A PERSONAL PLANE AIR TRANSPORTATION SYSTEM: THE PPLANE PROJECT

Claude Le Tallec, Moshe Harel
Onera, Intergam Communications
Claude.le_Tallec@onera.fr; mharel@netvision.net.il

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Abstract

The seventh European Framework Program (FP7) "Personal Plane" project (PPlane) aims to develop system ideas that enable personal air transport for the long term (2030 and beyond). Such a system will avoid the ever increasing congestion on European roads and offer an alternative to the current conventional transport system across Europe. PPlane will provide in all European countries, an additional component of a future efficient European multimodal transport system aiming at allowing all European citizen to travel anywhere in Europe, gate to gate, within 4 hour or lesss.

The preliminary assumption made in the PPlane project is that automation should be developed to enable a "regular Joe" to use a personal aircraft, in various weather conditions, without any command and control difficulties, using a "push button" navigation interface. In conjunction with adapted sophisticated ATM ground system, an on-board automatic system will take care of the complex issues of integration into the future airspace that includes many other sky users, while preserving navigation and emergency management capabilities.

A systematic and innovative approach has been developed and implemented within the PPlane project in order to identify and analyze future customers' needs and to propose novel ideas for a Personal Air Transport System (PATS). This system satisfies the end users while respecting all environmental and social constraints. Several concepts of operation have been initially developed followed by an optimization model that applies a number of selection criteria to define, analyze and prioritize these concepts. The main issues that have been addressed are divided into five domains: security and safety, automation and control, environmental impact, energy constraints, human factors and social acceptance. In each domain, areas such as technologies, regulation, and affordability are considered resulting in the design of viable systems ideas.

The project concludes that PPlane vehicle would be an aircraft that is fully automated and electrically propelled for environmental reasons. The ground infrastructure of the PPlane system has also been designed, an ownership model is proposed and a preliminary evaluation of the travel costs has been made.

The solution of "flying car" or "roadable aircraft" was ruled out since it would cause many difficulties including multiple safety problems.

PPlane is a 36-month project that started in October 2009. The PPlane consortium is coordinated by ONERA (France), administratively supported by Intergam Communications (Israel) and includes leading organizations from 11 European countries and associated states from different aviation domains in industry, research and academy.

1 General Introduction

In Europe, Personal Air Transport Systems (PATS) were not highly developed for historical, economical, technological and political reasons.

On the higher end of what could be considered as "personal air transport", business aviation is pretty wealthy, but due to its high cost, can only be used by a very limited number of persons often called “the Jet-set”. Historically, this segment showed a strong progress when business jets started to compete with airliners to fly nearly everywhere on the planet. Businessmen could save money by optimizing their travels despite the initial high cost of their personal transport mean.

At the other end, General Aviation (GA) is more dedicated to pilot education and to leisure travel. Most aircraft are poorly equipped and only a small part of this fleet is able to be flown using Instrumental Flight Rules (IFR); this limits their flight capabilities to good weather conditions only.

In between these two categories, there is room for “personal” 4 to 8 passenger aircraft. However, there is no business model equivalent to “ground” taxis since management of an "air taxi" is not feasible due to the limited number of airports and airfields compared with the large number of ground taxi stations that makes pilot shift logistics hard to manage. Also, the cost of a short flight is much higher than the cost of a short drive on the ground.

A straight forward statement would be that a PATS cannot exist if the user needs a pilot to fly the air vehicle (too expensive, logistics issues) or if he, or she, has to become a well trained pilot (demanding too much time and money). Thus, the solution is in automation.

Currently, GA pilots are trained and licensed. Nevertheless, accident rate for GA is much higher than for airliners: e.g. 6.84 accidents per 100,000 GA flight hours for U.S. vs. 0.128 accidents per 100,000 flight hours for U.S. commercial aircraft in 2007 [1]. In the early phase of the PPlane project, it has been assessed that, even with an increased level of safety reached through high automation of the aircraft, the accident rate of personal planes manned with an onboard non-professional pilot would greatly increase.

In the meantime, the emerging Unmanned Aircraft Systems (UAS) technologies are already paving the way towards aircraft flying safely with no pilots on board, fully monitored and controlled by a “remote pilot station” (RPS) generally located on the ground. The US congressional report [2] indicates that the Predator unmanned aircraft had, in 2011, only 7.5 accidents per 100,000 hours of flight, down from 20 accidents over that time in 2005 and just under the 8.2 rate for small, single engine private airplanes flown in the U.S. This report also states that most of the UAS accidents have been attributed to human errors.

Consequently, the decision in the PPlane project was made to consider the system that is illustrated in Figure 1.

The aircraft is occupied by passengers only, while remote pilots will supervise and monitor the system from the Remote Pilot Station (RPS) in communications with the Air Traffic Control (ATC). The communication networks shown in Figure 1 will be detailed later in the paper.

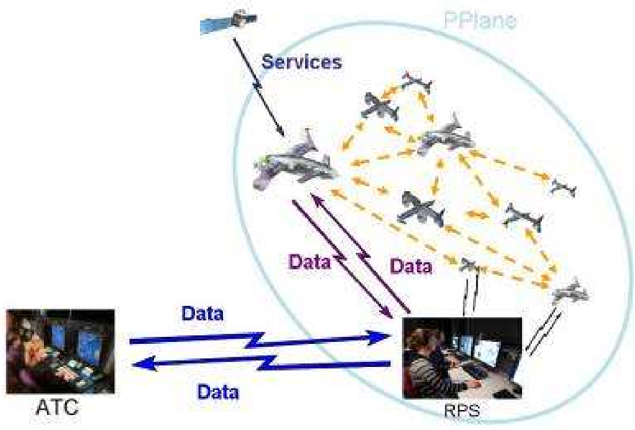

Figure 1: The Personal Plane system concept

The project focuses on global personal air transport system which includes ground segment analysis (Figure 2) air vehicle configurations (Figure 3), and the air transport management system of the future.

Figure 2: Example of a Remote Pilot Station

Figure 3: Examples of PPlane vehicles

The overall project work-plan addressed five areas, namely:

- Operational Concepts;
- Safety and Security;
- Automation;
- Human factors;
- Environment.

The activity related to "Operational Concepts" dealt with the user requirements and with a high-level description of PPlane system elements. A comprehensive methodology has been set up for defining and selecting the PPlane scenarios.

In the "Safety and Security" area, concepts for PATS were assessed in light of guidelines specified in the European work program ensuring customer satisfaction and safety. It also assesses constraints specified in the EC policy, such as protection of aircraft and passengers against unlawful actions (aircraft security and operational security).

As the PPlane system is highly automated, the area "Automation and Control" has been of primary importance. Existing and emerging automation concepts, which will be needed to operate PATS vehicles, have been reviewed taking into account their features by use of generic aeromechanic models. The current technologies that are used in UAS have been explored, both for the PPlane aircraft systems design and for the RPS concept.

Although the system is highly automated, the "Human factors" are of great importance since humans remain fundamental actors in the system. The PPlane aircraft occupants do not include pilots; they are passengers using a novel mean of transportation that is managed from the ground by remote pilots and operators. Advanced concepts and techniques have been taken into account; just like in UAS. The work performed has been focused on the overall performance of the flight, with special considerations to emergency situations.

Any new means of transportation in Europe has to rate "Environment friendliness" as high in the priority list, considering the growing trend of "greening" and protecting the environment. The project team followed European quantitative goals specified in European strategy: reducing CO_2 emission by 50%, reducing various NO_x emissions by 80% and reducing perceived noise by 50%.

The project has been concluded through the qualitative and quantitative analysis of scenarios and production of recommendations. During this stage, four additional topics (affordability, technologies, social acceptance and regulation) have been considered all along the technical work. Finaly, recommendations were given for implementing PATS in Europe in the coming decades of the 21st century.

2 Project methodology

The project work-plan has been based on an innovative and comprehensive methodology that combines two complementary methods: a

"Delphi" survey among experts and a design engineering tool named "House of Quality" (HoQ). The combined methodology is illustrated in Figure 4.

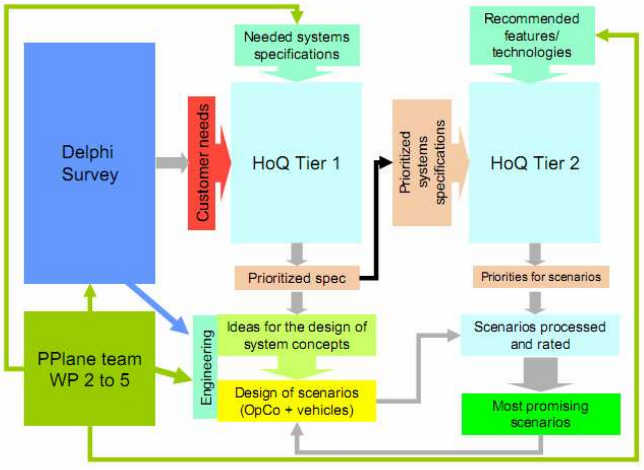

Figure 4: PPlane overall Methodology

The first phase includes a 2-stage Delphi Survey that was conducted among several hundred external experts in aeronautics and related fields such as regulation, air traffic control, aircraft design and manufacture, safety and security. The experts were asked to suggest and rank operational parameters, technical features and attributes of future PAT systems from the end-user perspective (in the year 2025 and beyond). The survey resulted in a comprehensive set of "customer needs". Interestingly, responders attributed a higher importance to the operational parameters than to the technical features of the aircraft and its performance, which resulted in more freedom for the aircraft designers.

The HoQ method (Tier 1 and Tier 2) was used for the 2nd and 3rd phases. PPlane system attributes were listed and ranked resulting in multiple "concepts of operations" and scenarios. Parameters that were listed and weighted included "Aircraft Characteristics", "Recovery Systems", "Mission", "Type of Runway", "Guidance", "Class of Airspace", "Visibility", "Wind" and many more. This methodology enabled to identify and classify the most promising system concepts and scenarios for further analysis.

3 Project Results

The selection process resulted in a concept of a personal plane system being one element of an intermodal transportation system relying both on highly developed ground transportation means and personal flying vehicles as illustrated in Figure 5.

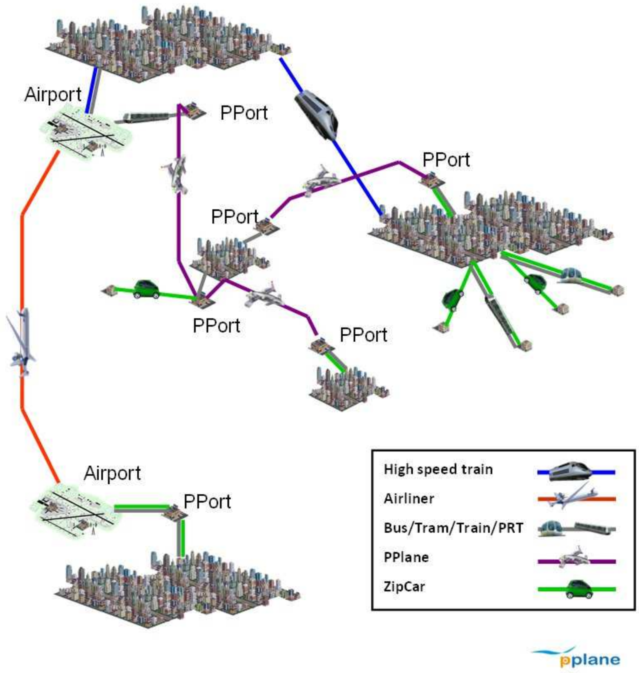

Figure 5: PPlane as an element of a multimodal transport system

Since the "non roadable" option has been chosen, PPort would serve as airstrip for take-off and landing. Ground transportation (Zipcar or public transport) would bring the passengers to these PPorts.

Figure 6 shows the highest scoring scenario for non-roadable vehicles. In this scenario, PPlane will be used for the air segment only; a ground vehicle would be used for the terrestrial part of the trip. A 4 to 6 seat plane is considered and it will be equipped with a number of electric engines. The trip will consist of a few stopovers or a single leg depending on the distance to be covered.

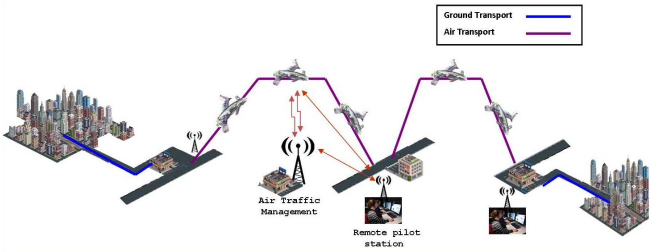

Figure 6 : Non-roadable PPlane system

Both the current state of the art for aircraft equipment and future trends have been analyzed with a focus on data network. The team has prepared an early version of the Functional Hazard Assessment (FHA) and definition of urban operations for the preliminary PPlane architecture. A first phase of “airport security plans” was also prepared.

During the first year of the project, inputs were collected from the project’s partners, which enabled building an ontology containing the main items concerned with operational and environmental constraints induced by the automation of a PATS. The purpose of this procedure was to agree on a common understanding of the issues to be solved.

Human Factors (HF) are an important and integral part of the PPlane work-plan. The preliminary operational concepts of PPlane are based on the operation of small aircraft controlled from the ground and designed to carry passengers to their desired destinations. Although the pilot is not on-board, a large number of HF issues are associated with the revolutionary operational concept of PPlane and need to be investigated and evaluated. In order to collect HF data, an online survey and two complementary HF experiments took place, focusing on different issues. The results of this survey and experiments are incorporated into the planned study.

Environmental constraints and their effect on the choice of PPlane’s operational concepts and scenarios were also studied. Several tools have been developed in order to better analyze the acoustic and chemical impact of PATS. An emissions model has been developed to compute the chemical emissions for a given type of plane. The propulsion systems that were considered include:

- single and multi diesel engine for standard aircraft configurations;
- single and multi diesel engine for aircraft with STOL (Short Take-Off and Landing) capability;
- single diesel engine for VTOL (Vertical Take-Off and Landing) configurations;
- multi-engine turboprops for standard aircraft configurations.

The emission model excludes hybrid and fully electric engines. The hybrid option could be analyzed using one of the systems above, with reduced operational time for the flight phase. The full electric engine would have almost no direct impact on the environment.

As the PPlane system features communalities with unmanned aircraft systems, a generic UAS ground station simulator has been transformed into a PPlane RPS. This station is coupled with a user interface in order to simulate the pilot/passenger exchange.

3.1 Air Traffic Management

3.1.1 Introduction

During the first phase of the analysis, a more global approach has been used to define the air traffic management system that is needed to operate a large number of personal planes in a busy airspace, while sharing resources with the other airspace users. The concept of operation that is proposed is based on the “4 dimension contract” idea that has been developed in the IFATS project [3]and that is being analyzed in the on-going 4DC-Co project [4].

Figure 7 shows the results of the preliminary analysis. The PPlane vehicles would utilize high density 4D operations airspace, supported by a dense networked environment. This includes an air-to-air network (illustrated in yellow) and a ground-to-air set of links (illustrated in blue).

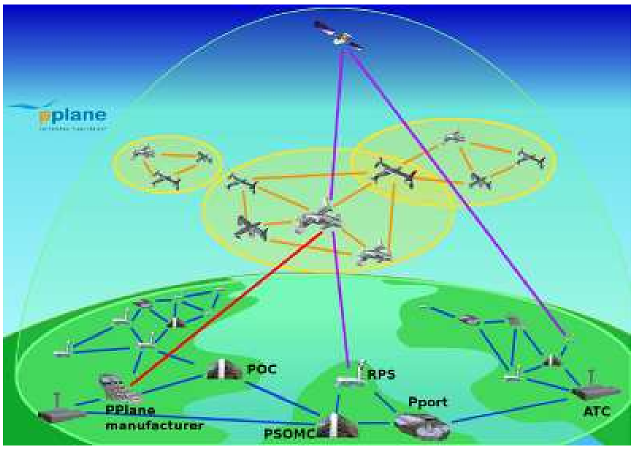

Figure 7: PPlane Network Centric Architecture

3.1.2 Strategic planning

Figure 8 shows the PPlane System Operation Management Centre (PSOMC), generating and managing the 4D contracts at the strategic level (before the flight).

The sequence of operations is as follows:

- The PPlane operators centres (POC) send contracts requests to the PSOMC;
- The PSOMC is in contact with the ATC (to check capabilities of contracts with the ones that are managed by ATC), with PPorts (to check availability and capabilities and/or capacity), with the ATS data base (for weather forecast, special use airspace activity information, NOTAM…) and with RPS (for current operation data);
- The network centric architecture enables the PSOMC to generate 4D contracts taking into account all the requirements that are being made. This "strategic planning" is ideally made in several steps, from well in advance to several hours before the flight in order to accommodate all demand in an efficient and safe (meaning "coordinated") way;

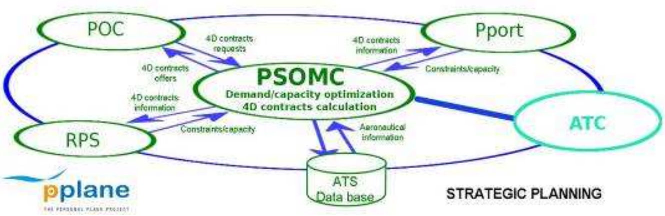

Figure 8: PPlane strategic planning

- Conflict-free 4D contracts are generated at a global scale for international airliners and regional scale for short haul PPlane aircraft, taking into account PPlane operators requests and PPorts capacity, under the management of the PSOMC;
- 4D contracts are updated just before the flights.

3.2 Emergency management

In case of emergency, there is no time for contract renegotiation. In that case, the PPlane in question uses its own information about the local traffic; permanently provided thanks to the local air to air network

It self-generates a short term conflict-free flight path to deal with the emergency.

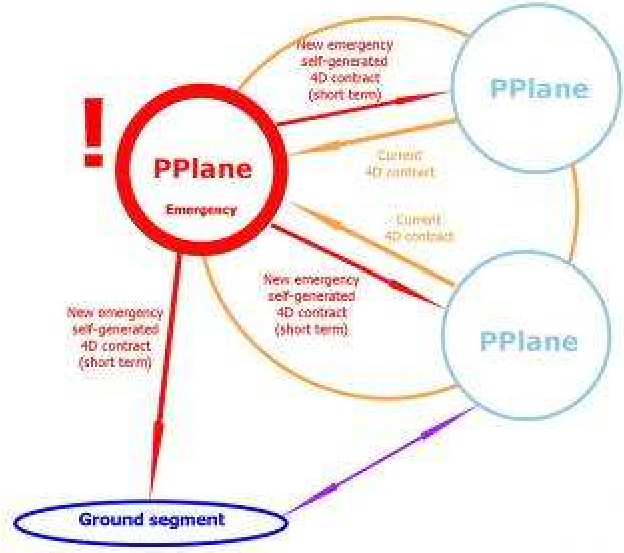

Figure 9: Emergency management

In the situation illustrated in Figure 9, we consider that the PPlane has an urgent need to change its flight path (for example if a passenger has an urgent health problem).

In this case, the PPlane in question uses its own situation awareness (local network):

- Upon request from the passenger to the RPS, or even through a specific onboard command, a request for a rapid change of flight path is generated. The on board PPlane system self-generates a temporary conflict-free flight path thanks to the knowledge it has from neighboring aircrafts;

- It broadcasts information about this flight path to the surrounding aircrafts and to the ground segment in order to maintain a conflict free situation;
- It asks the ground segment for a new long term 4D contract when the emergency management state allows time to do so.

3.3 Social acceptance

3.3.1 Introduction

Social acceptance of a transport system depends mainly on actual and perceived safety of the system.

Regarding actual safety, it is obvious that such a system needs to be designed according to standards carefully defined to guarantee the level of safety that will be requested by authorities. This requested level of safety will not be lower than the one currently required for public transport airlines.

Perceived safety is a more complex issue as it deals with human perception based on many types of information. Basically, the PPlane will first be perceived through the preliminary analysis of the measures that are taken to provide adequate safety. Then, its hazardousness will be shaped according to the events that might occur, and especially through their explanation.

Although safety is a primary concern for social acceptance, acceptability is also important, mostly by people that do not use the system, but have to endure the potential nuisance of such a system (noise, pollution…).

3.3.2 Actual safety

Unconventional PPlane system with high level of automation is expected to use the 4DCo (4D contracts) principle that should provide conflict-free trajectories with all cooperative aircraft, backed up by RPS. Their impact on safety was analysed in order to lower the risk of critical failures to an acceptable level. As expected, for the PPlane system, most of the critical functions revealed during the assessment were related to flight (flight control system of the air vehicle) and emergency systems. Conclusions indicate that careful design using practices leading to high reliability should enable creation of safe PPlane system.

Today, accidents caused by humans are a major part of the total number of aviation accidents. In fact, depending on the aircraft class, technical failures as a cause of an accident are only around 10% of all causes ([5] indicate around 16% of all accidents contributed to “mechanical/maintenance” problems, and only around 8% of fatal accidents related to the same cause). Therefore, a higher level of automation (when properly designed) can lead to improvements in safety.

Another important issue that arises from the use of RPS is the safe and secure data transmission through air data links. This issue opens a brand new area of protection against unlawful use. This is not related to simple reliability as it was known on conventional aircraft; it therefore requires new approaches and technologies.

Despite potential problems, higher automation shows promising potential to enhance safety in future transportation systems.

3.3.3 Perceived safety

As described earlier, automation in aviation has reached all the safety goals assigned in the 1960s. There is now a consensus that no-one should design a modern aircraft with less automation than the current glass-cockpit generation.

Safety statistics show that automation has contributed greatly to the current level of safety: the accident rate of recent aircraft is half that of the previous generation of aircraft. The global level of safety now appears to be equal to that of the nuclear industry or railways (in Western Europe). The only apparent concern is that this remarkable level of safety has not significantly improved since the 1970s: some aircraft still have catastrophic accidents killing hundreds of people every year. Those accidents are very often due to human errors.

Safety is mainly perceived by the community through these catastrophic accidents that appear on the news. The strong belief of the PPlane team is that human errors can be easily handled if humans have a supervisory role only, having to intervene only in particular situations.

In that case, the safety level of the system is determined by the safety elements of its design. Consequently, the design of the PPlane system should reduce significantly the rate of accidents

The possible problem we may have with the introduction of the PPlane system would be to have accidents in the early life of the system. These accidents could compromise building confidence in the system although there would be means to make the system better and safer along the years, as it has been the case since 1903 (first flight of the Wright Brothers) for manned aircraft in aviation.

Once this initial period is over, we expect a low number of problems due to automated systems, enabling a smooth social acceptance of this efficient and safe system.

This situation means that the design of an automated system such as PPlane has to be done considering the very large emphasis that will be put on any accident, and even incidents, no matter how small, that could compromise human life.

One way to deal with the safety issue is to propose a transition period whereby PPlane will be used to carry cargo only and no passengers. This period can be used for detailed analysis and suggested improvements that will be implemented in the system prior to passenger transport.

The recommendations of the PPlane team are:

- to set a high level of reliability on all system components;
- to design the systems through a thorough safety and security approach;
- to define a comprehensive set of simulation tools able to verify and validate, in a wide variety of situations, normal and emergency, all the software and hardware that will be used in the system.

As a result, the PPlane system will be in line with the following statement from a report that has recently been published: “It should live up to the highest levels of safety and security to ensure that passengers and freight as well as the air transport system and its infrastructure are protected.” [6]

3.4 Environment friendliness

Any novel mean of transportation that is proposed nowadays has to be environmentally friendly.

In a recent report [6], a statement is dedicated to environment “It should also help to reduce aviation’s impact on citizens and the environment. Aviation has an important role to play in reducing noise as well as greenhouse gas emissions, regardless of traffic growth. Aviation must move towards more sustainable energy sources”.

This calls for “a combination of measures, including technology development, operational procedures and market-based incentives

The preferred PPlane concepts are in line with the ideas highlighted in this report. A real new generation of air vehicles, fitted with ever-more efficient, environmentally friendly and quiet engines is proposed. The engines of these concepts cover the range of fully electric and hybrid (electric with traditional or advanced diesel engine) configurations, which will significantly minimize the chemical emissions and the noise at the airport surroundings as well as during the cruise phase. In addition, the design of the propellers are oriented towards a trade-off between noise and performance and their installation (buried in the wings), for a number of concepts, will further lower noise emission. Finally, advanced aerodynamic design is also envisioned, which on one hand would decrease the aerodynamic noise, while on the other hand would reduce the drag, and therefore the fuel consumption and the chemical emissions.

The proposed 4DCo based air traffic management system; will provide a range of services to handle the PPlane fleet together with the other types of airspace users, such as UAS, airliners, military aircraft and leisure aviation planes. A coherent ground infrastructure is also proposed; it includes PPorts with the relevant servicing and connecting facilities to other modes of transport that will link the cities and towns to these PPorts. Operations to specific PPorts would guarantee that the added traffic of PPlane would not lead to increased congestions, delays and therefore environmental impact at the presently congested “traditional airports”.

4 Conclusions

PPlane is a research project funded by the European Commission with the aim of defining a viable Personal Air Transport System of the future (2030 and beyond).

In order to assess such a system, the PPlane project team has considered all aspects of a new transportation system:

- Technical issues: types of aircraft including a description of key features such as propulsion, command and control systems. This includes an analysis of the challenges of the very high automation that is needed for such a system;
- Operation: system definition and operation, identification of users needs and expectations, integration to the current (air and ground) transportation system, management of abnormal situations;
- Social issues, covering safety and environment concerns.

The final results and recommendations of the project for the implementation of a PAT system should be available later this year.

In summary, the PPlane project is an important milestone in the long road towards a revolutionary personal air transport system. The analysis results and recommendations from PPlane will be useful to continue the European effort to pioneer the air transport of the future.

In the long run, the successful introduction of PATS will ensure the mobility of people and goods, fostering safe and secure commuting, while fighting to reduce the unwanted effects of environmental damage, social gap and economic “dysfunctions”.

References

[1] NTSB – Aviation accidents statistics (http://www.ntsb.gov/aviation/Table1.htm)

[2] US congressional report, Jeremiah Gertler, January 2012

[3] IFATS – Innovative Future Air Transport System – FP6 European Commission project

[4] 4DCo-GC – 4 Dimension (position and time) Guidance and Control – FP7 European Commission project

[5] AOPA Nall Reports – Published every year by the Aircraft Owners and Pilots Association

[6] “Flightpath 2050 Europe’s Vision for Aviation” report of the High Level Group on Aviation Research – Published by the European Commission

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For further details please access the project Website: http://www.pplane-project.org/

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