PATS
PERSONAL AIR TRANSPORTATION SYSTEM

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Abstract

The needs in personal transportation are increasing very rapidly by exponential way. Even intelligent highways and high-speed railways are not the final solutions of problems of personal traveling. As soon as possible we have to develop the personal air transportation system.

The technology is available to establish the safety, economical and environment friendly personal air transportation system (PATS).

This paper shortly describes and summarizes the general ideas, problems and tasks of developing the new transportation system.

1. Preface

NASA administrator, Daniel S. Goldin presented a very impressive lecture titled "Aviation Daydreaming" on the SAE World Aviation Congress in 1999 [1]. He called up our attention for nice citation. As T.E. Lawrence wrote ….

"Those who dream by night in the dusty recesses of their minds wake in the day to find that it was vanity. But the dreamers of the day are dangerous men, for they may act on their dreams with open eyes, to make it possible."

…. and as Mr. Goldin finished his speech: "So become daydreamers".

I think we are the real daydreamer. I would like to give short information about the special project titled Personal Air transportation System. I am sure, in this paper you will able to find a lot of new ideas seems to revolutionary, however, if you were used some time for evaluation of these new tasks you will have a nice conclusions, all described problems, tasks, all the recommended solutions could be realized today. Principally, all the solutions have described already in details by many scientists. So, we have to summarize and apply them.

2. Introduction

The members of Scientific Committee of series of the International Conferences on Unconventional Flight Analysis decided to initiate the large international project titled 'PATS - Personal Air Transportation System'. The objectives of this Project just have defined and now, it is under development. Next future goal of the project initiators is finding the strong international support.

In practice, the needs in transportation are rapidly increasing. Each percent of increasing in GDP generates growth in people mobility 2 and in cargo traffic 2.5 per cent respectively (Fig. 1.). Therefore in EU a lot of new rod construction troubles the travelers. During last decade (1990 – 1999) the length of highways was increased for 25 % [2]. Especially in well-developed country, like USA [3], the highway system and number of cars nearly stabilized (Fig. 2.). However passenger-miles of aviation is increased 14 times during last 40 years.

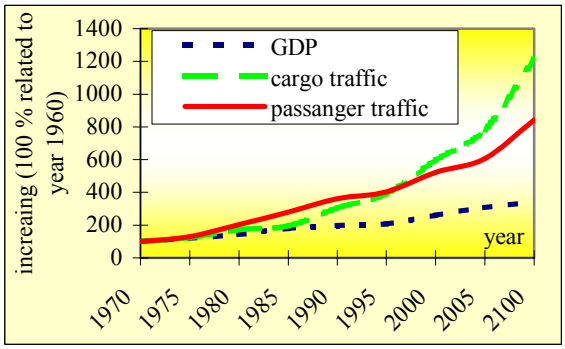

Fig. 1. Effect of economical development on the traffic needs

The high-speed railway transport and intelligent highway system concept are not solution of future transport. They can increase the road

and railway transport capacity, but they need mach more greater land for realizing the transportations and even they have greater influence and load on the environment than air transportation [4]. So, we think, we must develop the new air transportation system for wide public use at near future. Such type of new air transportation system can change completely the future world

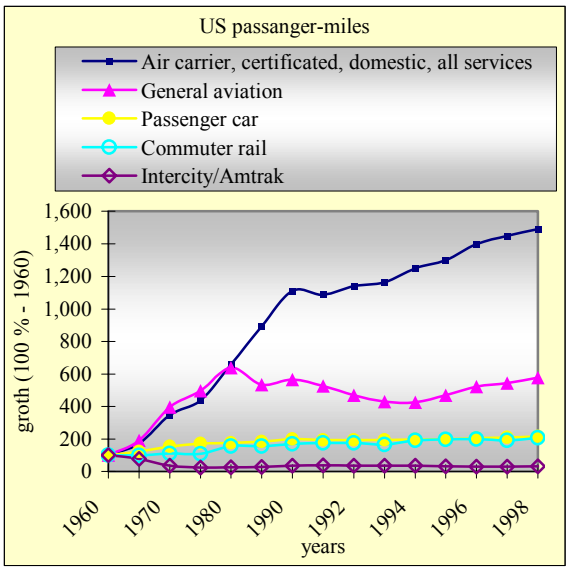

Fig. 2. Changes in transportation needs

and it will improve the quality of people's life.

In any case, it is clear, the technology is available to establish the safety, economical and environment friendly personal air transportation system (PATS).

The NASA has initiated already his similar project [5] called as small aircraft transportation system (SATS). The NASA program is focused on the new aircraft design, airports development and economical foundation of the project.

We think, the personal aircraft has to be design for using by common people. So, we need principally new aircraft, which could be piloted by everybody, without any special or extra knowledge and abilities. Such aircraft will be used very widely. Therefore we have to develop radically new air traffic control system and new airport set. It seems that the principle of organization and operational system of the personal air transportation system has to very closed to the philosophy of the personal car operation system.

This paper deals with the first rough draft of the planned PATS project. It describes the general idea, possible structure of the project and tries to define the principal tasks to be solved.

3. The Objectives

The general objective of the Personal Air Transportation System (PATS) Project is the establishment of the new

- safety,
- environment friendly and
- economic

air transportation system based on the

- new set of (smaller and closer to the city centers) airports,
- new air traffic control system (or better to say new air traffic rules) and
- new small and smart aircraft (could be piloted by anybody),

and results to

- increasing the from door to door sped 4 times comparing to the speed of highways in the region 200 – 800 km-s, and
- connecting the 20 % of the European cities in next 10 - 15 years.

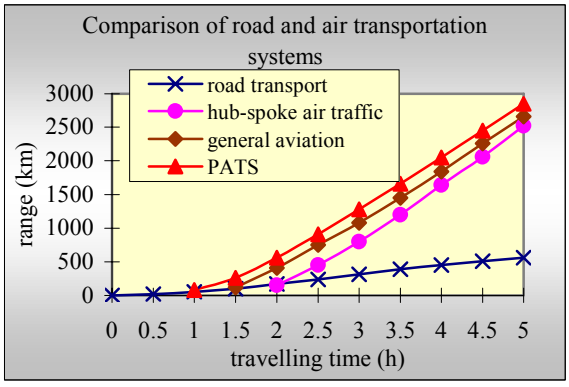

Fig. 3. Efficiency of the new technology air transportation system

The efficiency of the personal aircraft usage can be demonstrated with results of short evaluation of the range as function of traveling time (Fig. 3.). The curve of PATS characterizes the operation of the series of small aircraft designed for different flying distances.

4. Project Structure

The PATS project is the large, long period, multinational, multicultural program under development.

4.1. Participants

We have to involve into the project the followings:

- EC (even UN) and governments – for supporting,
- ICAO, JAA, EUROCONTROL, etc. – for development the new regulations and requirements,
- scientific and research centers, universities, major institutions – to develop the new technology,
- aeronautical industry – to produce the elements of the new technology,
- small and start-up companies – to generate and work out the radically new and innovative ideas.

4.2. Organizational structure

The general structure of the initiated project is shown in Figure 4.

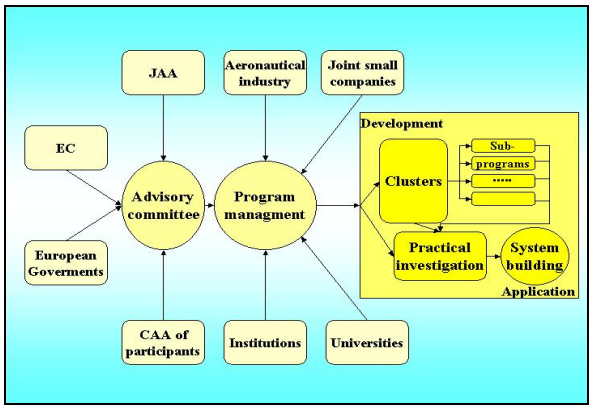

Fig. 4. General structure of the PATS Project managing

The mean part of the project is planned to built up on the cluster matrix structure, like it is shown in next Figure - table.

0	1	2	3	4	5	6	7	8	9	10	11	12
A												
B												
C												
…												

Here 0 marks the clusters and sub-clusters. The clusters are the followings:

1. project managing,
2. aircraft development,
3. engine development,
4. safety problems,
5. piloting,
6. airports development,
7. air traffic control and rules,
8. environment protection,
9. production,
10. technical support,
11. influence on public goods,
12. economics.

Each cluster is managed by different leader institution. The programs of the clusters can be divided into several sub-programs. The sub-programs can be elaborated by one or several different institutions. Some examples for sub-clusters:

3A – aircraft design, 3B – aerodynamics, 3C – airframe, 3D – aircraft systems, 3E – flight performance, …..

10A – technical operation, 10B – logistics, 10C – maintenance system, 10D – repairing,

11A – forecast, 11B – pilot schools, 11C – rent a plane organizations, ….

4.3. Modeling and investigation levels:

During development of the PATS the following models has to be used:

I. Verbal model - verbal description of PATS
II. Visual models - diagrams, 3D models, etc.
III. Mathematical/digital models - for design and investigation purposes
IV. Demonstration models - physical models
V. Experimental models - practical investigation on 4 specially chosen airports at least
IV. Prototypes - certifications
IV. Applications - final use of the PATS.

4.4. Working network

The involved organizations, institutions, companies can work together in network organized specially for this purposes.

4.5. Tasks

The contains and main tasks of the PATS project are shortly described in following points.

5. Aircraft development

The establishment of PATS needs several families of the personal aircraft. The market analysis shows that the 4 – 9 seats aircraft are required. They can be equipped by the propellered engines. Of course, the noise of the engines has to be reduced, because the personal aircraft will be operated at airports closed to the city centers. If the range of the aircraft would have greater then 400 km-s, the use of jet engines would be the right decision.

Principally, for last 40 years, the small aircraft applying the latest results of the sciences and technology have not developed. So we need absolutely new designed aircraft. The main objectives of the small aircraft development are characterized by

- developed aerodynamics – even use of revolutionary concepts,
- principally new designed engines – with reduced fuel consumptions, noise and air pollution, (possible diesel engine and jet solutions),
- excellent performance – for good and safety piloting,
- excellent ride control – with application of active and adaptive control methods especially in turbulence air (because the small aircraft fly at altitude 2 – 4 km, which is the region of most turbulenced air),
- good technical life – with reduced fatigue damages, use of damage tolerance design philosophy, etc.

The possible boundary of the performances can be characterized by very serous conditions. For example, as it was defined by leadership of the NASA's SATS project [6] the engines to be designed for small aircraft should have law weight, high reliability and radically reduced primary cost and low operational cost. The initiated GAP (General Aviation Propulsion) Project resulted to new piston and turbofan engines. The intermittent combustion engine is designed for a single engine, no more then 4 seats small airplanes having cruise speed maximum 200 knots. The images of a new Diesel engine designed [6] and its mean design features are given in Figure 5. This engine has fuel consumption of about 25 per cent less than current engines

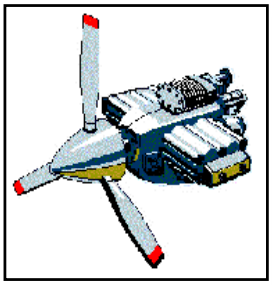

Fig. 5. A new Diesel engine developed by Teledyne Continental Motors and its industry team

- Compression Ignition Engine
- 2 stroke, direct injection
- Liquid Cooled
- 200-bhp @ 2200 rpm
- Jet-A fuel
- Single Lever Power Control
- Electronics Diagnostics and Display
- Low Noise, Vibration and Harshness
- Meets Expected Future Emissions Requirements
- 1/2 Cost of Current Engines

The turbofan engines are user friendly, environmentally compliant and the have very high reliability. Unfortunately still they had a high primary cost, too. The new FJX-2 engine developed by Williams International and his partners [6] is a high-bypass-ratio turbofan engine produces 700 pounds of thrust and its weight, 85 – 100 pounds, that is about one-fourth of piston engine propulsion system with similar capability. This engine makes possible to reach cruise speed about 380 knots by small jets. A most impressive result of the development is the reducing the primary cost of the small turbine engine by a factor of 10 (from hundreds of thousands to tens of thousands of dollars) [6].

Nowadays, the sciences and technology are developing very rapidly. Many new results, methods and technologies can be applied into small personal aircraft design and production. One, it may be a most important of them, is the micro-electro-mechanical systems (MEMS) technology [1]. The 10 – 100 μm size micro devices integrate sensors, actuators, control and transducer elements on a same silicon substrate. They have several very important and useful advantages [7] like

- small required supply energy depending on the specific dimension as function of dimension to the power minus five,

- missing of the fatigue damage because the specific dimensions are smaller then the characteristic dimension of crystalline structure,
- law price due to the production technology developed by microelectronic hardware production technology,
- advanced distributed and integrated control of the set of micro devices,
- very wide fields of possible applications including the micro and macro flow control inside the fluid systems and outside the aircraft, chemical, gas and fluid sensing and analysis, micro robots, etc.

As an excellent example, the works of professor Ho and his colleague demonstrate the possible application of MEMS to flow control [7] in aeronautics (Fig. 6.).

The MEMS can be applied to thrust vectoring, thrust generation, sensing and control in different aircraft systems, too.

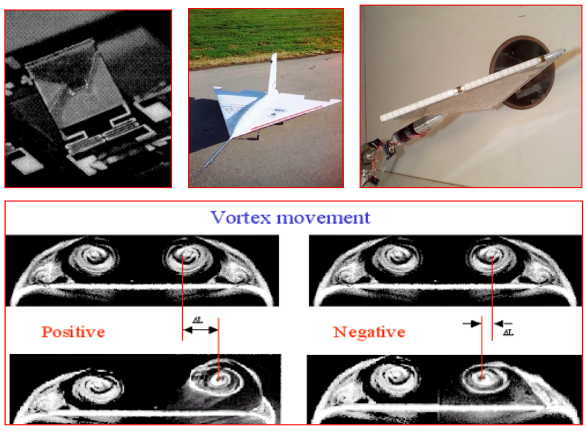

Fig. 6. Micro/flap and effects of leading edge vortex control on the rolling moment
(The model could be fully controlled by MEMS technology only, without use of conventional – aerodynamic – control surfaces.)

Another important specific feature possible development of aeronautical sciences and technology is the two-way technology transfer [1]. Earlier, the aeronautics catalyzed the other sciences. Nowadays, the other sciences can improve the aeronautical sciences. For example the biology can make revolution in technical sciences. As the NASA administrator Mr. Goldin told 'It is somewhat ironic to be saying this about aviation since the original inspiration for flight came from biology' [1]. However, from biology will come basic concepts for nanotechnology, new idea for sensors, brain-like computers and distributed nervous systems far beyond even the neural networks. For example, the nano-technology reaching the theoretical limits builds up the system on the principle atom by atom. Such material systems perhaps 100 times stronger than steel and 10 times stronger than the best graphite fiber.

The MEMS technology together the engineering results of biology may result to development the radically new technologies. They make possible growing up aircraft skins, not just for structure, but multi-layered for environmental protection [1]. Such skins will have imbedded sensor grids and when they will damaged they may even self-heal, like injured natural skins.

Another important result initiated by biology is the principle of so called soft computing. This is the new technology for working with uncertainties and risk in both the design and operational environment. This is a change in philosophical approach which will move us from the deterministic world into the real world of complex, dynamic processes for modeling, designing and operating of constructed engineering systems.

One of the well-known examples of such system is the neural networks based on the human brain principle. The neural networks deal with the real data and extract information about the changes in data, trends, patterns, solutions. So, they are able to learn and think. Today, the neural networks contain up to thousands of neural connections. In the future, the technology will ready to build up neural networks having millions of connections in a package the size of a sugar cube.

The possibilities of the new control systems based on neural networks was demonstrated by application it to the flight controls of an F-15 aircraft. The new control software [1] had lines of code 100 times less the traditional one. The system demonstrated improved performance, fault tolerance, system failure identification and self-correcting. Even in case of loss of aileron

roll control, the system adapted and returned aircraft control authority.

Fig. 7. One of the new aerodynamic forms developed by NASA SATS Project

These and other latest results of sciences and technology can result to the revolutionary new aerodynamic form (Fig. 7.), airframe, engines and aircraft systems.

6. Safety

It is well known; the aviation is the most safety transportation system. However, the number of accidents will be increased with increasing the number of flights even in case of decreasing the flight risk. The public does not care about accidents per passenger-miles. They afraid of color pictures about the fatal accidents, which are distributing by media making money on this. So, we have to develop safer aircraft for radically decreasing the flight risk, especially in case of their wide personal use by common pilot would have not special flight training.

The philosophical approach to flight safety of personal air transportation system can be characterized by

- application of automatic adjustment system for automatic setting up the best flying configuration, condition (for example automatic adjustment of stabilizers or reference model of control system depending on the center of gravity measured during taxiing),
- simplifying the control system, which can not more complicated then ordinary car control (computer assisted control system with automatic limitations on critical regimes, integrated engine and aircraft control, connecting the roll and yaw control into one channel),
- pilot assessment system (including automatic voice checklist, pilot load condition estimation, gust effect elimination, automatic detection of pilot failures, overtaking on pilot decision in emergency situation with leading to stabilized horizontal flight and switch on the distance control system, e.g. control from ground for land the aircraft in out of pilot control case,),
- ride control system for increasing the passengers' comfort (because the personal aircraft will used at altitude 2 – 4 km region, which is a most turbulenced region of air),
- advanced cockpit instrumentation with developed advisory system for safe piloting,
- specially equipped airport net (with use of radically new systems even),
- radically new air traffic control system or better to say, development of the air traffic rules for personal air transportation system.

The last three important features are described in next chapters.

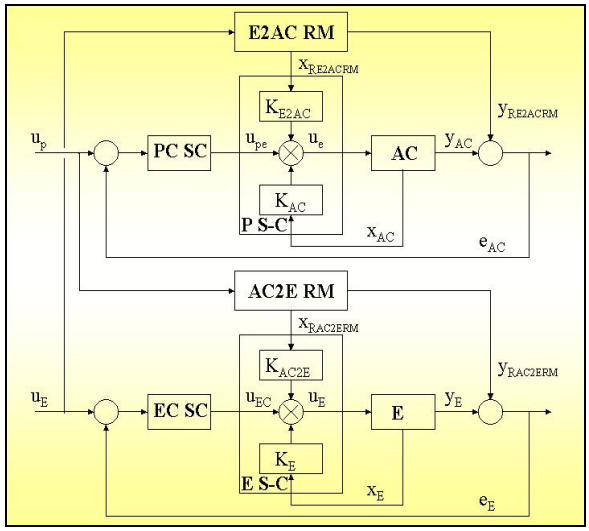

Fig. 8. Integration of the engine and elevator controls

(E – engine, AC –aircraft, E2AC RM – engine to aircraft reference model, AC2E RM – aircraft to engine reference model, PC SC – pitch control servo compensator, EC SC engine control servo compensator, P S-C – pitch servo-controller, E S-C – engine servo-controller, K - feed forward and feedback x – state vector, y – output vector, u control vector, e – different vector, extra indexes: p - pitch, pe - pitch – elevator, e – elevator, EC engine compensated)

Generally, it may the most interesting and revolutionary task is the simplifying the control system. For example, with help of internal model principle and feed-forward technique the engine and elevator (altitude) controls can be integrated into one system (Fig. 8.). In simple case, when pilot is pushing on the gas, pushing the throttle to forward, only, the system automatically will keep the airplane on the same flight direction (in horizontal flight or in climb with constant climb rate).

7. Developed cockpit for safety piloting

The personal aircraft should have a simplified flight control system as it was outlined already. However it is not enough. The possible pilots are not the professionals. They have practice with car driving, only. They are not familiar with motion in three-dimensional space by relatively high speed. They can loss themselves in the space. So, we have to do everything what we can for making aircraft could be piloted by common people. Therefore, radically new cockpit instrumentation required.

The developed cockpit contains 3 – 6 color displays for

- reproducing the flight instruments,
- color macro and micro (around the aircraft on the flight path) weather (radar) visualization with 3-D depiction of complex weather patterns that clearly identified the locations of hail shafts and wind-shear, lightning and storm cells (and possible showing the flight weather TV channel has to be organized if the PATS would be used widely),
- flight advisory system with
  - day – night visualization of the space near the aircraft (artificial vision generated by advanced sensors, digital terrain databases, accurate geopositioning, and digital processing to provide a perfectly clear 3-D picture of terrain, obstacles, runway),
  - depicting the real traffic situations on the ground and in the space around the aircraft (with help of establishment of the GPS based ATC infosystem),
  - automatic identification and voice avoiding the threats regardless of weather, nature or human built hindrances,
  - showing the recommended flight path, e.g. with 3D-tunnel/predictor,
- flight navigation display for design the flight routes on the general map of macro area,
- representing the information of the condition monitoring and diagnostic system (black display),
- extra display for special tasks like back and side situation visualization, special calculations, predicting the special information of control center in case of emergency situations, etc.

An example of advanced cockpit instrumentation of new small airplanes is shown in Figure 9.

The flight training of the public has to be organized on the principally new programs. The goal of these programs wills training of common people for safety piloting the small personal aircraft designed specially for PATS program, only.

Fig. 9. Cockpit vision of NASA developers (upper image) and HUD with 3D guidance information (lower picture) developed and investigated at TU Munich

8. Set of airports

The PATS will develop for increasing from door to door velocity of transportation on a relatively small and middle range (distance). Therefore a new net of small airports is needed. (May be, this is the most different of our PATS Project from the NASA similar SATS Project. The NASA try to use the airport system had realized already. While, in Europe, the density of population is higher and the estimated travel distances are much more less.)

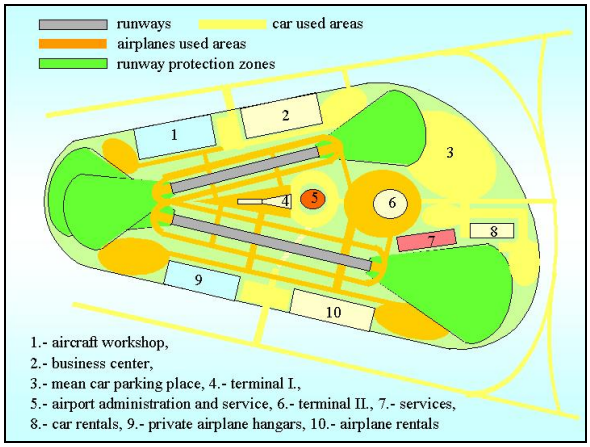

Fig. 10. Vision on the new small airport

These airports should have radically reduced area of airfields built up closed to city centers. We think, the typical airport of PATS will have form shown in Figure 10. with main dimensions 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. 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 tower can situate on the land between the runways.

The airport area is calculated with taking into account the new flight technology reducing the runway protection zones radically.

The airports will have the passenger terminal, car parking areas, fields of rent an aircraft, hangers for air taxes, private aircraft, maintenance shop, buildings for technical, control and business offices and hotel. Around the airport will be a small green area with trees and - under the land and takeoff directions - small parks.

9. New ATC system – air traffic rules

The personal air traffic system is an absolutely new traffic system. Principally it will use airspace under the space applied by traditional air traffic system. The pilots of personal aircraft will be not professional pilots. Better to say, these small aircraft will be controlled by air drivers. So, the air control of personal air traffic can separated from the control of air traffic of large, professional aircraft.

We think, the air traffic control of personal air traffic has to based on the radically new ideas. The main features of such ATC system are the followings:

- 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 measure 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 closed 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.

10. Environment protection

There is a lot of false information according to noise and air pollution of modern aviation. The effects of aviation on the environment much more less then they were 10 – 20 years ago. The noise is reduced for 10 dB and air pollution for 15 – 20 % each decades. Today, the modern aircraft use less energy for unit transport work then most cars or fast trains. Therefore air pollution of aviation relatively less then air pollution of road ground transportation. It is well known, the air pollution near the airports caused by air transport primary about ten times less then air pollution caused by road transport directed to given airports.

In any case, the noise and air pollution of personal aircraft should be reduced to the acceptable level of road transport.

The future small aircraft will built with wide use of composite materials. Therefore the application more environment friendly production technology and developing revolutionary new technology for recycling the composite materials will be one of the most important problem of environment protection of future personal air transportation system.

11. Influence on public goods

As it was told in the introduction even the intelligence high ways are not the final solution of increasing in transportation needs.

Today, some scientists are thinking that, the modern information technology will reduce the needs in personal transportation. They talk about the possibilities of video conference making radically reduction in needs of business trips. Another sociologist are wondering the artificial visions, which will able to reproduce the realistic, 3D situations of the tourist attractions giving filling even better then in reality. Therefore the tourist travel will reduced to minimum. We think, this is not true. We had heard a lot of about the death of books, theatres, even films. However the tourism is increasing rapidly. The distance between the hometowns of relatives is increasing. So, the travel needs are increasing, too (see Figure 1.).

Generally, the personal air transportation system will increase the quality of life. This man will left the ground. The technology developed for covering the need in personal air traveling will have a great influence on the science and technology development, will help in sustainable development.

We think, the PATS project has two difficulties in the eye of public. One is generated by too many automatisation. The common people are used not so many automatic machines. For example, in care they could fine the automatic gear-box, only. We have to minimized and make friendly the high level automatisation.

From another hand, the public is afraid of the flight risk. May be everybody has known already that the aviation is a most safety transportation system, but this knowledge is not enough. We have to explain to everybody that the ordinary life has a risk not less then risk of flight. For example, the risk ten to the power minus six is called as elementary risk. Flight from Budapest to Paris means 1.5 elementary risks. At the same time drinking of one cocktail on the board generates two elementary risk, traveling from

center of Budapest to the Budapest Ferihegy Airport by car equals to 60 – 80 elementary risk depending on the traffic situations.

12. Economics

The personal air transportation system, as it is described previously, is a really new large technogen system. Therefore, the economical analysis of this system and predetermining the possible market as well as profitability of this new system is a very complicated task.

The NASA SATS Project calculated with 5000 small airports. As it is readable on the NASA homepage (SATS program) [1], 'Our challenge is to expand the capacity of our major airports and open access to the over 5000 smaller airports that can serve small cities and communities across our country. The goal: safer, cheaper, more accessible air transportation for all.' Even they predict, today the latest technology can result to development of so called micro jet with operational cost 1.5 USD/mile.

We think, the market of PATS can be characterized by the followings:

- the PATS technology will be cheaper then the conventional air transportation because the dimensions,
- travel cost of use the PATS will be 15 – 20 % higher, only, with comparison the high quality road transport,
- the number of new, small airports, built next decade for this purpose, will be about 1000 in Europe,
- about 300 000 personal aircraft can be sold in Europe during next 10 years,
- the PATS system will generate about 0.2 million new job (system development and design, aircraft production, airport construction, aircraft and airport operation, rent a plane organization, any other kind of support like hotels) in Europe,
- the PATS will be used regularly by about 10 millions air travelers at and of next decade,
- generally, ten years after starting the project development, the PATS will serve 13 million movements pro year, with 52 million passengers.

This large market will is about 900 milliards EUR for next 10 years.

The special methods for passenger forecast, market estimation, new system for financial support, etc. should be developed. It is an important part of the project.

13. 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 a lot of new innovative and radically new ideas, tasks. We have described a very wide program. It may to hard. At the beginning we can start the project with the more simple aircraft and we can make less change in the conventional air transportation system. However, the personal air transportation system will be profitable, safe and acceptable by public if we would establish radically new system as it was described.

We think that the project has to be described until end of this year. All the participants have to do his best support for concluding this project idea into next EU program.

14. Acknowledgement

The ideas worked out in this article were initiated and supported by the members of Scientific Committee of the series of International Conferences on Unconventional Flight Analysis. First idea about the small aircraft development was initiated professor Kasyanov as the possible theme of international cooperation.

Later, on the third conference a special workshop was organized on the PATS Project. The committee members had discussed the goal, objectives, structure and tasks of PATS Project to be solved. They had evaluated of the problems and tasks, they had generated a lot of revolutionary ideas.

The members of committee are the excellent scientists working on the different problems and having practice with investigation and development of the small aircraft, too.

List of the members of committee of 3rd conference:

Prof. Hannes Fogt	**Austria**
Prof. Dr. Peter Thomasson	**England**
Prof. Seppo Laine	**Finland**
Prof. Dr. Vu N. Duong	**France**
Prof. Dr.-Ing. Gottfried Sachs	**Germany**
Prof. Dr.-Ing. Otto Wagner	**Germany**
Prof. Jozsef Rohacs	**Hungary**
Prof. Michele Onorato	**Italy**
Prof. D.Sc. Josef Shinar	**Israel**
Prof. Jerzy Lewitowicz	**Poland**
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Dr. Victor V. Vyshinsky	**Russia**
Prof. Mark R. Liberzon	**Russia**
Prof. Vladimir A. Kasianov	**Ukraine**
Prof. Vojin Tosic	**Yugoslavia**

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