# SAFETY ASPECTS OF THE PERSONAL AIR TRANSPORTATION SYSTEM

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## Abstract

*This paper defines the safety aspects / safety problems of the PATS (Personal Air Transportation System) and their possible solution. Such system opens a new market considerable different from the general aviation. The personal aircraft will be operated by less-skilled pilots (owners, renters) at the small smart airports located close to the city centre and mostly in the uncontrolled airspace. Therefore the PATS developer must solve several unique safety problems. The philosophical approach to PATS safety must based on the specially developed operational concept including the well developed automation, pilot full assessment system, distance (ground) control at least for emergency situation and sophisticated (technical and administrative - financial) support.*

## Introduction

In practice, the needs in transportation systems are rapidly increasing. The high-speed railway transport and intelligent highway concept are not only the solution of future transport. Therefore NASA has initiated his Small Aircraft Transportation System (SATS) Project [1, 2, 3], and EU has supported some projects like EPATS (European Personal Air Transport System) [4], PPLANE (personal Plane) [5], etc.

The Author (supported by the group of well known scientists working together in Organizing and Scientific Committee of series of International Conferences on the Unconventional Flight) gave a lecture at ICAS 2002 introducing the name of PATS (Personal Air Transportation System) and defining the structure of the PATS developing project [6]. The author plays leading role in developing a safety philosophy for small and personal planes in SAFE-FLY project that is supported by national found.

As of 2010, the technology is ready to develop a new, economic [6], and environmental friendly aircraft for the so-called less-skilled pilots (owners or renters having all the required licenses but flying not so often). In the view of this, the EU EPATS project [4] predicts that in 2020 about 50 million flights pro year will be performed by small aircraft. Such rapid development would call for about 150 000 - 180 000 new small aircraft in Europe, only [4]. Those aircraft will be operated by less-skilled pilots at the small smart airports located close to the city centre and mostly in the uncontrolled airspace. So, the new system requires new aircraft, new set of smart airports, new air traffic management, new technical, administrative and financial systems specially developed for this new business area. Therefore the PATS developer must solve several unique safety problems. The philosophical approach to PATS safety must based on the specially developed operational concept including the well developed automation, pilot full assessment system, distance (ground) control at least for emergency situation and sophisticated (technical and administrative - financial) support.

Even the European Commission has recognized the important future of the new small aircraft transportation system and call up the attention on its required development [7].

This paper aims to identify the safety aspects / safety problems related to the coming PATS and to develop their possible solution.

## 1. Some conclusions from the aircraft accident statistics

The analysis of the aircraft accident statistics makes possible to understand the flight safety peculiarities of the airlines and GA (general aviation) that may useful in identification of the PATS safety aspects. The most interesting conclusions from such analysis [8] are the followings.

At first, the reasons of the aircraft accidents [9] are the same for the airlines and general aviation, namely

- about 80 % of accident initiated by the human errors, half of them accountable to the pilots;
- aircraft accidents are generated by the complex effects of structure features, peculiarities of the pilot, air traffic and the surroundings;
- as usually the accidents are initiated by 3 - 6 different major failures or errors;
- *the probabilities of the second, third and the following errors are depending on the previous errors and might even be 30 - 80 times higher;*
- the special distribution at the left or right hand side (tails) of the empirical density functions related to the system characteristics plays a deterministic role in the accidents;

At second, from the flight safety point of view, there are not so big different in small and larger aircraft operation because

- the longest part of the flight (with about 50 - 80 % of flight time) is the cruise phase, which only accounts for 5 - 8 % of the total accidents and 6 - 10 % of the total fatal accidents;
- the most dangerous phases of flight are the take-off and landing;
- so, the different air transportation modes (e.g. commercial, general aviation) should have approximately the same flight risk; or at least the same accident rate for the number of flights.

At third, the general aviation has some major peculiarities [10, 11], like

- the GA has about 10 - 35 times greater accident rate (accident per 100 000 flight hours) than the commercial flights; however, the fatal accident rate of GA is only about 2,5 - 3 times greater than the same rate for the commercial carriers;
- the GA accident rates are highly depending on the type of operation; the corporate and executive aircraft operated by professional pilots are not more often involved into accidents than the airlines' aircraft;
- the AOPA (Aircraft Owners and Pilot Association) Air Safety statistics shows that *more than 70 % of GA accidents and fatal accidents are caused by personal pilots, while they flew less than 50 % of total flight time;*
- the fatal accidents per 1000 licensed pilots (Fig.1.) – partly characterizing the role of pilots (because the human factors) in the fatal accidents – are nearly the same for GA and airlines, by considering that airlines' aircraft are piloted by two pilots, while the GA aircraft are rather operated by one, and airlines' pilots are also more supported with different services (e.g. air traffic control);

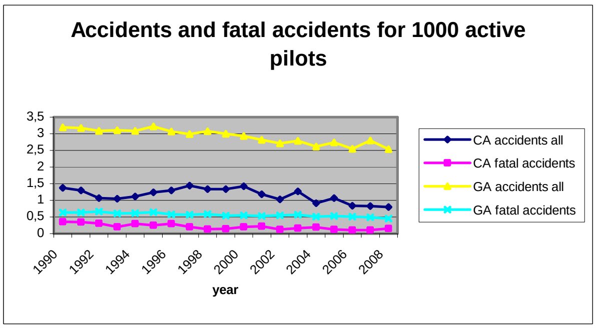


Fig. 1. Accidents and fatal accidents for 1000 licensed active pilots

- *the accident rate of private pilots is "only" twice higher compared to airlines' pilots, while GA commercial pilots are nearly four times more often involved into different accidents. As for the accident rate per 1000 active pilots, the safest flights are statistically made by student pilots [11].*

Finally, according to the skill of pilots, the following specific features must be taken into account:

- pilot skills can be divided into two different classes: hard and soft skills (hard skills means that the pilots know all the regulations, rules, technologies required for a safe operation, they have enough information on the theory of flight, performance and system characteristics of the given aircraft, operational conditions including the airport, weather, etc. limitations, rules / technologies of using the airspace and they can perform a flight safely e.g. define the flight plan, use the flight procedures, control the aircraft, use communication and information systems; while the soft skills are mainly defined by human personal characteristics, e.g. the pilots know everything that is required to have hard skills as it evaluated during flight tests - examination for licensing, but due to their actual psychophysical or mental conditions, as well as their own habits, they are not flying as it would be required; or they do it because they have limited practice / knowledge about the risks and emergency situations, or they believe more in their ability than it would be reasonable);
- less-skilled pilots are pilots with a license, but (i) having less practice or less information about the flight conditions, (ii) making false decisions,

(iii) overestimating their own ability or, (iv) just being negligent;

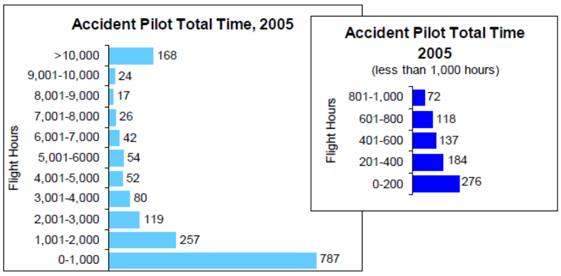


Fig. 2. The distribution of experience among accident pilots

- appears of the real accidents depend on the soft skills (for example, it might surprise experts, but *each tenth GA accidents are caused by pilots having a total flight time of more than 10 000 hours; on the other hand*, according to the investigations of the NTSB (Fig.2.) [11], from the accident pilots whom total flight experience data was available, 48% had 1,000 or less total flight hours; furthermore, *pilots having less than 200 flight hours are took part in 17 % of the accidents. 88 % of these accidents were made with a single piston engine aircraft);*

By the way the GA is a very large part of the aviation. For example in 2005, 215 837 aircraft, about 91 % of the US operated civil aircraft belonged to GA [11]. 211 940 GA aircraft were so-called active. According the statistical records of 2001 [11] more than 18 000 landing facilities served the US GA operating air vehicles from the one-person "ultralights" or powered parachutes up to the large or small business jets. GA aircraft were operated by 600 000 certified pilots and served 77 % of all air traffic with transporting approximately 180 million passengers in different aircraft sizes for business and personal reasons. The US GA accounted for over 637,000 jobs, with nearly $20 billion in annual earns, while its direct and indirect economical impact is exceeded to be $102 billion in different aircraft sizes for business and personal reasons.

## 2. Theoretical considerations

In a very general case, the safety is aimed to protect the human life. This approach includes the interaction of the societies and policies, direct effects of constructed technical systems on the individual human life, environment protection and natural disasters [12].

The modern safety sciences define the emergency situation [3-5] as any unplanned event or situation that has disadvantageous effect on the human life directly or indirectly through debasing the life quality and human life conditions. Generally, the emergency situation endangers the human life, material essentials, cultural values, nature and living world or even estate. The disadvantageous effects caused by emergency situations can occur directly (immediately) and indirectly (after short or even long time). The occurrence probability of the emergency situation is called as risk or hazard. Reasons “helping” in occurring the emergency situations are the risk factors.

The opposite category to emergency is the safety that situation in which the human life and property are saved. The safety can be defined as economic, criminal, society, political, environmental or military safety.

*So, the emergency is a lack in safety.*

The emergency management [13] is a set of instruments, technology, methods and procedures applied for protecting the human life and property. This is a process reducing the loss of life and property and protecting assets from all types of hazards through a comprehensive, risk-based, emergency management program of mitigation, preparedness, response and recovery.

Shortly, the emergency management is used to minimize the risk and losses associated with emergency situations occurring.

Safety and security are the twin brothers. The difference between them could be defined such as the follows:

Safety: avoiding emergency situation caused by ***unwanted*** system uncertainties, errors or failures appearing randomly.

Security: avoiding the emergency situations caused by ***unlawful*** acts (of unauthorized persons) – threats.

Safety related investigations start as early as the development of the given system. At the definition and preliminary phase of a new system, one should also concentrate some efforts on the (i) potential safety problems, (ii) critical situations, (iii) critical system failures, (iv) and their possible classification, identification. After the risk assessment, the next step is the development of a set of policies and strategies to mitigate those risks. Generally, the safety policies and strategies are based on the synergy of the followings:

- physical safety (characteristics of the applied materials, structural solutions, system architecture that help to overcome safety critical – emergency situations,
- technical safety (dedicated active or passive safety systems including e.g. sensors to enhance situation awareness),
- non-technical safety (such as policy manuals, traffic rules, awareness and mitigation programs).

The safety of any systems can be evaluated by using the risk analysis methods. Risk is the probability that an emergency situation occurs in the future, and which could also be avoided or mitigated, rather than present problems that must be immediately addressed. Risk (in statistics) is often mapped to the probability of some event which is seen undesirable. The probability of such event can be determined by the combination of believable scenario and expected outcome. Scenario contains the set of risks that might appear, while risk is the probability (expected value) of the outcome related to a given event.

There are many different methods developed for the risk analysis (Fig. 3.). In air transportation systems, the flight risk is associated to the probability that an incident, accident, or a series of accident occurs defined by authorities.

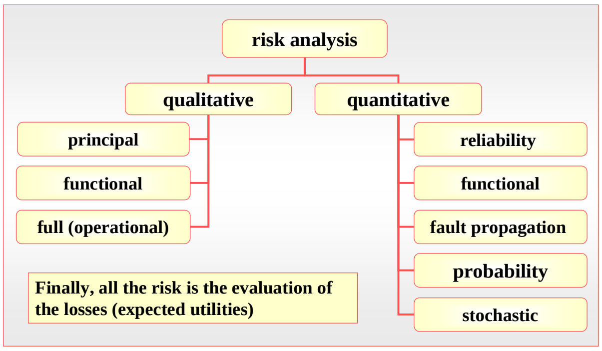


Fig. 3. The classification of the risk analysis methods

As a first thought, risk analysis might not be seen too complicated (like the determination of the system reliability), but generally it is rather a very complex task that needs knowledge in many different fields, for example basic sciences (mathematics, physics, mechanics, materials sciences, etc.) engineering and special sciences (as stress analysis, aerodynamics, flight dynamics, and so on) and additional sciences (system engineering, like psychology of operators, meteorology).

An interesting problem of risk analysis is the interpretation of the applied merit – the probability that an unwanted danger event occurs. In practice, the probability has four slightly different interpretations:

- classic - the unwanted event,
- logic - the necessary evil,
- objective - relative frequency,
- subjective - individual explanation of the events.

Many different methods and software can be used for risk analysis, ranging from the simple system reliability theory, event-tree, fault-tree, up to the complex stochastic methods. PPlane concept develops a pioneering technology that has two major attributes related to risk analysis. Firstly, there are no initial statistical data on the accidents of the newly designed airplanes flew by less-skilled pilots. Secondly, the pilots of the new airplanes will or might have limited practices, and therefore their decisions will depend more on the subjective evaluations than in the conventional cases. Risk analysis in such cases can be made with stochastic models combined with subjective analysis.

## 3. PPATS safety aspects

PATS is a complex system including:

- new small and smart aircraft developed especially for personal use,
- new net of small airports including improved existing GA airports, adapted conventional airports, and newly developed airport laced close to the city center,
- net of service providers e.g. ATM, rent a plane system, technical workshops, supporting units, etc.

The organization structure, working conditions and harmonization of the operational processes of the system elements are defined and developed from the PATS operational concept.

The specification of the system elements (e.g. geometric, aerodynamic characteristics, flight performance of the new small aircraft, behaviors of the special airports) might not directly derive from the operational concept. The user needs could determine a series of the system elements, for example the class of aircraft (fix or rotary wing), the type of propulsion system (piston, turboprop, jet), the desired cockpit instruments / features (e.g. ILS, unpressurized or pressurized cabin), or the category of the airport (e.g. special small aircraft dedicated to PPlane, adapted traditional). However, the operational concept should define the basic rules of using the system elements mentioned above, and the relationships between the stakeholders

The starting point of PATS operation is the personal travel demand. Once there is a demand, real PATS operations would be a function of e.g. cost, door-to-door time, affordability, safety and security. These driving factors would determine the major characteristics of the system (e.g. the type of aircraft, airport, ATM related services), since for example a high door-to-door time would require airports to be placed closer to the city centers, where land is more expensive, and environmental impact is more in focus, which therefore would lead to small and low cost operations (control tower-less airport without primary surveillance systems). On the other hand, to limit the environmental impact, special flight procedures, traffic rules, and flight operational technologies could be needed.

Such system should be developed with original solutions using the latest technological achievements, as PATS – as indicated above – is a complex and large system composed from several elements that might have thousands of errors, failures and deviations in its system parameters.

PATS has many safety aspects [14], which could be classified into the following groups (Table 1.): (i) general (e.g. innovation system, innovation process management, certification, society acceptation), (ii) development (e.g. operational concept, development philosophy, knowledge, technology), (iii) airport (e.g. geographical position, size), (iv) aircraft, (v) airspace, (vi) maintenance (e.g. airspace design, flight plan, surveillance, air traffic control, air traffic rules), (vii) support (e.g. training, ownership, rent a plane), (viii) additional safety aspects (e.g. system integration, sustainability, solution for the security problems).

The PPlane project identifies the major safety aspects, describes their shows some examples related to the given aspects (Table 2.) and even gives possible solutions. Seeing the high number of safety aspects, the table contains many different information as for example auto healing materials, MEMS technology, care-free control.

Due to the page limitations, this documents is not describing each of these aspects with their solutions.

Table 1. Major safety aspects

| No. | Area | Major problem |
|---|---|---|
| 1. | | **General** |
| 1.1. | Innovation system | Lack in innovation system helps in development of the safe personal transportation system |
| 1.2. | Certification | There are not clear certification rules for the personal air transportation system |
| 1.3. | Society acceptation | Some policy makers and institutions apprehend the using the personal air transportation system |
| **2** | | **Development** |
| 2.1. | Operational concept | There is lack in operational concept for the European PATS |
| 2.2. | Development philosophy | A lack in development philosophy and system |
| 2.3. | Knowledge | Methodology |
| 2.4. | | A lack in original and tested new ideas, solutions. |
| 2.5. | Technology | A lack in new technologies |
| **3** | | **Airport** |
| 3.1. | Position | There is not a suitable airport net for the SATS |
| 3.2. | Size | Smart city airport must/may have limited land |
| **4.** | | **Aircraft** |
| 4.1. | Aerodynamics | New aerodynamic design method is required. |
| 4.2. | Propulsion system | The new small aircraft need new smart and green engines. |
| 4.3. | Flight performance | Required flight performance origins from the operational concept. |
| 4.4. | Aircraft stability | Stability of the unconventional form; stability depending on the loading. |
| 4.5. | Aircraft control | Use of aircraft control system by the less skilled pilots |
| 4.6. | Aircraft control | Full support of the less-skilled pilots even by automatic (remote) control |
| 4.7. | Aircraft structure | Using new structural solutions |
| 4.8. | Cockpit | Redesigning the cockpit for less-skilled pilots. |
| 4.9. | Communication System | New communication system is required (as specially for remote control) |
| 4.10. | Pilot decision support system | Problems of pilot decision making. |
| 4.11. | Aircraft systems | Developing the simplified and low cost solutions for aircraft systems |
| 4.12. | Flight operation | Supporting the less-skilled pilots in flight operation |
| 4.13. | Passenger (ride) comfort | Passengers and even pilots may have problems in case of low ride control |
| 4.14. | Aircraft design and production | There is a lack in good designer and producer organization. |
| 4.15. | Line up service | Line up service and maintenance |
| 4.16. | Aircraft maintenance | Maintenance manuals and technologies for PATS |
| 4.17. | Aircraft repairing modernization | Overhaul (repair) technologies and ways of possible modernization of the PATS. |
| **5** | | **Airspace/ATM** |
| 5.1. | Airspace design | New airspace design methods are needed |
| 5.2. | Flight plan | Flight plan development |
| 5.3. | Surveillance | Passive and actives surveillance technology |
| 5.4. | ATC, traffic rules | PATS traffic control and control rules |
| **6** | | **Support** |
| 6.1. | Training | Pilot training |
| 6.2. | | Operator training |

| | | |
|---|---|---|
| 6.3. | Ownership | The personal aircraft might be own by private persons or group of persons (sharing ownership). |
| 6.4. | Rent a plane | Personal aircraft can be rented by private persons |
| 7. | **Additional safety aspects** | |
| 7.1. | System integration | PATS integration into the general transport system and economy. |
| 7.2. | Sustainability | Sustainability of the PATS elements (not only aircraft) |
| 7.3. | Solving the security problems | Solutions of the security problems may have influences on the safety. |

Table 2. Examples of descriptions of several safety aspects

| No. | Area | Description | Examples |
|---|---|---|---|
| 4.8. | Cockpit | The cockpit and its instrumentation must be considerable redesigned with using the latest technologies (as synthetic vision of full airspace around the aircraft, or color weather information) as well as with implementation of the developed pilot decision support for less-skilled pilots | errors in communication, characteristics measurement and displaying, wrong solution for information displaying, errors in support the pilots with information about the aircraft position, situation awareness, etc. |
| 4.9. | Communication system | The non-professional, less-skilled pilots are less-skilled in communication, too. They may have a problem with English phonetics, using the radio, etc. On the other hand the PATS will use the distance (remote) control at least in emergency situations that needs wide bandwidth, high speed communication, datalink. | Errors in communication, understanding the transferred information, noise, accuracy of information transferred may generate risk, and risk associated with the a lack of information transferred in time to the distance controller. |
| 4.10. | Pilot decision support system | The lest skilled private pilots and the remote controllers, pilots may have more soft skill need a sophisticated decision support systems. | risks associated with the shorting the time for decision, errors in subjective analysis and evaluation of situations, errors in chosen decisions, errors made by pilots loosing their orientation, etc. |

## 4. PATS safety philosophies

The philosophical approach to solve the safety problems of PATS [14] could be based on the

- carefree technology (originally developed for the military aircraft),
- H-methafor, as analogy with horse driving and
- analogy to car driving as accepted level of technical system controlled by common persons.

The control of civil and military aircraft (especially the fighters) is considerably different [15]. Principally in both cases the trained pilots are in the loop, but the civil aircraft are – so called – unmaneuverable aircraft not using all the areas of the flight and load envelopes. For the civil aircraft, the handling qualities, the avoidance of the critical regimes and the optimizations are the most important tasks. On the other hand, for the military aircraft, the maneuver characteristics, the flight mode optimization, the enhanced flight and load envelopes, the control on critical regimes, and the solution for the departure / recovery problems are also essential. So, for the military aircraft control design, a new term, the so-called "carefree handling" was introduced. It means the reliable limitation of commands from a trained pilot to keep the aircraft within the allowed envelope, to avoid departure, and to prevent aircraft overloading leading to pilot unconsciousness [16].

It seems little bit strange, but the carefree principle developed for assisting the well trained pilots, can be applied to the solving the less-skilled or/and less disciplined pilots, too. In this special case, the carefree idea must be applied for integration of the less-skilled pilots with their computers. The computers, as virtual captains are continuously monitoring the works of pilots, avoiding them to use the flights modes close to the critical regimes and even the computer can overwrite the pilots' commands if the realizing the commands may generate dangerous or emergency situations.

The carefree handling technology initiated with simple autopilots through stick shakers/pushers. In autopilot mode, pilots have limited command authority, "the computer flies the aircraft". The modern technology can provide fully automatic control, including recovery from dangerous situations. Therefore, today the control also deals with the coordinated motion of the centre of gravity of aircraft, while the 20-year-old control makes the coordination for the rotation around the centre of gravity. In the carefree mode, the computer is only monitoring and limiting how the pilot flies the aircraft. Because the high complexity of the fully automated control, an aircraft is often only carefree with respect to some critical parameters.

Generally, the maximum controllable areas of the flight and load envelopes are highly depending on the flight condition and configuration. Therefore, many input parameters are needed to guarantee the reliable limitations.

Depending on the applied control philosophy, the control of a characteristics could be made by two different ways [16]:

- Passive, with no control law change: a pure warning system (mostly acoustic) giving information about the distance to the actual boundaries of the flight envelope, in order to enable the pilot to control the aircraft closer and safer along these boundaries. Even this passive, and relatively simple systems can highly support the pilot, however, in many accidents such warnings were simply ignored.

- Active, with control law changes: an active limitation system is more complex and therefore considered to be more risky, but it offers better performance and increased safety. Naturally, carefree handling always requires active systems.

The effective carefree handling characteristics could enable [15, 16] for example (i) a higher success of the mission, (ii) a full concentration of the pilot on his primary goal, (iii) a more aggressive command inputs, while using the greater or even full flight performance, (iv) a reduction of the risk in human – machine interaction, or (v) a reduction of structural load factors. On the other hand, the development of carefree handling is more complex due to the additional software, the testing, and confusion in the pilots who prefer to have the full control in their hands.

The carefree control philosophy – the limiting the pilot actions – may result to set up the limitation adapted to the actual pilot's level of expertise.

Another appealing and useful philosophy is given by Moore [3]: "the sentience of a horse in that it is an intelligent vehicle that "sees" the environment, shares its intent with neighboring vehicles, "feels" the flow over its wings, senses its internal health, and communicates with its user. Instead of a user being required to instruct the horse along a specific path, the user is able to provide the 'intent' while performing higher level tasks that the horse could never perform effectively. From these perceptions, the sentient vehicle develops an integrated awareness of its situation and autonomously plans and executes a course of action that appropriately satisfies the user's directives. The resulting vehicle's capabilities will enable at least automobile levels of safety and convenience, while providing a balance between user control and security."

The H-methafor may go back to far. Safety philosophy of personal aircraft can be based on a simple idea: the aircraft control should be simplified to the level of driving a personal car. Such supporting system might include the following features: voice check-list, automatic situation awareness, flight path prediction, automatic recovery, or even switch to full automatic / distance control.

Finally the third approach is directed to develop a system can be operated by the common persons on level that is accepted and used by them everyday [6]. As it had been introduced that is a road transport known an used by everybody.

As mentioned, PPlane or personal aircraft is expected to be used by less-skilled, common persons in different ownership or rent-a-plane operations in the uncontrolled or unmanaged airspace, between small airports placed close to the city center that provides limited services. Under these conditions, there are several solutions for the control system [6, 14]:

- fully automatic intelligent control system, leaving the pilot out of the control (while it is technologically feasible and in the personal aircraft community it is often considered to be the best solution, the society does not ready to accept fully automatic systems. In addition, such operations might even lead to juridical problems once an accident occurs),
- distance control performed by well trained pilots from the ground (it would mean less human problems, but still, the majority of the accidents are expected to be caused by the humans),
- on-board control by less-skilled pilots (with the development of a supporting system to facilitate the duties of the pilot),
- combination of the third solution with the second or the first (with automatic monitoring of the pilot's work-load / condition with the possibility to switch – if needed – to distance or automatic control).

This last scenario seems more realistic, since it is expected that personal aircraft owners or renters would like to pilot their plane.

The difference between the less-skilled pilot and experienced remote pilot is not as much as it seems, since by not sitting on the plane, the attention of the remote pilot could be diverted. Therefore, both operational scenarios require advanced supports, for example info-communication, situation awareness, decision making, and simplified control.

The previously identified safety aspects are leading to the formulation of *the PATS safety philosophy, or strategic plan for the future de-*

*velopments and tasks to be solved*. PATS safety philosophy could therefore be given in the following form:

- development of a safe personal air transportation system using limited technological background (at tower-less small airports close to the city centre without conventional primary surveillance system, and flights mostly performed in uncontrolled / unmanaged airspace) by less-skilled pilots,
- decreased technological level that is comparable to road transportation and to the difficulty of driving a personal car,
- advanced info-communication system, automated situation awareness and decision support,
- possibility to switch to fully automatic system in case of emergency.

PATS needs new, revolutionary solutions [1, 2, 3, 6], in which all the system elements are radically improved, or even redesigned.

## 5. Possible solutions

The application of the above mentioned philosophical approach to the personal air transportation system leads to the following system improvements.

### *PATS development*

The PATS [6] is a very complex system including the (i) new small, low cost and highly automated aircraft, (ii) new set of smart airports), (iii) new forms of active ATM (including free flights, full automation and / or aircraft remote control), (iv) new forms of supporting (rent a plane system, share ownerships, financial support for owners, set of service providers, etc.).

### *Airports*

Aircraft development is investigated on the high level and many projects are running with aim to developing new personal aircraft. In SATS program, US has focused the activities on the demonstration of the system, demonstration of the operational concept. Therefore, the SATS program did not develop new airports, it has predicted to improvement of the set of small airports and utilization of the middle size airports.

In Europe, population density is higher, the distances between the cities and towns smaller and high speed train system is more developed then in US. So, the door – to – door speed is more important indicator for Europe and the PATS can be attractive, only, if the airports would be close to the city centre. Therefore new airport set must be developed.

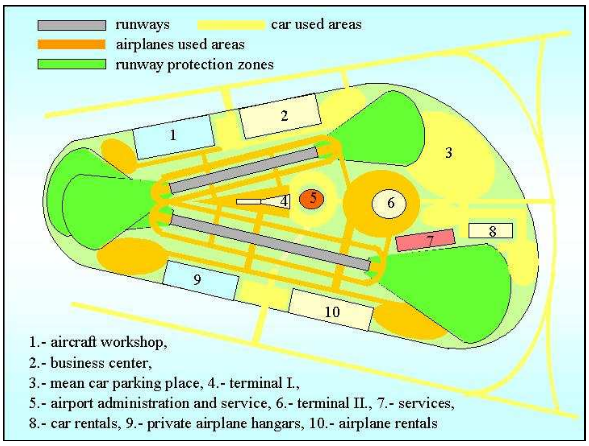


Fig. 4. Vision on the new small airport

*The PATS airports should have radically reduced area of airfields.* For example a typical PATS airport [6] may have form shown in Figure 4. Its main dimensions are maximum 1600 and 1000 m. The area of such airport is about 1.3 $km^2$. The length of runways will be maximum 600 m. (Typically the runway length must be less then 360 m.) Generally, in two direction, if it possible two – two parallel runways must be built. Angle between the differently directed runways cans rich 30 degrees. The control point (tower) can situate on the land between the runways.

Such airport (because it city centre location) may cause a lot of safety (and security) problems. Most important from them is the flight procedures design, redesign in airport area and definition of the secondary protected areas under the flight routes.

### *New ATC system – air traffic rules*

The personal air traffic system is an absolutely new traffic system. Principally it will use airspace under (or in case of flying by micro jets, upper) the space applied by traditional air traffic system. In idea, such spaces are out of the control. However (at least in Europe) the distances between the living areas are very short and the small aircraft must pass the large airport terminal areas, while the micro jets must pass the controlled airspace. Furthermore, the small aircraft will be piloted by common, less-skilled pilots. Better to say, these small aircraft will be controlled by air drivers. So, the small aircraft traffic can not be uncontrolled.

The air traffic control of small aircraft must be separated from the conventional ATC/ATM, from the control of air traffic of large, professional aircraft [17]. The PATS ATM has to based on the radically new ideas. The main features of such ATC/ATM system are the followings [6]:

- the control of air traffic is separated for traveling and airport control, areas
- during traveling or cruise flight, the aircraft position can controlled automatically by GPS positioning and transponder information,
  - the position of personal aircraft will identified by GPS and the system automatically will keep the aircraft on the design flight route or/and it will generate wondering signals in case of deviation from the design direction,
  - the information about the other aircraft will be generated on the transponders information and all the aircraft closer than 15 km to the given aircraft and their predicted motions will be represented on the special display,
- the control of air traffic at airport zones can solve by GPS based ATC info – system,
  - all aircraft at airport zones will transfer their GPS based measured position to the airport control information centers,
  - the airport information centers will visualized on the display the positions of all the individual aircraft,
  - the information center will determine the flight routes for each aircraft with accordance of the flight rules and safety instructions,
  - the determined information will visualized on the same display,
  - the images of the general and determine situation will be transferred back to each aircraft,
  - each aircraft has to follow its flight as described by information got from control center,
- at smaller airports the information center may not determined the flight routes automatically, the center will give an information about the positions of aircraft flying in closed area of airport and the pilot will drive the aircraft with accordance to the general air traffic rules has to be develop on the basis of road transport rules.

Even, we can imagine the use of traffic signalization system in close airport zones can be developed (like air balloons to show the right descent path, areas for flare, etc.).

All the information about the air traffic can be depicted on the display of the flight advisory system.

### *Aircraft*

There are many different aircraft under development, many projects dealing with them. Here are short description of some specific aspects that can determined the aircraft development and their operations.

**Certification:** Personal aircraft are not acrobatic aircraft, *however they are recommended to be certified in the utility category* (which is the highest certification level of non-acrobatic aircraft) to be capable of withstanding higher load limits and G forces.

Personal aircraft are expected to be used in all or in nearly all weather conditions, by pilots having less knowledge of flying in bad weather. In the view of this, and especially *the lightning meteorological conditions, personal aircraft are recommended to be certified as all-metallic aircraft.*

With accordance to the operational concept (competitive operational cost, wide usage by common people, flights mostly in uncontrolled areas, intelligent support the less-skilled pilots, full automation or distance control in emergency situation) and the large primary costs of certified systems, instruments, the certification process must be very simplified for series of elements, instruments. The low cost elements and instruments must be developed in all cases, when the situations initiated by failures of the given elements instruments will have no series influence on the safety or that situation are managed by emergency management system (for example by switching on the automatic or distance control, as well as the duplication of the low cost elements, etc.). A series of cockpit instruments and communications can belong to this group of low-cost, simple certified elements.

**Design and engineering:** There is no a special design and certification requirements for the personal aircraft. However, *the elements and the systems are recommended to fit FAR 23 and JAR 23 requirements.* This might be seen too strong, but the personal aircraft might have higher loads due to the complex operational conditions.

Safety is a factor of the applied design philosophy and must be „built“ into the structural solutions over the design and engineering processes. Therefore, the structure must have damage tolerance and the system should have fault tolerance. Presently, the airframe could be full composite using damage tolerance design technique, nano and auto healing technologies. Generally, the carbon-fibers are nowadays about three times stronger then aluminum based alloys. The metal–composite and the full metal structure might be based on frame solution for the fuselage, and on light way technology for the wings and the tails.

The main spar and joint elements as well as the systems must be very simple and redundant. With the dual philosophy, each spar must be apple to support the entire load alone. The redundancy in the electric system and in the avionics is especially important to support the less-skilled pilots with relevant information.

To further enhance safety and indicate the extreme situations, personal aircraft are also expected to have a load measuring and data recording system, which alerts the operator in extreme loads, and estimates the equivalent operational time.

***Production:*** The production of personal aircraft should be as simple as possible, seeing that these aircraft would have a lower total operational cost and they are expected to be produced by new small companies, having less practice in the domain. Some developers are thinking about the simplification of the aircraft surface, completing the lifting body from the plan panels even if the aerodynamic goodness factor (lift over drag ratio) will be reduced for 20 – 25 %.

The production time and cost can be reduced with the use of lean technology.

**Cabin safety and ride control:** Generally, the life of passengers in the emergency situations are saved, if the aircraft or at least the cabin stands the hard landing (with higher vertical touch-down velocity), the roll-over situations (with up to 3 G), the seats are strong enough, and the special active safety systems (as air bags in the cabin, emergency parachutes for all the aircraft or the entire cabin) are applied. Other influencing factors include the protection of the door to be opened in flight, the application of fire resistant materials that might decrease the risks for injuries and fatalities.

*Another important problem is the ride control, as personal aircraft are expected to be operated at relatively low altitude, which is the most turbulence region of the airspace.* To avoid its negative effects, personal aircraft could apply (i) passive (using the highly loaded wing), (ii) semi-active (control by limiting the pilots' sudden actions) and (iii) active methods (like a special system reducing the effects of turbulence by active lift – lift distribution – control system.

**Cockpit instrumentation:** After revising the current projects, programs and tools concerning cockpit development (e.g. NASA cockpit vision for SATS, US Capstone Project) the following main points can be concluded:

The developed cockpit could contain up to 6 color displays [6] for the following tasks :

- digital reproduction of the basic flight instruments,
- color macro and micro weather visualization (around the aircraft on the flight path) with 3-D depiction of complex weather patterns that clearly identify the location of e.g. wind-shear, lightning or storm cells. A good example for such an instrument is the NASA Aviation Weather Information System. The AWIN project is developing enabling technologies and coordinated practices for using near real-time aviation weather information in the cockpit in order to reduce accidents where weather is a contributing factor.

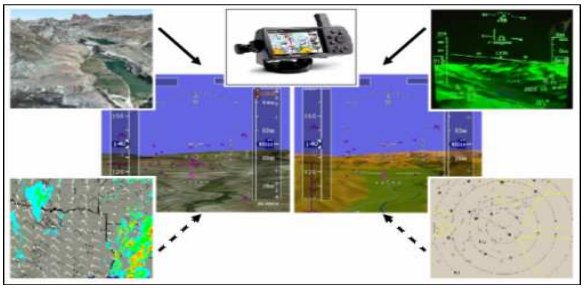

Figure 4. Possibilities of weather and synthetic vision systems for enhanced visualization of aircraft surroundings.

- flight advisory system with
    - day – night visualization of the aircraft surroundings: artificial vision (Figure 4.) generated by advanced sensors, digital terrain databases, accurate geo-positioning, and digital processing to provide a perfectly

clear 3-D picture of terrain, obstacles, or runway. An advanced tool for such visualization is the NASA's Synthetic Vision System. This targets to eliminate one of the most important contributing factor to aviation accidents, the Controlled Flight Into Terrain (CFIT). It provides a clear electronic 3-D perspective of the airplane surroundings (figure 3.), no matter what the weather or time of day. The database is given by the combination of Global Positioning System satellite signals and an onboard photo-realistic record to give a terrain picture for the crew. Accuracy can also be checked by sensors comparing the real world with the generated pictures,

- automatic identification and alerts to threats, regardless of weather, nature or human built obstacles,
- recommended flight path (for example with 3D-tunnel/predictor) visualization,

➢ flight navigational display to represent the flight routes on the general moving map based on macro data,

➢ condition monitoring and diagnostic system display,

➢ other supplementary displays for further goals not mentioned here such as the visualization of the back or side surroundings, or the information in emergency situations.

By using the new technological achievements described above (and others not mentioned), the difference between the existing and the developed cockpit is remarkable.

**Communication:** Cockpit development could pose new requirements and obligations in several domains, such as accuracy and availability of data. Thus, communication and information sharing (like those of the GPS) between airspace users and ground stations is also a domain to be ensured. Because the possible radio communication jam and due to rapid development of IT (like bandwidth) the future communication system might be based on the datalink developing and tsting by EUROCONTROL, too.

One solution for that problem is a kind of datalink, where even complex massages can be passed with high reliability. One of the solutions is EUROCONTROL's controller / pilot datalink communications (CPDLC) program where voice transmissions can be replaced by messages displayed on controllers' and pilots' screen, which can be accepted and acknowledged by a simple press of key.

Even if CPDLC could be a good solution, there are other concepts as well, which are mentioned at the followings in the aim to have a wider view of the existing technological achievements, and possible utilization. An ideal solution might also be an internet based $IC^3$ (information, communication, commend, control) system combined with positioning and secondary surveillance systems (using GPS records for air traffic monitoring).

**Aircraft control system (in general):** Control system is a crucial element of personal air transportation. Due to the size of the aircraft, control system might be made in mechanical form. In case of fully electric aircraft solution, the control system can be fly by wire, or even wire-less, but this would require the system to be duplicated. The control system for such small (up to 9 seats) aircraft [6, 18] must be developed for

➢ automatic adjustment of the aircraft centre of gravity (that can be important for the 4+ seats aircraft),

➢ position control of aircraft elements (under carriage system) and mechanical systems (like flaps deflections) as well as the active system elements (like lift or drag control by MEMS based active elements),

➢ control of the propulsion system (engine speed, propeller blade position, thrust vectoring),

➢ control of power distribution (including the electric power distribution) and

➢ control of aircraft position with aerodynamic control surfaces, and

➢ use of other possible control elements.

As mentioned above, the aircraft control needs simplifications, which might be the most challenging, revolutionary new and interesting task. Automation might be applied in several areas. For example, the engine and altitude control can be switch on into one system [18] (Fig. 5.) as the directional and roll control. By this way the controls will be harmonized and realizing the primary wills of the pilots.

*Operation and support*

Aircraft operation and maintenance (line up maintenance- services, on condition maintenance and repairing) should also be strongly supported. The support of the private pilots could be made at three different levels:

➢ economical support (credit to purchase an aircraft, establishing the rent a plane system),

- technical support (providing full services, maintenance and overhaul programs),
- personal support (including the flight plan development services, on board decision support system and even the virtual co-pilots),
- other supports (e.g. pilot training schools, weather information services).

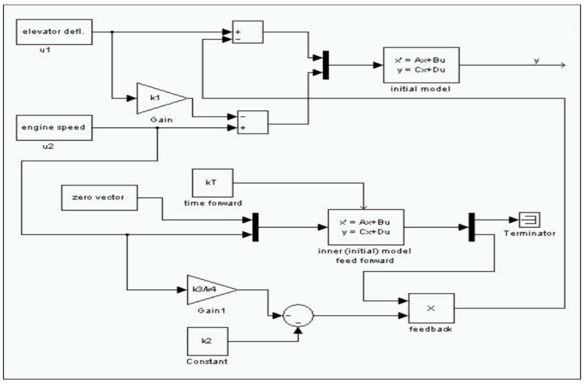


Fig. 5. Integration of the engine and elevator controls

## Conclusions

The personal air transportation system is an innovative new project initiated by the needs. The latest results of sciences and technology are available to establish this new system.

The PATS system has many safety aspects defined by this paper, too. the solution of the identified safety problems needs radically new solutions. Some important EU and national projects, like PPlane or Hungarian SafeFly have tried to develope a safety philosophy for the PATS. basic elements of such philosophy had been outlined by this paper.

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