Final Project Report WP-E

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Abstract

The final report of the AGATHA project provides a publishable summary of the results. In addition it lists all deliverables, dissemination activities, eligible costs, deviations, bills and lessons learned.

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Publishable Summary

The AGATHA project addresses the challenge of seamlessly integrating General Aviation (GA) into the SESAR Concept [3]. The existing gap between Commercial Air Transportation and General Aviation in terms of Communication, Navigation and Surveillance (CNS) and Air Traffic Management (ATM), e.g. level of equipment and concept of operations, may prevent harmonization of the European ATM system. Technology innovation and adaptation for the GA sector are needed.

The main objective is to consider the feasibility for the General Aviation world of using promising wireless technology innovations to support a wide variety of CNS/ATM applications and concepts defined in or derived from SESAR ConOps step 2 [3] to allow aircraft to safely operate in a “connected” mode.

The **AGATHA** project is structured around two interdependent spheres of activity:

- The **technical sphere,** which analyses priorities as defined in the operational sphere in order to define and assess the General Aviation wireless CNS system. The iterations between these two sets enable the progressive refinement of the technical solution and analysis/simulation results.

- The **operational sphere** which identifies the priority levels of GA applications and assesses operational scenarios.

A key activity of the **technical sphere** was to assess several wireless systems in order to determine their ability to provide services identified as necessary in the contexts considered, i.e. the “Operational scenarios”.

The aforementioned wireless systems can be allocated for the uses of communication, navigation, or surveillance. In regard to the communication wireless systems, allocated for air-ground communication purposes, three types of systems have been particularly studied:

1. A system based on direct link and derived from the well-known LTE system, currently in deployment for ground mobile telecommunication.

2. A system based on AANET (Aeronautical Ad Hoc NETworks). This system can be considered as a multi hop air-ground communication system, in that each aircraft acts as a forwarding equipment (or router), forwarding data in order to ultimately reach a ground station that is out of the range of the first sender.

3. A system based on the VHF network, which represents a necessary fallback option as it could ensure a stable quality of service.

The first system has been mainly investigated and assessed on the basis of real experiments. LTE systems already provide mobile 4G ground communications in some areas, which led to the decision to use LTE as a preliminary means of assessing the capacity and coverage that could reasonably be expected for GA air-ground communications.
The idea behind this method is an LTE system specifically extended (i.e. modified Antennas, modems identification…) for GA use would subsequently be deployed. Note that the question of cellular network reuse or not and the detailed how-to remains an open question that could be clarified by liaising with cellular service providers in order to assess COB & CBA.
Several experiments have been conducted using specifically developed tools – first during motor vehicle-based tests in order to validate a method; then during flight tests. Hence several experiments have been conducted using specifically developed tools – first during motor vehicle-based tests in order to validate a method; then during flight tests.

The obtained results confirm that our assumption concerning the possible use of cellular based networks for data link communications to and from a GA aircraft is pertinent. However, this innovative system will be required to deal with several issues: for instance, initial development costs or technical implementations. The proposed idea was to use a system designed and distributed for cellular-based communications in order to assess the possibility of implementing a communication means based on similar technology and methods for a future wireless system reserved for General Aviation.

The future "Aero LTE" would be able to integrate and harmonize GA and CAT data link with the interconnection of their ground communication systems via ground infrastructure. Although the existing wireless system with LTE, 3G, and 2G antennas is still far from presenting an allocated use for aviation. It certainly presents potential advantages regarding costs and technical deployment for first experiments.

This research is a first step towards a new data link communications system conceived and designed primarily to serve General Aviation. Assuming the presence of a simple transmitting antenna working at the lower LTE frequency, and with reasonable input power and receiver sensitivity, propagation simulations show that providing the service in the APT/TMA zone may be considered without great difficulty. However, reflections on the ground create narrow zones of weak electromagnetic field, i.e. loss of service. Therefore, the need must be specified in order to determine whether this is an issue. If so, more complex transmitting antennas should be considered in order to overcome the issue. In this project, a monopole antenna has been considered. It is omnidirectional in azimuth, and focuses the field on lower elevations. Moreover, it presents a low-cost design. It is therefore a relevant antenna type for the present application. An additional design with choke rings to mitigate the effect of the ground reflection has also been tested, but without great success.

Finally as the number of ground stations necessary to ensure an exhaustive airspace coverage of could represent a brake on the timely deployment of the first solution, Aero LTE is considered as an air-ground communication system reserved for selective areas in which aircraft density is sufficiently high.

For other airspaces, an alternative solution the “AANETs”, based on multi hop transmissions is proposed and has also been studied in the current project. AANETs take advantage of inter-aircraft links to relay data farther than the ground station range, thus allowing a potentially unlimited coverage. The main limitation in this case is the aircraft density required to relay the messages. This innovative solution was studied through simulations in order to evaluate its feasibility and performance. The study has shown that inter-aircraft links allow a significant increase in coverage (200% more aircraft connected) with no requirement of additional ground stations – provided the aircraft density or link range is high enough. For instance, in a typical case, if aircraft are equipped with a communication system providing a range of 70km, then a reachability of 90% of aircraft can be achieved. Although AANETs are at an early experimental stage, they represent a promising complementary solution to a cellular system, improving the coverage of a general aviation communication system with expected limited costs.

For ENR airspace, the LTE suffers from a lack of coverage that could be complemented by the AANET. However, the AANET also requires a certain level of aircraft density in order to be efficient and viable. Therefore, a third communication means has been studied: the VHF network. Different simulations for the VHF network have also been conducted, covering the three typical scenarios: TMA/APT, ENR and AOA (including low altitude).

The management of these three communication technologies has been centralized by proposing a preliminary design of a Multi-link entity. The Multi-link management selects the communication technology to be used by the aircraft during different flight phases. It takes into account several parameters, and by applying a specific algorithm, chooses the best way to use the underlying and the available communication means.

Regarding navigation, the study’s aim was to assess the feasibility of hosting DVOR & DME transceivers in software-defined radio based equipment. This approach seems to be an innovative and feasible one that could allow a seamless transition from legacy technologies to new ones based on SBAS. The main challenge of this type of proposal will be the aircraft antenna that should support in this case the VHF frequencies (108-118 MHz), in addition to the UHF ones (960 MHz-1300 MHz) in order to avoid multiplying the aircraft antennas. In this case additional requirements which could be added to this antenna are the support of VHF data link frequencies, the LTE frequencies (~800 MHz), the ADS-B (1090 MHz ES), and eventually the GPS ones. The addition of these technologies would require a special study, which was not included in the scope of this project.

In regard to surveillance, an assessment of the 1090ES has been conducted, and the ADS-B 1090ES seems to be the best solution for GA. It allows to fulfill the surveillance requirements and seems to be the best solution that allows to take advantage of interoperability with CA aircraft. The main challenge of this type of solution for GA is the equipment cost and the certification aspect mainly for the GPS information. In the near future if we suppose that SBAS-based solutions are going to be available at the lowest prices, GA could take the advantage of this type of SBAS receiver as an input for navigation and for surveillance. Additionally, the implementation of a 1090ES transceiver could be easily achieved by hosting the implementation on software-defined radio equipment. This same equipment could also host other technologies, just as VOR, DME for navigation and VHF, AANET for communication, which could also lead to a lowest price, as the same equipment is capable of the three CNS means. Finally, the output power identified for GA aircraft is relatively low when compared to CA aircraft, either for surveillance or for communication. This requirement is also a factor that leads to a lowest price for the transceiver design as well as for the transceiver size.

On the **operational part**, the activities started by identifying 7 priority CNS / ATM applications aiming at facilitating the integration of General Aviation into the future Single European Sky ATM systems while satisfying both SESAR objectives (capacity, safety, costs, environment, etc…) and GA objectives (equitable access to resources, continuity, safety and pilots' working environment improvement). Organized as a Concept of Operations, it defines the scope of the study, synthesizes operational needs that were gathered from GA stakeholders and experts, proposes logical building blocks grouped into 3 CNS "basic" enabling applications and 4 ATM applications, and analyzes their benefits and possible issues. Requirements Management, Modeling, and Knowledge Management techniques are used to structure, keep control of, and trace abundant and heterogeneous information.

The intermediate step was to establish typical scenarios based on the Subset of GA priority CNS/ATM applications, where these applications are exercised. Three main scenarios have been identified to fully represent the GA environment, and more specifically, the integration of GA into SESAR. The main elements that have been highlighted are:

- Preparation of the flight
- Flying ENR in uncontrolled airspace
- Entering a controlled airspace for landing/transit.

In these 3 scenarios, it is considered that SESAR existing services can be both used by the GA community, and at the same time AGATHA-equipped GA aircraft may contribute to the SESAR services.

The final step uses the operational scenarios to demonstrate that undertaking the AGATHA functions provides benefits for both GA and ATM stakeholders, but subject to the availability of a suitable data link telecom network. Due the necessary GA fleet modernization, aspects related to human factors have been also evaluated.

As the AGATHA concept maturity in terms of E-OCVM[1] is still in the V1 stage, which corresponds to defining the main concept of operation and the benefit mechanism (initial business case), the assessment of operational benefits relied on a panel of operational experts from the different categories of General Aviation profiles:

- Private company pilots flying VFR and IFR in all environments
- ATC controllers
- Professional Pilot, Type Rating Instructor, aeronautical projects manager

These operational experts have volunteered to participate in the organized interview sessions to provide their views on the benefits of AGATHA solution to their daily tasks. The role of the team of

[1] European Operational Concept Validation Methodology

professionals in the AGATHA project is to bring an operational assessment and evaluation of the proposed solution. As they are the best positioned to evaluate the potential benefits of the AGATHA's solution proposals, their feedback and comments are essential to correctly describe the use of AGATHA and to assess the potential impacts.

The **operational assessment** has assumed that technical enablers were available. It is a theoretical assumption based on the **technical** conclusions. Nevertheless, some studies must be further undertaken before to achieve this goal. Mainly, some questions are still unresolved:

- What could be an affordable data link network, could it use a unique support or must it be designed on a multilink architecture?
- Could the GNSS + SBAS capability be applicable for VFR flight, taking into account the VFR pilot skills and regular training?
- Concerning the ADS-B In-Out 1090 MHz, is it realistic to expect such a device at an affordable cost and usable by ATC?
- The aircraft flight deck should evolve to include suitable display for both information and aircraft position; how should this objective be addressed in an affordable cost and with a suitable ergonomics?

The operational assessment emphasizes the impacted KPAs as following:

- ATC information addresses the majority of KPAs
- MET, AIM, are expected to provide high operational benefits
- Other information, Flight intention, ADS-B uncertified for ATC, downlink of uncertified aircraft position, EFB use, IFR low speed / altitude procedures, GNSS capabilities, FOC for GA, are expected to provide medium operational benefits
- aircraft as MET sensor, VFR route towards TMA entry points, are expected to provide low operational benefits

The result of the assessment shows that the most addressed KPA is SAFETY (both crew and ATC). Mainly, the importance of information sharing (MET, AIM, ATC, other) on both planning and in-flight phases (CDM concept, role of a FOC for GA, information known by ATC, use of data link to receive updating information) has been highlighted.

Increased CAPACITY, PREDICTABILITY and CAT/A INTEGRATION are expected by both crew and ATC thanks to better information exchange, flight time management and adhoc basic CNS technology. The GA actors claim again that these KPAs will be improved but at low cost condition and without prevent from flying freely for those that want that (COST EFFECTIVNESS KPA result)

ENVIRONMENT result focuses on fuel burn. But in VFR operations, when MET updating by data link, the trajectory change management could take into account the noise protected area (needed visualization of such areas). That means that, in flight, the noise protected area should be visualized as AIM information

The operational benefits assessment point out some precautions, and finally, taking into account all the comments and assumptions, it is clear that some domains must be further investigated. These domains are mainly:

- The data link network, including satellite connection: this technology has not been retained for the AGATHA solution due to the actual cost. However, this technology could be a solution to fill in the performance gaps of the existing AGATHA solution.

- The low cost ADS-B certified for ATC use
- The cockpit design mainly for light certified VFR and IFR aircraft
- The human factors and the workload addressed by the use of new applications (ATCO and PILOT)
- The Cost-Beneficial Analysis in relation with the new applications
- The management of the traffic in uncontrolled airspace and at low altitude
- The basic and permanent training for both ATCO and PILOT which will be faced to new applications / procedures
- The information sharing, including ATC information, via a GA CDM, with a GA FOC?

1 Introduction

1.1 Purpose of the document

The purpose of this document is to:

- Summarise the technical results and conclusions of the project (Publishable Summary);
- Provide a complete overview of all deliverables;
- Provide a complete overview of all dissemination activities (past and in progress). Where appropriate, provide feedback from presentations. Describe utilization plans.
- Provide a complete overview of the billing status, eligible costs, planned and actual effort (incl. an explanation of the discrepancies).
- Analyse the lessons learnt at project level.

1.2 Intended readership

This document presents interests for the following stakeholders:

- SESAR stakeholders involved in the General Aviation in order to highlight the suitable CNS systems.
- General Aviation stakeholders, especially those who have been involved in the AGATHA project, were interviewed and they helped to enrich the project inputs.
- AGATHA project team members, as valuable input for subsequent projects around the GA and future CNS technologies.

1.3 Inputs from other projects

- SESAR GA/R WG Recommendations [1], a glimpse into the future of European Air Traffic Management
- Links with another WP-E project, the PROGA project (Probabilistic 4D trajectories of light General Aviation operations), who started within the same period as the AGATHA project.
- COCR [2], Communications Operating Concept and Requirements for the Future Radio System

2 Technical Project Deliverables

Number	Title	Short Description	Approval status
D.1.1	Subset of GA's priority CNS/ATM applications	Identification of GA priority CNS/ATM concepts of operations and applications for general aviation and small airports.	Approved
D2.2.1	Wireless Technologies' State-of-the-Art & Technology Screening	Builds the state-of-the-art situation of existing technologies (not limited to the sole General Aviation or restricted to Small Airport application).	Approved
D1.2	GA Operational Scenarios	Definition of a set of operational & traffic scenarios of reference for TMA,APT & ENR on determined test airports (very small, small and medium)	Approved
D2.1.1	GA's priority CNS applications profiles	Translation of priority CNS applications and services into "technology-profiles": required bandwidth / data rate (up/downlink), expected residual error rate, security, etc.	Approved
D2.1.2	Typical Deployment Scenarios & System Performance Requirements	Translating the operational environment & scenarios into a set of operational requirements.	Approved
D2.2.2	Wireless System Requirement Specification	Translate the D2.2.1, WP1.2, WP1.1 into System Requirement, this deliverable is a main input for the D2.3 capacity assessments.	Approved
D2.3	Wireless system capacity assessment results	From D1.2 & D2.1.2 Operational Scenarios as input prepare the simulation input and verify results according to D2.2.2	Reviewed, waiting approval following update
D1.3	Ops Benefits Assessment Report	From D1.2 Operational Scenarios as input and the WP2.3 as System assesses the operational Benefit of the proposed system	Reviewed, waiting approval following update

Table 1 - List of Project Deliverables

3 Dissemination Activities

3.1 Presentations/publications at ATM conferences/journals

Participation in the third SESAR Innovation Days, 2013 in Stockholm, Sweden:

- Present a poster for the project.

Participation in the Fourth SESAR Innovation Days, 2014 in Madrid, Spain:

- Present a teaser for the project
- Present a poster for the project
- Send a paper summarizing the approach and the preliminary results that have been developed within the project, but unfortunately the paper has been rejected due to a lack of references and final results.

3.2 Presentations/publications at other conferences/journals

Aerospace Valley / SSTA & SA, 2013 & 2014 meetings in Brive, France

- Present the project and the benefits of such approach for GA.

CleanSky meeting, Brussels 2014

- Introduce the project and the challenge of seamlessly integrating General Aviation into the SESAR Concept

3.3 Web presence

Join the HALA Network & introduce the AGATHA Project on the HALA Network webpages:

- http://complexworld.eu/wiki/AGATHA

Link to the SESAR innovation days 2014, poster & demonstration:

- http://www.sesarinnovationdays.eu/sites/default/files/media/SIDs/Posters/SID%202014%20poster%20AGATHA.pdf
- http://www.sesarinnovationdays.eu/2014/postersAndDemostrations

3.4 Utilization plans

AGATHA is a challenging project that allows ALTYS to understand in detail the General Aviation environment, constraints and issues. It was a great opportunity to be in contact with GA stakeholders by meeting them and collecting the high-level needs and requirements in order to propose innovative solutions.

For M3S, the AGATHA project was a great opportunity to investigate the needs of GA aviation and analyze the adaptability of the SESAR initiatives to the General Aviation operations. It was also an opportunity to investigate how General Aviation can also be an active participant to the SESAR initiatives and contribute to a better overall understanding of ATM. During the project, through interviews with operational experts, M3 Systems had the opportunity to confront the technical solution proposed to the actual needs of General Aviation and discover the use of the technology in very specific situations. The AGATHA project has been an opportunity for M3 Systems to understand better GA issues and constraints both on the ground and airborne. This knowledge and understanding is key for future projects working to integrating regional airports (operating commercial and general aviation) into the overall network.

ENAC's skills about GA operations were rather based on experience gained through the fleet it operates and the training it proposes to Professional Pilots and Flight Instructors. The AGATHA project brought a strong work on how SESAR ConOps could take into account the GA operations. This additional skill will benefit to the ENAC's students and provide further topics to address by the Research department.

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Moreover, the relationship established with the GA community will be maintained and used to launch both Research activities at the French level and to prepare "future topics to explore" to the R&D Community at the European level.

4 Total Eligible Costs

Date	Deliverables on Bill	Contribution for Effort	Contribution for Other Costs (specify)	Status
November 2013	D0.1,D1.1,D0.2	88886.50 €	N.A.	Paid
October 2014	D0.3, D0.4, D1.2, D0.5, D2.2.1, D2.1.1, D2.1.2, D2.2.2	209718.2 €	N.A	Paid
September 2015	D0.6, D0.7, D0.8, D0.9, D2.3.1, D2.3.2, D0.10, D1.3, D0.11	266987.94 €+10,000.00 € (travel and subsistence)	To be done	Not issued
GRAND TOTAL		575,591.72 €	To be done	

Table 2 Overview of Billing

Company	Planned man-days	Actual man-days	Total Cost	Total Contribution	Reason for Deviation
ALTYS Technologies	427	427	319,907.04 €	239,930.28 €	
ENAC	467	438	201,671.58 €	201,671.58 €	Time sharing has been changed: more time from “expert”, less time from “EC”. The total cost will probably higher than expected.
M3S	183	183	165,319.83 €	123,989.87 €	
GRAND TOTAL	1077	1048	699,398.44	565591.7215	

Table 3 Overview of Effort and Costs per project participant

5 Project Lessons Learnt

What worked well?
The coordination between the technical thread and the operational thread of the project was regular, which allowed to align the benefit analysis of the AGATHA solution to the operational reality of general aviation.
The team was well balanced to meet the project requirements
The project addressed two main legs (a technology leg and an application leg), which forced the team to permanently share the proposals
The project starts with interviews and ends with an assessment by experts. The operational GA's needs will thus be already taken into account
The link with other SESAR projects on comparable topics (P04.10, ProGA, EVA, E-CRA) has increased knowledge and interest
The feeling to contribute to GA's needs integration into the SESAR world while working on innovative topics
What should be further investigated?
Data link for GA including satellite capabilities.
The question of cellular network reuse and the detailed how-to remains an open question that could be clarified by liaising with cellular service providers in order to assess COB & CBA
Go further to the prototype phase in order to test the CNS transceiver that includes the AGATHA solution (1090ES, VOR, DME, VHF Datalink…) in all in one SDR box
CDM for GA, including via a FOC capable to exchange information between stakeholders, including ATC
Flight deck evolution capable of integrating future CNS enablers, including information saved at the planning phase and updated in flight
Humans factors in relation with the expected changes
Training to prepare pilots to fly safely with future information and tools

Table 4 - Project Lessons Learnt

6 References

[1] SESARJU GA/R WG, A glimpse into the future of European Air Traffic Management, September 2011

[2] EUROCONTROL / FAA, Communications Operating Concept and Requirements for the Future Radio System, 2.0

[3] SESAR Concept of Operations at a Glance Update, Edition 02.00.00, July 15, 2011