SIXTH FRAMEWORK PROGRAMME

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Project acronym: Project MINERVAA

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Mid-term Networking technologies in-flight and Rig Validation for Aeronautical Applications

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Content list

Annex A: Confidential plan for using and disseminating the knowledge

Annex B: Publishable results of the plan for using and disseminating the knowledge

1 Publishable executive summary

1.1 Aimed innovations and derived objectives of Project MINERVAA

Central target of the Project MINERVAA is to build up an airborne datalink terminal to be installed and used within an advanced network concept for the provision of new onboard broadband communications services

The Project MINERVAA activity report is a compilation of the R&D work performed and achievements made within the framework of Project MINERVAA during reporting period 01 March 2007 – 31 August 2010. It considers additionally the exploitation & dissemination activities and project management aspects.

The project aims at the validation on aircraft and in-flight of Free Space Optical communications technologies and to continue the basic research on some specific technological areas in the field of Ka band antennas.

Namely the network components MINERVAA focus on are:

- Outside aircraft optical link (OOL);
- Inside aircraft optical passengers network (IOPN);
- Ka band data link based on avionic phase arrays

Those innovative technologies have been selected as key elements in the prospective of achieving wider bandwidth with respect to other state of art communications technologies. Moreover as well known, optical connections ensure lower level of interference with other on board equipment. Ka band antennas are the most suited for on board installation versus available bandwidth and physical size

In order to achieve these objectives, the project has been structured into Work packages (WP): 3 technical WPs (WP2000, WP3000 and WP4000), 1 Demonstration WP (WP5000), 1 Dissemination WP (WP6000) and 1 management WP (WP1000). The WPs are sub-divided into tasks.

WP1000: The project management has included effective leadership, provision for monitoring processes and budget expenditure, and ensuring that all deliverable are received on time and to specification. Within this WP, internal processes such as communications to the CEC are managed.

WP2000: This WP has been devoted to design, develop and validate an Outside-aircraft Optical Link with the following characteristics:

- Higher data transmission rate (at least 100 Mbit/s, target 500 Mbit/s)
- Higher range (at least 12 km, target 25 km)
- Capability to operate in-flight and provide broadband connections between aircraft and/or high altitude platform and/or satellites

For this technology to be practically viable for aircraft installation, the following constraints have been taken in account:

- High safety (including eye-safety in this specific case)

- High availability and reliability (i.e., capability to provide stable and continuous performance)
- Limited installation impact (low mass, aerodynamical drag, power consumption, etc.)
- Low life cycle costs, easy upgradeability, limited maintenance.

WP3000: This WP has been based on the creation of an innovative wireless optical in-cabin link to serve health monitoring application as well as safety and security in cabin systems. Further research on wireless optical modulation schemes for further evolvement of the wireless optical physical layer has been carried out. The health monitoring systems along with the safety & security system application have shown the possibility of increasing in-flight safety by minimizing cost and crew workload.

WP4000: An integrated Rx/Tx Ka-band phased array antenna has been designed and a ¼ scale test bed realized and measured. Test-bed EIRP is comprised between 18.7±0.5 dBW and 19.8±0.5 dBW, test-bed gain is larger than 18 dBi, and steering capability is more than ±36° at -3 dB level.

WP5000: The creation of the flight certification Documentation for the Airborne Terminal of the Outer Optical Link was carried out with success. Furthermore, the In-Flight-Validation was executed and a total of three Measurement Flights was carried out. It was possible to show the principle functionality of the demanding free-space optical communication technology.

WP6000: This WP has been devoted to the exploitation and dissemination of the generated knowledge from the MINERVAA project, establishing workshops and presenting the results at international conference, printing handouts and leaflets.

1.2 Overview over the consortium

The MINERVAA consortium consists of Industrial partners and Research establishments. Each one of them has brought in its specific skills, tools and knowledge in the highly inter-disciplinary MINERVAA project.

The consortium composition is closely related to the one of ATENAA. MINERVAA has aimed at increasing the Technology Readiness Level (TRL) of some of the emerging technologies herein studied within the framework of the ATENAA Network, from the laboratory test environment to the in-flight test environment.

For this purpose SAGEM has been added as a large avionic equipment supplier who has a specific expertise on implementation of low-drag, compact airborne optical terminals aimed to be installed onboard aircrafts. This partnership composition has integrated and maximised complementary industrial and technological experience and established a pan European effort.

This has led to a partnership of 7 participants from 4 European countries that include:

- 2 leading telecommunications equipment supplier (SEL, THC)
- 1 large avionics suppliers (SAG)
- 1 leading aerospace company (EAD)
- 1 Research institute specialised in Aerospace (DLR)
- 1 University department of Computer Systems Engineering (TEI)
- 1 SME company specialised in navigation systems and stabilised platforms manufacturing (INS)

The MINERVAA consortium composition is shown in Table 1.

No	Organisation	Short Name	Activity Code	Country	Nr of empl.	Business Activity	RTD role in project (main activities)
1	**Selex Communications**	SEL	IND	I	5000	Telecommunications	Project management and coordination. Leader in Outside aircraft broadband optical link and airborne terminal prototype implementation. Within ATENAA ii has been Project coordinator and responsible of OOL laboratory validation platform.
2	**Deutsches Zentrum für Luft- und Raumfahrt (German Aerospace Centre)**	DLR	RES	D	4500	Aerospace Research	DLR has been the leader of the in-flight validation and also responsible for the optical ground station and for the Ka-band calibration and beam forming algorithm development.
3	**EADS Deutschland GmbH Corporate Research Centre Germany**	EAD	IND	D	200	Aerospace	EADS has been the leader in studying and developing Inside-aircraft broadband optical data-bus. Within ATENAA it has been responsible of IOL laboratory validation platform.
4	**IN.SI.S. SpA**	INS	SME	I	15	Navigation and stabilisation systems	Strongly Participate in Outside-aircraft broadband optical link validations and stabilisation aspects
5	**SAGEM D.S.**	SAG	IND	F	6800	Optronics	Leader in Outside-aircraft Optical Link system design and the implementation of the airborne terminal pointing system section (optical turret). Leader of WP6200 (Final implementation issues)
6	**Technological Educational Institute Of Piraeus**	TEI	HE	GR	450	Computer Systems Engineering	Strongly involved in Inner Optical Passenger Network and in User community concepts and Results assessment
7	**THALES Communications SA**	THC	IND	F	5000	Radio telecommunication	THC has been leader in studying and developing Ka-Band Antenna compactness technology and Ka Band "Intraflight" antennas demonstrator. Within WP4400 has also had a strong involvement in Ka Band antennas laboratory tests.

Table 1: Consortium composition

Project co-ordinator address:

Selex Communications SpA

Mr. Angeloluca Barba

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1.3 Final results

WP2000: This work package has been devoted:

• To define the detailed architecture (Pointing turret, stabilisation module, Transmitter/Receiver and software) of the airborne terminal

• To develop an innovative and simplified pointing and stabilizing turret providing:

- Hemispherical coverage
- High agility
- Low drag and low weight for the mobile part, thanks to innovating architecture and new materials
- Efficient and accurate line of sight stabilisation based on optical tracker information

• To analyse and test exploitation of innovative MEMS technologies in the field of stabilization and attitude/position measurement

• To develop a System Management Software (including piloting the line of sight pointing and inertial stabilisation, Beam acquisition (space scan), tracking and stabilisation.

• To validate the subsystems performances through laboratory tests benches

• To certify for safety the avionic system as a MAJOR modification of the platform following EASA standards

• To validate the Outside-aircraft Optical Link in flight in an air-to-ground configuration.

Finally the demonstrator has been certified for flight and satisfied flight testing during July 2010, with partial success.

WP3000: It has been proven that seat sensors for safety, security and medical purposes can be connected wireless by a diffuse, non-line-of sight optical data link providing sufficient data rates to connect several seat rows to a single access point

The optical link is easy to install in aircraft cabin due to the advantages of

- no interference with RF systems
- no EMI
- no frequency band regulations for RF

Further, it is intrusion safe as a non-commercial, proprietary link.

The wireless system provides full flexibility for fast aircraft cabin re-configuration

The examples of sensors demonstrated enable the

- reduction of cabin crew work load
- increase the cabin safety by permanent overview over passenger seat safety status
- increases the cabin security due to event triggered information to crew
- reduces risks and costs for unnecessary emergency landings especially with respect to large aircrafts and older growing society.

WP4000: An integrated Rx/Tx Ka-band phased array antenna has been designed and a ¼ scale test bed realized and measured. Test-bed EIRP is comprised between 18.7±0.5 dBW and 19.8±0.5 dBW, test-bed gain is larger than 18 dBi, and steering capability is more than ±36° at -3 dB level.

WP5000: The creation of the flight certification Documentation for the Airborne Terminal of the Outer Optical Link was carried out with success. Furthermore, the In-Flight-Validation was executed and a total of three Measurement Flights was carried out. It was possible to show the principle functionality of the demanding free-space optical communication technology.

Management details

The project management has included effective leadership, provision for monitoring processes and budget expenditure, and it has ensured that all deliverable have been received on time and to specification. The management structure has also dealt with internal processes such as communications to the EC.

1.4 Comparison of expected results and achievements

1.4.1 WP2000

The demonstrator has been certified for flight and satisfied flight testing during July 2010, with partial success.

This WP has:

- defined the detailed architecture (Pointing turret, stabilisation module, Transmitter/Receiver and software) of the airborne terminal
- developed an innovative and simplified pointing and stabilizing turret providing:
    - Hemispherical coverage
    - High agility
    - Low drag and low weight for the mobile part, thanks to innovating architecture and new materials
    - Efficient and accurate line of sight stabilisation based on optical tracker information
- analysed and tested exploitation of innovative MEMS technologies in the field of stabilization and attitude/position measurement
- developed a System Management Software (including piloting the line of sight pointing and inertial stabilisation, Beam acquisition (space scan), tracking and stabilisation.
- validated the subsystems performances through laboratory tests benches
- certified for safety the avionic system as a MAJOR modification of the platform following EASA standards
- validated the Outside-aircraft Optical Link in flight in an air-to-ground configuration

1.4.2 WP3000

The achievements correspond very well with the expected results:

1. Optical link

- Assuming 1 camera and 2 medical box per 2seat-seating bench, maximum data rate per seat row is 1.123 MBit/s=562 kBit/s average

- Assuming 1 camera per 4-seat seating bench + 4 medical boxes, maximum data rate per seat row is about 2.1 MBit/s=525 kBit/s average

⇒ With current 10 MBit/s optical link system (8.5 MBit/s netto proven) up to 4-7 seating benches or 15 seats can use a single access point (limited mainly by data rate) => cell size

⇒ With future expected technologies (25 MBit/s or 50 MBit/s) up to 10 seating benches or up to 60 seats can use a single access point (limited by range)

⇒ Taking into account seating and cabin layouts and classes as well as range restrictions, e.g. for an A340 (2 aisles, 247 seats) about 10-16 access points=cells are necessary

2. Server => FAP link

- Standard Ethernet 10/100 MBit/s sufficient (max. 4.5 MBit/s peak; if bandwidth lower refresh period has to be adapted)

Additionally to the expected results the wireless optical terminals have been improved, a compact medical box been developed.

1.4.3 WP4000

Expected minimum Ka-band test-bed gain was 18 dBi, this objective is met.

Expected test-bed EIRP was 19 dBW, this objective is met.

Expected steering angle capability was □30°, □36° was demonstrated, so this objective is met.

The test-bed design allows nominal behaviour with simple forced air at 25°C: no liquid fluid cooling is required. The design is therefore successful on a thermal point of view.

High integration and low profile size could been obtained with reaching the expected high performances.

Calibration and Beam-forming take into account phase and amplitude quantization and dispersion. Sidelobe level lower than –20 dB for the full size-antenna is achievable according to the simulation results. Very good agreement between simulated and measured test-bed confirms the pertinence of the simulation hypotheses.

1.4.4 WP5000

It was foreseen to demonstrate a high-rate optical data communication link by means of a video-conferencing application. This included the creation of certification documentation for the purpose of achieving a proper airworthiness approval for the Airborne Terminal.

The airworthiness approval, including all necessary tests (e.g. EMC/EMI Ground-Tests, Conformity Inspections of the Equipment), was achieved successfully and a total of three demonstration flights were carried out.

The principal functionality of the system could be shown during the demonstration activities. The video conference – carried out via an RF-Link in Uplink Direction, and with the Optical Link in Downlink Direction – and the corresponding activities, as e.g. pointing, acquisition and tracking both of the Ground- and the Airborne Terminal, were successfully verified during pre-flight Ground Tests.

Due to technical challenges occurred during the integration phase of the airborne terminal, the very ambitious goal of demonstrating the video conference during the flight tests could not be achieved. However, the principal functionality of the system, including the Pointing, Acquisition and Tracking of the Ground- and Airborne Terminal was demonstrated during the In-Flight-Validation.

1.5 Impact and intentions for use

WP2000

The WP moves from state of the art requirements and available research, and concentrates on the implementation of an innovative, low drag, compact, high data rate terminal to be installed onboard of an experimental aircraft.

In this project, FSO (Free Space Optical) links are preferred to the RF links because of the low power consumption due to the lower radiated power, low air drag impairments because of the reduced "antenna" size, small overall equipment weight and a negligible EM (Electro Magnetic) Interference, thanks to the directive transmission in the optical band.

For this reason this technology, adequately developed, could bring to a completely new branch of the avionic communications product line based on the Free Space Optics.

WP3000

The results on seat sensors and their wireless optical connection will be discussed with Airbus for further usage. The medical box was presented in specific conferences on medical measurements and applications, where it has found interest. The data base structure can in future be applied in other context.

WP4000

Ka-band phased-array antenna design elements will be reused in further work, and test-bed results establish our European know-how in this technology. Airport to aircraft Ka-link is also planned through to the same antenna as the one envisioned in MINERVAA, which will lead to wireless ultra fast data upload from ground to aircraft at the airport, thus allowing update of data such as IFE data without manual box handling and requiring less aircraft time at the airport.

WP5000

The results of WP5000 are precious for DLR, as they allow further optimizations of the Ground-Station Equipment as well as of free-space optical communication demonstration activities in general. The relevant results will be published on national and international conferences, if this is applicable

WP6000

The results will be used to evolve the existing technologies and motivate student and the academic community to invest time in these critical aspects. The publications generated have increased the scientific interest, by work referencing, and also in-situ by a future knowledge exchange.

Project logo

Project website: http://www.minervaa.org

2 Project execution

2.1 State of the art at project start

2.1.1 WP2000

Free Space Optics systems have been introduced since ten years ago for ground-to-ground, short distance (some Khms) connections. Such systems, however, are not intended for being used in mobile platforms, and furthermore feature characteristics (optical pupil size, system size, volume and mass), which prevent their installation on board an aircraft, due to lack of dynamic pointing, suitable stabilization and tracking capability, installation constraints and achievable link operational range.

In the last years, some research initiatives have been presented to address the possible implementation of free-space optical data links in an aeronautical environment, both in the military field (namely US experimentation on unmanned platforms) and in the civilian scenario.

Anyway, most of these initiatives refer to air-to-ground communications from large platforms (e.g. High-Altitude Platforms - HAPs, see CAPANINA project), or consider medium-short range communications only, or do not take in account the possibility to implement air-to-air communications.

This work package has intended to address the specific issues not covered by other initiatives, assuming as a target the implementation and in-flight validation of an airborne optical terminal capable to operate at higher ranges and in other configurations (e.g. air-to-air, air-to-HAP and air-to-satellite connections), taking in account the constraints for installation on board civilian airliners

2.1.2 WP3000

At project start the results from project ATENAA on optical wireless links were available and were the basis for the application of that link in MINERVAA project for in-cabin applications. The terminals from ATENAA have been used for improvement and adaptation to the needs of MINERVAA scenario.

Several seat sensors were available at start of the project, some from other industries (e.g. seat sensors from automotive industry), some were new and appeared during the first phase of MINERVAA (e.g. seat belt sensors with woven cables, or novel concept of optical seat occupation sensing, which both were used in the project).

Health sensors were available for medical applications.

For all of those no integrated approach was available to integrate those sensors in aircraft seats and link them wireless with a central data server to give the cabin crew a complete overview over cabin safety and security status; state of the art was based on singular sensor check or wired connection only.

At the start of the project, the principal usage of diffuse wireless optical links in the aircraft cabin have been demonstrated already e.g. ATENAA-project), mainly for IFE applications. The usage for seat related sensing as a “cabin network” was not addressed before

2.1.3 WP4000

The Ka-band communications technologies are being intensively investigated in recent years, due to the specific prerogatives associated to the transmission at these frequencies: availability of relatively large bandwidth in accordance with the current regulations, limited antenna size or, conversely, possibility to reach high antenna gain, etc.

Nevertheless, most of the current avionic antenna implementations for broadband communications in the civilian environment are currently targeted at the lower-frequency Ku-band, both for technological reasons and for availability of a much larger connection infrastructure (i.e. satellites). Connexion® by Boeing is indeed the most representative example using Ku-band phased array antenna technology.

However, more and more Ka-band satellites have been developed and put in orbit (e.g. SES Americom AMC-15 and AMC-16) or are planned in the near/medium term, promising to offer much larger transmission capabilities. Moreover, the possibility to realize also Ka-band A/A connections represents an additional opportunity to increase the aircraft communications capability in a networked environment.

In United States, the Multi-Aircraft Network demonstration being developed in the frame of the FAATC, is probably one of the most advanced project relative to this subject. Using Ground to Air, Satellite to Air and Air to Air radio links, it relies on an Ad hoc discovery network , based on several radio frequency bands as VHF , L-Band, Ku and Ka-Band. This project aims to demonstrate the capability to exchange reliable information for 4D trajectory Flight Plan, Weather, email, web services, VoIP, TCAS advisory or live video images thanks to data rate up to 45 Mbit/s to be compared to the 64 Kbit/s actual satellite service.

This project has the same goals than ATENAA and MINERVAA for what concerns the applications and the kind of network foreseen. It privileges radio solutions while ATENAA / MINERVAA also rely on OOL links.

Whatever the project, the success of this kind of solution is driven by the added value offered by the system versus the cost and on aircraft integration solution of added equipments. For this reason, MINERVAA Ka-Band activity mainly focused on optimization of Antenna compactness aiming the best trade off between performances and cost.

2.1.4 WP5000

The Objective of WP5000 was to create the flight certification documentation for the Minervaa Airborne Terminal, to carry out the necessary Ground Test Procedures to achieve the airworthiness approval and to execute the In-Flight-Validation.

2.2 Aimed innovations and derived objectives of Project MINERVAA

2.2.1 WP2000

The project moved from state of the art requirements and available research, and concentrated on the implementation of an innovative, low drag, compact, high data rate terminal that has been installed onboard of an experimental aircraft.

Main goal of the MINERVAA research activity was to progress on technologies to enable a compact and competitive airborne optical transmission system.

The technological objectives were:

- To investigate advanced terminal design supporting arbitrary and point-to-multipoint connectivity;
- To investigate advanced error protection mechanisms to increase system robustness and reach higher link availability;
- To define an optical transmission system which, starting from the ATENAA basic technology research, takes in account the specific aircraft's integration constraints;
- To define an overall system architecture that will make the most efficient use of the laser transmitting power thus reducing volume, mass, cost, power consumption;
- To take advantage of most advanced new technologies and devices such as:
    - Innovative multi-wave length tuneable laser sources (and filters)
    - High power and compact optical amplifiers for increased transmit power levels
    - Opto-mechanical design and motorisation of gyro-stabilised turret

  - Passive/active tracking with single multifunctional Focal Plane Array sensor
  - New stabilization subsystem, exploiting strap-down architecture, very large bandwidth piezoelectric actuated multi-axes mirror devices, Coriolis effect VSG (Vibrating Structure Gyro) or, as an alternative, MEMS solid state gyroscopes, featuring high level of performance even against the severe vibrating environment generated by A/C engine operation, aerodynamic stress, windage effect.
  - Attitude and position subsystem, centred, as far as inertial section is concerned, on innovative MEMS technologies (gyroscopes, accelerometers), specially suitable to meet conflicting requirements of high class performance and volume, weight, consumption and cost saving
- To develop a new piezo-electric Ultra Sonic Ring Motor for turret compactness, steering accuracy and design simplicity (low costs and low maintenance with high reliability);
- To use a new piezo-electric motorization in combination with a high speed piloting software for efficient acquisition (specific working modes) and high stabilisation performance (active optical tracking loop).

2.2.2 WP3000

The envisaged concept is on connection of passenger seat sensors via a diffuse wireless optical link. Thus the project aims at major innovations:

1. Providing a wireless optical communication linking in the aircraft cabin

2. Implementation of a set of sensors in passenger seats to check the safety status of each seat and the whole cabin

3. To reduce cabin crew workload in displaying security status on a flight attendance panel in all situations and generate automated alarms

4. To extend sensing to security of the cabin.

5. To extend the sensing to medical monitoring of high risk persons or sudden risk persons in order to better qualify the decision on emergency measures, accounting for an elder growing society.

The main innovations are broken down into objectives:

- Provide a wireless optical link, which is

  - free of frequency regulations

  - uses a proprietary physical layer#

  - does not generate EMI or EMC

  - does not conflict with RF systems

  - offers advantages regarding cabling, weight, cabin flexibility

- Provide a passenger seat equipped with sensors to monitor the seat status, which data are forwarded via the wireless link to a central server, that can be interrogated by a flight attendance panel
- Implement a medical box consisting of sensors for the main vital parameters to be monitored for medically risked people, whose data can be further forwarded to ground stations for support

2.2.3 WP4000

With this package, MINERVAA focuses on antennas on board integration and technology validation.

One technological test bed relative to air to air communications was planned as well as calibration and beam forming algorithm development for Tx/Rx Ka Band antennas:

- The test bed is focused on the validation of technologies for antenna co-location; hence, it was be targeted to merge transmit and receive antenna phased arrays inside the same structure. It was be developed in the frame of aircraft to aircraft links.

  Indeed, in this case the integration was made possible by the fact that the TX and RX frequency might be quite close one another (which is not the case for Satcom antennas).

  Also, thanks to the shorter range (versus Satcom links) and the high frequency band, small size antennas might be used. Adding technological efforts relative to phased array compactness would allow making easier integration of several antennas dedicated to “Intraflight” links on the aircraft, hence optimising system performances and coverage.

  This test beds allows analysing and benchmarking the achievable performances of this technology.

  The target performances were accurately defined during first phase. EIRP of 25 dBW was initially envisioned the product target for transmit antenna as well as a 25 dBi gain receive antenna.

  The main results of this study concerned:

  - The Intraflight system design, frequency plan and link budgets
  - The multilayer technology development relative to merged transmit & receive Ka-Band antennas
  - The “Intraflight” transmit & receive steering antenna test bed development
  - The “Intraflight” test bed evaluation regarding transmit EIRP, receive G/T and steering capability

  The calibration and beam forming algorithm would be applicable to both Satcom and Intraflight Tx/Rx Antennas and would improve ATENAA development by adding antennas steering control capability . The outcomes of this topic are :

  - The calibration procedure and software
  - The development of specific beam forming algorithm

2.2.4 WP5000

The main objective of WP5000 was to carry out the In-Flight-Validation including the necessary task. This was mainly a technical activity and included no novel innovations.

The objectives of WP5000 were:

- Creation of flight certification documentation
- Carry out the necessary On-Aircraft Ground-Tests (EMI/EMC-Test, Conformity Inspection, etc.)
- Planning of In-Flight-Validation Campaign
- Accomplishment of In-Flight-Validation

2.3 Work performed and main achievements made

2.3.1 WP1000

Objectives and starting point

The aim of WP1000 was to manage the whole project by performing the tasks described hereafter:

• collecting Activity and Managing Reports, assembling them and distributing the official reports to the Commission;

• commenting, approving - at technical and quality level - and delivering the Project Deliverables;

• ensuring the consistency of the Project with the declared objectives;

• organizing the liaison with the European Commission;

• managing the interaction between WPs.

Efforts and achievements, name involved partners and contractors

SEL has been the partner mainly involved in this work package.

The aimed objectives have been achieved by monitoring both processes and budget expenditure, and it has been ensured that all deliverables have been received on time and to specification. Within this WP, other aspects such as management of delays, deviations and corrective actions, meetings (KoM and PMB) and internal processes such as communications to the EC have been managed.

Deviations and corrective actions

During the project life there has been the need for a six months extension of the original project duration. All aimed goals have been reached in the overall 42 months.

2.3.2 WP2000

Objectives and starting point

The objectives for this work package have been defined following the list that follows:

- The arbitrary connectivity of OOL terminals in ad-hoc networks imposes restrictions due to wavelength incompatibly. New solutions for that problem have been investigated on the basis of first estimations made in ATENAA.
- One single optical terminal has to serve more than one partner in a network structure. Detailed investigations in new concepts and concepts which are introduced in ATENAA have been performed.
- Advanced investigation in error protection including protocols fitting to the behaviour of the optical channel: ARQ, FEC, packet-layer-coding and combination of physical- and packet-layer coding. Packet layer coding results generated in ATENAA have been used as input.
- Implementation of an enhanced lab-level error-protection test-rig will be done to evaluate and compare different coding schemes, for the free space optical channel.
- Definition of the characteristics of the Outside-aircraft Optical Link system for in-flight validation (OOL-FV), based on the hypothesis and results of ATENAA project
- Design of the relevant system sections for compliance to the in-flight validation
- Implementation of the OOL-FV Airborne terminal in accordance with the inputs of WP2200
- Execution of a set of functional tests in order to verify the compliance to requirements
- Execution of a basic set of environmental tests to achieve the airworthiness for experimental flight
- Modification of an optical ground station as a communications partner for the A/C-terminal
- Implementation of a tracking system which is able to track fixed-wing-A/Cs
- Integration and stationary tests of the A/C-terminal and the Optical Ground station
- Integration within the OOL-FV platform of auxiliary channel for remote node position signalling and implementation and integration of data servers

- Verification of the functionality of the OOL-FV platform with the airborne equipment mounted on a moving platform

Efforts and achievements, name involved partners and contractors

During this period, optics were assembled and aligned in the optical head, the electronic boards were integrated in the rack, and the development of command and control of the motors has been carried out.

In May 2009, I/F between turret and INSIS system were checked during a coordination meeting (S/W and mechanics).

New requirements to obtain the flight clearance appeared after the turret design and manufacturing, especially regarding lighting effect. Design modifications and retrofit of some mechanical components were done to comply with those requirements.

During summer 2009, and due to technical difficulties during turret integration finalisation, Sagem committed to deliver the turret end of October.

The turret was fully validated during factory acceptance tests and qualification trials and finally actually delivered to INSIS the 30 of October.

Beginning of 2010, some communication problems occurred between turret and main computer. Several returns of the turret to Sagem for maintenance were necessary during the first half 2010 to solve communication problems then to replace the elevation motor.

Several missions of Sagem team were necessary to assist to system integrator during the final critical phase of system assembly and finalisation.

Deviations and corrective actions

The two mains technical problems have been:

- communication between turret and main system computer which have lead to several turret interface board failure and replacement; no design modification has been done due to the tight time schedule,
- use of elevation piezo motor in a continuous mode which has lead to elevation motor failure and replacement; software adaptation has been done by Sagem to adapt motor control to this mode.

2.3.3 WP3000

Objectives and starting point

The objectives at starting point have been to prove that seat sensors for safety, security and medical purposes can be connected wireless by an diffuse, non-line-of sight optical data link providing sufficient data rates to connect several seat rows to a single access point.

Furthermore, the usability of diffuse wireless optical links shall been demonstrated for the reduction of cabin crew work load, increase of the cabin safety by permanent overview over passanger seat safety status, increase of the cabin security due to event triggered information to crew and reduction of risks and costs for unnecessary emergency landings especiallywith respect to large aircrafts and older growing society

Efforts and achievements, name involved partners and contractors

TEI of Piraeus and EADS Innovation Works have been involved in this work package.

- The wireless optical link terminals have been improved.
- Several sensors have been implemented in the passenger seats, including

Safety sensors to decrease crew workload, to monitor cabin status, to generate alarms if safety equipment is not used, for

- seat occupied
- seat belt fastened
- seat upright
- table folded
- display stored

Security sensors to monitor and record for homeland security applications

video camera with live image / event triggered image

Medical sensors to be attached to the seat in case health monitoring is needed for certain passengers

- ECG
- temperature
- blood pressure
- oxygen saturation

A medical box has been developed:

- Optionally attachable to any seat
- Containing medical sensors (ECG electro-cardiogram, blood pressure, temperature, oxygen saturation, respiration rate) for vital function monitoring
- Target: Monitoring of high-risk passengers or in unexpected cases of emergency
- Data transfer to ground support (medical doctors) possible via server downlink
- Reduces risks for passengers and cost for airlines (unneeded emergency landings)
- Increasing demand due to very large aircraft (550-850 passengers) and older growing society , in which older people holding stake of a large market segment

All data were collected by a central seat data interface electronics, which delivered them via the optical link to a central aircraft data server. Via a GUI interface those data were displayed on a touchscreen mounted in the cabin (flight attendance panel). Actual cabin security requirement sets were selectable via flight phase selection. Automatically or on demand safety warnings are generated if configuration of the cabin is not according to safety requirements, e.g. if seats are not upright in take-off phase.

Medical data were analysed on demand or automatically or could be forwarded to ground support stations

Deviations and corrective actions

No deviations occurred.

2.3.4 WP4000

Objectives and starting point

Starting point is ATENAA results, from which were derived the link requirements, identification of technological key challenge, and expected performance quantization for a given set of hypotheses.

The objectives were:

1. To define and validate through budget **link analysis** the **specifications** and frequency plan of the antenna from the link requirements.
2. To define an **implementation design** which would meet those specifications, with integration, cost and thermal considerations taken into account
3. To validate the implementation design drafts through **preliminary test boards**, and **improve the final design** from the measured results on the test boards.
4. To identify the best suited calibration technique, define **calibration procedure** and develop **calibration software**.
5. To develop **specific beam forming algorithm**, for optimizing beam forming taking into account measured phase-shift and magnitude quantization errors and dispersion.
6. To **realise a test-bed** according to the final design, to **measure** the passive part, the active part, and the assembly of both parts of it.
7. To **compare the test-bed measurement to the test-bed expectations** in order to validate the antenna design pertinence and foreseeable performances.

Efforts and achievements, name involved partners and contractors

THC, TEI and SEL were involved in work towards objective 1.

THC was involved also in objectives 2, 3, 6 ,7.

DLR was involved in work towards objectives 4 and 5.

The main achievements are the following :

1. The full size antenna would have 24 dBi gain and 31 dBW EIRP. The link budget analysis in demonstrates a **2.5 Mbits/sec in the air data link at 100 km** in en-route phase with a comfortable margin, such that the sun can illuminate the Rx antenna, or the aircrafts can both be at the limit of the steering and aperture angles, without causing trouble to the 2.5Mbits/s link. At a **30 km range**, the data rate in the air could reach about **1 Gbit/s**. The test-bed would have a 18 dBi gain and 19 dBW EIRP. TDD scheme in the Rx Ka-band is chosen, with a targeted evolution towards TDMA for a MANET network. OQPSK modulation was chosen for robustness to non-linearity and current use in satellite communications. The E-scan capability will then allow to switch quickly from one aircraft to another between TDMA time slots. The results are collected in D4.1.1.

2. Every component of the Rx chain is a component of the Tx chain. The substrate layers have the same affectation in Rx chain and Tx chain (the alimentation feeding plane in Tx is the alimentation feeding plane in Rx, for instance). The sole of the full-size antenna will have a better thermal conductivity than the sole of the test-bed, and a simple fan was used for the measurement of the test-bed (though it was not required for short time, we used it for long time measurement). These results are presented in D4.1.2, D4.3.1

3. The main components have successfully been tested, chain parts and Tx equivalent chain were measured and tuned before freezing the final design. The results are presented in D4.1.2.

4. Offline calibration was chosen, as the best compromise between complexity, cost and accuracy. This is detailed in D4.2.1.

5. The characteristics of the phase shifter and attenuator being known, the beam forming computations lead to radiation pattern for the test-bed and radiation pattern for the full-size antenna. Phase shift and attenuation quantisation and errors, Chebyshev amplitude tapering and defective row influences on the radiation pattern were investigated. The results on the simulated full-size antenna lead to better than –20 dB sidelobes with

Chebyshev tapering, and still comfortable sidelobes level even with a defective row. This is detailed in D4.2.1.

6. The test-bed has been realised and measured. This is detailed in D4.3.1.

7. The passive part of the test bed exhibits a gain per line between 12 dBi and 13 dBi, and the measured radiation pattern in very good agreement with test-bed simulations, as detailed in D4.1.2. The active part of the test bed measurement indicated a lower gain for one of the HPAs, but it was kept as is for assembly. The assembled test-bed measurement demonstrate the steering capabilities (more than ±30° at -3 dB level), see Figure 1 and the radiation pattern along the steering axis is also in very good agreement with the simulations. The gain of the test-bed is slightly over 18 dBi and the EIRP is comprised between 18.7±0.5 dBW and 19.8±0.5 dBW. This is detailed in D4.3.1.

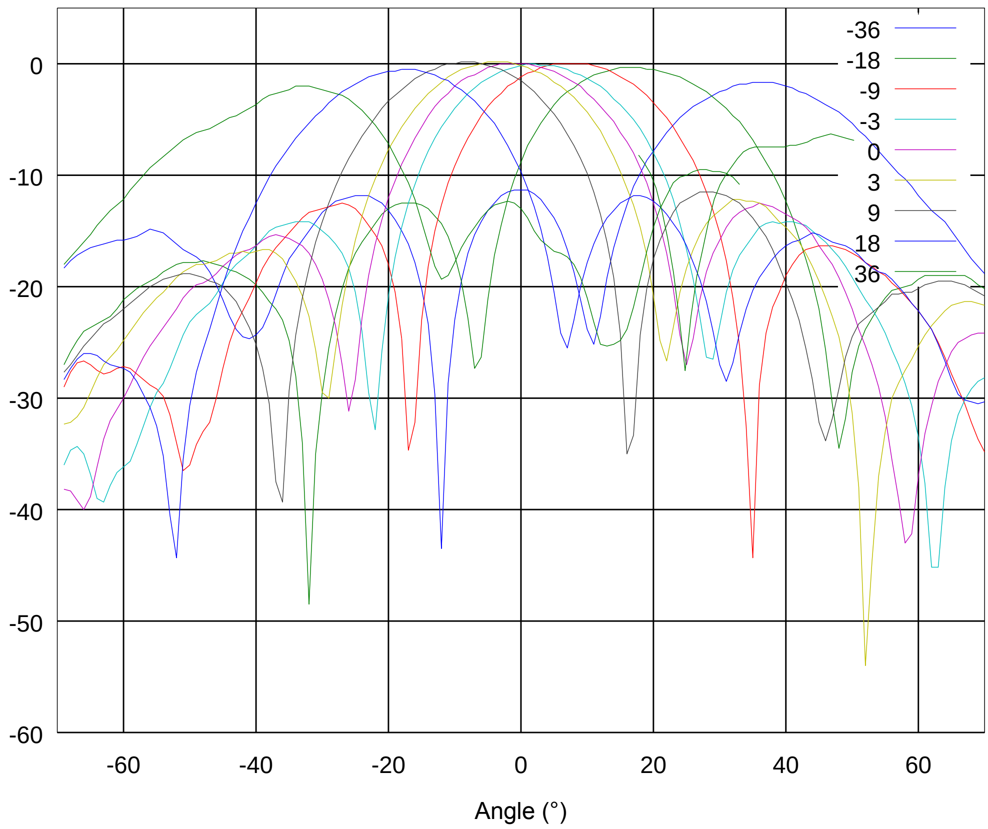

Figure 1: Test-bed Tx radiation pattern for 0°, ±3°, ±9°, ±18°, ±36° steering angles at 19.5 GHz, no amplitude tapering.

The complete full-size antenna, including active panel and HPA current regulations, would be about 16 cm x 32 cm (for comparison, A4 sheet is 21 cm x 29.7 cm). The thickness of the test-bed is 7.5 cm, including the sole, the 4 cm coaxial cables between active and passive panels (which could be reduced to nearly 0 cm, but 4 cm were more convenient for studying test-bed characteristics such as active panel coupling). The full-size antenna thickness is expected to be no more than 4 cm.

Deviations and corrective actions

No deviations occurred.

2.3.5 WP5000

Objectives and starting point

The Objectives of WP5000 were to create the necessary documentation to achieve an airworthiness approval for the Minervaa Airborne Terminal and to execute the In-Flight-Validation. Furthermore, the necessary Ground Tests – to ensure a proper function of the components under a certification point of view – had to be carried out.

At the beginning of the activities, the design of the Airborne Terminal was finished.

Efforts and achievements, name involved partners and contractors

To achieve the airworthiness approval, a large amount of documentation had to be created. DLR was the focal point for these activities: A service supplier requested the necessary information from DLR, and DLR handed the request over to the corresponding partners (INS,SEL,SAG). The partners sent the information back to DLR, where the information was checked and further compiled. Finally, DLR forwarded all documentation to the service supplier, where a final check had been carried out before the documentation was filed to the German airworthiness authority (Luftfahrtbundesamt, LBA). At the end of the procedure, the airworthiness of the Minervaa Airborne Terminal was approved and the flight tests could be executed.

Furthermore, the validation flights were planned in WP5000. This included the creation of possible flight routes, the discussion of these routes with DLR's flight operations staff, and the agreement among the partners (SAG, INS, SEL, DLR).

Also the validation flights itself were carried out in WP5000. For this, the airborne terminal was installed onboard the experimental aircraft (SAG, INS, SEL, DLR). After the installation, all necessary ground tests were accomplished together with DLR's and Ruecker's certification staff. After the airworthiness approval, a total of three validation flights were carried out.

Deviations and corrective actions

Initially, it was foreseen that DLR takes care of creating all certification documentation and filing this documentation to the Luftfahrtbundesamt. However, the Luftfahrtbundesamt considered the "Minervaa Airborne Terminal" as a so-called "Major-Change" and not – as it was foreseen – as a "Minor-Change". This had a large impact on the certification procedure, as each document had to be reviewed by the Luftfahrtbundesamt separately. Furthermore, DLR's certification staff was suffering from a high workload due to several new experimental planes (A-320 ATRA, HALO) with corresponding flight certifications in the pipeline. To reduce the risk of the certification procedure, DLR decided to carry out the flight certification with a specialized service provider that handled the compilation of the documentation and the communication with the Luftfahtbundesamt.

Furthermore, the In-Flight-Validation was foreseen to be carried out in three separate weeks during Spring 2010. Due to the problems that occurred during the integration of the Airborne Terminal, this schedule was changed several times. In the end, the flight tests were carried out in 7 consecutive working days. This procedure reduced the risk of damages due to several installation/ uninstallation of the AT and allowed for a finish of the activities before the final dissemination event at the Farnborough Air Show.

2.3.6 WP6000

Objectives and starting point

The objectives for the WP6000 were to increase the scientific community interest by constantly publicizing the results at international conference as well as in international workshops. At the beginning of the project a website has been implemented to address the above purposes. The website is updated with latest news, actions and events that took place during the MINERVAA project.

Finally a set of leaflets has been printed along with posters and handled over to several conferences and workshops as a overview of the entire project and its workpages presenting some results and development concept of each partner.

Efforts and achievements, name involved partners and contractors

There was not any contractor involved at the WP6000 in order to address its requirements and fulfill the need for exploitation and dissemination of the knowledge generated from the MINERVAA Project.

A workshop has been arranged at the international airshow in Farnborough England in co-operation with Selex. The event took place at the Finmechannica booth and all partners have presented the achieved results in their work packages (check MINERVAA website).

Moreover, a student workshop has been established at the main track of the OPENFEST festival at the technological education institute (T.E.I) of Piraeus demonstrating the application implemented at WP3000 in order to motivate student to evolve the existing technologies.

Deviations and corrective actions

No deviations occurred.

2.4 Results gained and milestones achieved

In the following, Table 2 and Table 3 respectively present the list of achieved deliverables and milestones.

Deliverable no.	Deliverable Title	WP no.	Lead Particip.	Nature	Dissemin. Level	Delivery date
D1.0.1	Project management manual	1000	SEL	R	CO	2
D1.0.2	First intermediate progress report	1000	SEL	R	CO	12
D1.0.3	Publishable executive summary (first period)	1000	SEL	R	PU	12
D1.0.4	Second intermediate progress report	1000	SEL	R	CO	24
D1.0.5	Publishable executive summary (second period)	1000	SEL	R	PU	24
D1.0.6	Final progress report	1000	SEL	R	CO	42
D1.0.7	End of project executive summary report	1000	SEL	R	PU	42
D2.1.1	Advanced terminal design investigations report	2100	DLR	R	CO	30
D2.2.1	OOL-FV platform design specification	2200	SEL	R	CO	9
D2.3.1	OOL-FV airborne terminal implementation report	2300	SEL	R	CO	42

Deliverable no.	Deliverable Title	WP no.	Lead Particip.	Nature	Dissemin. Level	Delivery date
D2.3.2	OOL-FV airborne terminal functional and environmental test report	2300	SEL	R	CO	42
D2.4.1	Optical Ground Station implementation report	2400	DLR	R	CO	19
D2.5.1	OOL-FV ground test evaluation report	2500	SEL	R	RE	37
D3.1.1	Seat applications, technical requirements and IOPN layout design report	3100	EAD	R	CO	12
D3.2.1	IOPN Seat Network Equipment implementation report	3200	EAD	R	CO	28
D3.3.1	IOPN Data server development report	3300	TEI	R	CO	28
D3.4.1	Report on test analysis and evaluation of the IOPN	3400	TEI	R	CO	33
D4.1.1	Intraflight Antenna Subsystem requirement analysis report	4100	THC	R	CO	8
D4.1.2	Intraflight Tx / Rx Antenna sub-assemblies design report	4100	THC	R	CO	20
D4.2.1	Ka-band Satcom Tx/Rx antenna calibration and beam forming implementation report	4200	DLR	R	CO	24
D4.3.1	Ka-band Intraflight Tx/Rx antennas test report	4300	THC	R	CO	28
D5.1.1	Flight Tests definition and certification documents	5100	DLR	R	CO	39
D5.2.1	OOL BTP's results report	5200	DLR	R	CO	42
D5.2.2	OOL In-flight test results report	5200	DLR	R	CO	42
D6.1.1	Analysis of results and functional trade-off report	6100	SEL	R	RE	42
D6.1.2	Cost Benefit Analysis for IOPN	6100	EAD	R	CO	35
D6.2.1	Plan for using and disseminating the knowledge	6200	SC	O	CO	12
D6.2.2	Web site establishment and maintenance	6200	TEI	O	PU	6
D6.2.3	Workshop documentation	6200	TEI	O	PU	42

Deliverable no.	Deliverable Title	WP no.	Lead Particip.	Nature	Dissemin. Level	Delivery date
D6.2.4	Presentation of project results	6200	TEI	R	PU	42

Table 2: List of deliverables

Milestone no.	Due date	Milestone description	Decision criteria
M1.0.1	0	Kick off Meeting	Acceptance of project mgmt. refinement by the Consortium
M1.0.2	12	First intermediate review with EC	Acceptance of first review results by European commission and authorization to proceed
M1.0.3	24	Second intermediate review with EC	Acceptance of second review results by European commission and authorization to proceed
M1.0.4	36	Final review with EC	Acceptance of final MINERVAA project results by the European Commission
M2.1.1	24	Delivery of D2.1.1	Delivery of D2.1.1 to CEC
M2.2.1	5	OOL-FV requirement specification available to partners	Internal milestone - Draft version of D2.2.1 with OOL-FV requirement specification section circulated with partners
M2.2.2	9	OOL-FV design specification available	Delivery of D2.2.1 to CEC
M2.3.1	16	OOL-FV Airborne Terminal sub-systems module developed	Delivery of D2.3.1 to CEC
M2.3.2	19	OOL-FV Airborne Terminal functional and environmental test performed	Delivery of D2.3.2 to CEC
M2.4.1	16	Readiness of the communications system	Internal milestone - Ground Terminal connected to Server and data exchange properly working
M2.4.2	18	Readiness of the PAT system	Internal milestone - OOL-FV Ground terminal ready for integration with airborne terminal
M2.4.3	19	Delivery of D.2.4.1	Delivery of D2.4.1 to CEC
M2.5.1	17	OOL-FV platform static tests completed	Internal milestone – Preliminary interoperability static test between relevant Comms and PAT modules performed
M2.5.2	19	OOL-FV platform pointing and acquisition tests (internal)	Internal milestone – Pointing and acquisition subsystem tested
M2.5.3	21	OOL-FV platform stabilization and tracking tests completed (internal)	Internal milestone – Stabilization and Tracking subsystems tested
M2.5.4	24	OOL-FV platform ground tests completed	Delivery of D2.5.1 to CEC

Milestone no.	Due date	Milestone description	Decision criteria
M3.1.1	10	Seat related application(s) and requirements defined.	Internal milestone
M3.1.2	12	IOPN layout and design report completed.	Delivery of D3.1.1 to CEC
M3.2.1	18	Seat Data Interface definition available	Internal milestone - Seat Data Interface defined
M3.2.2	26	IOPN Seat Network Hardware realized and testable	Internal milestone – equipment available for starting tests
M3.2.3	28	IOPN Seat Network Hardware tested in the network mock-up.	Delivery of D3.2.1 to CEC
M3.3.1	15	IOPN application defined	Internal milestone
M3.3.2	24	Data server realized (software and hardware)	Internal milestone - Servers HW and SW available for implementation of applications
M3.3.3	28	Applications integrated on server report	Delivery of D3.3.1 to CEC
M3.4.1	25	IOPN Test plant available for ground tests	Internal milestone - test plant available for beginning of ground tests
M3.4.2	26	IOPN tested	Internal milestone - end of IOPN tests
M3.4.3	27	Tests results of the IOPN analyzed and evaluated	Delivery of D3.4.1 to CEC
M4.1.1	8	Intraflight Antenna Subsystem requirement analysis completed	Delivery of D.4.1.1 to CEC
M4.1.2	20	Intraflight Tx / Rx Antenna sub-assemblies design completed	Delivery of D.4.1.2 to CEC
M4.2.1	18	Tx/Rx Satcom antenna calibration tests definition completed	Internal milestone – Consortium acceptance 1st Draft of D.4.2.1
M4.2.2	20	Tx/Rx Satcom antenna calibration tests and validation completed	Internal milestone – Consortium acceptance 2nd Draft of D.4.2.1
M4.2.3	24	Tx/Rx Satcom antenna beam forming tests and validation completed	D4.2.1 delivery to EC
M4.3.1	26	Ka-band intra-fligth TX/RX antennas integration completed	Internal milestone – Consortium acceptance 1st Draft of D.4.4.1
M4.3.2	28	Ka-band intra-flight TX/RX antennas test completed in laboratory	Delivery of D.4.4.1 by CEC
M5.1.1	21	OOL-FV Flight tests definition report	Internal milestone - Flight tests definition report available to partners
M5.1.2	28	Delivery of D5.1.1	Delivery of D.5.1.1 to CEC
M5.2.1	26	OOL-FV platform equipment integrated on-board	Internal milestone – equipment installed onboard and interference tests and evaluations performed
M5.2.2	27	Executed Build Test Procedures (tests with aircraft on ground)	Delivery of D.5.2.1 to EC

Milestone no.	Due date	Milestone description	Decision criteria
M5.2.3	30	OOL-FV tests completion	Internal milestone – flight tests completed
M5.2.4	31	Delivery of D.5.2.2	Delivery of D.5.2.2 to EC
M6.1.1	35	Delivery of Analysis of results and functional trade-off report	Delivery of D6.1.1 to CEC
M6.1.2	35	Delivery of Cost Benefit Analysis report	Delivery of D6.1.2 to CEC
M6.2.1	6	Establishment of the web site	Web site availability (D6.3.1)
M6.2.2	12	Dissemination plan (first period)	Delivery of D6.2.1 (ver1) to CEC
M6.2.3	12	Update of the web site with intermediate results (first period)	Internal milestone
M6.2.4	24	Dissemination plan (second period)	Delivery of D6.2.1 (ver2) to CEC
M6.2.5	24	Update of the web site with intermediate results (second period)	Internal milestone
M6.2.6	35	Dissemination plan (final)	Delivery of D6.2.1 (ver3) to CEC
M6.2.7	35	Final workshop organization; delivery of workshop documentation	Delivery of D6.2.3 to CEC
M6.2.8	36	Update of the web site with final results	Internal milestone
M6.2.9	36	Presentation of project results	Delivery of D6.2.4 to CEC

Table 3: List of milestones.

2.5 Comparison of expected results and achievements, current state of the art

2.5.1 WP2000/5000

The goals, that were expected to be fulfilled, could mainly be achieved. Most of the system's functionalities, as e.g. the RF Link for GPS-Position- and Video-Transmission, the communication system, the pointing, acquisition and tracking of the Airborne Terminal could be demonstrated during Ground-Tests and the In-Flight-Validation. Due to a very demanding time-schedule in the integration phase, the algorithms regarding the closed-loop tracking of the Airborne Terminal could not be fully verified. This led to the unfortunate fact that a stable communication link could only be shown during ground tests and not during the few In-Flight-Validation Flights. However, the principal operability of the system was shown.

2.5.2 WP3000

The achievements correspond to the expected results.

More publications were published than expected, also in other areas like medical measurement.

2.5.3 WP4000

Thermal considerations had to be considered. The test-bed design allows nominal behaviour with simple forced air at 25°C: no liquid fluid cooling is required. The design is therefore successful on a thermal point of view.

Calibration and Beam-forming were meant to improve the performances and sidelobes on the full-size antenna. Simulation results are obtained for the full-size antenna and the test-bed, and take into account phase and amplitude quantization and dispersion. The very good agreement between test-bed simulation results and test-bed measured radiation pattern confirms the pertinence of the simulation hypotheses: simulated results for the full-size antenna can be seriously taken as hypotheses for full-size antenna behaviour, thus allowing sidelobe level significantly lower than -20 dB, and still comfortable sidelobes level even with a defective row..

The passive part of the test bed fulfils the expectations, with a gain per line between 12 dBi and 13 dBi, a measured radiation pattern in very good agreement with test-bed simulations. The active part of the test bed measurement indicated a lower gain for one of the HPAs, but it was kept as is for assembly. The assembled test-bed measurement demonstrate the steering capabilities (±36° measured compared to ≥ ±30° target at -3 dB level), see Figure XXX1 and the radiation pattern along the steering axis is also in very good agreement with the simulations. The gain of the test-bed is in-line with expectations (over 18 dBi) and the EIRP is comprised between 18.7±0.5 dBW and 19.8±0.5 dBW, meeting the 19 dBW objective. The fact that those results were obtained despite of a lower than nominal gain for one of the HPAs make us confident into the robustness of the design.

Current state of the art

Satellite to mobile link up to 432 kbps per channel on the move is now available with Swiftbroadband® from Immarsat, but still in low frequency band.

On the Ka point of view, the Hylas 1 and W3B will provide some Ka capabilities and will be launched at the end of 2010, and the KA-SAT satellite will be launched for Eutelsat at end 2010 or beginning 2011 for providing high speed internet, HDTV, 3DTV, Tooway® Eutelsat service to Europe.

These capabilities and the ATENAA project results would give satellite to aircraft capability. MINERVAA will provide the basis for the complementary link tools, with OOL link for very high speed link between two aircrafts and Ka link for high speed link between several aircrafts within a MANET network.

Phased array Ka-band antenna are used in space, the radiating element is then a horn and the network step is larger, as the maximum required steering angle in the satellite is low (±30° is not required to steer the along the whole Earth from the satellite), the cost and constraints are far different from On-The-Move antenna ones. Radar Ka-band antenna also exist, but the cost, efficiency, and size constraint are very different from the MINERVAA concept.

Articles are regularly published about Ka-band Antenna, but main commercially On-The-Move Ka-band antenna solutions are still parabolic dish antenna, are not electronically steerable, or have a low efficiency or big size or cost.

Within the MINERVAA project, we achieved to keep a single low profile active layout instead of multiple connected modules, to deal with thermal dissipation through HPA careful relative placement and configuration, thus obtaining a highly integrated antenna with a good efficiency (EIRP and dissipated power are in-line with objectives). The main Tx efficiency loss is due to the HPA efficiency itself, as the active panel combiners, phase-shifters and attenuators are at low microwave level.

Annex A

TEI's plan to exploit the knowledge of the MINERVAA project is basically to continue updating the website with content regarding the project and give more opportunities to the scientific society to observe to milestones of the research implementation procedure.

However, TEI as an institute is constantly promoting its activities in workshop in and also motivates student to start bachelor and master thesis based on its research activities. As a results student of TEI will have the change to evolve the tasks that TEI has implemented throughout the project period (e.g. WP3000).

In general leaflets will be handed from every participation from partners to disseminate the project giving an overview of the MINERVAA concepts and results.

Finally, a further continuation of the project in order to implement a commercial product will be promoted to partners and also to all the EU community in order to keep the knowledge acquired from MINERVAA vibrant and aid to the social good.

Section 1: Exploitable knowledge and its use

No.	Exploitable knowledge	Exploitable products or measures	Sectors of applications	Timetable for commercial use	Patents or other IPR protection	Owner and other partner(s) involved
1	*Ka-band antenna*	*Ultra-fast wireless link Aircraft/Ground at the airport*	*1. Aviation*	*2012*	*Know-how*	*THC*

Table A.1 Overview table of exploitable knowledge

Exploitable knowledge 1:

Ka-band antenna will be used for an ultra fast wireless link between ground and aircraft at the airport, which could be used for IFE data upload.

Thales is a major player in avionics and airborne systems, and Thales Communications has already been contacted for such an application. A corresponding product could be added to the Thales Communications catalogue.

The market would include civil passenger aircrafts providing IFE. Due to certifications considerations, the most widespread aircraft models among high capacity ones would be targeted in a first time, for the best per passenger certification and development cost.

EMC and public safety at the airport should be analysed and checked, particularly public exposure to electromagnetic radiation will be minimised.

Such a link would allow faster IFE upload than current one. The aircraft would need to spend less time at the airport, thus improving airport management and reducing companies costs.

Annex B

Publishable results of the plan for using and disseminating the knowledge

For the exploitation of the MINERVAA knowledge to the scientific community the main website has been implemented to address the purpose of informing for the development procedure of each task.

At the MINERVAA website all news, presentations and publications that have been done during the project are uploaded in order to help external institutes and companies to have a feedback for the technologies addressed during the development phase of the project.

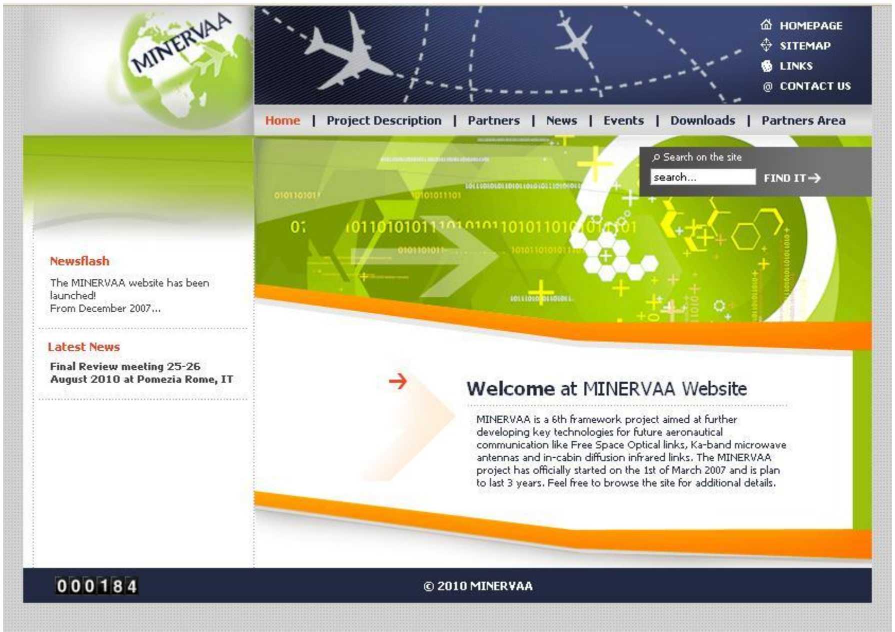

Figure 1: MINERVAA website

Finally, a video streaming session has been created offering snapshots of the MINERVAA events as well as some testing actions from partners. Presentation with the general aspects of implementation scenarios will also be uploaded in order to promote a rough overview of each workpackage task.

Below is the full list of the publications, per workpackage, of the MINERVAA project publicized in international conference and magazines:

WP2000:

1. H. Henniger: Multi Layer Error Protection on Simplex Links. SPIE, San Jose 2008.
2. B. Epple et. al.: "Implementation concepts for a bridging protocol for the high data rate slow-fading Free-Space Optical Channel" Photonics West, 2008
3. B. Epple et. al.: "Performance Optimization of Free-Space Optical Communication Protocols based on results from FSO Demonstrations" Optics & Photonics, 2007
4. H. Henniger: "Link performance of mobile optical links." Proc. SPIE, Vol. 6709, 670913, Free-Space Laser Communications VII, 2007.
5. M. Kubicek, H. Henniger: Bit error distribution measurements in the atmospheric optical fading channel. SPIE, San Jose 2008.
6. K. Karras, D. Marinos, P. Kouros, "Optical Terminal Requirements for Aeronautical Multi-Hop Networks", SPIE Optics & Photonics 2008, August 2008, San Diego, CA
7. K. Karras, D. Marinos, P. Kouros, " Beam queuing for aeronautical free space optical networks", SPIE Optics & Photonics 2010, August 2010, San Diego, CA

WP3000:

1. "Passengers health monitoring application for aircraft cabin environment" D. Marinos, K. Aidinis, C. Vassilopoulos, G.Pagiatakis,N. Vlissidis, C. Giovanis, N. Schmitt, T. Pistner, J. Klaue 3rd international conference IC-SCCE "From scientific computing to computational engineering", Athens, Greece, 9.-12.July 2008
2. "Portable embedded medical box implementation for health monitoring applications in avionic environments" K. Anastasopoulos, P. Kouros. D. Marinos, K. Aidinis, N. P. Schmitt, J. Klaue, Th. Pistner IEEE internat. Workshop on medical measurements and applications, Cetrano, Italy, May 29-30th 2009
3. "In flight inner optical communication network for entertainment and medical applications"; N. Vlissidis, D. Marinos; K. Karras, C. Giovanis, F. Leonidas, C. Vassilopoulos, C. Aidinis, G. Pagiatakis, P. Kouros, N. Schmitt, T. Pistner, J. Klaue. SynErgy Forum(S.E.F.) -2. International Conference, 24.-26.9.2009, Athens/Greece.
4. "Wireless Optical OFDM implementation for aircraft Cabin communication links", D.Marinos, C.Aidinis, N. Schmitt, J. Klaue, J.Schalk, T.Pistner ,IEEE -ISWPC conference, Modena Italy, May 2010.
5. "Performance Analysis of Modulation Schemes for Wireless Optical In-Cabin Aircraft Networks" D. Marinos, C. Aidinis, N. Schmitt, T. Pistner, J. Schalk, J, Klaue, C. Vassilopoulos, P. Kouros International Symposium On Information Technology ITSim´10, Kuala Lumpur, Malaysia, 15.-17.5.2010
6. "Integrated medical and safety monitoring system over in-cabin wireless network for avionic operations"; D. Marinos, F. Leonidas; C. Giovanis; C. Aidinis; C. Vasilopoulos, G. Pagiatakis, T. Pistner, N. Schmitt, J. Klaue; International Journal of Electronics (accepted)
7. "Wireless optical data communication in aircraft cabin demonstrating passenger seat based sensing"N. Schmitt, T. Pistner, J. Klaue, D. Marinos, N. Vlissidis, C. Giovanis, F. Leonidas, C. Vasilopoulos, G. Pagiatakis, K. Aidinis, P. Kouros Workshop at Farnborough Air show, Farnborough, UK. 21.7.2010

WP4000:

1. L. A. Greda, M. Shalaby and A. Dreher, "Calibration and element failure correction of an intra-flight antenna at Ka band",at the IEEE Antennas and Propagation Symposium, Toronto, Canada, Jul. 2010
2. J.-F. Allaeys, L. A. Greda, D. Marembert, Y. Guillerme, A. Dreher, "Ka-band Phased Array Antennas", Workshop at Farnborough Air show, Farnborough, UK. 21.7.2010

WP6000:

Project presentation by TEI at 2008, 2009 and 2010 at the ATC Global conference in AMSTERDAM.

  - Promotional project advertising material were handed out
- Publication at e*Navaire* magazine
  - (uploaded at .www.minervaa.org)
  - Next *eNavair* will publicise the MINERVAA results
- Presentation of MINERVAA project at
  - 2008 (Oestend, Belgium)
  - 2009 (Toulouse) IFATSEA* international conference in Toulouse
  - Promotional project leaflet were handed out
- The above activities were carried out at a minimal cost for the project

All publications are based on actual results generated during the project implementation procedure.

Section 3: Publishable results

As it has been noted at Annex B introduction, there are numerous publications for WP3000. The main reason was to inform the scientific society and exploit results and knowledge from the implemented wireless optical in-cabin link as well as for the health monitoring application.

Below it is presented an abstract version of the publicised and granted documents:

1. The “Passengers health monitoring application for aircraft cabin environment” publication took place in Athens in July 2008 at the international conference IC-SCCE. The main target was to present the concept of the forthcoming developed application. Abstract:

With regard to the ever increasing average age of the passenger population and to the needs of passengers with particular health problems, there is a growing demand for the implementation, within the confines of a commercial passenger cabin, of some sort of passenger health monitoring application that could facilitate pre-emptive action in case of an emergency for these special passenger groups. Within this framework, the application presented in this article is based on a highly sophisticated Human-Machine-Interface (HMI) for alert and retrieval of information stored in the cabin integrated database server. Special purpose medical sensors, integrated in a portable enclosure - with a concomitant decrease in the cost of system integration - provide health monitoring services where they are needed. A minimalist design results in a portable passenger medical box which interfaces to the individual sensors and is based on two levels of off-the-self microcontrollers, for data processing and framing purposes. Data, containing information from specific passenger seats, are routed and forwarded to the communications backbone by an embedded Linux PC via a diffuse optical link, overseeing several seats. A two-wavelength physical layer approach results in a cell-type network architecture for the intra-cabin communication - as already envisaged in the ATENAA predecessor project - with a maximum data rate of 10Mbit/s per cell.

2. The “Portable embedded medical box implementation for health monitoring applications in avionic environments” publication took place in Cetraro, Italy in May 2009 at the international and prestigious medical measurements conference MeMEA. The main target was to present the portable medical device and its implemented characteristics. Abstract:

In the work described in this article, several types of health monitoring sensor modules have been integrated in a compact portable enclosure - such as Electrocardiogram, pulse rate, blood pressure, oximetry, temperature. In addition, a control board was designed and implemented with the purpose of interfacing and processing the data arriving from the sensor modules, and their transfer to a standard RS232 interface. The board was designed for low power operation at the minimum output data rate. To this end, maximum measurement time and also low sampling rate regarding the continuous health monitoring measurements (ECG, Oximetry) were considered. A two layered (Master-Slave) microcontroller architecture was configured to process the sensor output frame and embed relevant information, such as seat number, in order to make storage and data retrieval possible over a large network. A graphic display was also integrated with the aim of projecting passenger health state and triggering alarms when necessary. The medical box is connected to a wireless optical data network inside the aircraft cabin providing maximum flexibility. Although the primary purpose of the system realized was the alerting of trained onboard staff about a broad spectrum of possible health failures, remote health monitoring at ground presents itself as a possibility under the network infrastructure already in place.

3. The “In flight inner optical communication network for entertainment and medical applications” publication took place in Spetses Island, Greece in September 2009 at the international and conference eRA. The main target was to present the concept of the portable medical device and its integration characteristic along with the wireless optical in-cabin link. Abstract:

Due to the latest technological progress in optical devices, wireless optical communication is able to offer high data rate transmission as well as a high quality of service for inner or outer aircraft optical links. This work is focused on utilizing and implementing optical links for demanding high bandwidth applications such as in-flight entertainment and other passenger services. Regarding the inner optical link, we have demonstrated a 10Mbit/s communication using standard Ethernet over a cell-type network architecture with two alternating wavelengths. The demonstration took place at an AIRBUS 340 Mock-up at EADS Innovation Works in Munich. Furthermore, we have implemented a health monitoring application using a portable enclosure with medical sensors and a database system for storage, measurements and display of alert events. Furthermore, in order to reduce the workload for the flight attendants we have implemented safety sensors to inform for cabin safety state (e.g. table upright, seat belt closed etc). The data from both applications will be transmitted over the wireless optical links and will be stored at a rack-mounted data server. The crew will be able to access the medical or safety data using a touch panel PC mounted in the aircraft cabin.

4. The "Wireless Optical OFDM implementation for aircraft Cabin communication links" publication took place in Modena, Italy in May 2010 at the international conference ISWPC. The main target was to present modulations and implementation steps considered to investigate a high-speed optical OFDM cabin link. Abstract:

The state of development of optical devices has led to increased interest in high data rate wireless optical communication schemes that today constitute a viable alternative to conventional wireless technologies for information exchange. In this work, a high data rate wireless optical link, based on OFDM modulation, conventional laser diodes and large area photodiodes, was implemented and investigated. A laboratory prototype was used to demonstrate a data rate of 19.6Mbit/s. A 64-subcarrier OFDM signal with different subcarrier modulation schemes (BPSK, QPSK) was examined. Target applications are video, high speed internet etc. within the confines of an intra-cabin wireless optical topology.

5. The "Performance Analysis of Modulation Schemes for Wireless Optical In-Cabin Aircraft Networks" publication took place in Kuala Lumpur, Malaysia in June 2010 at the international Telecommunications symposium ITSIM'10. The main target was to present achieved results and an analysis of the optical OFDM in respect to other wireless optical transmission schemes. Abstract:

One of the major tasks in the future of aircraft in-flight entertainment is to provide wireless connectivity throughout the cabin. In this work an optical OFDM modulation scheme for cellular network architecture is investigated in comparison to other conventional optical modulation techniques (PPM, OOK). An analysis of efficient cabin link layout with respect to seat rows per cell and available data rates, allowing high quality services for specific application (e.g. Video, data transfer), is presented for an implemented minimum of 10Mbit/s per cell. A wireless optical OFDM communication prototype has also been implemented in a laboratory experiment and compared to a conventional diffuse optical 2PPM, achieving 17.2Mbit/s data transmission, thus doubling the previously achieved performance, but being based on line of sight links in the laboratory only. Both implementations prove the usefulness of the investigated modulation schemes.

6. The "Integrated medical and safety monitoring system over in-cabin wireless network for avionic operations" scientific journal paper has been granted, but not yet publicized, at the international Journal of Electronics magazine. The main target was to sum-up all the implemented work and give implementation guidelines and figures of merit of all the integrated systems. Abstract:

An integrated health and safety monitoring system for aircraft environments using commercially available medical sensor modules and custom made safety sensors in conjunction with an appropriate database supervised through a human-machine interface is implemented. The application described aims at preventing critical health or safety related situations during flight. The health monitoring part of the system is capable of collecting all relevant data, essential in analyzing a passenger's health profile. These data, comprising of body- temperature blood-pressure, pulse *oximetry and electrocardiogram, are throughput and transmitted over a wireless optical intra-cabin link to a server. Furthermore, and in order to reduce the cabin crew workload, along with the health data from a specific passenger group, seat-embedded safety sensors provide information for all passengers' flight safety parameters (such as table upright, seat-belt closed etc). The data gathered by the system in a central server can, in its entirety, be stored, processed or acted upon in real time.*

- THC presented MINERVAA during the Technodays 2007 & 2008 in Thales Colombes Centre to collaborators and customers from most of Thales countries.
- THC presented MINERVAA to French Engineers and international experts at a System@tic seminar about millimetric waves and Ka wave activities, and evolution for securing the future. System@tic is a French competiveness cluster.
- THC presented MINERVAA at several regional meetings of other French R&D clusters.

Moreover, a presentation has been give from Dr.Nikolaus Schmitt from EADS Innovation Works GmbH at the Farnborough Airshow in order to inform the industry and researchers for the implemented systems.

Finally, except of the first conceptual paper all of the above are presenting already developed systems and experimental measurement results.