SatNEx, the European Satellite Communications Network of Excellence: Air Interface Activities

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Abstract

The SatNEx project has brought together twenty-two partners from European research organisations and academia to form a pan-European research network. A major objective of SatNEx is to rectify the fragmentation in satellite communications research by bringing together leading European academic research organisations in a durable way.

Furthermore, the Network aims to establish critical mass and allow access to a range of expertise currently distributed across Europe. In this respect, mobility is an important aspect of SatNEx's work, with academic staff and research students being encouraged to move between institutions to allow access to specialised research equipment and to facilitate research integration.

Training represents an important part of SatNEx's remit and is supported through a number of initiatives including the hosting of internship projects, the establishment of summer schools and the dissemination of papers of a tutorial nature

This paper discusses the background and motivation for implementation of the network and highlights the SatNEx mission and key objectives. A top-level overview is provided including a description of the consortium and the Joint Programme of Activities (JPA). Details of the activities carried out under the Work Package 2400 "Access", dealing with the Air Interface system components (physical and access layers) are provided.

Nomenclature

ASMS-TF = Task Force on Advanced Satellite Mobile Systems (http://www.asms-tf.org)
COST = European Co-operation in the field of Scientific and Technical Research (http://cost.cordis.lu)
EC = European Commission
FP6 = European Sixth Research Framework Programme
IST = Information Society Technologies
JA = Joint Activity
JPA = Joint Programme of Activities
JER = Jointly Executed Research
NoE = FP6 Network of Excellence
WP = Work Package
WWRF = Wireless World Research Forum

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I. Introduction

WITHIN the broad field of communications, satellites are successfully used for broadcast, mobile, and broadband communication. They play an important role for the competitiveness of the European Union in the field of communication technologies and support the autonomy of Europe in space matters. Beside the players in the US and Asia, European space industry, satellite operators and space-related organizations constitute a world leading force. Europe has always retained a major presence in both manufacturing satellites (Alcatel, EADS/Astrium, Alenia Aerospazio…) as well as launching and operating satellites (Arianespace…) and providing satellite services (SES Global, Eutelsat, Inmarsat…).

Satellite communications has been an area in the satellite field that has been commercially successful so far and this has been helped and pump primed by the R&D programs of the European Space Agency (ESA) and by the European Union (EU) Framework Programmes. European research carried out a large number of successful activities in satellite communications (ESA and EU projects, COST actions, the ASMS-TF, etc.). Their efforts have made it possible to create a solid industrial base and to give Europe recognized capabilities and capacities. However, these actions show only limited collaboration and lack of critical mass. Compared to the leading power in space, the United States, where the use of space systems is not only a technological instrument, but a strategic, political and economic instrument guaranteeing the American leadership, Europe in the past has shown only limited interest in developing a common European approach to put its resources together and cooperate intensively even without the support from ESA.

In latter years, satellite communications has been viewed as a mature area that is more the responsibility of industry and commerce and less that of the R&D agencies. This has resulted in reduced staff support for R&D in the area in preference to the science and navigation/positioning areas. At the same time we have seen a rationalization of the industrial business due to economic pressures manifested in mergers of the large industrial companies both within Europe and globally. The growth has been in the smaller and medium size companies that have sprung up in abundance in the applications and services area.

II. SatNEx Motivation and Mission

A. Inner-European Fragmentation

With varying levels of financial support, industrial countries within the EU have established their own national space R&D programs (France, Italy, Germany and the UK for example), which reflect both their support for national industries as well as political priorities for space. Again within these areas the role of communications vis-a-vis science, remote sensing and positioning has been small. Most of the R&D has been technology push driven, rather than applications pull. Industry has focused on the next satellite platform in a fairly conservative and incremental fashion even to the exclusion of applications. The satellite industry also has been very late into the standards arena preferring to provide proprietary solutions and this is in stark contrast to both the fixed and mobile terrestrial operations.

Within the European academic and research institutions, there has also been little critical mass concentration on satellite communications. Expertise is largely spread and where it exists it is not entirely focused on satellite communications but more generally applicable with satellites being merely one application.

B. Role of SatNEx

A major aim of SatNEx is to rectify this fragmentation by bringing European research in Satellite Communications together in a durable manner, enabling critical mass and access to a range of expertise across Europe. We intend to make this available to staff and students moving between institutions and using specialists' facilities of these institutions as well as research students who can spend periods of time in any institution of the network. Most importantly we intend to produce a common platform with delivery via satellite for all partners who will use this as a means for integrated research, teaching and training – the SatNEx platform.

Satellite industry is living through very difficult times, due to a general market regression and to some recent failures that have affected the possibility to receive adequate loans and investments from banks. As a consequence, industry is looking only at short-term results and revenues. Universities and research institutes can play a crucial role in supporting European industry, using SatNEx as a structure facilitating the identification of needs, generation of new ideas and concepts, coordination of activities, and development of new knowledge in the strategic field of satellite communications.

Research in satellite communications across Europe needs a long-term vision from which to develop a technology and service roadmap that will drive the longer-term research program. SatNEx aims to produce in collaboration with industry this vision and to maintain and update it during the lifetime of the project. Such a detailed vision has already been produced for mobile communications and we intend to link with WWRF in producing the satellite vision. We will need to create this vision in the fixed broadband, mobile, broadcast and navigation/positioning areas.

C. SatNEx Mission and Key Objectives

The prime objective of SatNEx, to overcome fragmentation of European Satellite Communications research through the integration of partners, cannot be dissociated from the production of new knowledge. Integration is a very sensible objective, but it must be finalized to the achievement of breakthrough ideas. Limiting all efforts to integrating partners, relocating staff, developing common simulators, reorganizing the structure, and filling gaps in the research portfolio would fully comply with the criteria for NoE acceptance. But this would not achieve the critical objective of producing the evolutionary or revolutionary ideas that may serve to shift the satellite communications paradigm in favour of the European industry.

Advancing European research in satellite communications is a central objective of SatNEx. SatNEx has been designed as a Joint Venture between institutions that have as their mandate the production of new knowledge and the transfer of this knowledge to industry and to society at large. The network has a specific focus in satellite communications, which has been recognized as a strategic field of knowledge for Europe, both in terms of its commercial return and, perhaps more importantly, in terms of its impact on the Continent's security and the connectivity of all Countries, particularly the new enlargement Countries.

An important objective of SatNEx is knowledge transfer to both the research community at large as well as the existing satellite industry. Knowledge transfer will take place via training courses, conferences and workshops and skills development into existing business as well as via specific briefings to industry.

III. SatNEx Overview

A. Consortium

In the SatNEx NoE, 22 partners from 9 European countries join their research forces and bring in a widespread expertise for integration, ongoing joint research and spreading of excellence. A well-balanced mix of Higher Education (HE) Institutions and Research Organisations (RES) makes up the consortium, where two of the latter also have the SME status (Table 1). Industry partners are integrated into SatNEx via the Advisory Board. SatNEx is co-ordinated and managed by the Institute of Communications and Navigation of the German Aerospace Center (DLR).

Collectively the SatNEx partners have the necessary critical mass of expertise and resources to successfully carry out the Joint Programme of activities (JPA), which is outlined in the following.

B. Joint Programme of Activities (JPA)

Figure 1 shows the work package breakdown structure of the Joint Programme of Activities:

- The Integrating Activities (WP 1000) support the Jointly Executed Research (WP 2000) by co-ordinating the participants research (WP 1100), integrating research tools and test beds (WP 1200), providing a communication and collaboration platform (WP 1300), organising the exchange of students and personnel (WP 1400), and performing integrated management of knowledge and intellectual property (WP1500).

• The Jointly Executed Research activities (WP 2000) produces new knowledge and supports WP 1000 by developing common research tools and test beds, proposing suitable cases for personnel exchange, and providing new knowledge and expertise.

• Finally, WP 3000 primarily aims at the Spreading of Excellence to Europe beyond SatNEx. This activity provides training opportunities, disseminates information and transfers knowledge, influences standardisation and regulation, and enhances public awareness of the benefits of satellite communications.

The activities and work packages of the JPA are interconnected by a dense mesh of integrating relationships (See Figure 2). On top of the support from Integrating Activities (WP 1000), there is a strong connection between the Jointly Executed Research (WP2000) and the Spreading of Excellence: WP 2000 produces new knowledge and intellectual property which gives input for standardisation and regulation (WP 3300). Vice versa, WP 3000 provides information from standardisation and regulation bodies to WP 2000. Moreover, WP 1000 supports the Spreading of Excellence (WP 3000) by offering the communication and collaboration platform.

Efficient management and implementation of Jointly Executed Research (WP2000) is insured thanks to strong relationships between the work packages in the WP 2000 activity: the research strategy and visions (WP 2100) drive the system studies (WP 2200) which in turn have influence on the research in networking (WP 2300) and access (WP 2400) as well as on the research trials (WP 2500).

The philosophy underlying the SatNEx approach consists in the selection of focused actions within the broad framework described by the overall JPA, in order to capitalize on the expertise that are present within the network and to make sure that the integration is effective and durable. These focused actions are to be carried out jointly by the partners, and are identified as Specific Joint Actions (SJAs). They include research, integration, and disseminating activities.

The research activity, in particular, focuses on knowledge gaps that may be present within the network and on extending the knowledge that is brought in at the project start-up by the various partners. The emphasis will be on the challenge to existing concepts and ideas, in the never-ending search for improvements and breakthroughs, which can only be achieved by leaving the field open to exploratory research activities.

Besides collaborative research, personnel exchange, training and dissemination are the other key elements to ensure effective and long-lasting integration.

C. Joint Activities

The implementation of the SatNEx NoE requires the definition of a number of specific and more concrete activities, both for thematic planning and work organisation in the group of partners and for the financial planning. In the following we explain the concept of SatNEx joint activities (JAs).

The JAs are the fundamental unit in the implementation of the SatNEx JPA. A SatNEx JA is defined as a set of coherent activities, cost elements and procedures to achieve a specified objective within an associated time frame. A JA is jointly performed by a team of SatNEx partners, and must be focused on a relevant part of the JPA. The JAs are the elements specifying how the work is performed and are the way/methods of putting the SatNEx objectives into practice, allowing to bridge some gap between the classical (vertical) WP breakdown structure, and the (horizontal) NoE elements: integration, joint research, spreading of excellence.

IV. Work Package 2400 – "Access"

A. Objectives of WP2400

The future success of communication satellites is based upon the capability to remain competitive in terms of capacity versus cost and supported services with respect to terrestrial systems. This work package aims at developing know-how and expertise in all facets involved in the optimised design of the link between terminals and multibeam satellites, so as to maximise capacity of the system, minimise terminal cost, guarantee QoS requirements, while preserving flexibility to cope with evolution of services and users expectations.

Various issues to be investigated in the definition of the air interface and the management of the satellite resource are addressed in the following three sub-work packages:

- WP 2410 Channel and Propagation, with the objectives of improving, developing, and validating channel models to be integrated in system simulation tools, altogether with the goal of constituting a databank of propagation data for system performance evaluation or emulation.
- WP 2420 Physical Layer, where of all issues related to physical layer are considered, including design of efficient and flexible modulation and coding techniques, implementation of receivers with synchronization and parameter estimation, fading, interference and distortion countermeasures.
- WP 2430 Layer 2 and Resource Management, aiming at the development of concepts and algorithms for optimised radio resource management able to support multimedia traffic with QoS guarantee.

The research activity focuses on addressing knowledge gaps, and for the first two-year phase of SatNEx, WP 2400 has been restricted to one joint activity for each of the three sub-work packages WP2410, WP2420 & WP2430:

- JA 2410: Channel Modelling and Propagation Impairments Simulation (Channel)
- JA 2420: Flexible Waveforms (Flexwave)
- JA 2430: QoS and Radio Resource Management with Cross-Layer Approach (QoS&RRM).

B. JA 2410: Channel Modelling and Propagation Impairments Simulation (Channel)
The JA2420 action is lead by ONERA/TeSA and is supported actively by 14 SatNEx partners.

1. JA-2410 objectives
Optimisation of satellite systems requires taking into account propagation information early in system design. Indeed, either for navigation, mobile, HAPS or broadband systems, the propagation channel has a strong impact on system performances and relevant channel models (including models of the dynamic behaviour) should be available to assess by simulation the end-to-end quality of service and the satellite system performances.
The pre-existing knowledge portfolio has been collected and has been classified according to the following areas: Keywords, Publications, Scenarii, Propagation models, Propagation data.

The objectives of this JA are therefore to improve, develop, and validate channel models to be integrated in system simulation tools. These models will take into account cross-layer issues that concerns the physical layer (JA 2420) with Fade Mitigation Techniques (FMT) (issues of propagation channel dynamics, short-time real-time prediction), and the Adaptive Resource Management (ARM) techniques (JA2430) where the main issues could be spatial correlation of fade events and short to mid-term real-time prediction.

2. Delta-Research activities
Delta-research activities are organized according to three focussed topics:
JA-2411: Mobile/indoor multipath.
Integration activity will concern model and tool improvement and validation, focussing on deterministic ray-tracing models. In terms of delta-research, it was agreed to concentrate on three following topics: Slant path in-building penetration, modelling Doppler effects to infer the impact on fade duration, in-aircraft cabin propagation.
JA-2412: Atmospheric effects
Integration will be achieved thanks to the constitution of a databank of radio-climatological and propagation measurements and propagation models. Then, a databank of prediction models will be constituted. Delta-research is related to two hot issues in propagation: time series synthesis and spatial correlations
JA-2413: Clear sky optics
The following activities will be carried out: Wavelength diversity tests; Background light measurements to design FSO IM/DD systems, taking into account sun elevation, sun distance, weather situation and wavelength; Activity on coding and channel modelling, on clock and data recovery as well as on interfacing with upper network layers.

The final deliverable of JA-2410 will take the shape of a book in digital format (or e-book). This e-book will present state-of-the-art and delta-research in satellite propagation carried out in this JA. This E-book will be constituted into three parts: Mobile /indoor multipath, atmospheric effects and clear sky optics. The book will be entitled “Influence of the propagation channel on satellite communications - Channel dynamic effects on mobile, fixed and optical multimedia applications ” and it will collect the efforts and contributions of all partners.

C. JA2420 Flexible Waveforms (Flexwave)
The JA2420 action is lead by UoB and is supported actively by 15 SatNEx partners.

1. JA2420 objectives
JA2420 Flexwave is a joint activity dedicated to Physical Layer issues. Indeed, the physical layer shall be adapted in an optimal way to the specific satellite peculiarities, considering the system applications developed in WP 2200 and the channel propagation environment characteristics identified in WP 2410. The pre-existing knowledge portfolio has been classified according to the five areas: Keywords, Publications, Scenarios, Software and Hardware tools, and Theoretical tools. The analysis of the knowledge portfolio seems to indicate that the best scientific focus area for the Flexwave JA2420 should be searched in a vision of the future, and therefore this JA will be focused on the study and design of extremely efficient and flexible physical layers for broadband mobile and fixed satellite links in the years 2015-2020.

2. JA2420 Delta-Research activities
The rationale is to point at the broad research area of Flexwave physical layer that is projected in the long-term. The technological framework in 2015-2020 is uncertain, although it is an easy forecast to predict that progress in terms of computational power, circuit integration, and power consumption will be fantastic. Many new ideas will come up in trying to achieve such a far-fetched objective, and by no doubt this focus area is not covered by existing initiatives, thus fulfilling the principle of innovation (or of delta-research).
The key words that characterise the focus areas are: efficiency (both in terms of spectrum efficiency and in terms of power efficiency), flexibility, broadband communications, mobile and fixed systems, synchronization and parameter estimation, channel countermeasures, complexity and feasibility.

The research activities have been organized into the framework of a book, which would have embodied both integration and research objectives, meeting the fundamental mission of the Network. The book entitled: "Advanced Digital Satellite Communications", will consist of eleven chapters and an appendix, as follows: 1. Introduction; 2. System and applications; 3. Theoretical background; 4. Channel impairments; 5. Forward Error Correction; 6. Modulation Techniques; 7. Parameter Estimation & Synchronization; 8. Distortion Countermeasures; 9. Diversity techniques; 10. Multiplexing & Multiple Access; 11. Software radio; Appendix - Simulation methodology.

D. JA2430 QoS & Radio-Resource Management with a Cross-Layer Approach
The JA2430 action is lead by CNIT-Siena and is supported by 15 SatNEx partners.

1. JA2430 Objectives
Satellite networks must be designed to be as cost-effective as possible. To this end, efficient resource management concepts are necessary, which distribute the system resources adequately among the users and applications. Furthermore, suitable concepts for quality of service (QoS) provisioning are necessary to support adequately all different kinds of multimedia services. The main focus of JA2430 is the realization of novel radio resource management schemes able to support multimedia traffic with QoS guarantee in future satellite communication systems.
The optimisation of layer 2 is of fundamental importance, since radio resources are costly and scarcely available. The radio resource allocation algorithms shall take into account the packet nature of traffic and its QoS objectives, the demands originating from the fade mitigation control logic, the adaptive user information rate, the frequency reuse capability over non adjacent beams, etc.

A rich research portfolio that has been classified according to the same areas as above, emerged from the different partners in the field of layer 2 protocols for satellite communications and, in particular, on: Broadcast and multicast services, Cross-layer air interface architecture, Radio resource management protocols, RRM and TCP protocol behaviour, Integration of IP QoS and layer 2, Dynamic bandwidth allocation, Fade countermeasures, Call admission control, QoS requirements for multimedia traffic, DVB-S and DVB-RCS resource management, Multimedia traffic scheduling, Adaptivity in the RRM.

2. JA2430 Delta-Research activities
This research activity is targeted to provide the basis for an adequate implementation of the air interface (at layer 2) for future mobile and broadband satellite systems. Delta-research deals with the definition of novel access schemes (uplink) and scheduling techniques (downlink) on the basis of the knowledge of the behaviour of the air interface

protocols at different OSI layers (OSI 1, 3, 4 and 7, mainly), integration of layer 3 IP QoS with resource allocation techniques at layer 2. A 'vertical' (i.e., cross-layer) approach will be assumed in the definition of the air interface of the satellite system, allowing that a communication layer provides input to other layers and uses inputs from other layers.

E. Integration and Dissemination activities

The philosophy underlying the SatNEx approach revolves around the selection of focused actions in order to capitalize on the expertise that is present within the network, and to ensure that the integration is effective and durable. The partners carry out these focused actions that include collaborative research and dissemination activities jointly.

1. Collaborative Research

As discussed above the implementation of delta-research varies from one joint activity to another.

Integration activity within JA 2410 concerns model and tool improvement and validation, focussing on deterministic ray-tracing models. Another integration activity consists in the constitution of a databank of radio-climatological and propagation measurements and propagation models. The state-of-the-art review of propagation effects, data and models review has been coordinated with the work performed within the COST 280 action.

JA2420 has worked toward the definition of a single federating objective, encompassing all desired integration dimensions. This unifying objective, constituting the common ground for growing the wanted integrated results in terms of scientific research, exchange of personnel, and spreading of excellence, is the development of an edited book.

The partners in JA 2430 are collaborating to define a set of new cross-layer enhancement options combining physical, link and transport level techniques to optimise application layer performance to improve the efficiency and performance of Internet applications in next generation wide-area satellite networks. The output of this activity will be specification and analysis of a set of new link-layer techniques.

2. Personnel Exchange

The Network allows access to a range of expertise currently distributed across Europe. In this respect, mobility is an important aspect of SatNEx activities, with academic staff, researchers and PhD students being encouraged to move between institutions to allow access to specialised research equipment and to facilitate research integration.

3. Training and Dissemination

Training represents an important part of SatNEx's remit and is supported through a number of initiatives including the hosting of internship projects, the establishment of summer schools and the dissemination of papers of a tutorial nature.

An example of dissemination activity is the SatNEx tutorial entitled "Broadband Satellite Communications" that has been organised in ESA/ESTEC on 20 September 2004 prior to the EMPS/ASMS Conference. The tutorial discussed the role of satellite in future broadband access and the opportunities for new applications that emerge with advanced satellite delivery, focusing on the current state-of-the-art in all aspects of broadband satellite systems.

Another example is the "International Workshop on Satellite and Space Communications" (IWSSC'05) to be held at in Siena on 6-9 September 2005 that will bring together people from Industry, Universities and Standardization Bodies to discuss the current status, technical challenges, standards, fundamental issues, and future services and applications. A new concept *"Young Researchers Sessions"* has been planned to foster integration. The aim of these sessions at IWSSC'05 is to give young researchers and Ph.D. students a forum to present their ongoing research work to an audience consisting of other young researchers and Ph.D. students as well as experts and senior researchers. SatNEx as an important contribution to both its Training and Dissemination targets particularly supports this element of the workshop open to the widest participation.

Finally another key element of the NoE Training and Dissemination programme is the "SatNEx Summer School" to be organised by ISTI/CNR in Pisa on 22-26 August 2005. Targeting mainly post-graduate students and practicing researchers from industry, the first four days provide a comprehensive programme of lectures covering all key areas in satellite communications. Detailed programme is available from the SatNEx server and is complemented by selected industry presentations featuring "IP over satellite" on the fifth day, forming at the same time the final COST 272 event. The SatNEx Summer School is open to all interested people from the target community.

V. Conclusion

The European *Satellite Communications Network of Excellence (SatNEx)* has been presented (www.satnex.org.). The primary goal of SatNEx is to achieve long-lasting integration of the European research in satellite communication and to develop a common base of knowledge, thus contributing to the realization of the European Research Area. The paper discusses also activities carried out under the Work Package 2400 "Access", dealing with the Air Interface system components (physical and access layers), and aiming at developing know-how and expertise in all facets involved in the optimised design of the satellite link.

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Table 1: Overview of the SatNEx consortium

Partner	Partner Acronym	Partner	Activity	Key Person(s)	Country
1	DLR	Deutsches Zentrum für Luft- und Raumfahrt	RES	Prof. Erich Lutz Dr. Markus Werner	D
2	AUTh	Aristotle University of Thessaloniki	HE	Prof. Niovi Pavlidou	GR
3	BRU	University of Bradford	HE	Prof. Ray Sheriff Dr. Fun Hu	UK
4	BUTE	Budapest University of Technology and Economics	HE	Prof. István Frigyes	HU
5	CNES	Centre National d'Etudes Spatiales	RES	Robert Rumeau	F
6	CNIT	Consorzio Nazionale Interuniversitario per le Telecomunicazioni	RES/ SME	Prof. G. Albertengo, G. Benelli, F. Davoli, E. Del Re, G. Giambene, S. Palazzo,	I
7	FhI	Fraunhofer Gesellschaft zur Foerderung der Angewandten Forschung e.V.	RES	Dr. Thomas Luckenbach Prof. Karl Jonas	D
8	GET	Groupe des Ecoles des Télécommunications	HE	Prof. Gérard Maral	F
9	ICCS	Institute of Communication and Computer Systems of NTUA	RES	Prof. Nikolaos Uzunoglu Dr. Philip Constantinou	GR
10	ISARS	National Observatory of Athens	RES	Prof. Takis Mathiopoulos	GR
11	ISTI	Istituto di Scienze e Tecnologia dell'Informazione "Alessandro Faedo"	RES/ SME	Dr. Erina Ferro	I
12	JSI	Jozef Stefan Institute	RES	Prof. Gorazd Kandus	SLO
13	RWTH	Rheinisch-Westfaelische Technische Hochschule Aachen	HE	Dr. Carl-Herbert Rokitansky	D
14	TeSA / ONERA	Co-operative Research Lab on Aerospace Communications /ONERA /SUPAERO	RES/ HE	Prof. Michel Bousquet Dr. Laurent Castanet	F
15	TUG	Institut fur Kommunikationsnetze und Satellitenkommunikation, TU Graz	HE	Prof. Otto Koudelka	A
16	UCIIIM	Universidad Carlos III de Madrid	HE	Dr. F. González Serrano	E
17	UniS	University of Surrey	HE	Prof. Barry Evans	UK
18	UoA	University Court of the University of Aberdeen	HE	Dr. Godred Fairhurst	UK
19	UoB	Dipartimento di Elettronica,Informatica e Sistemistica, Università di Bologna	HE	Prof. Giovanni Corazza	I
20	UToV	Universita Degli Studi Di Roma "Tor Vergata"	HE	Prof. N. Blefari-Melazzi Prof. Francesco Vatalaro	I
21	UVI	Universidad De Vigo	HE	Prof. Francisco Javier González Castaño	E
22	UAB	Universitat Autònoma de Barcelona, Spain	HE	Dr. Marian Vázquez Castro	E

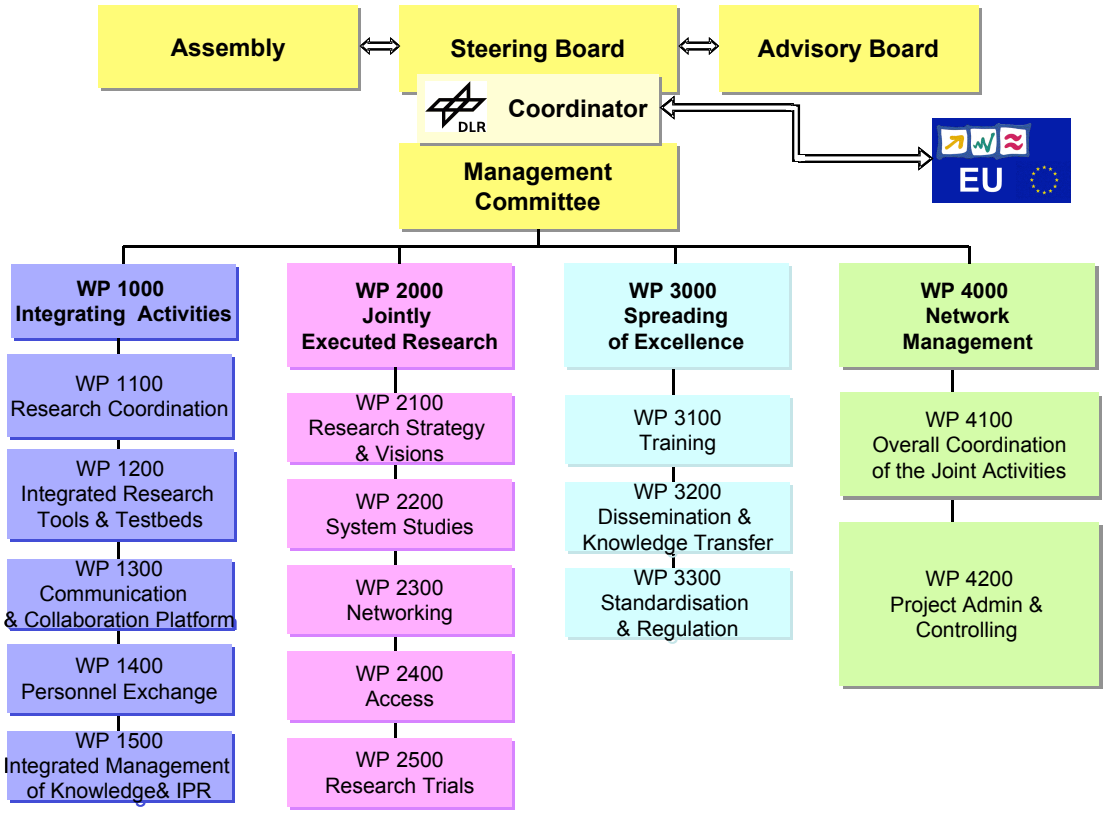

Figure 1: Breakdown of the SatNEx organisational structure and the Joint Programme of Activities (JPA)

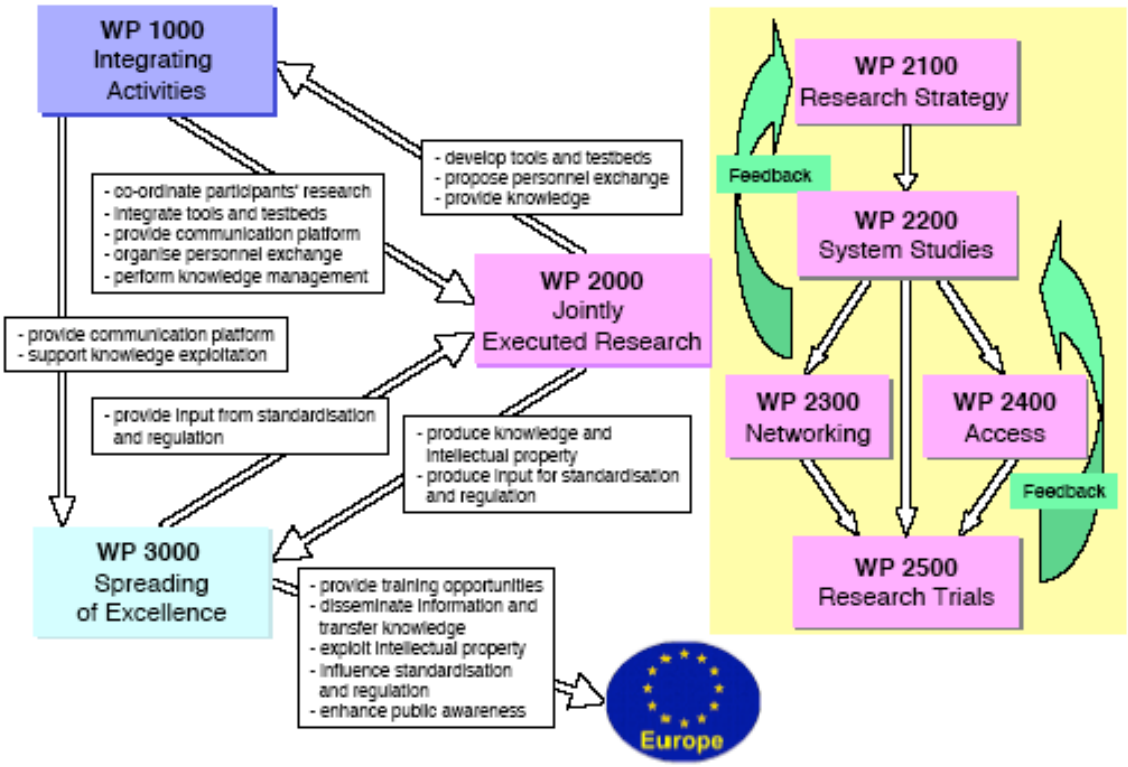

Fig 2: Interdependencies between JPA elements