

THE ANASTASIA PROJECT: A CONTRIBUTION TO THE DEFINITION OF A FUTURE AERONAUTICAL COMMUNICATION SYSTEM

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ABSTRACT

ANASTASIA : A 6th Framework EC programme : BACKGROUND

Project Objectives

The core of ANASTASIA research is to provide on-board Communication, Navigation and Surveillance (CNS) solutions to cope with the foreseen doubling of air traffic by 2020.

ANASTASIA will carry out research of future technology and system architectures for navigation, resulting in the development of a new generation of airborne GNSS receivers for all phases of flight. Such systems will offer accurate and safe global navigation while reducing avionics cost through the optimisation of the number and complexity of on board equipment.

On the communication side, work will concentrate on the design and implementation of a prototype Satcom system that will meet the evolving European Air Traffic Management (ATM) requirements. Research will also be made into higher bandwidth services, systems and airborne equipment to efficiently meet long term future aircraft communication requirements, including both ATM and passenger needs.

The future needs of Surveillance will be consolidated with the requirements and key technology tests from Communications and Navigation.

Expected results

The main goal of ANASTASIA is to pave the way for the introduction of new satellite-based technologies into aircraft operations in both Navigation and Communications.

The main outcome of ANASTASIA will be recommendations for future civil aircraft operation and a set of evaluated technologies and avionics architectures achievable from 2010 that will enable more autonomous, satellite-based aircraft operation.

PAPER FOCUS:

After a general description of the rationale of the project and of its global CNS objectives, the focus is made in this paper on the communication side where more detailed objectives are presented. The paper concludes with the description of the main achievement after 2 years, and a presentation of the orientations for future work

KEY WORDS:

Aeronautical Communication, EC 6th framework programme , ANASTASIA, Satcom, satellites, ATC, CNS, Avionics

1 ANASTASIA'S BACKGROUND:

1.1 Scope of the project:

In the first 20 years of the 21st Century, air traffic is expected to approximately double in volume.

The expected performances of Space Based Technologies such as Satellite Communications (SATCOM) and Satellite navigation (renewed GPS, GALILEO....) beyond 2010 offer the prospect of increased autonomous aircraft operation that will improve the operational capacity and safety of the air transport system with regard to the "Single European Sky" initiative.

Anastasia aims to carry out research, evaluation and cost benefit analysis to define COM and NAV new technologies and new avionics architecture suitable for aircraft operation in the future satellite based European Air Traffic Management environment for the future corresponding CNS functionality. Outputs will be validated by theoretical analysis, by mock-up evaluations and selected flight-testing.

1.2 ANASTASIA: a 6th framework EC programme:

In order to perform these research activities, ANASTASIA project [1], [2], ([figure 1](#)) gathers a consortium of 29 partners, composed of some of the major stakeholders in the European aeronautical domain, including a balanced set of air-framers, avionics suppliers, satellite systems suppliers and providers, as well as universities and research centres specialised in aeronautical systems. ([figure 2](#))

ANASTASIA (Airborne New Advanced Satellite techniques & Technologies in A System Integrated Approach) is an IP (Integrated Project) which receives funding from the European Community's 6th framework programme (DG Research). The total cost of the project is around 20M euros, about half of it being funded by the EC, and the other half by the partners themselves.

It started April 1st 2005 and will last 4 years.

2 ANASTASIA'S OBJECTIVES:

2.1 CNS objectives:

The overall scientific & technical objective of ANASTASIA is to define navigation and communications avionics based on satellite services that will best meet the needs of civil aviation in the period 2010 to 2020. The project includes the definition of an optimised avionics architecture and the resulting recommendations for ground and space infrastructures. It includes the preliminary system development of advanced airborne systems for flight trial evaluation and the dissemination of the results for standardisation activities.

2.2 Communication

The project objective with respect to communications is three fold:

- To establish the requirements for an affordable SATCOM system for ATM, considering also the synergy with passenger use.

- To design, implement and demonstrate a preliminary system development of an affordable aeronautical SATCOM system that will meet evolving European ATM requirements such as using satellites to complement the congested VHF spectrum. The design will be based on the current or planned space segment and will have maximum synergy with existing and planned non-ATM aeronautical SATCOM systems
- To carry out research into higher bandwidth services, systems and airborne equipment to meet future SATCOM requirements for ATM. Due to the very high cost of satellite communication systems, the synergies with revenue-generating passenger use shall also be considered in order to ensure a cost efficient approach.

These ANASATASIA objectives in Communication, together with the main results achieved after two years will be detailed in the following up of this paper.

2.3 Navigation

Objectives in the Satellite Navigation Domain are:

- To consolidate air navigation performance requirements and map to potential operational benefits from the use of space-based navigation systems in future aircraft and airspace.
- To investigate and evaluate the following techniques and technologies that are the keys to the success of future space-based navigation systems:
 - Multi-constellation, multi-frequency GNSS receivers (GPS/Galileo) for real world-wide autonomous robust navigation
 - Signal processing techniques and antenna design for high robustness to critical Radio Frequency Interference environments
 - High accuracy and integrity techniques for up to Cat III landing and gate-to-gate operations (SMGCS)
 - Low cost inertial sensor technologies (MEMS) and techniques to optimally combine inertial and GNSS sensors for air navigation and landing
- To define, based on these evaluations, a set of new candidate architectures for navigation taking advantage of the new constellations, as the best trade-off between performance capabilities and cost requirements
- To contribute to standards and regulation

2.4 Surveillance

Objectives in the Surveillance Domain are to assemble the surveillance needs of the future (2010 to 2020) in order to provide the necessary requirements on the definition of the navigation and communication systems.

3 MORE ABOUT COMMUNICATION STUDIES IN ANASTASIA

3.1 Aeronautical communications State of the art

Currently, for the majority of civil aircraft operating today, VHF is the primary overland ATM communication channel. Communications over the oceans normally uses HF communications. However most long-range aircraft are now also equipped with SATCOM for global communication over oceans.

In the satellite communications field, different systems are used right now:

- SATCOM Inmarsat L-band

Inmarsat aeronautical service is widely used in aviation because, apart from HF, it is the only way to communicate over oceans. Two principal services are offered, Aero-H and Aero-I that can provide up to 6 voice channels plus a limited data channel.

- Inmarsat planned evolutions:

Using the current satellites new higher data rate systems, known as High Speed Data (HSD) or Swift64 are being introduced into aviation.

From 2005-2006, a new higher rate voice and data service will be introduced using new Inmarsat IV satellites. Called Broadband Global Area Network (BGAN) it will have a maximum bit rate of 432kbits/s.

- Iridium

Iridium offers true global coverage, low bit-rate, low-latency voice and data services to aircraft from its 66 LEO satellites in polar orbit. Inter-satellite links are used routing all traffic to a US based gateway.

3.2 Future Needs:

The predicted large increase in air traffic volume would undoubtedly benefit from an improved ATM system, and a key requirement is to get worldwide, safety critical digital communications with the aircraft and other services like weather map, electronic flight-bag, etc.... SATCOM is a possible solution to providing global digital communication channels.

For optimal communications, the aircraft must ideally be kept continuously connected to the ground with digital links.

Rising passenger expectations will require the same facilities on-board the aircraft as are found at home or in the office. This implies high bandwidth with digital links (several Mbits/s). Current satellite communication is 64kbits/sec (4 people talking at the same time), but BGAN will extend to 234kbits/sec (14 people talking at the same time) and in near future (2010) the need could be 50 people talking at the same time.

Fierce competition between airframe manufacturers and airlines alike requires cost effective communications, the solution for which is a key driver.

3.3 Satellite Communications:

3.3.1 Limitation of the Existing Systems:

The existing L band satellite based system for communications is used primarily for passenger application (APC) or administrative communications (AAC); initially analogue voice and now data are tending to evolve towards wideband digital applications. In spite of their high throughput potential, and of the interest of ATM community, they are not much used for safety critical applications (ATC).

3.3.2 ANASTASIA Objectives to Overcome These Limitations:

- Use of satellites for ATC

Using satellites for ATC would improve the existing aeronautical solution and would not require the design of a new system from scratch. A key question is: “Can the system (existing or foreseen) be made robust enough, even with some add-ons, to meet the requirements of ATC use?”. A solution solely for the aeronautical market would be too expensive to justify the launch of the necessary satellites. Therefore, existing and future SATCOM systems from many providers including Inmarsat will be studied in ANASTASIA to see if a system can be identified that can provide a service for ATM. Work to identify an initial service will concentrate on BGAN and its successor because of its potential to decrease the cost of current services by up to an order of magnitude. This will open a large market to this new system.

- Common antenna for cockpit and cabin communication

To decrease the cost of communication avionics (target is to halve), and then to make the service possible, a key technology to develop for the 2015-2020 timeframe is a dual frequency airframe-conformal antenna. This means that only one antenna would be needed instead of two because it will provide access to two frequencies (L and probably Ku). Being conformal will decrease installation and exploitation costs.

4 ANASTASIA: ORGANISATION AND STRUCTURE:

4.1 General organisation of the project:

4.1.1 Work breakdown structure

The project is organised in 5 sub-project ([figure 3](#)), which are:

- SP1, Project management: to manage the consortium and ensure the reporting to the commission and the technical coordination with the partners.
- SP2, Needs and future aircraft requirements: to identify the requirements for the new satellite based CN(S) functions for both business jets and air-transport.
- SP3, Space based navigation technologies: to investigate the space based systems and to define the different techniques and technologies that must be implemented for an optimal use of new space based technologies in an on-board system.
- SP4, Space based communication technologies: to investigate the space based systems and to define the different techniques and technologies that must be implemented for an optimal use of new space based technologies in an on-board system.

- SP5, Operational characterisation and evaluation: to investigate specific environmental characteristics and verify in a quasi-realistic environment, behaviour and performance of the key navigation and communication technologies.
- SP6, Dissemination: exploit and disseminate results in order to contribute to standards.

4.1.2 Planning

See [\(figure 4\)](#)

4.2 SP4: Sub-project « Communications space based technologies »

4.2.1 Introduction

In this paper, the focus is made on the communication part (SP4) of the ANASTASIA project. As can be seen on the planning [\(figure 4\)](#) this Subproject has very few relationships with the navigation one (SP3) but it has inputs from SP2 (user's needs) .from which it expects requirements. It provides outputs to SP5 (Operational characterisation and evaluation) to which it delivers mockups for test and evaluation The SP4 is separated in different work package, the flowchart of which is presented on [\(figure 5\)](#).

4.2.2 Review of Technologies and Systems (WP4.1)

In this WP, data was gathered on the space segment technology, the end to end system, avionics, and the services provided that could have applications for use in civil aviation for Air Traffic Management (ATM). This information established the key drivers and issues associated with future aeronautical SATCOM systems. The output of this WP is an analysis of current and planned satellite communication services, system and technology that could have applications in the civil aviation environment.

- Analyse current and planned satellite systems

Current and planned aeronautical and non-aeronautical SATCOM services, systems and technology was studied and there was an assessment of the main characteristics for each SATCOM system and the associated services and their suitability for ATM communications, passenger communications (APC) cabin crew use (AAC) non-safety critical cockpit communications (AOC)

The performance of each SATCOM system was evaluated in terms of multiple satellite coverage, service availability including channel/propagation/weather aspects, capacity, quality of service, analysis of satellite and payload issues. Current and planned aircraft and terminal architecture including antenna is being investigated together with the implications on terminal size, weight and cost. The main characteristics of current ground infrastructure networks for satellite systems was assessed.

The study includes analyses of the approximate costs and market sizes in terms of both avionics and service provision as well as analysis of the regulatory and institutional environment.

The upgrade potential of the SATCOM systems and limits or boundaries to such upgrades will be estimated and was be followed by a competitive analysis on the current and planned satellite communications systems and services.

- Satellite Payload

The state of the art, probable future developments, and key issues of satellite payload technology was described and analysed with particular emphasis on mobile communication and expectant future aeronautical requirements. The description and analysis should include satellite technologies that could be launched up to 2015.

- Determine Issues and Drivers

Issues and drivers for aeronautical SATCOM systems including those for safety services were identified together with high-level implications on aircraft terminal size, weight and cost.

Key drivers such as frequency, bandwidth, availability were identified together with issues that will establish how current systems and services should evolve to meet future needs.

4.2.3 System Design (WP4.2)

The requirements from WP2 together with information collected from WP 4.1 will be used as the basis of the candidate architectures. Three high-level candidate SATCOM system architectures, one short term and two long term, is being defined to the following level of detail:

- The ground segment
- The aircraft terminal
- The satellite constellation
- Typical link budget and end-to-end performance calculations
- Key characteristics of the air interface
- The candidate protocols and networking options

There will be a critical appraisal using defined evaluation criteria including performance analyses of the new satellite communication technologies. An analysis of airborne equipment suitable for all relevant aircraft types operating in controlled airspace will also be included together with a commercial analysis that identifies a structured break down of all costs and benefits including revenue generation from services. The revenue generation will detail a numerical estimation and projection of both the passenger and the ATM markets. Two suitable system architectures will be recommended, one for meeting the near term requirement, the other to meet a far term requirement utilizing satellites launched in about 2012-15. The near term recommendation will be in sufficient detail such that appropriate aspects can be designed in WP 4.3.

The expected output of this WP is a study report defining and appraising candidate architectures with selected near term and far term systems. A commercial analysis will be included.

4.2.4 Aircraft Terminal and Ground Infrastructure Design (WP4.3)

There are a number of identified tasks required to achieve the near term system design. Experience has shown that to identify and mitigate risk, an aircraft terminal technology assessment needs to start as soon as practicable. This will determine the high level architecture and address the key technical risk areas including:

- Digital hardware
- RF up/down converter stages

- Digital to analogue conversion
- Physical layer modem
- Software architecture

The assessment will be followed by the prototype aircraft terminal design that will comply with the key characteristics of the near term system architecture as described in WP4.2.4. Major aircraft terminal components will be prototyped as necessary as well as base-band processing and the protocol stack software.

The major effort in the far term avionics research architectures will be to study conformal multi frequency antennas as these are believed to be the key aircraft sub-system. The antenna study will consider requirements derived from the need to operate with satellites launched in about 2010-15. Two of the most promising candidate conceptual designs for phased array of radiating elements will be selected for detailed analysis that will include computer simulations in terms of radiation patterns (possibly L-band and Ku-band), gain and de-coupling. Beam forming algorithms will be developed for the conformal multi-frequency arrays and there will be limited manufacture and test of promising radiating elements. Other areas to be investigated include the specification of requirements for multi-tracking antenna controllers and handover managers, adaptation of steering algorithms (open-loop and closed loop PAT algorithms), to the multi-frequency scenario, development of multi-tracking PAT algorithms as an adaptation from single-tracking ones and development of a combined antenna / modem control for satellite handover in the multi-frequency system. There will be implementation of a controller in a simulation test-bed followed by a demonstration and verification in the simulation test-bed.

The expected outputs of this WP are technical reports for the near term aircraft terminal and associated ground infrastructure and a report into the study on the long term conformal multi-frequency antennas.

4.2.5 End to End System Development/Upgrade (WP4.4)

The prototype aircraft terminal development will follow on from the design phase. Major prototype components include digital hardware, RF up and down converter stages, analogue to digital converters, physical layer modem, software architecture, base band processing and protocol stack software. Suitable Antennas and Diplexer/Low Noise Amplifier (LNA) will be procured.

The end-to-end system integration will test over a satellite link the prototype aircraft terminal:

- Integration Plan
- Internal lab testing of terminal using channel and network emulators.
- Reception of live satellite signals and demodulation

The final stage is the analysis of the end-to-end system integration testing. A review of the system performance and the generation of a revised version of the System Definition will follow the analysis. This information will be presented to industry for a such as ICAO and EUROCAE.

The expected outputs of this WP are validated near term satellite terminal prototypes.

5 PROGRESS OF RESEARCH AND ADVANCES IN THE COMMUNICATION FIELD:

The programme has been running now for over 2 years and the preliminary results, which have been achieved in the COM domain, are reported hereafter. Up to now, work is progressing normally in all the workpages, but only the deliverables which have been presently produced to the EC, and have a link with the communication part are presented hereafter.

5.1 Future Needs

The Subproject 2, “Needs and future aircraft requirements” aims at identifying the requirements for the new satellite based CN(S) functions for both business jets and air-transport. It is an input for the both NAV (SP3) and COM (SP4) subprojects. A first milestone has been achieved end of the first year of the project, with the collection of the user’s need which is reported in the deliverable D2.1.: “CNS Requirements for use of space based Communication and Navigation subsystems for civil aviation”

This work has been performed in two steps : First an extensive analysis of the documentation in the domain, completed with airlines interviews, has been performed. Then a user’s forum has been organized with the main stakeholders of the domain, to present the findings, and get feedback about them. The complete minutes of this event are available on the Anastasia web site [2].

5.2 Review of Technology and Systems

The deliverable D.4.1 : “Analysis of Requirements and Technologies” which was issued end of the first year of the project reports the result of the work undertaken in the WP4.1.

It provides description of existing and planned SATCOM systems that are/could be used to provide communication between aircraft and ground. Current and planned aeronautical and non-aeronautical SATCOM services, systems and technology have been studied including some assessment of the main characteristics for each SATCOM system and the associated services.

The performance of each SATCOM system has been evaluated in terms of multiple satellite coverage, service availability including channel/propagation/weather aspects, capacity and quality of service, analysis of satellite and payload issues. Current and planned aircraft and terminal architecture including antenna has been investigated together with the implications on terminal size, weight and cost. The main characteristics of current ground infrastructure networks for satellite systems have been assessed.

The study includes, whenever possible, analyses of the approximate costs and market sizes in terms of both avionics and service provision as well as analysis of the regulatory and institutional.

The upgrade potential of the SATCOM systems and limits or boundaries to such upgrades have been estimated.

A competitive analysis of the various SATCOM systems have been performed based on their adequacy for ATM communications, passenger communications (APC) cabin crew use (AAC) non-safety critical cockpit communications (AOC).

Finally, critical items and key drivers for future SATCOM systems have been identified.

5.3 Aircraft terminal technology assessment

The D4.3.1 : “Aircraft terminal technology assessment “ describes the work done to identify and mitigate key technical risks for the Aircraft Terminal. This includes a high level terminal architecture and identification, investigation and mitigation of key technical risk areas.

Initial investigations were conducted to determine the overall requirements for the Aircraft Terminal. The Aircraft Terminal will use a Low Gain Antenna and thus restrict itself to a subset of the full BGAN channel set which comprise the low rate channels. This will result in

a terminal which would be representative of an ATC/ATM only unit, which might be used for aircraft which were unable to support the fitting of a full directional High Gain Antenna supporting full BGAN. The Aircraft Terminal unit will support a simple audio interface and an Ethernet interface. Control of the unit will be by means of an external test PC controlling the Aircraft Terminal via the Ethernet connection.

5.4 Conclusion; Future work

Up to now, the ANASTASIA project is on the track and the preliminary results have been obtained after this second year concern mainly the user's needs and requirements, the extensive review of the existing systems, and some preliminary studies aiming at identifying and mitigating the risks for the design of the short term SATCOM architecture.

At the same time, work is studying the long term architecture including systems and technology research; but these tasks will only produce deliverable during the third year of the project.

After this review and requirement phase, the work will concentrate on the design of the best long term and short term selected solutions. It will go on with integration, which will be performed during the last year of the project, under SP5 supervision.

The results of these experiments will be used to refine initial requirements made under SP2, allowing to assess the capacities of these technologies.

All along the project, close links will be maintained with other European or international initiative, and in particular in the Communication domain with the Eurocontrol AGCFG [3], and with the SESAR project [4], which aims at defining the road map for the deployment of the ATM system of the future.

ACKNOWLEDGEMENTS

The authors would like to emphasize that this paper presents the scope and initial result of the Anastasia project which is the result of the collective work of the whole ANASTASIA consortium; and then they would like here thank all the Anastasia partners for their contribution

Also, this work would have been impossible without the support of the European community, not only financial, but also human resources through EC administrative officers and reviewers

REFERENCES:

[1]: Anastasia EC contract AIP4-CT-2005-516128

[2]: www.anastasia-fp6.org

[3] AGCFG :The "Air Ground Communication Focus Group", led by EUROCONTROL gathers the main stakeholders in the aeronautical communication domain. Under the AGCFG, there is also the EUROCONTROL "NexSAT Steering Group" which is dedicated to satellite based communication for aeronautical purposes.

[4] SESAR : "Single European Sky ATM Research"
www.sesar-consortium.aero

Figures:

Figure 1: Anastasia's poster



Figure 2: Anastasia's partners

<i>Participant Role</i>	<i>Participant Number</i>	<i>Participant name</i>	<i>Participant Short name</i>	<i>Country</i>	<i>Date enter project</i>	<i>Date exit project</i>
CO	1	Thales Avionics	THAV	F	0	48
CR	2	AIRBUS-F	AIRBUS-F	F	0	48
CR	3	INMARSAT	INMARSAT	UK	0	48
CR	4	Deutsches Zentrum für Luft-und Raumfahrt	DLR	D	0	48
CR	5	DASSAULT	DASSAULT	F	0	48
CR	6	Airbus Deutschland	AIRBUS-D	D	0	48
CR	7	Thales Avionics Ltd	TAUK	UK	0	48
CR	8	EADS Astrium France	ASTRIUM	F	0	12
CR	9	EADS CRC France	EADS CCR	F	0	39
CR	10	EADS Deutschland C R C	EADS CRC	D	0	45
CR	11	Selenia Communications S.p.A	SELENIA	I	0	46
CR	12	ASCOM	ASCOM	CH	2	33
CR	13	NLR	NLR	NL	0	46
CR	14	Institut National des Sciences Appliquées	INSA	F	0	46
CR	15	ERA Technology	ERA	UK	0	46
CR	16	Joanneum research	JOANNEUM	A	0	39
CR	17	Imperial college of science technology and	IMPERIAL	UK	0	46
CR	18	SIREHNA	SIREHNA	F	0	46
CR	19	SKYSOFT	SKYSOFT	P	0	48
CR	20	Data Respons	DATAR	N	9	33
CR	21	Technische Universität Braunschweig	TUB	D	0	46
CR	22	University of Surrey	UniS	UK	0	45
CR	23	University of Vigo	VIGO	E	0	27
CR	24	Gatehouse	GH	DK	8	33
CR	25	University College of London	U C L	UK	0	46
CR	26	Rhea system	RHEA	B	12	19
CR	29	TriaGnosis	TGS	D	9	39
CR	30	Thales Research and Technology	TRT	UK	0	30
CR	31	Wireless Intelligent Systems Ltd	WIS	UK	4	28

Figure 3: Work Breakdown Structure

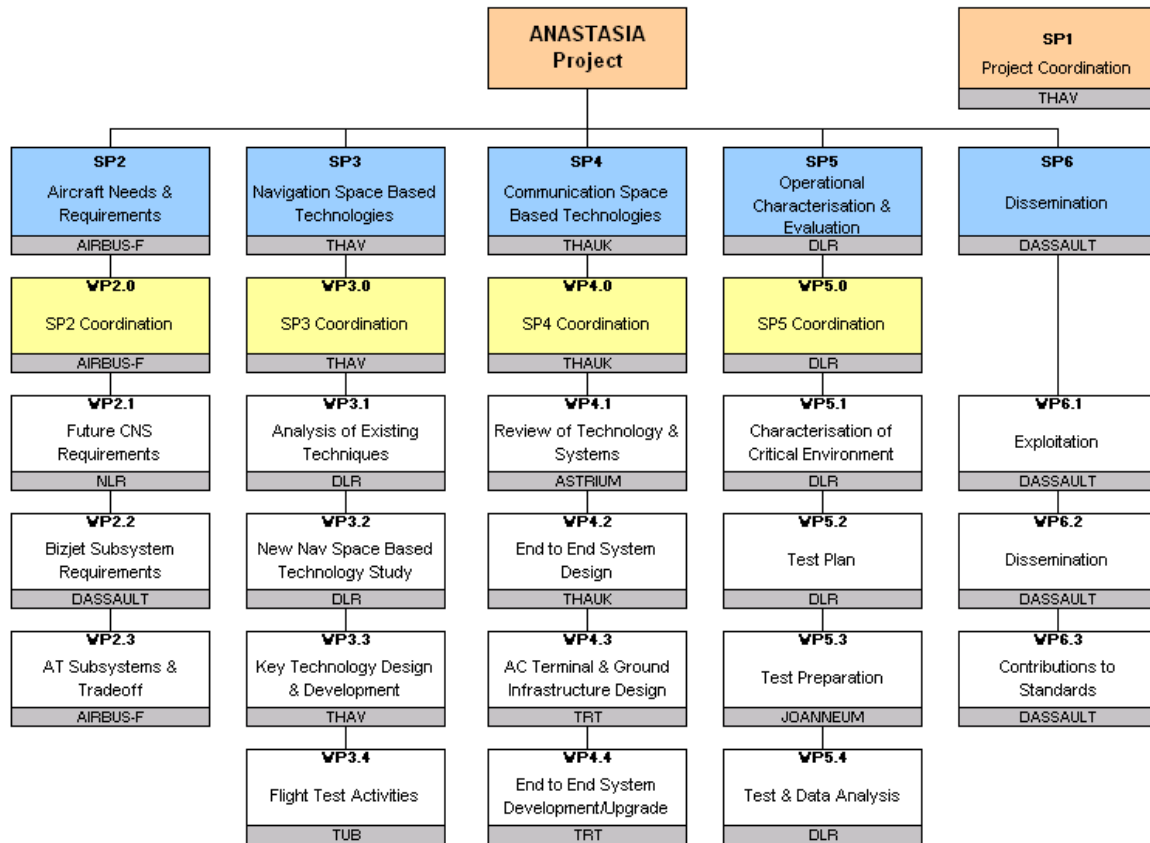


Figure 4: Overall planning of Anastasia

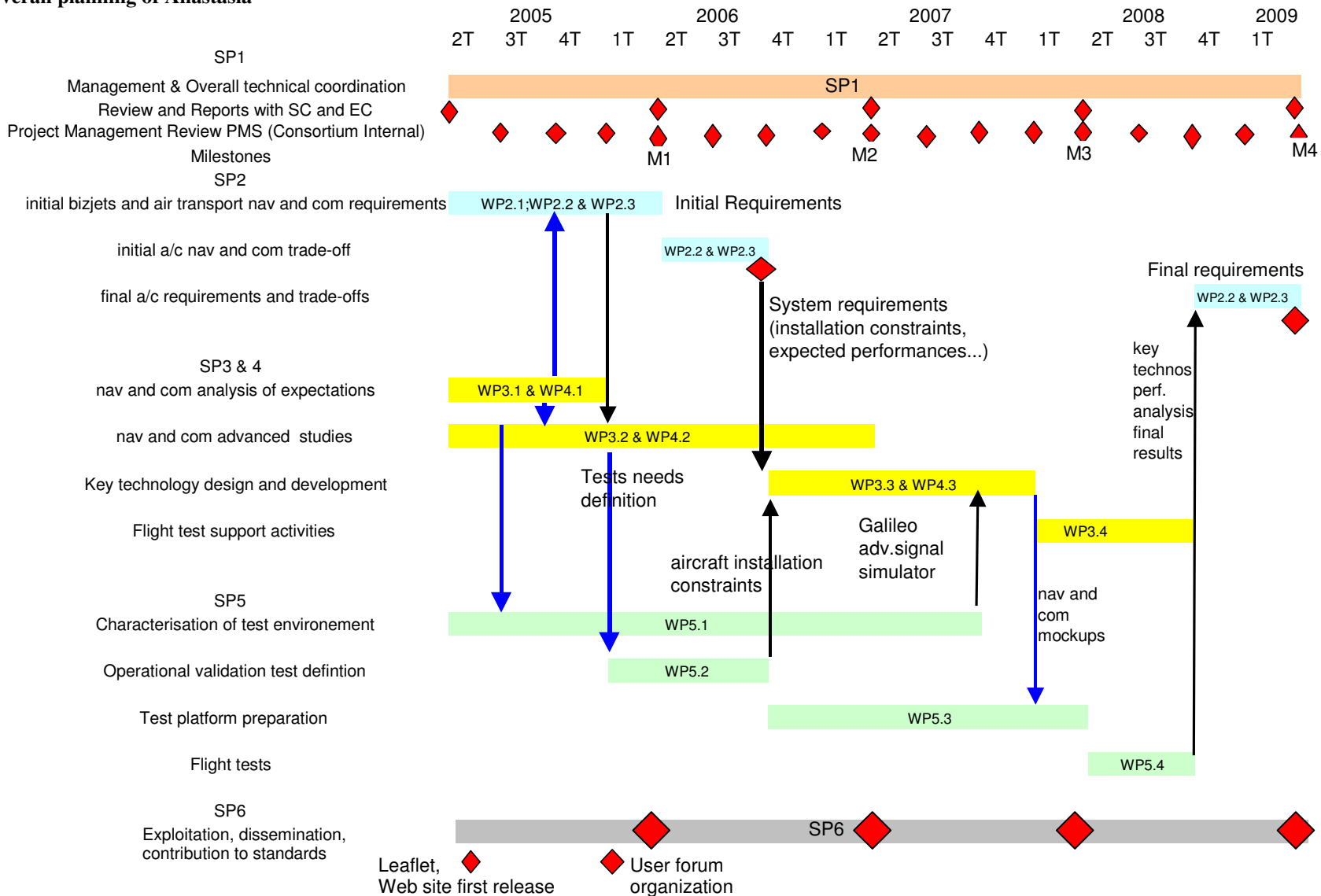


Figure 5: Flowchart of SP4

