the infrastructure required for validation, will be carried out upon the satisfactory confirmation of the programmatic conditions that will have to be met for the full deployment of the system.
8. **The European Data Relay Satellite System: ARTES 7.** The TLTP proposes the adoption of a new ARTES element dedicated to the design, development and initial deployment of the European Data Relay Satellite System (EDRS). This new telecommunications infrastructure is meant to serve mainly space system users, e.g. Earth observation with the accent placed on the GMES, ISS, etc. but could also be used later on by other users such as Launchers and those based on UAVs. It is foreseen that the EDRS system will be deployed in a scalable manner through a combination of piggy back and dedicated satellite(s) and the model of service provision assumes partnership with the potential operator of the resulting services.

The proposed allocation of resources to the different components of the TLTP and thecorresponding allocation to ARTES Elements is presented in the table below.

TLTP (2009-2013)	ARTES 1	ARTES 34	ARTES 5	ARTES 8	ARTES 11	ARTES 7	ARTES 10	Total
Preparatory	60							60
Technology, Equipment and Systems								400
·Space Segment and Systems		200	120					
·Ground Segment and User Terminals		50	30					
Telecom-based Applications		50						50
Missions								195
·Extension of ARTES 8				65				
·Extension of ARTES 11					30			
·Opportunity mission (e.g. S band)		100						
Institutional/ Special projects								265
·IRIS Phase II.1							35	
·European Data Relay System						230		
Total	60	400	150	65	30	230	35	970

Table 1: Planned Allocation of Financial Resources in TLTP (2009-2013).

4 Review of European National Space Programmes

According to Euroconsult research report “Government space markets, world prospect 2020 (edition 2011), European government expenditures in M$ in Satellite Communications programs are listed hereunder:

Year 2010	Civil	Defense	Total
ESA	427		427
UK	1	215	216
Germany	42	132	174
France	59	50	108
Italy	38	50	88
Spain	-	20	20
Finland	5		5
Austria	1		1
Norway	1		1
Total	574	467	1040

Table 2: ESA and European governments expenditures in Satellite Communications programs (M$)

Typically governments invest in SatCom at two levels:

- The acquisition of operational satellite communications systems (SatCom) for domestic civil and/or military needs
- The funding of R&D and technology demonstration programs in order to develop acquire and validate domestic capabilities

The ESA budget on SatCom was 427 M$ in 2010 which corresponds to less than 10% of ESA + Eumetsat budget (4378 M$) which is relatively low considering the SatCom revenues which exceed 65% of revenues generated by European space industries.

Table 2 is to be compared with government expenditures in Satellite Communications programs of other countries having a space industry:

Year 2010	Civil	Defense	Total
US	26	5794	5820
Canada	11	48	59
Russia	280	0	280
India	181	0	181
China	109	0	109
Japan	21	0	21

Table 3: Non-European government expenditures in Satellite Communications programs (M$)

4.1 France

Founded in 1961, the Centre National d'Etudes Spatiales (CNES, www.cnes.fr) is the government agency responsible for shaping and implementing French space policy in France and contribute to European Space policy.

Its task is to invent the space systems of the future, bring space technologies to maturity and guarantee France's independent access to space and maintain France and Europe at the top level of space capabilities.

CNES is a pivotal player in Europe's space programme, and a major source of initiatives and proposals that aim to maintain France and Europe's at competitive edge.

It conceives and executes space programmes with its partners in the scientific community and industry, and is closely involved in many international cooperation programmes—the key to any far-reaching space policy.

The agency's more-than 2,400-strong workforce constitutes a pool of talent, with some 1,800 engineers and executives,

CNES is helping to foster new technologies that will benefit society as a whole, focusing on:

- access to space
- civil applications of space
- sustainable development
- science and technology research
- security and defence

France had the highest investment in Europe into its national space program reaching 1.6 B$ in 2010 for both civil and defence activities. When combining ESA and Eumetsat contributions, the overall expenditures reached 2.5 B$ (source: Euroconsult research report "Government space markets, world prospect 2020, edition 2011).

4.1.1 French policy with respect to SatCom

In the SatCom domain, France via CNES has invested 108 M$ in 2010 in both civil (55%) and defence (45%) satellite communications programs. This is a unique position since most countries will spend most on Defence SatCom programs.

In addition to this effort, one should also mention the CNES contribution to ESA budget allocated to civil SatCom programs.

4.1.2 On going & planned French SatCom activities

4.1.2.1 Defence SatCom programs

ATHENA-FIDUS (French Italian Dual Use Satellite) French-Italian project to provide broadband satellite telecommunications services for the French and Italian defence and civil protection teams and armed forces. It is planned to launch a high capacity broadcasting satellite into geostationary orbit in 2013.

France has completed the procurement of its new generation system Syracuse-3. The last dedicated satellite Syracuse-3B was launched in 2006, while the third planned one Syracuse-3C will finally be replaced by a hosted payload on board the Sicral-2 spacecraft

Next generation Mil SatCom system is in discussion with the UK focused on mobile broadband in X and Ka band at the horizon of 2018

4.1.2.2 Civil SatCom programs

CNES has been instrumental in the development of the ALPHABUS platform, bus designed for very large and high power Telecommunications satellites. This very powerful bus is designed to meet the needs of commercial satellite operators, and thanks to its capacity offers lower price per transponder and the opportunity to fly complex and ambitious missions. Its first flight, used for the @Sat mission, is planned with Inmarsat beginning of 2013.

At platform level, and to ensure a better competitiveness of French Satellite prime contractors, CNES has been entitled to initiate development of a new generation of satellite platforms, based on common work performed by the 2 French prime contractors.

This initiative is implemented through a first phase of 37 M€ (2011-2014) and will be enlarged to Europe, giving the opportunity to European suppliers to participate to this programme and to be embarked on the future platforms. This first phase is funded by the Conseil General d'Investissement (CGI).

At mission level, CNES is actively supporting studies on 2nd generation Multimedia satellite able to deliver high speed broadband access. Mid 2011, CNES has been mandated, under a funding from the "Conseil Général d'Investissement" to implement a program which will focus on development necessary to ensure a mission focused on (see http://investissement-avenir.gouvernement.fr/content/action-projets/les-programmes/transports) on very high speed broadband access. A budget of 40 M€ in a 1st phase (2011 – 2014) then 60 M€ in a second phase are planned to support these activities.

The main target of the dossier "Investissement d'Avenir" is to prepare the European space sector to reach a level of excellence in the coming years. Apart from the two above mentioned subjects, other subjects are development of a next generation launcher. All these actions in space have to meet economical & societal challenges of the sustainable development and to contribute to create innovative and added value industrial seeds.

4.2 Germany

The space strategy of the German Federal Government was published in November 2010 and can be downloaded from http://www.bmwi.de/en. An extract concerning the envisaged objectives for satellite communications is reported below:

In satellite communication, Germany will extend its systems capability with regard to the building of geostationary communication satellites and will drive forward strategic satellite technologies such as laser communication. In this way, Germany will acquire a strong competitive position in this commercially and strategically important space sector, while at the same time making an important contribution towards ensuring the efficiency of Europe's communication infrastructure for security-related applications, Earth observation, space research, and exploration.

4.2.1 National Programmes

4.2.1.1 COMED Programme

The COMED programme (Constellation & Multimedia Entwicklungs- und Demonstrationsprogrammlinie) is a general purpose programme for research, development and qualification of new technologies, techniques and solutions in both platform and payload areas for multimedia broadband satellite network of the future.

4.2.1.2 LCT (Laser Communication Terminal) Programme

The increasing demand on high speed communication networks has stimulated the development of optical free space data transmission during the last years. The company TESAT has developed a laser communication terminal (LCT) that fulfills the need of a power efficient system whose capability has been successfully demonstrated at bidirectional space-to-space links and bidirectional space-to-ground links (SGLs) at a data rate of 5.625 GBit/s with a homodyne detection scheme and a BPSK modulation format. In

comparison to a direct detection system, the homodyne detection scheme works as a bandpass filter. The transmission is immune to false light and even data transmission with the sun in the receiver field of view (FOV) is possible. Furhter technical details about LCT can be found here:
http://congrex.nl/icso/Papers/Session%208a/FCXNL-10A02-2012697-1-GREGORY_ICSO_PAPER.pdf

Figure 3: the LTC Terminal mounted on the German Earth Observation TerraSAR-X, started in June 2007 (courtesy of Tesat-Spacecom GmbH).

4.2.1.3 National Telecom Mission: Heinrich Hertz Satellite

The Heinrich Hertz satellite will take advantage of the small GEO platform developed by the German company OHB under ESA ARTES 11 programme (for more information about ARTES 11, see http://www.esa.int/esaTE/SEM1HGKTYRF_index_0.html).

In a contract awarded by the German Federal Ministry of Economics and Technology, the German Aerospace Center is examining the feasibility of a national satellite communications mission based on the preliminary studies (Phase 0) conducted by an industrial team lead-managed by OHB-System. This will form the basis for a national project (Heinrich Hertz communications satellite, aka H2Sat).

The Heinrich Hertz mission aims to explore and test new communications technologies in space at a technical and scientific level in order to determine how broadband communications, for example, can result in high data rates for mobile final users.

As well as this, the mission will offer universities, research institutes and industry a platform for conducting numerous scientific/technical experiments. The selection of the new German satellite SGEO will simultaneously support the goal systematically being pursued by ESA and Germany in the ARTES 11 program of building up system skills in this area in Europe and extending German capabilities in the area of satellites and telecommunications payloads.

Newly developed technologies in space are still a long way from future use. Even extensive testing on the ground is no replacement for experiments in orbit over protracted periods of time. The results of such in-orbit experiments can form the scientific basis for new technologies. As satellite operators shun the additional technical risk in launching new technologies, the scientific/technical verification of new technologies in orbit is crucial for ensuring the competitiveness of many space products. Proven space flight capabilities will help to preserve and extend German skills in the production of bus and payload components.

The space agency of the German Aerospace Center has awarded OHB-System as the responsible party a contract for the development and coordination of the overall mission and the satellite in Phase A. As the system manager, OHB-System AG, Bremen, together with its core partner Astrium GmbH in Ottobrunn is managing a consortium comprising Audens Telecommunications, GSOC, IABG and the DLR Institute of Communications and Navigation (IKN). Via a further contract with the space agency, TESAT Spacecom GmbH, Backnang, has been gained as a further key partner and will be responsible for working on the payload and payload technology.

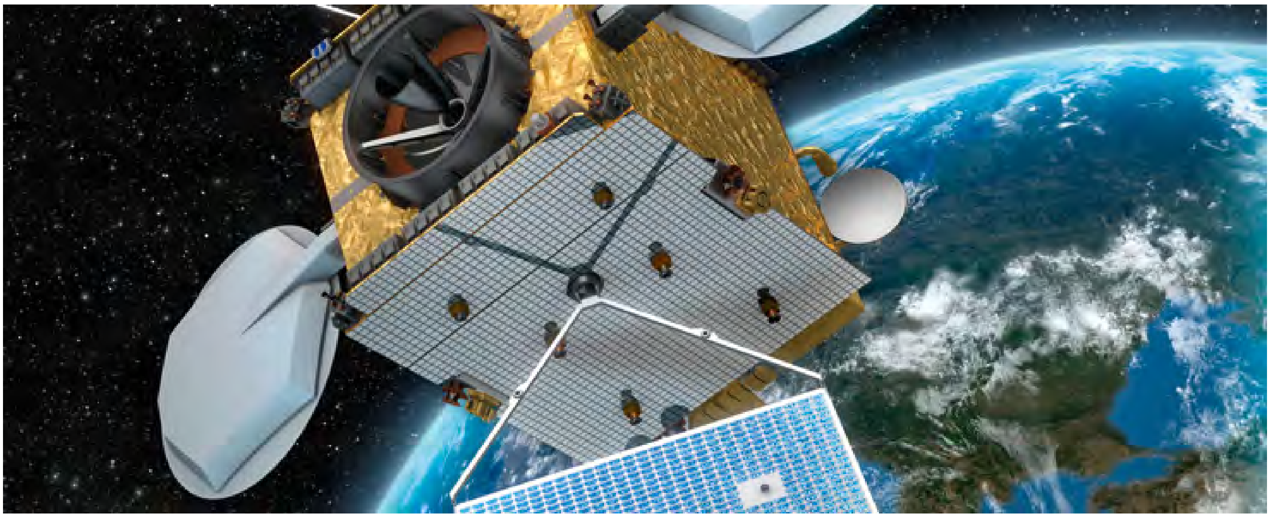

Figure 4: Artist view of H2Sat (Courtesy of OHB-System AG).

Mission objectives:

- Scientific/technical verification of hardware and software and scientific experiments in the area of communications.
- Preparations/testing of pre-operational satcom services for German (public-sector) users.

Status:

- Phase A work on the Heinrich Hertz communications satellite commenced in June 2009 and has been completed in July 2010.
- The follow-up phases for a satellite launch in 2015 are currently in the planning phase.

4.2.2 SATCOMBw

With the SATCOMBw programme, the German Armed Forces owns a secure information network for use by units on deployed missions. This will allow voice and fax as well as advanced data, video and multimedia applications. For the first time the Bundeswehr has a secure communications system with dedicated military communications satellites.

Astrium was prime contractor of the space segment, which is composed of two satellites and based on a Spacebus platform. The first satellite was launched in autumn 2009, the second in spring 2010, both on board an Ariane 5 from the European space centre in Kourou, French Guiana.

Along with the in-orbit delivery of two communications satellites (COMSATBw 1 & 2) for operations in military frequencies (SHF/UHF) and the provision of additional commercial capacity in Ku- and C-band, the SATCOMBw Stage 2 contract includes the COMSATBw operation, the delivery of a comprehensive ground user terminal segment (fixed and transportable equipment) and upgrading the network management centre already installed with the Bundeswehr.

Both SATCOMBw satellites are positioned in geostationary orbit and provide communication services over an area stretching from America to eastern Asia, during their operational life of 15 years. The German space agency (DLR) assumes responsibility under a MilSat Services subcontract for operating the two satellites using several of its locations. In addition to that DLR channels important parts of the user traffic via its ground installations.

The contract runs for 10 years and there is an option to extend it for a further seven and a half years. The customer is the Federal Office for Information Management and Information Technology of the Bundeswehr (IT-AmtBw). The contractor is MilSat Services GmbH based in Bremen, which is owned by Astrium (74.9%) and the Friedrichshafen satellite network specialist ND SatCom (25.1%).

	COMSATBw-1	COMSATBw-2
Launch Date:	Oct 1, 2009	May 21, 2010
Orbit Altitude:	36000km	36000km
Orbital Position:	63.0° E	13.2° E
Mass:	2440kg	2440kg
Dimensions:	2.8 x 1.8 x 2.9m	2.8 x 1.8 x 2.9m
Launch Site:	Kourou	Kourou
Launcher:	Ariane 5	Ariane 5
Mission Duration:	15 years	15 years
Control Center:	DLR / GSOC	DLR / GSOC
Ground Stations:	Weilheim + Bw	Weilheim + Bw

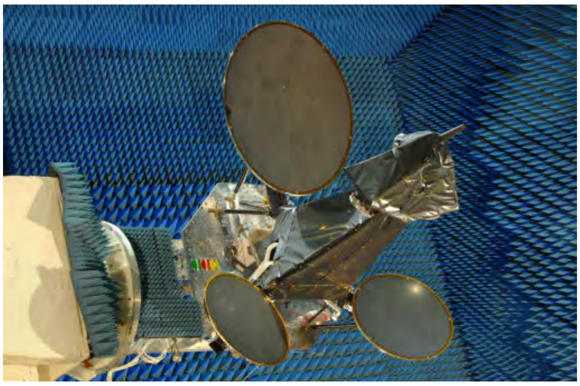

Figure 5: COMSATBw-1 and -2 orbital paramter and COMSATBw-2 (Courtesy of EADS Astrium).

4.2.3 European Data Relay Satellite (EDRS)

Though this is a European Programme, a major participation of Germany to its realisation is envisaged. More information about EDRS can be found here http://www.esa.int/esaTE/SEM5GGKTYRF_index_0.html.

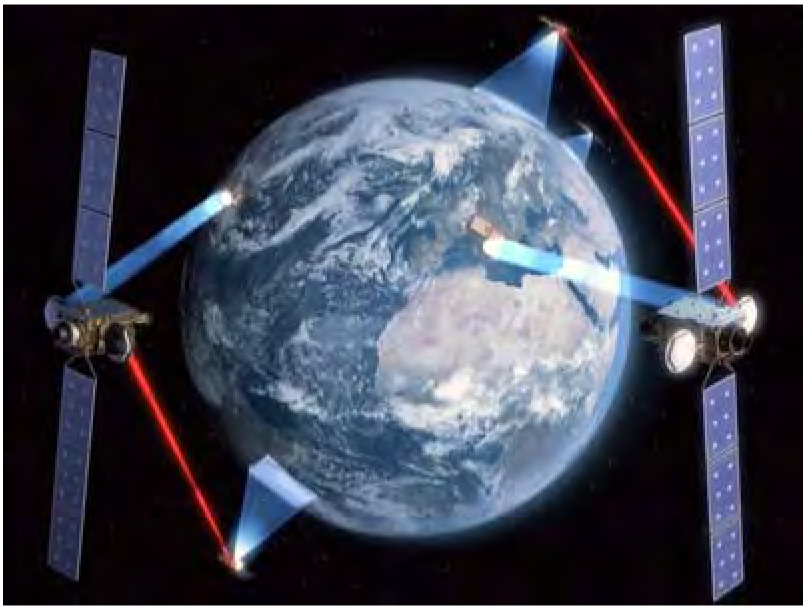

Figure 6: Artist view of the EDRS Concept (Courtesy of ESA).

4.3 Italy

The National Aerospace Plan 2006-2008 (*Piano AeroSpaziale Nazionale*, *PASN*) according to the National Research Programme and the previous national space plans, has highlighted the relevance of the following themes: Environment, Telecommunication, Transport, Health, and Observation of the Universe. Within these areas, national programmes, as well as programmes of international cooperation, have been developed by the Italian Space Agency (ASI, http://www.asi.it/en). In particular, the ASI activities are carried out in the following areas:

- Space exploration (Solar system and deep space)
- Human spaceflight and space colonization
- Space transportation
- Earth observation and monitoring
- Telecommunications and Navigation

Regarding the last item, ASI work is mainly devoted to experiment and develop new services and technologies for the ground segment as well as for the space segment, as reported in the following.

4.3.1 Telecommunications Programmes

4.3.1.1 **ATHENA-Fidus Programme**

The ATHENA-Fidus project deals with the development of a geostationary satellite for dual broad-band communications services dedicated to independent users and proprietors, for Italian and French military and government use. Broad-band telecommunications services in the entire hemisphere of the geostationary orbit are also foreseen to support military actions and Italian institutional and humanitarian missions abroad.

ATHENA-Fidus will realize a telecommunications infrastructure that can substitute or integrate ground networks in case they are not available or if they are damaged and will provide the following services:

- Broad-band access to Internet for fixed or portable terminals located in areas with low levels (or degraded levels) of communications infrastructures (for the management of natural or harmful disasters in situations of general emergency).
- Broad-band telecommunications services for police force terminals (for example, access to remote multimedia databases).
- “Seamless” interconnections (LAN-to-LAN, Virtual Private Network) between sites that have local telecommunications infrastructures.
- Telecommunications services to provide remote surveillance in critical areas (ports, airports, railway in both natural disaster and non-disaster areas, etc.).
- Telecommunications services for Armed Forces that complement existing or provided military solutions foreseen in the near future.

4.3.1.2 **EMERSAT Programme**

The EMERSAT programme has as its primary objective, the development, integration and testing of satellite solutions for applications and communications services to national institutional agencies dedicated to security and emergency management.

The project also aims at developing a multiservice applications architecture that foresees providing integrated low-band (LB) communications (fixed, mobile) of satellite navigation and geo-referenced localization and high-definition remote sensing. The objective is giving the institutional agencies operators devoted to emergency security and management all the technology for receiving and transmitting the information needed for the most effective and safest management of emergency interventions.

The main objective in this scenario is the enhancement of the satellite role, the essential considering essential problems such as: interoperability between different networks, security of communications and access, back up and complementariness of solutions, enhancement of all synergetic applications that optimizes the use of satellite technology.

4.3.1.3 Telecommunications at very high frequency bands

During last years ASI carried out projects relative to technologies and devices of telecommunications at very high frequency bands (Q/V, W, optic). These projects are focused mainly on Q/V and W bands. In particular:

Q/V Line
Development activities (B, C/D and E phases) of the Q/V band mission have been transferred to ESA to provide for the embarkation of the ESA mission AlphaSat. Nevertheless the development of the ground stations is under ASI's complete authority.
W Line
ASI is working on the WAVE project (W-band Analysis and VErification) whose objective is to design and develop a payload in W band. The project is in the 10-month long A2 Phase during which time the definition and design of the experiment flight system on the stratospheric Geophysica airplane (mission Aero-WAVE) will be ongoing.

4.3.1.4 TELESAL Programme

TELESAL aims at defining technological architecture for operating and managing a broad-band satellite communications system integrated and interoperable with ground communications networks that can ensure the foresee institutional services of Telemedicine, especially in the two specific sectors of operations for emergencies and home care assistance.

4.3.2 Navigation Programmes

4.3.2.1 Vehicle Traffic Management (VTM)

The VTM programme aims at developing prototypes and analyzing and testing applications for the payment of tolls and the control of road traffic and of gates to urban centres (virtual gates); traffic monitoring and control; first aid and assistance in case of accident.

4.3.2.2 Safe Transport of Dangerous Goods

The programme aims at promoting experimental satellite navigation applications and services to the transport of dangerous goods also including intermodal transport and management of transport emergencies, in cooperation with corresponding Authorities.

4.3.2.3 Safety in sea traffic

The programme aims at promoting the development and testing of pre-operative applications and services, based on the employment of satellite navigation infrastructures in sea traffic, to contribute to a greater efficiency of safety-at-sea applications, such as search and rescue, management of navigation and sea traffic support services.

4.3.2.4 "Software Radio" Systems

The Software Radio System programme for navigation applications aims at analyzing, researching and developing software architectures, algorithms and modules for the production of satellite navigation receivers, based on flexible software technologies, capable of integrating with multi-purpose and communication terminals.

4.3.2.5 Italian National Satellite Navigation Programme for Civil Aviation

ASI and ENAV (*Ente Nazionale per l'Assistenza al Volo, National Agency for Civil Aviation*) successfully cooperate for the safeguard of Italian interests in the satellite navigation business and have devised a joint programme which sums up the initiatives already started by the two agencies severally with the purpose of enlarging the range of applications of satellite navigation systems based on EGNOS and GALILEO programmes. The new programme follows the guidelines of the Italian DPCM of 13th May 2005 and includes the preliminary actions provided for by ASI PERSEUS Air Project.
The satellite navigation joint progamme for the civil aviation aims at the following targets:

- Ensuring a wide-ranging and timely application of EGNOS to the Italian civil aviation
- Organizing the aeronautical business for the transition from EGNOS to GALILEO
- Promoting innovation and research in the field of satellite navigation.

The Programme includes the following actions:

- Support of EGNOS navigation system certification practice
- Check of EGNOS operational performances within the National Air Space
- Introduction of satellite navigation into Civil aviation (procedures and systems)
- Development of Advanced Services and Applications of Satellite Navigation
- Trial of GALILEO, EGNOS and GPS Streamlining technologies.

4.3.2.6 **GALILEO Test Range**

The GALILEO Test Range aims at creating, by means of land infrastructures, an environment capable of generating Galileo signals, (signal, modulation, codification, data injection, etc.), by also simulating the effects of signal emitted by orbit satellites. The GALILEO Test Range, will also provide a test environment for multiple applications, allowing a partial integration of platforms for the experimentation of Application Projects which will avail of the contribution of joint development labs and experimental instruments.

4.3.3 Earth Observation Programme

4.3.3.1 **COSMO-SkyMed**

COSMO-SkyMed is a Space-Earth Observation Dual Use System devoted to provide products/services for environmental monitoring and surveillance applications for the management of exogenous, endogenous and anthropogenic risks; provision of commercial products and services.

The driving Mission requirements for the constellation development are the following: capability to serve at the same time both civil and military users through a integrated approach (Dual Use System); large amount of daily acquired images; satellites worldwide accessibility ; all weather and Day/Night acquisition capabilities; very short interval between the acceptance of the user request acquisition and the release of the remote sensing product (System Response Time); high image quality (e.g. spatial and radiometric resolution); intrinsic capability to be a cooperating, interoperable, expandable to other EO missions, multimission-borne element providing EO integrated services to large User Communities on a worldwide scale (Concepts of Expandability – Interoperability – Multisensoriality).

Figure 7: Stripmap image of Richat, in the Sahara Desert, taken by COSMO-1 on October 8 2007 (source: http://www.asi.it/en/multimedia_en/photogallery/cosmoskymed)

4.4 Spain

On 20th December 2006, the first Spanish Strategic Space Plan (2007-2011) was presented by the Ministry of Industry Mr. Joan Clos. The plan was prepared by CDTI and outlined the main elements that shall serve to strength the space sector in Spain.

The Strategic Space Plan for 2007-2011 constitutes the first systematic action carried out by a government in Spain on the Spanish space community as a whole. The Spanish government, and particularly the Ministry of Industry, Tourism and Commerce, demonstrated in this way that they were aware on the role that the public sector should play in attaining the necessary growth of the space sector.

Space has traditionally been one of the most attractive sectors for public investment, because it is particularly R&D&i intensive and provides services to society, addressing some of the more critical societal challenges in areas as important as broadband extension, citizen security or environmental management. This is why, with the exception of the satellite telecommunications market, governments often manage space programs directly, whether on a national level or as part of international cooperation.

The global objective of the Strategic Space Plan is to situate the space sector in the place that corresponds to a country that is the eighth world economic power. Furthermore, it establishes specific objectives for each one of the three key elements of the Spanish space sector: the public sector, industry and space infrastructures.

In terms of the public sector, the Strategic Space Plan should make it easier for Spanish institutions and users to play the role that corresponds to them in accordance with Spain’s economic weight. Likewise, it should satisfy the needs of Spanish users in terms of information and, finally, although the high degree of coordination in space management in Spain ensures adequate return on investments, Spain’s investments in space may still be optimised somewhat more.

In industrial terms, the objective of this Strategic Space Plan is for the Spanish space industry to achieve, within the international context, a position in line with the place held by the Spanish economy. This should be defined quantitatively, in terms of market share, as well qualitatively, in terms of the development of the capacity to integrate complex space systems, accompanied by technological leadership in suitable niches.

With regard to space infrastructures, three specific objectives were identified: achieve the rating of the ESA Astrophysics Centre in Villafranca del Castillo as an ESA establishment, promote the use of Spanish installations in international programmes and exploit the potential synergies among technical centres and industry.

Four lines of action are proposed:

- **boosting of public resources**
- **selection of priorities**
- **development of a complete space system**
- **coordination among all actors of the Spanish space sector**.

Each one of such proposals shall favour the attainment of the objectives established, for the public sector as well as for the space industry and infrastructures located in Spain.

The boosting of public resources is defined as a substantial increase in the volume of investment allocated toward space and the diversification of these that will make it possible to optimise the results.

Secondly, the selection of priorities. Specifically, a greater investment shall be made in: programmes targeted first at the citizen and second at science.

The third line of action proposed, and possibly the most significant, is the development in Spain of a complete space system, as a project integrating all existent capabilities. This shall benefit all Spanish actors in space: the public sector and communities of space users; the companies that manufacture satellites and equipment as well as those that develop software and applications; it shall furthermore promote those centres and infrastructures located in Spain. For all of these reasons, this project shall establish the foundations for achieving the integrated management of Spanish investments in space.

Lastly, it proposes the strengthening of coordination among all actors of the sector. To this regard, the CDTI already directly manages approximately 75% of public investment in space, in addition to participating in the management of the practical entirety of the international space activities in which Spain takes part. Nevertheless a margin is still considered to exist for the maximum exploitation of synergies in the management of space programmes undertaken by Spain.

Specifically, the following is proposed: coordination among centres of the Government Administration for Spanish representation in international forums, CDTI financing of space technologies applicable to programmes in which other Spanish institutions are investing, public as well as private, and systematic coordination among all actors.

The current 2007-2011 budgets amount to 1,071 million Euros, a substantial 63.5% increase with respect to the previous period.

On a secondary level, but no less important, within the scope of the effort undertaken by the government for the promotion of entrepreneurial R&D&i, the budget entry devoted to the National Space Programme for 2007 has increased by 10%, and the CDTI has approved a new financial tool to support the development of projects defined in the bilateral agreements that Spain has signed with different national agencies of the main space sector powers. This line allows us to access very high technology programmes led by other countries, and it is our intention to promote this in the future.

4.4.1 Bilateral programs with other space agencies

Since 2006, the CDTI manages a budget line dedicated to the development of space projects in cooperation with other space agencies. The criteria for selecting these projects are similar to those used to establish priorities among the various programs developed under the ESA. However, this new line of activity allows Spain to have a new tool to promote the entire space that also offers a particularly attractive conditions in terms of flexibility and speed in decision making, compared to projects in the under the ESA, for approval require consensus among a large number of countries.

In particular, until on October 10, 2006, CDTI has already signed cooperation agreements for the development of bilateral programs with the major world powers in the space sector:

- NASA (American Space Agency)
- Roskosmos (Russian space agency)
- CNES (French Space Agency)
- CSA (Canadian Space Agency)

There are also plans to negotiate similar agreements with other major space agencies. In this sense, we should mention China and India, who have an advanced space program and are increasing their role on the world stage and short / medium term will become very competitive alternative for the construction of space systems (the cost is two-thirds lower than in Europe or the U.S.).

4.4.2 Spanish earth observation satellite program (As part of the national Space programme 2007-2011)

The Spanish Earth Observation Program, referred to as PNOTS (*Programa Nacional de Observación de la Tierra por Satélite*), is based on two complementary satellites, namely:

1. **SEOSat/Ingenio** with the optical payload to serve the civilian users (space segment lead by CDTI/ESA)
2. **SEOSAR/Paz** (*Satélite Español de Observación SAR - SAR Observation Spanish Satellite*)/Paz, is an X-band SAR (Synthetic Aperture Radar) spacecraft based on the TerraSAR-X platform, to serve the security and the defense needs. The SEOSAR/Paz mission is a dual-use mission (civil/defense) funded and owned by the Ministry of Defence and managed by HISDESAT (*Hisdesat Servicios Estratégicos, S.A.*, a Spanish private communications company providing also its services to the Ministry of Defense, since 2001.

PNOTS is funded and owned by the government of Spain. INTA (*Instituto National de Técnica Aeroespacial*), is managing the common ground segment of the two missions. HISDESAT together with INTA, will be responsible for the in-orbit operation and the commercial operation of both satellites. EADS CASA Espacio is the prime contractor leading the industrial consortia of both missions.

A major objective of PNOTS is to maximize the common developments, services, and to share the infrastructure between both missions (whenever possible). Both missions will also contribute to the GMES (Global Monitoring for Environment and Security) European programme. According to contract, the ESA SEOSat/Ingenio project team must ensure that the European ground segment will allow the SEOSat/Ingenio system to become a candidate national mission contributing to GMES and to participate to the ESA third party mission scheme, within the EO multi-mission environment - and therefore to support HMA (Heterogeneous Mission Access) services.

The PNOTS program schedule calls for:

- March 2009: SSR (System Requirements Review)
- November 2009: PDR (Preliminary Design Review)
- Q4 2011: CDR (Critical Design Review)
- Launch of SEOSat/Ingenio in late 2012
- Launch of the SEOSAR/Paz spacecraft in 2013.

4.4.2.1 **SEOSat/Ingenio**

SEOSat (Satélite Español de Observación de la Tierra - Spanish System for Earth Observation Satellite) / Ingenio, is an optical high-resolution imaging mission of Spain - the flagship mission of the Spanish Space Strategic Plan 2007-2011.

The mission is devoted to providing high resolution multispectral land optical images to different Spanish civil, institutional and government users, and potentially to other European users in the framework of GMES and GEOSS. The overall mission objective is to provide information for applications in cartography, land use, urban management, water management, environmental monitoring, risk management and security. The requirements call for panchromatic imagery of 2.5 m and multispectral imagery of 10 m resolution.

CDTI is funding the mission and is responsible for the programmatic aspects of the program. The project development is overseen by ESA as a national contribution within the framework of Europe. A procurement assistance agreement to this effect was signed between ESA and CDTI in July 2007. Within the agreement, CDTI has entrusted ESA with the technical and contractual management of the industrial activities, thus being in charge of the procurement of the Space Segment and of the Ground Segment of the SEOSat/Ingenio system.

The basic mission requirements are defined according to these main criteria:

- Provision of data services to comply with the Spanish institutional user needs. The global land mission primary objectives call for a “Carpet mapping of Spain”+ image acquisition over main areas of interest (Europe, South America and North of Africa).
- The SEOSat/Ingenio mission is also regarded to provide complementary services to the GMES program, in particular to the objectives of the Sentinel-2 mission.

4.4.2.1.1 Mission parameters

Mission and System Requirements		
Geographical coverage	World coverage, with latitudes from 83ºN to 56ºS. Systematic coverage of zones of special interest: - The Spanish Territory - Europe	Including main world islands

	- Ibero-America - North of Africa down to 10º N	
Imaging capacity	2.5 x 10^6 km^2 / day with reference compression rates of: - Spanish territory compression to 4 bpp (bit per pixel) - Non Spanish territory compression to 3 bpp - Available compression rates from 2 to 6 bpp	Monthly average when available: Spanish stations, and polar station (e.g. Svalbard)
Performance	- Pointing accuracy better than 200 m - Pointing accuracy better than 1000 m - Geo-location better than 50 m without GCP, 20 m with GCP - Roll tilt capability of spacecraft = ±35º	Cross-track (2σ) Along-track (2σ) 2σ Nominal roll de-pointing angle including slew capacity around pitch axis
Ground segment baseline	Two TM/TC stations for command and control	Torrejón (Madrid region) and Maspalomas (Canary islands)) and potentially additional high latitude station.
	Two stations for payload data reception	Torrejón and Maspalomas with capability to include high-latitude stations (one additional polar station is the baseline)
Sun-synchronous orbit	- Altitude of ~670 km - LTDN (Local Time of Descending Node) at 10:30 hours	49-day repeat cycle, 3 days accessibility
Launcher	Based on Vega	Compatible with Rockot, PSLV, Dnepr and Soyuz
Mission performance	- Lifetime = 7 years - Reliability > 0.65 - Product availability > 95%	Design and consumables sized for additional 3 years
	Primary Payload	
Spectral bands	- Panchromatic band - 4 MS (Multispectral) bands	Pan B, G, R and NIR
Performance	- Swath > 55 km - GSD (Ground Sample Distance) ≤ 2.5 m (Pan), ≤ 10 m (MS)	Equivalent FOV= 5.13º
	Satellite	
Mass at launch	- Dry mass = 750 kg - Propellant mass ≤ 80 kg	Including all margins and propellant sized for 10 years
Electrical power	Average power consumption = 580 W Maximum satellite demand = 850 W	
Payload data management	- X-band downlink = 280 Mbit/s - Storage memory > 512 Gbit	X-band TWTA (Travelling Wave Tube Amplifier)

	- Image data compression capacity with factors from 2 to 6 - Security level	BOL capability TC authentication and encryption TM (mission and HK) encryption
On-board data handling	- OBC = LEON3 - S-band communication	1553 data bus For TM, TC and ranging
Propulsion	Monopropellant: hydrazine, 80 kg	Sized for 10 years

Table 4: Overview of SEOSat/Ingenio mission parameters

4.4.2.2 **SEOSAR/Paz**

In 2007 the Ministry of Defense commissioned HISDESAT to begin the development of a system of Earth observation by satellite with synthetic aperture radar technology to meet the armed forces operational requirements, which need permanent and very high resolution access.

Because of this, HISDESAT began work on program development, In December 2007 Hisdesat hires the design and manufacture of the satellite to EADS Astrium. This was a key milestone for the Spanish space industry, since it was the first time it is assumed the challenge of building in Spain a satellite of this size and complexity.

The launch has been arranged with the Russian launcher DNPER, and it is foreseen by the end of 2012 or beginning 2013.

The INTA is responsible for developing the ground segment, which includes control and monitoring stations, which will be located in Torrejón (Madrid) and Maspalomas (Gran Canaria) and centers for processing and storage of data, located in the previous locations and in the Torrejon Air Base (CESAEROB).

4.4.2.2.1 Mission parameters

With an estimated total weight of 1400 kg, PAZ dimensions are 5m-tall and 2,4m-diameter. It consists of a platform or service module and a synthetic aperture radar as the main instrument. It also includes a Radio Occultation and Extreme Precipitation Experiment as well as an AIS receiver (Automatic Identification of Ships) as secondary instruments.

The platform is based on TerraSAR and Tandem-X and it allows:

- Average power 100W per orbit
- Memory for images: 256 GB
- Images transmission throughput to Earth: 300Mbits/s in X Band.
- Simultaneous data collection and transmission of images

Orbit characteristics:

- Helio-synchronous 514km.
- Ascending node 18:00 h
- Repetition cycle: 15 + 2/11.

Accuracy of the satellite orbital determination:

- GPS mode: 10 m.
- Precise GPS mode: 2m.
- High precision with post-processing mode: 10cm.

Images:

- Size: From 100x100km to 5x5km
- Resolution: From 15m to 1m.

Spanish Industry players working in the Project:

- EADS CASA Espacio: Main contractor.
- INDRA Sistemas: Tx/Rx Modules.
- CRISA: PCU - RTU.
- RYMSA: S and X Band platform antennas.
- NTE-Sener: PSU.
- IberEspacio: Ground support equipment for cooling
- HV Sistemas: front-end simulator, power EGSE y trigger unit.
- ACORDE: ICCS and SW / RF EGSE.
- Inventia: Mechanical equipment for ground support.
- Cachinero: Mechanical equipment for satellite support from ground.
- LANGA: Mechanical equipment for ground support.
- ERZIA: Power SCOE.
- ELATESA: antenna radar.
- INTA: Antennas and radar tests.
- TTI Norte: RF Engineering support.
- Universidad Politécnica de Cataluña (UPC): Radar mathematical models
- Universidad Politécnica de Madrid (UPM): Electrical architecture simulation
- Escuela Politécnica de la U. de Alcalá de Henares: Radar antenna tests

4.5 United Kingdom

In UK two disctinct agencies deals space programs

4.5.1 Civil space program

The **UK Space Agency** is a United Kingdom government agency responsible for its civil space programme. It was established on 1 April 2010 to replace the British National Space Centre and took over responsibility for government policy and key budgets for space and represents the UK in all negotiations on space matters. It brings together all UK civil space activities under one single management".

The UK Space Agency (see http://www.bis.gov.uk/ukspaceagency) is an executive agency of the Department for Business, Innovation and Skills (BIS) and at the heart of UK efforts to explore and benefit from space.

It is responsible for ensuring that the UK retains and grows a strategic capability in the space-based systems, technologies, science and applications. The UK Space Agency therefore leads the UK's civil space programme in order to win sustainable economic growth, secure new scientific knowledge and provide benefits to all citizens.

However it doesn’t invest significantly in civil SatCom programs

4.5.2 Defence space sprogram

The UK’s main strength is in telecoms: the Skynet network supports the UK Armed Forces. Skynet services have been provided since 2005 via Paradigm, a private contractor. The UK has no exclusively military satellites of its own. The existing network, Skynet 4, is being replaced at a cost of £2.5 billion. The first of three Skynet 5 satellites will be launched in 2007. The UK is described as being ‘reliant on the United States for [space based] security and defence technology’ in an ESA-funded paper.1 However, UK industry is developing expertise in small satellites.

4.5.2.1 UK military space policy

There is no agency within the Ministry of Defence (MoD), and no specific budget, dedicated to military space. The Assistant Chief of the Air Staff within the Royal Air Force (RAF) co-ordinates space activities across the MoD. Activities are funded if they are a cost-effective way of achieving a specific objective. While the MoD’s military space policy is classified, the RAF’s Future Air and Space Operational Concept (FASOC) document indicates priorities over the next 20 years. FASOC highlights the role of small satellites and also the need for space surveillance (detecting and tracking objects in space).

4.5.2.2 Technological development in the UK

The MoD's space research priorities are small, low-cost satellites, surveillance of space systems, and space weather effects (page 3). It collaborates with other UK government departments on technological development activities such as TopSat. Preliminary talks are underway on a follow-on to TopSat (Box 4), which may employ advanced synthetic aperture radar (SAR) technology. SAR is less dependent on weather conditions than optical imagery. Initial estimates for a small low-cost SAR satellite are £~50 million but no decisions have been made on how to finance it.

The MoD spends £~1 million per year on space research. The British National Space Centre (BNSC) say there is a need for greater investment across government in developing space technologies. Various commentators say that, in addition to small satellite development, the UK should consider whether to develop its own launch facilities (there are currently no plans for this). This could reduce reliance on other countries’ facilities, and bring benefits for UK industry.

For more info, see http://www.parliament.uk/documents/post/postpn273.pdf.

5 Technological Gap Analysis

5.1 Other ETPs

All SRAs of other ETPs refers (directly or indirectly) to the objectives set forth in the EU digital agenda as far as broadband access is concerned.

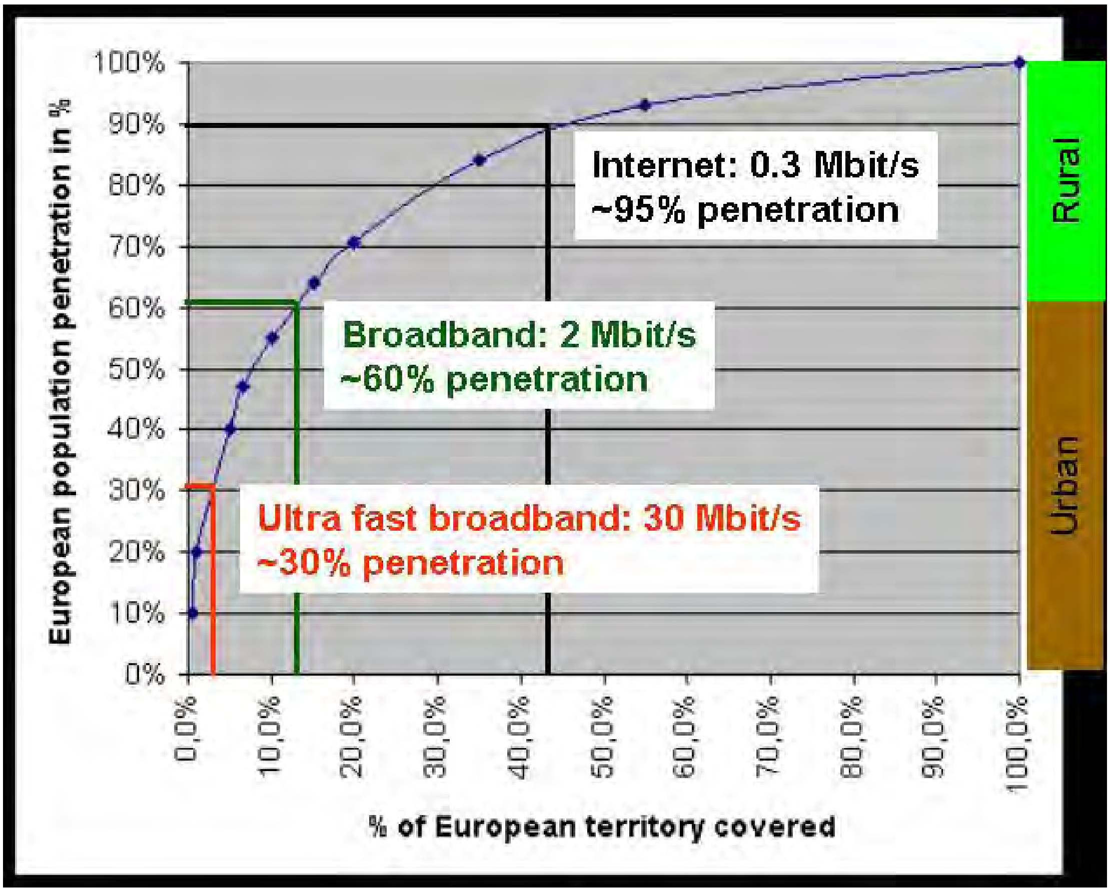

Figure 8: Broadband access penetration in Europe for 2009 (Source Thales Alenia Space, based on data taken from the 1st Digital Agenda progress report published by the European Commission in June 2011)

The figure above shows the geographical distribution of the European population and highlights the service penetration of internet access (0.3 Mbit/s), basic broadband access (2 Mbit/s) and ultra fast broadband access (30 Mbit/s).

Terrestrial broadband access network (Optical fibre, cable, xDSL and wireless solutions) are expected to cover at most 97% of the population due to exponential infrastructure deployment cost in the low density populated areas.

Assuming 500 M of inhabitants in the Europe Union (Source Eurostat, European demography, newsletter 110/2010 – 27th July 2010) and an average of 2.4 inhabitants per house holds (Source Eurostat: Households structure in the EU, 2010 edition, ISSN 1977-0375), up to 15 M households in Europe are located in unserved or underserved areas. Consequently, usage of satellite communications becomes essential to meet the Digital Agenda objective that seeks to ensure that, by 2020, all Europeans have access to higher internet speeds of above 30 Mbps (peak rates).

Moreover, the dramatic consequences of recent major natural disasters, such as the tsunami in the Indic ocean in 2004, the 'Katrina' hurricane over New Orleans in 2005, the 'Tomas' hurricane in Haiti in 2010, or the tsunami in Japan this year, have drawn the attention of society in general and of the research community in particular to deficits in crisis preparedness and response. Restoring reliable communications for rescue teams and civilians in the very first hours after the disaster is of paramount importance. Even for less dramatic events, it is worth mentioning that a strong storm in winter 2007 left tens of thousands people in southern France with no fixed or mobile connection for more than one week. Similarly, several catastrophic situations happened in the period 2004-2008 in the Spanish region of Castilla-La Mancha demonstrated the chaos provoked when no reliable communications means were available in the rural environment. Dependability and broadband connectivity rapidly available in specific areas is a key requirement for future mobile networks, also considering the fact that Internet access is becoming an increasing necessity for the efficient coordination of rescue operations. Satellite communications can offer direct connectivity to users equipped with professional terminals (such as e.g. rescue team) for low data-rate though safety-critical services, especially in the very first hourse after the disaster, but also offer an effective solution to overcome terrestrial infrastructure unavailability thorugh satellite backhauling. Users within the disaster area can use COTS devices to communicate to a local base station, which then re-establishes a connection to the public networks over satellite.

In all cases, integration with terrestrial infrastructure at different levels (terminals, service, network management, etc…) is considered a key asset which required a major R&D effort to be carried out in close cooperation with other ETPs.

5.2 ESA TLTP and National Programmes

Considering that the last update of the TLTP is almost three years old (revision 7), a detailed gap analysis is considered not meaningful at this point in time. Still, some general consideration concerning the interaction and pontential synergies between the TLTP and the EC programmes are in order, as this has been a critical point since the launch of the FP7 programme.

As pointed out in section 2.3 of the ESA TLTP, *ESA and the EU are partners in the definition of a European Space Strategy for Europe. With respect to Telecommunications Systems the ARTES Programme finds its corresponding equivalent on the Telecommunications related activities of the 7th Framework Programme (FP7). The major themes that permit the development of Satcom related activities are ICT, Transport and Space and Security*.

For the commercial market, ESA activities foreseen within the TLTP are grouped according to the traditional market segments, namely broadcasting satellite service (BSS), further subdivided into fixed and mobile broadcasting, mobile satellite service (MSS), fixed satellite service (FSS) and broadband satellite services. Though this classification might appear not fully appropriate from an end-user and serivce oriented perspective, it is sill considered sound from a technological perspective. ESA funded and co-funded activities in these areas shall constitute the technological building blocks around which EU co-funded activities aiming at enabling integration of satellite communications with other access technologies from an end-to-end and user-centric perspective shall be built.

In particular, it is expected that ARTES programmes shall be the **exclusive** home for

- **Preliminary system and architectural studies, aiming at assessing the feasibility of novel ideas.**

  However, it shall be noted (see Table 1), that ESA funding for preparatory activity is currently limited to ca 12 M€ per year (which is roughly 3 times the size of a typical STREP under FP7), ofter fragemented into many small studies. This is in many cases limiting the effective impact of such studies and hinders the achievement of the necessary critical mass. In particular, participation of key partners from other ICT sectors than SatCom is rather limited in ARTES 1. A better coordination between ARTES 1 studies and FP7 actions would ensure a bigger funding on strategic actions

- **All space segment related activities, including:**
  - **study and development of new payload and platform technologies**
  - **definiton and implementation of experimental missions**

  As seen in Table 1, technology development for the space segment obtained an (average) funding of 64 M€ per year through ESA, to which national programmes like the German COMED shall be also added.

For experimental missions, the average ESA funding is 39 M€ per year. The only national mission aiming at launching a communication satellite carrying experimental payload is the German Heinrich Hertz, based however on technological development carried out in the ESA ARTES 8 programme. Apart from this national mission, many initiatives of different nature are on going:

- Piggyback:
  - ASI contribution to the Q/V Technology Demonstration Payload (TDP#5)
  - AmerHis in Spain, followed by Redsat with OHB platform for an Hispasat mission
  - EDRS, Iridium piggy back missions
- Public Private partnership:
  - ESA/Inmarsat Alphasat mission
  - Hylas 1/Avanti communications

- **Study and prototyping of RF components for the ground segment such as antennas, amplifiers, etc… and more generally support to the development of SW and HW components for the purpose of mass market industrialisation**

  For the above bullet, the ESA funding is 16 M€ per year.

In turn, for the following type of activities, a synergic and complementary approach between ARTES and EC programmes would be extremly beneficial in order to forster integration of satellite communications with other ICT sectors and to ensure a sustainble growth for the European SatCom industry:

- **In depth system and architectural studies, building upon the results of preliminary system and archtectural studies and overcoming the aforementioned fragmentation and segregation issues.**
- **Contributions to standardisation and actions towards regulatory bodies, both as addtional output of large projects (STREP or IP) as well as**
- **Large scale system-level prototyping and demonstrations**
- **Design and development of new applications** (currently only supported with 10 M€ per year through the ESA TLTP)

For the institutional market, a general characterisation is rather difficult. For those scenarios where the usage of commercial satellites is envisaged, the same considerations given above apply. Those scenarios where dedicated missions are needed, such as e.g. ATM, EDRS or SATCOMBw, shall be analysed on a case by case basis.

6 Roadmap and Mapping onto FP7 and FP8

This chapter maps the key concepts and technologies reported in the roadmap onto a list of concrete research topics, divided in different categories, which address the objectives of the FP7 and FP8 work programmes[1]. Such mapping enables to better identify priorities in the R&D activities which have to be performed to effectively implement the roadmap, taking into account the ESA TLTP and the different National Programmes.

6.1 Research topics related to space segment

R&D activies on the space segment should take into account the increasing demand of high access capacity per user at reduced costs as well as the long life cycle for the design, procurement and launch of a satellite in order to:

- optimise in-orbit capability for broadband applications;
- increase the achievable throughput;
- enhance the level of flexibility of communications satellites;
- enhance the level of reconfigurability of communications satellites.

The optimisation of in-orbit capabilities should enable to further reduce the cost per Mbps, which is one of the key competitive enablers for serving the broadband market as depicted in the Digital Agenda expressed by the European Commission. The increasing demand for more satellite capacity at lower unit cost will drive further technology development efforts, aiming to double the capacity per satellite in-orbit by 2014-2015 and to approach the terabits in the 2020 timeframe. For the first step, the critical areas for technology development will concern the reduction of beam size (around 100 km diameter, while current state of the art is around 250km), and the ability to use wider spectrum. Impact of satellite platform performance is also to be addressed (better pointing performance, more internal and external accommodation, power, thermal dissipation capacity, larger reflectors, more compact repeater building blocks, easier and more efficient test process). With limited satellite spectrum available, its reuse becomes the key driver in achieving capacity. Frequency reuse in a multi-beam structure will, thus, be a key technology.

Yesterday's 1-2 Gbps satellites with regional beams are already changing into today's 10's Gbps satellites with upwards of 100 beams and are leading the way to the Terabit/s satellites for 2020 with several hundreds of beams. The research challenges here are in the system designs to select the antenna structures, polarisation and frequency reuse patterns that minimise interference between the beams of the same type. Interference rapidly becomes the determinant of "quality of experience" rather than thermal noise. As well as antenna design new techniques of interference management and cancellation may be needed to achieve quality and capacity. The antenna design also drives the number of amplifiers needed on board the satellite and as we have seen there is limited power from the payload. Research issues here are the amplifier efficiencies, linearity and bandwidth. For very high capacity satellites the feeder links will impose high spectrum demands and necessitate moving upwards to Ka/Q/V bands where more spectrum is available but where the payload equipment including amplifiers, LNA's oscillators etc. needs to be developed for these new bands.

Ground networks and user terminal capabilities should be investigated as well, aiming to increase the individual user download speed to at least 30 Mbps by the 2014/2015 timeframe, with a target to exceed 100 Mbps by the year 2020.

Regenerative payloads can be an additional step to consider for providing high flexible and reconfigurable satellites systems, suitable for adapting the network for the service scenario needs. The key challenge will be to propose fully in-orbit reconfigurable processors (Software Defined Payloads - SDPs), which would ultimately combine the advantages of fully regenerative payloads with the waveform agnostic flexibility of transparent payloads.

[1] Note that such research topics are in line with those reported in the ISI Strategic Research Agenda – Edition 2011.

Finally, whilst larger GEO platforms represent one solution to meet the above challenges, the use of clusters of smaller satellites is an alternative approach which will also be investigated to assess cost and benefits for the considered target markets.

6.2 Research topics related to ground infrastructure

The increasing number of spotbeams, together with a desirable high capacity per beam might lead feeder links to a bottleneck. In order to overcome this limit, high capacity feeder links need to be investigated. Within this context promising research trends are toward higher frequency bandwidth such as Q/V bands, and laser communications systems. Although Q/V bands are attractive for their large amount of frequency bandwidth that the satellite can use, they are severely limited by the radio-wave propagation through the lowest layers of the atmosphere; with this aim specific techniques need to be implemented in the satellite system to guarantee the capacity, the availability and the quality of service. As the operating frequency is increased, the attenuation due to atmospheric gas, clouds and rain becomes more severe; the direct consequence is the need to implement high system static margins, in order to minimize the service outage. However, technology limitation (on both terrestrial and space segments) combined with cost efficiency requirements refrain from considering fixed static margins as the only mean to compensate propagation impairments at high frequency bands, and push towards the implementation of Fade Mitigation Techniques (FMT).

On the other hand, the advantages of optical communication compared to radio wave communication include a wider bandwidth, a larger capacity, lower power consumption, more compact equipment, greater security against eavesdropping, and better protection against interference. Moreover, the demand for high-data-rate transmissions is increasing. Laser communication systems should play an important role in such high-data-rate communications. However, maintaining a line of sight between the transceivers is particularly difficult due to the small divergence angle of laser beams. Thus, ensuring steady operation of the on-board optical terminal and successfully completing many in-orbit demonstrations of free space optical communications are important goals leading to commercial applications. Moreover, laser communications still suffer the atmosphere attenuation as the Q/V bands communications.

Interference management and cancellation is also a key research area to be considered whenever ground infrastructures are designed. Their development has been facilitated in the last years by advances in processing as adaptive beam forming on board. The satellite systems are usually suffering interference from previously deployed fixed satellite (FS) systems. It is necessary to search on new mitigation techniques capable to detect the interference, adopt protection measures (channel hoping, alternative modulation and forward error correction schemes, etc.), in order to save the interference free operation of the FSS system, irrespective whether a FS transmission is sharing the same spectrum.

Interference is becoming the major system quality determinant as the number of spots increases. There are ways around this which either manage the interference in a system sense or cancel it. At the ground infrastructures, such as gateways or user terminals, post interference cancellation (e.g., MUD) needs to be considered. This will be the case for bent pipe satellites; however it has to be noticed that by using on-board processing the interference can be reduced on the satellite. This issue is not related with this section that is concerning the ground infrastructure.

The interference management and mitigation can be also faced by exploiting the cognitive radio approaches for minimizing the interference between terrestrial networks and satellite ground terminals. The main advantage of Cognitive Radio is to exploit at transmission level the unused spectrum resources by employing intelligent sensing and reconfigurability characteristics. This will allow the coexistence of different access technologies and thus exploiting the frequency spectrum better.

If the same frequency is strongly reused, the resulting interference when serving simultaneously many co-frequency users requires some sort of pre or post-cancellation process. In this regard, and following terrestrial systems, MU-MIMO schemes seem to be essential to deal with this scenario, exploiting the spatial dimension by appropriate precoding when transmitting and detecting simultaneously the different users when receiving at the gateway. Even further, some degrees of freedom exist to distribute this spatial processing between the satellite beamforming network and the gateway transceiver, which could be potentially exploited. Moreover, adaptive beamforming in combination with joint resource allocation and multibeam processing at the Ground station can provide enhanced interference management adapted to the traffic demand and the channel conditions.

A novel approach at the ground infrastructure is to use fully software-based techniques to implement interference cancellation algorithm on GPU-based computers. GPU computing can open a complete new way to design scalable ground systems that can be easily reconfigured when the protocol changes or new functions are needed. Such an approach can be also considered for prototyping fully scalable gateways based on novel protocols, but it can be extended to a variety of different applications.

6.3 Research topics related to air interfaces

New satellite radio interfaces should exploit synergies with terrestrial ones, pending they do not put into danger the quality of service currently offered by satellite solutions, in order to maximize commonalities and thus benefit from economy of scale. In this attempt, it shall be ensured that the resulting radio interfaces contain all of those elements that are essential to enable high performance also in satellite environments. In particular, performance shall be interpreted as spectral efficiency, flexibility, robustness, power consumption, and impact on ground, space and terminal segments.

In this perspective, several research areas are considered fundamental to be explored in support of SatCom, such as:

- *Cognitive Radio:* spectrum sharing among satellite systems and terrestrial systems will become fundamental for future high capacity systems. In particular, all frequency bands should be available for Satellite Communications services, thus, avoiding the current situation where blockage of spectrum availability hinders the full deployment of satellite system capabilities.
- *Cooperative Communications:* cooperative approaches should be addressed at all level of the architecture, from physical layer, e.g., code cooperation, cooperative synchronization, etc., to gateway cooperation for user terminal management; from multi-beam multi-feed cooperative joint processing for denser frequency reuse to architecture segments cooperation, e.g., broadcast and broadband segment cooperation.
- *Multi beam/feed Transmission Techniques:* Novel MIMO techniques are required to enhance the available data rate for mobile/portable users and allow for reduced cost and reduced energy consumption of user terminals, providing new paths to the implementation of “green” satellite solutions.
- *Interference Management Techniques:* The research should be addressed towards applications to multi-beam/multi-feed/multi-gateway satellite systems of advanced concepts like pre-coding techniques, multiuser detection, interference cancellation, and interference alignment and coordination.
- *Waveform Design:* Waveform design shall also embed elements to enable smart and efficient countermeasures for non-linear distortion in both multi and single carrier systems, as well as support for adaptive fading countermeasures. To this aim, channel estimation mechanism and pilot patterns shall be carefully designed to allow the implementation of algorithms for communication link adaptation to channel characteristics, keeping into account the hybrid terrestrial/satellite nature of the communication channels.
- *Fading and Channel Impairments Countermeasures:* More flexible and general adaptive mechanisms shall be addressed at all level of the radio interface protocol stack. In particular, mobile and higher frequency bands scenarios, characterized by more severe fading events shall be considered keeping into account the degrees of freedom which can be exploited under various system constraints, e.g. average power or QoS constraints.
- *Channel Modelling:* special care must be taken to furnish the most reliable channel models in the foreseen scenario, i.e. fixed satellite systems (FSS), mobile satellite systems (MSS). Also, future research efforts shall address the modelling of hybrid satellite/terrestrial MIMO channels, including also dual polarization.

- *Flexible Radio Interfaces Approaches for QoS:* Novel radio interface should have the capability to adapt themselves to different frequency bandwidths, channelization, as well as interference and channel impairments scenarios. Such adaptivity should be also reflected in the capability to provide multiple levels of Quality of Services, in dependence on the user needs, system load and link quality. Flexibility is therefore also desirable in the selection of the most appropriate medium access control scheme, where enhanced random access schemes can play a major role in many concrete applications.

6.4 Research topics related to Networking

Fixed mobile and broadcasting convergence is an emerging technology, which aims at integration and creation of a unified communication infrastructure from fixed and wireless mobile networks. In this converged communication infrastructure, users move across networks and access services seamlessly using different devices. The future all-IP network is expected to involve systems based on different technologies, such as WiFi, WiMAX, 2G/3G/3G+, LTE/SAE and satellite. Integrated and hybrid networks must be defined in the framework of ITU Next Generation Networks (NGN).

The cooperation between networks provides the realization and proliferation of alternate modes of communications. This must be translated into advantages not only for end users, but also for services providers and operators. For end users, in enables them to maintain a single number identify, unified billing, ubiquitous and seamless connectivity, and access to a consolidated set of services. For operators, integrated and hybrid networks reduces the stress on the available spectrum and last mile access network, operators may improve signal quality to end users through efficient use of the different access network. It enables operators to offer user-based services and gain customer loyalty.

Traditionally network architectures have been built to support specific types of services. Voice and video over IP in one is boosting technology in convergence networks. To achieve a convergence network solution, a multilevel convergence architecture is required. The multilevel convergence is based on four primary levels built on each other: devices, application, services and networks, as reported in the following.

- *Devices*: a multi-modal and multifunctional devices for ubiquitous access and UI frameworks to access services through a common client based framework.
- *Application* convergence can be defined as offering unified instances of voice, multimedia and data services across heterogeneous access networks. SIP is an application layer signalling protocol offering seamless interoperability and flexibility with all types of networks as well as establishing control of traffic sessions.
- *Service* framework implies the creation of a generic service framework independent of the underlying networks to enable transparent services across heterogeneous networks. Its functionalities include session awareness and continuity, user awareness across services, a framework for deployment of user location independent policies, and enabling seamless roaming of terminals between network domains. The IMS is the architectural framework for delivering IP-based multimedia services.
- *Network* convergence making the user experience independent of the underlying access and core networks. It implies leveraging the IP layer and IP-based technologies for delivering unified instances of services across all networks.

An integrated and hybrid network must achieve service portability and continuity across composite networks through the service network interface with ubiquitous access, involving any network, any technology and domain and any administrative domain. The future architecture will be service oriented, the network will be pervasive, and important application will include peer-to-peer application, video on demand and multicast.

The next generation networks paradigm should allow seamless mobile and fixed broadband access for consumer and professional portable devices such as laptops, tablet PCs, PDAs and handheld devices. A satellite complementary access when outside of terrestrial coverage is essential to reach 100% of the population so to bridge the digital dividend as well as to guarantee the necessary level of dependability, for the purpose of emergency communications and other societal challenges.

For scenarios based on mobile ad-hoc networks (MANETs) and vehicular ad-hoc networks (VANETs), the presence of a satellite component could allow inter-connecting isolated ad-hoc clouds in a seamless and efficient way. This combination raises significant challenges in terms of optimising network resources, link availability, providing Quality of Service and minimizing costs and energy. In this context also the delay tolerant networking (DTN) principle could be a viable trend to be considered when user mobility and low coverage areas are present.

In all cases, to avoid spectrum shortages, the usage of techniques to increase the overall spectral efficiency presented in the previous sections (network coding, ground based beamforming, multiuser detection, pre-coding, etc…) and, more generally, of advanced interference management paradigms aiming at exploiting the structure of the colliding signals, requires also the design of low-overhead and highly efficient protocols in order to be technically effective and to become cost effective.

An all-IP network is favourable when deploying an integrated or a hybrid satellite/terrestrial network allowing a flexible resource management among different radio interfaces. Within this scenario, multihoming techniques allow a transparent connection with several network interfaces at the same time thus exploiting both satellite and terrestrial connections at the same time. This could be even more exploited if novel vertical handover techniques are introduced between the terrestrial and the satellite interfaces.

6.5 Research topics related to terminals

On the user terminal side, the prioritisation of the R&D challenges depends on the terminal category being considered.

For hybrid (consumer and professional) handheld devices, power consumption of COTS products for usage in L and S Band is today in line with that of terrestrial-only devices. Moreover, adding new base band functionalities for the support of additional radio interfaces is not the main cost driver. On the contrary, RF and antenna can significantly affect cost, form factor and performance. Therefore, an effort has to be put on the antenna side to allow e.g. the support of cross-polarisation re-use with low gain antennas and to improve reception at edge of coverage. In more general terms, novel proposals are required for reduced hardware complexity MIMO terminals. A promising technique for compact antenna terminals is the beamspace MIMO scheme with a single RF front-end. A terminal with a single active element and many parasitic elements shall provide increased functionality allowing for beamforming, diversity or even multiplexing gains.

Regarding collective terminals, concepts for very low profile antennas shall be further developed in order to allow high bandwidth communication on the move for collective mobile broadband; the foreseen bands are Ku and Ka on the short/mid-term; however research for higher frequency bands shall be started as well (Q/V bands). For compact vehicular applications, multiband / diversity radiating element in the same antenna for compact vehicular applications.

For fixed terminals, self-pointing antennas allowing user-friendly self-installing procedures and wireless connection between outdoor and indoor units are crucial. Wideband receivers will be developed to allow the effective usage of the wideband transponders. The receivers will be used in the terminals for the reception of x00, Msbs outbound; each terminal will use its own data for the broadband receiving as well as for the broadcast reception. This might call for a new standard that will be suitable and optimal for the MSB Terabits satellites support. Lastly, integration of satellite access with other wired and wireless access technologies into one unique set top box is a fundamental step for the provision of truly broadband connectivity also for today unserved and underserved areas. Satellite services will be used to extend the capabilities of other access technologies using multicast to deliver content and intelligent routing of traffic will optimise the use of multiple available infrastructures depending upon the nature of the data and status of the other available networks.

Finally, the forecast for satellite M2M shows significant growth in all industrial segments. However, some market segments tend to be more satellite affine than others such as transportation, logistics and supply chain, SCADA and energy. The major reasons for selecting satellite to connect devices are coverage and lack of alternatives, real time machine data collection and high security requirements. The reported major disadvantages of satellite communication are costs for the service and hardware. A strong demand is expected in real time communication and the use of video which would require high data transmission capabilities. Also power efficiency is a strong requirement that needs to be addressed as well as interoperability. As new emerging applications are seen remote reconnaissance, environmental monitoring, pollution control, traffic control as well as video surveillance and consumer M2M personal tracking. Finally, there is clearly an opportunity to considerably increase satellite M2M use through new developments to reduce hardware costs including low form factor and to provide greater standardization. Greater standardization should increase interoperability and thereby increase competition, further acting to reduce operating costs for adopters. In this direction, a frequency flexible approach (e.g., operating in C, Ku, and Ka band) is preferable.

6.6 Satcom role in and support to Future Internet

Over the last years the impact of satellites for the Internet has been pushed by various technological advances. Today satellites provide broadcast delivery to end users, content delivery to network head ends, data distribution functionality, connectivity in the Internet backbone, Backhaul, as well as mobile, nomadic and fixed broadband services in rural areas and handheld services. Moreover satellite systems are used as reliable fallback for major links and operate as gap-fillers for mobile users and as a complementary technology for ground components and terrestrial networks.

The Future Internet (FI) Architecture shall merge seamlessly future services and application requirements. The core of the FI will be based on shared frameworks, technologies, common enablers and architectural principles and must evolve from a set of communication-centric, content-centric, service-centric, resource-centric isolated infrastructures to a polymorphic infrastructure.

Satellites comprise the following (non exhaustive list of) primary features which may have a major role in Future Internet: (i) all the time: satellite networks are key to provide service continuity and robustness under disaster cases; (ii) everywhere: especially in rural, low density populated areas, satellites are the most economical access technology and provide the means to access non-traditional networks as SCADA sensor networks. This induces also the potential of satellites to allow for/or accelerate the high-speed Internet access in developing countries; (iii) native support for wide area broadcast / multicast; (iv) support for inter-planetary communication and deep space networks; and (v) Satellites support security and content reliability on an operational level, since the infrastructure is easy to protect, network management is centralized and under operator control and the access to the network is strictly under control of the network control manager.

It is therefore necessary to study the applications and services that are typically susceptible of being used in a satellite network, so that its evolution goes online with the Future Internet guidelines. The development of future satellite systems will not consider only the network aspects as the connection bandwidth required or the necessary traffic engineering, but also higher level factors (such as scalability, security, mobility,…) that impose requirements to the lower levels.

A promising Future Internet (FI) technological solution which seems pertinent to integration with SatCom networks refers to Information/Content-Centric Networking. It constitutes an alternative to the conventional, IP-based internetworking, with information being identified rather than the host where it resides (which is the case for IP networking). That is, rather than interconnecting pair of end hosts, FI information-centric networks will evolve as a substrate for information dissemination and will be based on named data identifiers instead of end hosts addresses. These identifiers relate to content and/or services. This approach appears to be very promising in the Future Internet.

Especially, the Publish-Subscribe Internetworking (PSI) approach seems well suited to SatCom because of the related Broadcast/Multicast nature. A PSI architecture involves three major entities: the publishers, the subscribers and an event notification service. Publishers hold the role of information providers. They advertise the availability of specific pieces of information and they provide these pieces of information to the network. They perform these operations by issuing publication messages. Subscribers are information consumers, who express their interest for specific information items by issuing subscription messages.

From a long-term perspective satellite should be compatible with the overall Future Internet. In this regard, a macroscopic view of a potential migration from current Internet towards FI solutions underlies the following main R&D features:

- *Polymorphism:* FI will consist of interconnection of different networks with a large degree of architectural and technological diversity, encompassing both evolutionary and disruptive solutions.
- *Information-/Content- Centric Networking:* Rather than interconnecting pair of end hosts, FI networks will evolve as a substrate for information dissemination and shall be based on named data identifiers instead of end hosts addresses. These identifiers relate to content and/or services.
- *Networks & Services Composition:* FI networks will dynamically compose to answer to specific services and applications requirements. FI networks will consist of generic components/services having a high degree of autonomy and self management capabilities. The networking shall be based on semantic descriptions of the components' capabilities.
- *Network Virtualization/Federation:* In current Internet implementations, virtualization techniques are regarded as link virtualization techniques or IP forwarding and provide merely traffic isolation. FI virtualization involves partitioning of individual resources as communication links, routers/switches, etc and abstracting functions/attributes with full customization and interconnection of Virtual Networks and composition/ decomposition of control & management functionalities. FI networks will support concurrent operation of different networks instances, Virtual Networks, over a single, shared infrastructure to enable rapid development of new architectural solutions and protocols and provide interworking facilities. Federation covers the aggregation of resources/ Virtual Networks and of the multiple management entities.
- *Network, Services and Context Awareness:* In the FI, the consumer/end user–facing and the resources–facing services/applications are aware of the properties, the requirements, and the state of the network environment, which enables services/applications to self-adapt according to the changes in the network context and environment

However, to meet the requirements of Future Internet (FI) and to allow for a seaming-less integrated satellite component in the FI, further research is necessary. This may focus on delay tolerant and error resilient protocols and applications, on-board processing and switching (already part of DVB-RCS NG/S2 interactive broadband satellite networks), self-configuration, interference and handover management in mobile scenarios. In a FIN, network nodes should be able to take advantage of spontaneous networking opportunities and (mobile) devices which shall be agnostic to heterogeneous access technologies. Moreover, already existing or applied techniques such as efficient random access techniques, Header Compression, HTTP-prefetching, web caching, data compression and DNS caching need to be reconsidered. Additionally inter-satellite link, on-board processing (OBP), on-board routing (possibly taking into account methods as flow aware networking and protocol agnostic congestion management) and on-board packet switching on various layers is and will be part of further research in the satellite community (aiming also at efficient mesh connectivity over satellite links e.g. DVB-RCS2). Additionally, bulk and packet encryption/decryption, multi-beam or steerable communication antennas, dynamic bandwidth and resource allocation techniques (e.g. enhanced DAMA), and enhanced Random access techniques that integrate security, privacy, and mobility for Hybrid Terrestrial/Satellite Networks must be considered.

The current development of FI provides an excellent opportunity for satellite industry. Satellite can provide essential functions such as large coverage areas, flexible bandwidth allocation, dynamic multicasting/broadcasting capability, optimised backhauling, or ubiquitous services that will help to satisfy the FI user requirements.

Appendix: FISI internal document control

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