LESS-SKILLED PILOT DECISION SUPPORT

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Abstract

Nowadays, several EU supported projects (like EPATS - European Personal Air Transportation Systems, PPlane - Personal Plane, SAT-Rdmp Small Aircraft Transport – Roadmap, or Esposa – efficient Systems and Propulsion for Small Aircraft) and national programs (as NASA SATS - Small Aircraft Transportation System) develop the next generation small and personal aircraft. The new aircraft will be controlled by highly automated systems supporting the pilots. In case of personal aircraft, the pilots having normal pilot licenses may have limited practice. Such, so called less-skilled pilots need special supporting systems, help them in situation awareness and decision. The developing decision support system should take into account the subjective features (knowledge, human behaviours, practice, and mental conditions) of less-skilled pilots. The key novelties of such systems are the (i) introducing methods of subjective analysis into the situation awareness and decision-making process and (ii) decision support depending on the pilot load measurements. The lecture will (i) investigate the available accident statistics; (ii) analyse the safety and security aspects of the small personal aircraft; (iii) describe the safety philosophy for small aircraft development; (iv) present the recommended new control systems; (v) introduce the methods of subjective analysis in investigation and simulation of the less-skilled pilot decisions; (vi) define the pilot load model and load monitoring system and (vii) specify a new system as decision support system for the less-skilled pilots.

Keywords: small / personal aircraft, safety, less-skilled pilot, subjective decision, decision support system

1. Introduction

The latest results of sciences and technologies allow to develop a safety, environmental friendly and economic new Personal Air Transportation System (PATS) (Rohacs, 2002; Piwek, Wiśniowski, 2016). Nowadays many EU supported projects (like EPATS - European Personal Air Transportation Systems (Piwek, Iwaniuk and Gnarowski, 2010), PPlane - Personal Plane (Le Tallec and Harel, 2012; Le tallec, et al., 2013), SAT-Rdmp Small Aircraft Transport – Roadmap (Small, 2017), or Esposa (2017) – Efficient Systems and Propulsion for Small Aircraft) and national programs (as NASA SATS - Small Aircraft Transportation System (Holmes, Durhan and Tarry, 2004; Moore, 2006) develop new small and personal aircraft, new small aircraft transportation system.The authors were involved into these projects and were leading experts in several Hungarian national project like SafeFly and special acrobatic aircraft development.) This paper summarizes the research results of mentioned above projects in development the safe small /personal aircraft and small air transportation systems. The paper widely uses the reports and articles published earlier by authors.

The projects develop new small aircraft and small aircraft transportation systems (SATS) open new business sector in air transport supporting the FlightPath (2011) vision (Piwek, Wisniowski, 2016). Of course, this new business area requires new business model, new regulations, aircraft, set of smart airports close to city centres, integration of transport into the developing ATM, wide support systems including the technical and economic (share ownerships, rent a plane) systems. The system of course must be predicted and their influence on the ATM, sustainability, etc. must be preliminary investigated (Rohacs et al., 2005; Rohacs, 2006; 2007; 2013) The SATS and the personal planes will be an integrated part of the future multimodal transportation system (Fig. 1). The Figure 2. shows the prediction of the European small aircraft transport in case of consistently use of new business models.

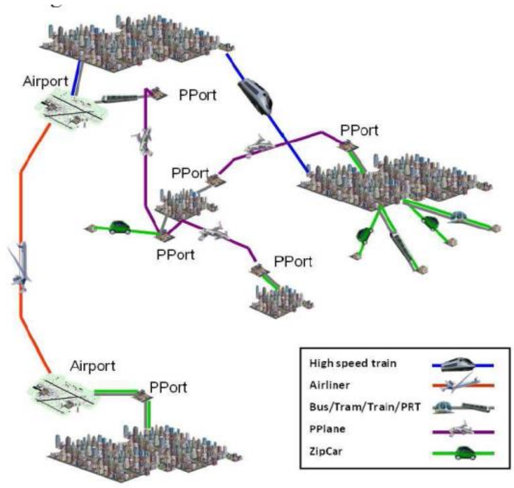


Fig. 1. PPlane as multimodal transport system (Le Tallec and Harel, 2012)

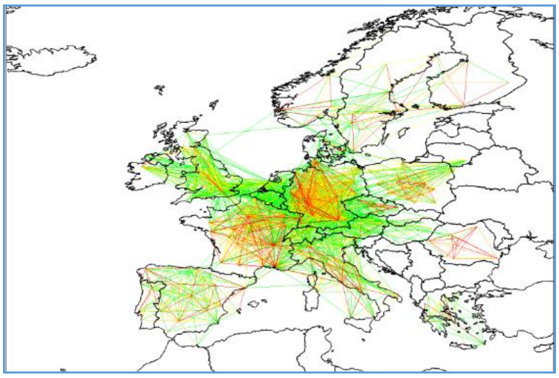


Fig. 2. Prediction of the small air transport flights routes in 2035, coloured by number of daily flights (Ghijs and Rohacs, 2013) (Green stands for 5-20, yellow for 20-50, orange for 50-100, while red for 100+ movements a day respectively)

The small / personal aircraft will be controlled by highly automated systems supporting the professional pilots (air taxi, or remote controllers) and owner- or renter-pilots. In this last case, the private - so-called - less-skilled pilots having required knowledge and licenses may have limited practice and they will have decision on situation by use their subjective evaluations (Rohacs, 2010b).

Today, still the central deterministic element of the aircraft conventional control systems is a subject that is an operator - pilot. Such systems are active endogenous systems, because they actively controlled by solutions produced from inside by pilots (organism: nervous cells). The pilots make decision on control depending on their situation awareness, knowledge, practice and skills. They must create decisions in situations characterized by a lack of information, human robust behaviours and their individual possibilities. So, the decisions origin from analysis of pilot-subjects that might be investigated by using the methods of the subjective analysis (Kasyanov, 2007; Rohacs, Kasyanov, 2011).

In future, when the aircraft will be highly automated or even they may apply autonomous flights, the pilots' role will change from active control, to passive monitoring, passive supervising. Even in such cases, the pilots will generate decision on their subjective situation evaluations. So, the support the (less-skilled) pilot subjective decision becomes to level of most important problems.

The lecture will (i) investigate the available accident statistics; (ii) analyse the safety and security aspects of the small personal aircraft; (iii) describe the safety philosophy for small aircraft development; (iv) present the recommended new control systems; (v) introduce the methods of subjective analysis in investigation and simulation of the less-skilled pilot decisions; (vi) define the pilot load model and load monitoring system and (vii) specify a new system as decision support system for the less-skilled pilots.

2. Accident statistics investigation

Safety is a term related to the operational quality and emergency management. The emergency management is used to minimize the risk and losses associated with emergency situations that danger for human health, life, built properties, environment and culture. Safety and security are the twin brothers. The difference between them could be defined such as (Rohacs, 2010a):

- 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.

The safety policies and strategies are based on the synergy of

- 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).

It is well understandable, the safety is „built” into the system (aircraft, airport, air traffic management) during design and production and kept on the accepted level by applied operational processes.

Safety often is characterised number of accident, fatal accidents, or reliability indicators. The Figure 3. shows the reason why the personal aircraft flown by private pilots require special attention from the safety point of view. As it can be seen, the personal (owner, renter) pilots are involved into about 5 – 8 times more accidents.

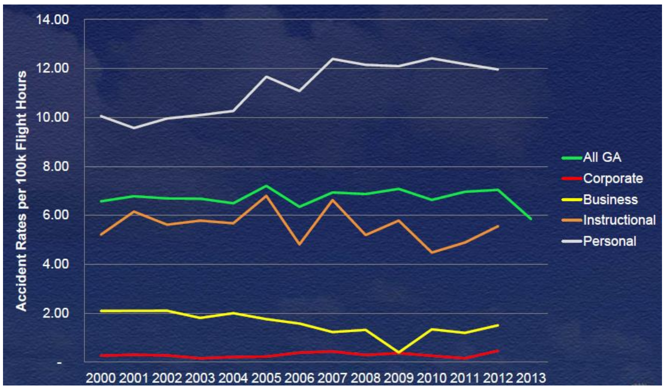


Fig. 3. General aviation safety indicator (Weener, 2015)

The operators (pilots) have hard and soft skills. Hard skills mean the operators know what to do in different situations. There is a reason why they may have licenses. In reality they may know what is the best or required control solutions in given situations, but they applying something else (“passing on red lights”). This is a simplified “explanation” of the soft skill. Another terms used for defining the hard and soft skills are the technical and non-technical skills. The last one includes the intelligence, physical condition, creativity, emotional quotient, adversity (and spiritual intelligence). The soft skills are important in the situation awareness, problem solving, especial in safety-critical situations. Nowadays, the development of the non-technical skills is included into the pilot training standards (IFALPA, 2012).

Real accident statistics as shown in the Figure 4. demonstrates the complex role of soft skills. For example, it might surprise experts, but pilots having a total flight time of more than 10 000 hours cause each tenth GA accidents. On the other hand, a lack in practice causes accidents, too. According to the investigations of the NTSB (Annual, 2005), from the 1626 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.

Another interesting point is that the commercial pilots are 3 times less involved in the accidents and fatal accidents than the GA pilots are. It is also observed that the accidents per 1000 pilots are decreasing, while the fatal accident per 1000 pilots are scattering around the nearly same values (Figure 5).

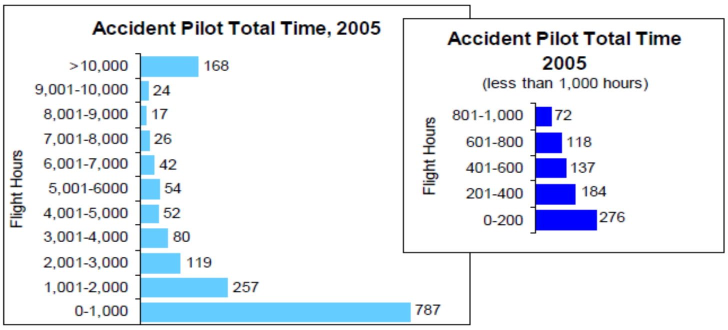


Fig. 4. The distribution of experience among accident pilots (Annual, 2005)

The detailed investigation of the curves of the Figure 5. had leaded to two interesting hypotheses.

- The fatal accidents per 1000 pilots – 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 the small aircraft are flown on shorter routes. In addition, airlines' pilots are also more supported with different services (e.g. air traffic control).
- The number of fatal accidents per 1000 pilots - as a function of calendar time - is slowly decreasing because of slowly increasing human intelligence, which has a positive influence on the human situation awareness and reaction time.

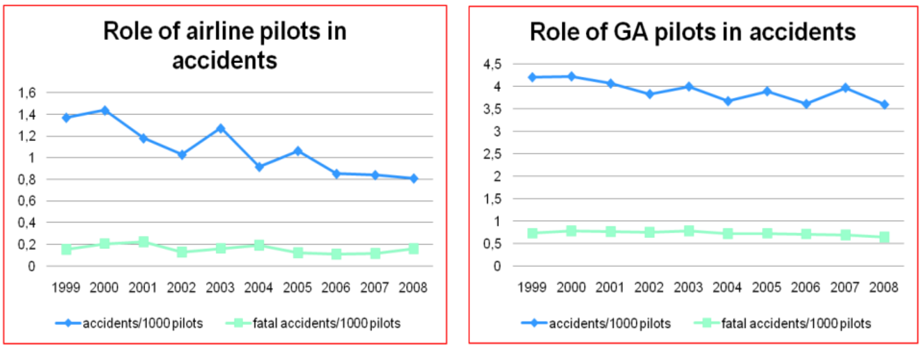


Fig. 5. Accidents and fatal accidents for 1000 certified pilots

The analysis of accident statistics leads to another two interesting conclusions. The Figure 6. shows that the private pilots are "only" involved in two times more accidents than the airlines' pilots, while the GA commercial pilots take part into nearly four times more accidents. With respect to the accidents per 1000 active pilots, student pilots make the safest flights.

Finally, the next conclusions might be formulated as a hypothesis: air transportation system (including training, regulations, research and developing, production, infrastructure, monitoring and control - ATM, maintenance, services, etc.) has developed, organized and managed by taking into account the risk level accepted by the society. At least, this hypothesis can be confirmed by the records presented in the Figure 7. According to the US accident data and fatal accident ratio, GA and airlines accident ratios are approximately the same. This means that while GA aircraft usually targets less complex structures, they are still based on resembling design rules and major structural solutions than those related to the larger commercial aircraft. Although ratio "all accidents/fatal accidents” is same for airliners and smaller aircraft, there is a great difference in total number of accidents. Small GA aircraft (PPlane sized aircraft) suffer from significantly higher fatal accident rate, approximately 1 fatal accident per 100 000 flight hours compared to airliners with 0.01 fatal accidents per 100 000 flight hours.

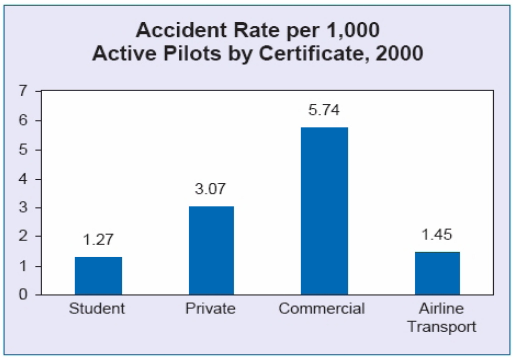


Fig. 6. Accidents per different classes of pilots [Moore 2006].

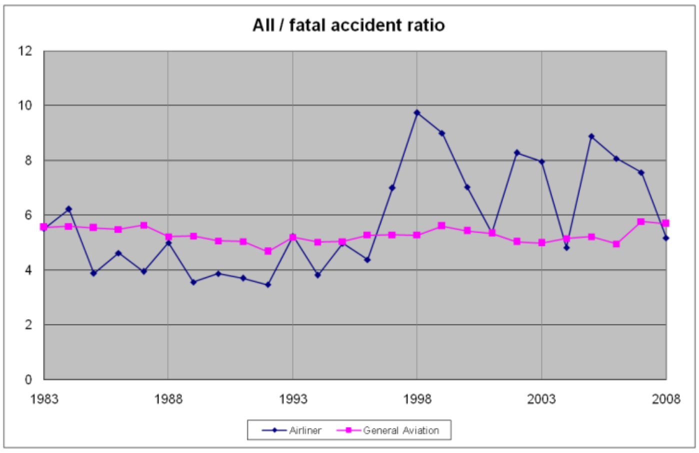


Fig. 7. An original way to compare airliner and GA accident statistics (Rohacs et al., 2011)

3. Safety and security aspects of the small / personal aircraft

Theoretically, the safety and security can be investigated by applying different methods and approaches. The projects (PATS, SAT-Rdmp, PPLANE, ESPOSA) developing the small aircraft and SATS (Baron, 2007; Rohacs et al., 2011; Bicsak et al., 2011), had applied:

i. probability method, when the flight risk is characterized by probability of difference in real and nominal (design) qualities of operation (defined by a set of characteristics),
ii. approximation of the stochastic changes in operational characteristics by know stochastic process like Markov chain.,
iii. practical functional analysis defining safety aspects,
iv. security prediction method based on sum of weighted probabilities of possible targets and treats.

Some example of identified and analysed safety aspects are summarized in Table 1. There were identified more than 100 safety aspects and problems at the beginning. After preliminary analysis, the small / personal aircraft specific aspects were chosen for detailed studies. The shorted list of safety aspects of small/personal aircraft and SATS described in PPLANE project (Rohacs et al., 2011) includes 40 identified and analysed aspects.

The security aspects had been identified and analyzed, too. Finally, there was created an idea of centralized, remote security checking. In this systems, at the checking system works without direct attendance of security officers. The checking process might be controlled from central station through interactive internet systems. Interactive, because the security officers may ask the passengers to pass the security line again, or to show their open luggage. In case of any problems, the passengers must wait for authorized person (like cooperating policeman from the city) for finalizing the checking process. The general requirements to such security checking system architecture are the followings

- the system must be reliable : failure ratio of element less than 10^{2} - 10^{4} 1/h and failure ratio of the full system less than 10^{6} 1/h
- mean time to the maintenance must be more than 100 days,
- the failure of the system can not have any influences on the other technical system and safety of using the SATS /PPLANE concept,
- the system may use the elements of the other technical, technological systems (for example information from the logistic support), but in action must be independent,
- in normal cases the security system may need not more time then 3 minutes for one aircraft (including the checking of pilots, passengers, goods - because this is the business area very sensitive to the time and service provided on the small airport for individual people or small groups - except the joint service provided by air taxi),
- the security service will be centralized, therefore max one security persons must be employed by a small airport with more than 50 flights pro day and working with unattended security persons in other cases,
- the centralized systems will be operated by 3 - 5 persons with close cooperation by police and other agencies and such center may perform security checks for 10 – 12 small airports

Table 1. Examples of the identified safety aspects (the numbers are shows the number of analysed aspects in PPLANE)

No.	Area	Major problems	Description	Examples	Possible solution
1.			**General**		
1.1.	Innovation system	Lack of an innovation system that may support the SATS developments	Development of the radically new technologies as SATS are supported in very limited forms by EU and safety seems as a particular problem.	Errors in the definition of the safety problems, underestimation of the safety aspects, developing and using low reliable or unsafe technology	Initiating new projects (as the deployment of a radically new aircraft control system, low cost on-board instruments to support less-skilled personal pilots or the development a special low cost surveillance, traffic monitoring and control system)
1.2.	Certification	Certification rules for the personal air transportation system are unclear	EASA's opinion on the development of the new personal aircraft and SATS, as well as the airworthiness requirements, the certification rules, applicable technologies are not clear. The European general aviation is slightly out of the direct focus of the EASA.	errors in the identification of the requirements, in the development of the test programs, and also in testing and certification	Discussions with the policy makers and stakeholders. Improving the existing rules, developing new regulations. Many ideas, rules and requirements could be based on the FAA and US SATS, PAV and NextGen projects. The personal aircraft controlled by less-skilled pilots might be developed as a non-acrobatic aircraft, but with enhanced load and g limitations. Certification, in case of remote controlled aircraft might fall in the UAS category.
2			**Development**		
2.1.	Operational concept	Lack of the operational concepts available for the European PATS philosophy	Several European projects have worked on the development of the operational concept for European S/PATS, but there is no commonly defined concept.	Development of GA aircraft with improved performance instead of the development of a novel aircraft for the future PATS, over sizing or underestimating the required performances, applied technologies, etc.	The US NASA SATS (Small Aircraft Transportation System) project developed several concepts to operate the new small aircraft, small airports, small aircraft traffic monitoring and control, etc. Even the operational concept for the rent a plane system and financial support of SATS are developed. A new SATS operational concept and business models must be developed with taking into account the European features as greater road density, large set of high speed railway transport, etc.
2.3.	Knowledge	Methodology	Design methods dedicated specially to personally used aircraft are not available.	Several problems might occur due the remote piloting, increasing the pilot soft skills, the use of the aircraft in the uncontrolled airspace, etc.	After development of the operational concept and its risk analysis, additional efforts need to develop and implement the small aircraft design methodology.

2.4.	Ideas	Lack of original and tested new ideas, solutions.	Development of the cost effective safe, sustainable new aircraft, SATS require original ideas, new solutions, which are not being tested so far.	Unconventional forms of aircraft, new lift generation technologies, flying car concepts, low cost instruments, etc.	There is a clear need to initiate pioneering projects, develop, test possible new solutions, structures, systems, as well as to develop testing technologies to evaluate the new emerging technologies and their potential applicability.
3			**Airport**		
3.2.	Size	Smart city airport must / may have limited size	Seeing the requirements on the airports placed close to the city centres, the new small airports should be designed and built with limited size.	Risks of accidents due to the incapability to follow SIDs or STARs	New and improved SIDs / STARs tolerating the anomalies and errors of the pilot. New procedures might be based on advanced GPS systems adapted for PATS operations.
4.			**Aircraft**		
4.2.	Propulsion system	The new small aircraft requires new, smart and green engines.	Because of the strict requirements on the efficiency and environmental impact, small aircraft must apply a new, smart engine.	Risks associated with the reliability of the accelerated developing new engines based on radically new technologies to reduce noise and emission.	The development, the test, and the certification of the new propulsion systems are very expensive that unacceptably increase the primary cost of small aircraft. One solution is to initiate a special international project to develop a new small, reliable and green engines for small aircraft applications. Testing of the possible new methods, rules, technologies and even the certification should be organized on the international cooperation level.
4.5.	Aircraft control	The use of the aircraft's control system by less-skilled pilots or remote pilots	The unconventional control system of PPlane may cause difficulties for the remote pilots. Automated systems are also needed to avoid the departure to critical regimes and also to perform remote control recovery from critical flight regimes.	Accidents due to poorly completed control, for example unwanted deviation in the altitude during flight speed reduction	Developed the improved car-free or H - methaform types and /or coordinated controls (see point 5.) Develop a pilot and remote pilot load monitoring system, which in emergency situation might even forbid the pilot to control the aircraft. Develop a management rules to perform control in emergency situations.
4.10.	Pilot decision support system	Problems of pilot decision making.	Personal and remote (ground) pilots having more soft skill require a sophisticated decision support system.	Risks due to the reduced decision time, errors in the subjective analysis, in the evaluation of the situations, in the selected decisions, errors made by pilots loosing their orientation, etc.	Develop new methods to understand and model the decision making process of the pilots, based on the stochastic hypothesis analysis (minimization of the Baye's risk) and on the application of subjective analysis technology. Decision making should be supported with correct information on conflict detection and resolution. Orientation of remote pilots could be supported with synthetic vision systems.
4.13.	Passenger (ride) comfort	Passengers and even pilots could have problems in case of low ride control	Personal aircraft will be operated at the most turbulent altitude. Under such conditions, the aircraft's oscillation motion and the extra g load initiated by the air turbulences might be uncomfortable for the pilots and the passengers.	Risks of wrong decisions and errors made by pilots having health problem, risks of wrong passenger actions by the passengers having health problems.	Develop a manoeuvring limitation, gust effect elimination system, including (i) advanced design processes (resulting for example in smaller wing and higher wing load to have better ride comfort), and (ii) passive and active technologies (e.g. distributed system of micro sensors and actuators for flow control to reduce the aerodynamic effects from air turbulences).
5	**Airspace / ATM**				
5.3.	Surveillance	Passive and active surveillance technology	Nowadays the GA (and the present personal air transport) is mainly made between small airports without traditional primary (and even secondary) surveillance systems	Risk of incidents and accidents in the air.	Develop new, low cost passive and active surveillance system. Passive system could use for example sonic waves (since the flight speed of small aircraft is smaller than those of the "traditional"). The active system might be based on the combination GPS positioning and advanced datalink methods (like ADS-B). Besides, new methods, technologies for the non-cooperative target recognition and classification, as well as new low-cost conflict detection and resolution systems are also needed.
6			**Support**		
6.1.	Training	Pilot training	Pilots might only have a limited number of flight hours pro year, which calls for a special training and even examination program.	Errors and faults made by the less-skilled and less-trained pilots	Develop new training programs, training systems and new examination systems to train PATS pilots.

7.	Additional safety aspects				
7.3.	Solve the security problems	Solutions of the security problems that influence the level of safety.	PATS needs a detailed investigation on its security problems. The solution of these might cause safety problems.	Risks due to the strict use of several new methods and technologies performed. Errors in the required actions to perform the security solutions (like detection of authorizations) that lead to flight risks.	After the detailed investigation of the PATS security problems (including aircraft, airport, and airspace), it seems that the new or the radically new solutions should be applied in a way to minimize their influence on safety and flight risk. Initiate projects for the investigation of the non-technical security aspects, society acceptation on the new security rules, technologies.

4. Safety philosophy for small aircraft development

Only in Hungary, about 15 small companies produce small, lightweight aircrafts (Aerospace, 2012; Hideg, Rohacs, 2010). The National SafeFly project had created the safety philosophy for small aircraft developments. There were applied new scientific approaches based on innovation theory and technology policy (open innovation process, innovative and disruptive technology developments), systems engineering (definition project phases, life cycle analysis, V-model, etc.), lean technology approaches (in production organisation, supply chain management), technology identification, evaluation and selection methodology (for selection of enabling and emerging technologies), application of the new solutions (as micro-electro-mechanical systems, support the pilot subjective decisions) and so on. The project defined three major key-elements:

- set of safety requirements,
- description of the aircraft development process and
- introducing the outside innovation process.

The set of safety and security requirements contains six parts: (i) creation the operational concept for the planned product, (ii) identification and selection of the airworthiness requirements including the methods of certification process, too, (iii) requirements to small aircraft (including recommendation for airframe design, developing the controls, required cockpit instrumentation possible control the emergency situations), (iv) requirements for operational environment (airport, ATM integration, supporting services), (v) requirements for process of application (selection, integration into the system, testing and certification) of the new technologies, solutions and (vi) security requirements.

The small companies produce new small aircraft as usually have limited financial, technical and human support for realizing the full aircraft developing process. For them the modern product development process had been described. As the product - generally - is the result of the human activities or processes with aim to cover human and market needs. The product can be appear in its physical forms or in form of service provided or even as (cultural) value. The product development is the improving the existing product or developing new kinds of product.

Generally, the product development process, as the innovation theory and systems engineering teach, is more than a very complex process (Fig. 8.) and it covers all the life of the product (Rohacs et al., 2010a; 2010b).

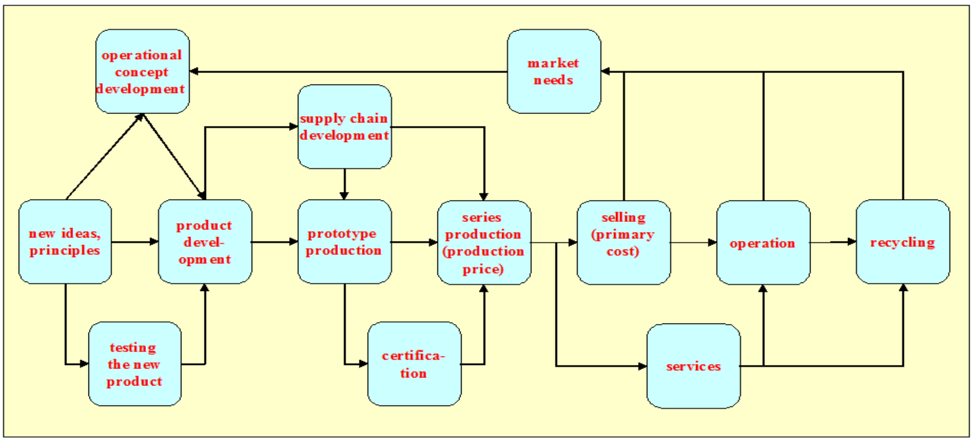


Fig. 8. The modern product development and commercialization process

The process starts with development of the operational concept on the basis of the market needs and possible implementation of the latest results of sciences and technologies. The product (aircraft) specification must derived from the operational concept. Realization of this concept requires new ideas, technologies and solutions that should be tr4ested preliminary. The engineering (design of the product and production process) is integrated with supply channel development and certification process. So, the product development and production is realized as the results of strategic networking of the producer, suppliers, partners, costumers, and even competitors. This is the basis for the fifth generation innovation process. Often, especially in case of aircraft development, the certification sub-process may have determining role in development. (Nowadays, the lifetime of aeronautical electronic devices may be shorter than the time required for their certification.). The product development process managed by use of systems engineering principle as total life cycle project process (Fig. 8.) contains the selling, after market service, operation and even recycling of the product, too.

Nowadays, the so-called open innovation described first by by Chesbrough (2003) is very recommended by many scientists and policy makers to use as a key element for developing the SMEs innovativeness. The open innovation means, the firms uses the new - available free or on the market - scientific results, emerging technologies and developing the new product or service (partly) together with other firms, institutions, universities, etc. and even makes their results applicable for others. Unfortunately, the investigations on European practice demonstrate that 75 - 85 % of innovative SMEs are using the closed innovation system (Fig. 9.), when the SMEs realize their research and development on in-house basis. They must have the required staff, infrastructure, financial support for all the innovation cycle including research, development, engineering, production, product distribution and after-market support.

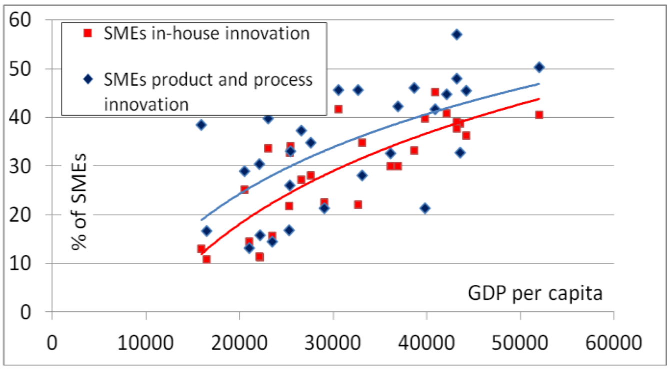


Fig. 9. Percent of innovative SMEs depending on GDP per capita of the European countries (drawn by use of data from (Innovation 2013; 2014))

It might be the most important different between the closed and open innovation systems is ability of the companies using the closed innovation (i) to create the best new products, (ii) to be first (or at least earlier) on market by their new products and (iii) to save their results (get profit from them). So, the closed innovation system may result to win the competition in given market field if the firm may apply this innovation system, namely, if the firm has excellent staff, excellent ideas, excellent possibilities (infrastructure combined by stable financing) and it able to save its results and market.

Of course, in practice there are not really closed and absolutely open innovation systems. The two extreme system realized by the hidden champions (relatively small but highly successful companies that are concealed behind a curtain of inconspicuousness, invisibility, and sometimes secrecy (Simon 2009).

The outside innovation process management (Rohacs et al., 2010b) may synthesized the advantages of the open and closed innovations, by use of external sources. Generally, in cases, when (i) the economic environment is relatively poor, (ii) the country belongs to the modest or moderate innovators, but (iii) a small firm has a really excellent and innovative idea, or may have a special contract given by the large or global market "player", and (iv) it has not enough source for using the closed innovation, while (v) saving the market may result to extra (real or even only a moral) profit, this new innovation system, the outside innovation support is recommended to apply.

At the beginning, during burning the innovative idea, making initial and basic research, as well as at starting the product development the open innovation is realized. Later, at transition period, the small firm contracts with a special service providers, research institutions and individual experts forming an outside advisory team following the product (or service) development, its engineering production and introducing it into the market. Finally, the closed innovation is applied, by the small firm and its contracted partners together (Fig. 10.).

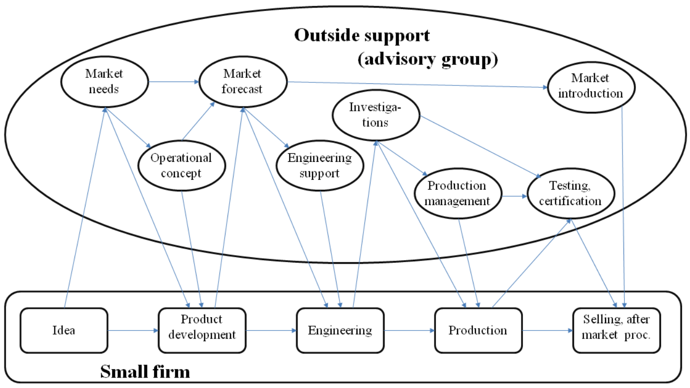


Fig. 10. Outside innovation

The outside innovation process had been applied in developing a new acrobatic aircraft for Red Bull Air race. The development was supported by the advisory group in work of which more than 40 expert were taken part from different universities, research institutes and organizations (Rohacs, et al., 2010b). The developed aircraft was flown within two years after a contracting.

5. Control system for personal aircraft

The analysis of the small / personal aircraft safety aspects has shown that the control system development might be the most important task, because less-skilled pilots having limited practice (Rohács, Rohács Jankovics, 2010; Rohacs et al., 2010a) will control such aircraft.

The philosophical approach results to four possible solutions

- considerable improving and automation of the control system,
- car-free technology (originally developed for the military aircraft),
- H-metaphor, as analogy with horse driving and
- analogy to car driving as accepted level of technical system controlled by common persons.

In first case, the control system must be improved and optimized for minimizing the risks causing by the les-skilled pilots. There are several possible new technologies and solutions can be utilized. For example (Rohacs et al, 2011):

- automatic adjustment of the control system (namely adjustment the centre of gravity and control system (physical) characteristics),
- improving the information support (for instant introducing a weather channel showing the weather condition exactly at the aircraft positions, all around vision by use of artificial screens, night vision system, 3D flight path tunnel prediction vision),
- automatic digital voice checklist (virtual co-pilot working together with the pilots),
- pilot load condition estimation, overload detection,
- automatic detection of pilot failures,
- overtaking on pilot decision in emergency situation with leading to stabilized horizontal flight,
- switch on the distance control system, e.g. control from ground for land the aircraft in out of pilot control case,
- 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, etc.

The control of civil and military aircraft (especially the fighters) are considerably different. For the civil aircraft, the handling qualities, the avoidance of the critical regimes and the optimizations are the most important tasks. For the military aircraft, the manoeuvrability, 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. Therefore, 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 (Flight 2000).

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, only. 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 characteristics could be made by two different ways (Flight 2000):

- 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 for example (i) a higher success of the mission, (ii) a full concentration of the pilot on the target, (iii) a more aggressive command inputs, while using the 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 – might also be applied for personal aircraft piloted by less-skilled pilots. The approach can be further improved and the limitation can be adapted to the actual pilot's level of expertise.

Moore (2006) gives another appealing and useful philosophy: "the sentience of a horse in that it is an intelligent vehicle that "sees" the environment, shares its intent with neighbouring 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-metaphor (Flemisch, et al., 2003) 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 checklist, 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 every day. As it had been introduced that is a road transport known and used by everybody.

Nowadays, when the fly – by – wire systems are introduced, this last solution can be applied easily.

As it well known, because of airframe symmetry, the controlled motion of aircraft can be divided into longitudinal and lateral motions. In case of longitudinal motion, aircraft is moving in vertical plane, only. Elevator and thrust unit control this longitudinal motion. Deflection of elevators and changes in thrust unit are realized separately (in principle independently), however they have to harmonized. For example: for acceleration of aircraft in horizontal flight, we must push throttle forward for increasing thrust and we must push forward the control rule for decreasing the aircraft angle of attack because the lift generated on aircraft wing and depending on angle of attack and velocity square has to be kept constant. So, in case of conventional control, pilots harmonize the elevator and thrust control.

The new control philosophy means that the harmonization of the elevator and trust control should be realized by special digital control system (Fig. 10.). Such system can be called as reconfigured and integrated, because the conventional control system is reconfigured with integration of elevator and thrust control channels into one system. Better to say, in case of changes in thrust unit a new system will keep accelerated or decelerated aircraft in previous horizontal flight or climb with constant climb rate. On the other hand, in case of deflection of elevator, flight path angle will be changed, why velocity will be kept constant automatically. Such system is based on using an internal models and feedforward technique (Rohacs 2002; Rohacs D., 2004).

This new control philosophy was tested by simulation method in Matlab environment.

As it known, the aircraft longitudinal motion in simplified cases, can be modelled by a linearized equations of motion given in state space representation:

$$\begin{aligned} \dot{\mathbf{x}} &= \mathbf{A}\mathbf{x} + \mathbf{B}\mathbf{u} \\ \mathbf{y} &= \mathbf{C}\mathbf{x} + \mathbf{D}\mathbf{u} \end{aligned} \qquad (1)$$

where $\mathbf{x} = [\Delta V \; \Delta\alpha \; \Delta q \; \Delta\vartheta]^T$ and $\mathbf{u} = [\Delta\delta_E \; \Delta n]^T$ are the state and control vectors and V – aircraft velocity, α – angle of attack, q – pitch rate, θ – pitch rate, δ_E - elevator deflection angle, n – engine rotation sped.

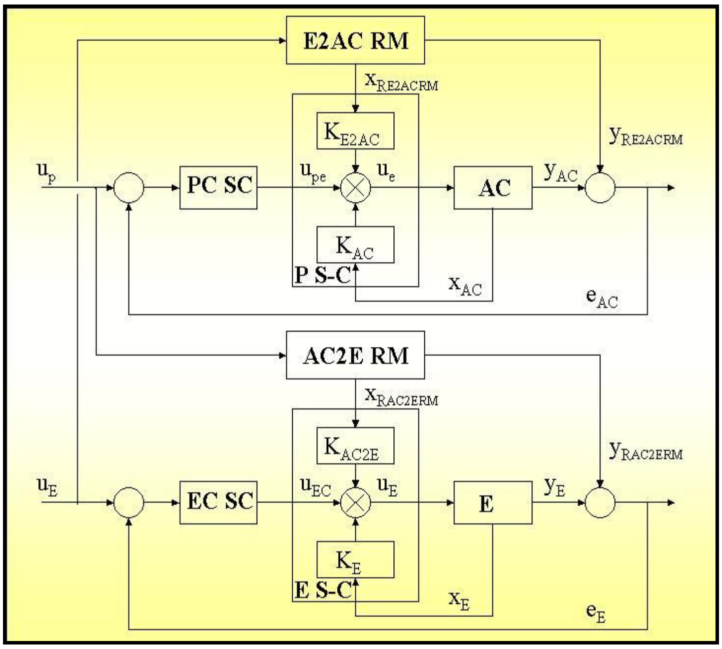


Fig. 10. Integration of the engine and elevator controls (Rohacs D. 2004)

(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)

During simulation, there were applied the model contains real data of the middle size small aircraft that determined (Rohacs 2004) by used data published Nelson (1989):

$$\dot{\underline{x}} = \begin{bmatrix} \Delta \dot{V} \\ \Delta \dot{\alpha} \\ \Delta \dot{q} \\ \Delta \dot{\vartheta} \end{bmatrix} = \begin{bmatrix} -0.017938 & 1.779147 & 0 & -9.81 \\ -0.006883 & -2.029455 & 0.944587 & 0 \\ 0.022188 & -5.154428 & -5.890203 & 0.010374 \\ 0 & 0 & 1 & 0 \end{bmatrix} \cdot \begin{bmatrix} \Delta V \\ \Delta \alpha \\ \Delta q \\ \Delta \vartheta \end{bmatrix} + \begin{bmatrix} 0 & 17.93356 \\ -0.160444 & -0.00893 \\ -11.675895 & -1.36058 \\ 0 & 0 \end{bmatrix} \cdot \begin{bmatrix} \Delta \delta_E \\ \Delta n \end{bmatrix},$$

$$\underline{y} = \underline{\underline{C}} \cdot \underline{x} + \underline{\underline{D}} \cdot \underline{u} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} \Delta V \\ \Delta \alpha \\ \Delta q \\ \Delta \vartheta \end{bmatrix} + \begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix} \cdot \begin{bmatrix} \Delta \delta_E \\ \Delta n \end{bmatrix} = \begin{bmatrix} \Delta V \\ \Delta \theta \end{bmatrix}.$$

Here θ is the flight path (climb) angle.

The results of simulation with use of the recommended integrated control are shown in Figures 11. Here C. A/C and IC nominate the conventional aircraft and aircraft with integrated control. Integrations were made for 100 and 1000 sec. Figure 11. demonstrates that the integrated control fully realized the idea drawn earlier. After changes in thrust the aircraft speed was changed, however the flight path angle does not changed.

The investigation has resulted to the conclusions. the small / personal aircraft control can be realized as

- fully automatic intelligent control system, leaving the pilot out of the control (that might be the best solution, but society may not ready to accept fully automatic systems);
- remote control performed by well trained pilots from the ground ;
- 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).

The pilot – owners, renters like fly with their aircraft may prefer the last solution.

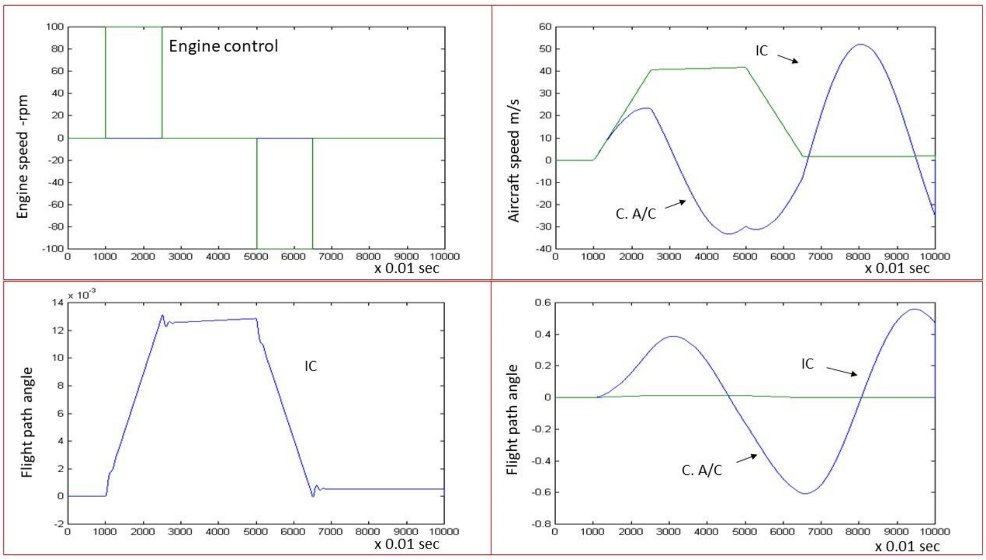


Fig. 11. Comparison of the integrated (IC) and conventional control (C. A/C) in case of change in engine speed, only (Rohacs 2002)

A global solution could be a computer assisted control system with automatic limitations on critical regimes which integrates engine and aircraft control, and connects roll and yaw control into one channel (Rohacs, 2007).

6. Pilots' subjective decision

The pilots use the so-called subjective decisions, namely they apply subjective situation awareness, situation analysis and decision process in aircraft controls. They must define the problem and choose the solution from their resources. (Rohacs, 2012). Resources are methods or technologies that can be applied to solve the problems (Kasyanov, 2007). These could be classified into the so-called (i) passive (finance, materials, information, and energy - like aircraft control system in its physical form) and (ii) active (physical, intellectual, psycho-physiological behaviours, possibilities of subjects) resources. The passive resources are therefore the resources of the system (e.g. air transportation system, ATM, services provided), while the active resources are related to the pilot itself. Based on these, decision-making is in fact the process of choosing the right resources that leads to an optimal solution.

Subjects (pilots, system operators) could develop their active resources (or competences) with theoretical studies and practical lessons (Kasyanov, 2007; Rohacs, Kasyanov, 2011). However, the ability of choosing and using the right resources is highly depending on (i) the information support, (ii) the available time, (iii) the real knowledge, (iv) the way of thinking, and (v) the skills of the subject. Such decisions are the results of the subjective analysis.

There is insufficient information on the physical, systematic, intellectual, physiological characteristics of the subjective analysis, as well as on the way of thinking, and making decision of subjects-operators like pilots. Only limited records are available on the time effects, possible damping the non-linear oscillations, the long term memory, which makes the decision system chaotic (Basar E. 1990; Freeman, 1992; Dartnell, 2005).

The subjective decisions process can be summarizes by the following way. At first, the pilot as subject (Σ) must identify and understand the problem or the situation (S_i,), then from the set of accessible or possible devices, methods and factors (S_p) must choose the disposable resources (R^{disp}) available to solve the identified problems, to finally decide and apply the required resources (R^{req}) (Kasyanov 2007) (see Fig. 12.a). For this task, the pilot applies its active and passive resources. The active resources will define how the passive resources are used:

$$R_{\mathrm{a}}^{\mathrm{req}} = f\left(R_{\mathrm{p}}^{\mathrm{req}}\right). \qquad (2)$$

Instead of the function between the resources (2), the literature often uses the velocity of transferring the passive resources into the actives:

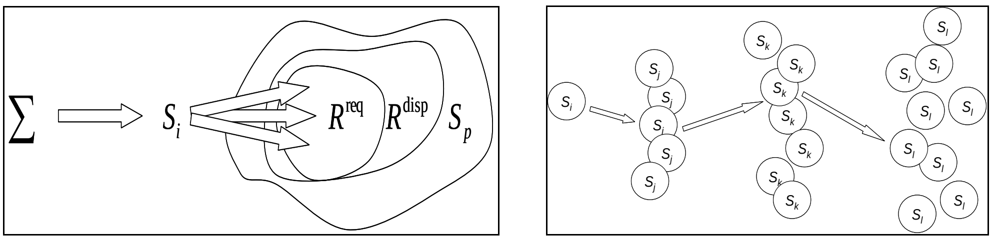
$$v_{\mathrm{a}}^{\mathrm{req}} = f_v\left(v_{\mathrm{p}}^{\mathrm{req}}\right), \qquad (3)$$

where

$$v_{\mathrm{a}}^{\mathrm{req}} = \frac{dR_{\mathrm{a}}^{\mathrm{req}}}{dt}, \qquad v_{\mathrm{p}}^{\mathrm{req}} = \frac{dR_{\mathrm{p}}^{\mathrm{req}}}{dt},$$

and in simple cases

$$f_v = \frac{\partial R_{\mathrm{a}}^{\mathrm{req}}}{\partial R_{\mathrm{p}}^{\mathrm{req}}}.$$



a, Pilot decision – action process   b, Situation chain process

Fig. 12. Aircraft operation as the active endogenous system

It is clear that the operational processes can be given by a series of situations: pilot identifies the situation (S_i,), makes decision, applies the control (R_a^{req}), which transits the aircraft into the next situation (S_j,). (The situation S_j, is one of the set of possible situations). This is a repeating process (see Figure 12.b), in which the transition from one situation into another depends on (i) the evaluation (identification) of the given situation, (ii) the available resources, (iii) the appropriate decision of the pilot, (iv) the correct application of the active resources, (v) the limitation of the resources and (vi) the affecting disturbances (Rohacs, 2012).
The situation chain process can be given by the following mathematical formula:

$$c(t): \quad \left(x_0, t_0, \omega\left(t_f \in [t_0, t_0+\tau]\right), R^{disp}(t_0), R^{req}(t_0), \ldots\right), \tag{4}$$

or in a more general approach:

$$c(t): \quad \left(P : \sigma_0(t_0) \to \sigma_j\left(t_f \in [t_0, t_0+\tau]\right) \in S_f \subset S_a, R^{disp}(t_0), R^{req}(t_0), \ldots\right); \tag{5}$$

where x_0 is the vector of parameters at the initial (actually starting) state at t_0 time; σ gives the state of the system in the given time; τ defines the available time for the transition of the state vector into the set of ω not later than $[t_0, t_0+\tau]$; P are the problems how to transit the system from the initial state into the one of the possible state $S_f \subset S_a$ not later than τ .
This decision process described here can be investigated by two ways. On one hand, during a flight, one flight situation is followed by another. Therefore, the aircraft flight operational process with continuous state space and time can be approximated by the stochastic process with continuous time and discrete state space, flight situations. This means that a flight is a typical situation chain process that can be approximated by the Markov chain. (Rohacs, 2012).
On the other hand, the pilot decision process is recommended to model by use of methods of subjective analysis.
In simple case when for example during final approach, the pilot must decide to land or go around. For this decision they need time, which is the sum of (i) the time to understand and evaluate the given situation, σ_k , (ii) the time for decision making and (iii) the time to react (covering also the reaction time of the aircraft for the applied decision) (Kasyanov 2007):

$$t^{req} = t_{ue}^{req}(\sigma_k) + t_{dec}^{req}(S_a) + t_{react}^{req}(\sigma_k, S_a) \ . \tag{6}$$

Here σ_k defines all possible situations (e.g. σ_1 might be the situation of landing at first approach without any problems, σ_2 could be related to the situation when the under carriage system could not be opened, σ_3 might stand for a landing on the fuselage, σ_4 for go-around, or σ_5 for a successful landing after second approach).
S_a is the chosen solution from the set of possible solutions. It is clear that all solutions have a limited drawback, such as extra cost, or extra fuel.
The subjective factor of pilots might be introduced with the use of the ratio of the required and disposable resources (Kasyanov 2007):

$$\bar{r}_k = \frac{R^{req}(\sigma_k)}{R^{disp}(\sigma_k)} = \bar{t}_k = \frac{t^{req}(\sigma_k)}{t^{disp}(\sigma_k)} . \tag{7}$$

In this case, an endogenous index can be defined as

$$\varepsilon_k(\sigma_k) = \frac{\bar{r}_k}{1-\bar{r}_k} = \frac{t^{req}(\sigma_k)}{t^{disp}(\sigma_k) - t^{req}(\sigma_k)} \quad or \quad \varepsilon_k(\sigma_k) = \frac{t^{req}(\sigma_k) + t^{dec}(S_a)}{t^{disp}(\sigma_k) + t^{dec} - t^{req}(\sigma_k)} \ , \tag{8}$$

where $t^{dec}(S_a)$ is a time required to recognize the set of alternative strategies.
Naturally, we can assume that pilots are able to evaluate the consequences of their decisions, and therefore they can evaluate the risk of the applied solutions. Such evaluation can be defined as the subjective probability of situations: $P(\sigma_k)$, canonic distribution of which as the distribution of canonic assemble of the preferences is assumed to hold the following form:

$$p(\sigma_k)=\frac{P^{-\alpha}(\sigma_k)e^{-\beta\varepsilon_k(\sigma_k)}}{\sum_{q=1}^{2}P^{-\alpha}(\sigma_q)e^{-\beta\varepsilon_k(\sigma_q)}} \quad , \qquad (9)$$

where $p(\sigma_k)$ describes the distribution of the best alternatives from a negative point of view.
The time-depending coefficients α and β should be chose in a way to model the endogenous dynamics, model the subjective psycho physiological personalities of pilots. The qualities of the pilots are depending on different factors including "periodical" incapacity to make decisions that increases while getting closer to the decision time (altitude) of go-around.
The (9) has special features: in case of

$$\bar{t}_k=\frac{t^{req}(\sigma_k)}{t^{disp}(\sigma_k)}\to 0 \quad ,$$

preferences are determined by the subjective probability, $P(\sigma_k)$, only, and in case $\bar{t}_k\to 1$, the preference turn into zero. The (9) comes from the solution of the following function:

$$\Phi_p=-\sum_{k=1}^{N}p(\sigma_k)\ln p(\sigma_k)-\beta\sum_{k=1}^{N}p(\sigma_k)\varepsilon_k(\sigma_k)-\alpha\sum_{k=1}^{N}p(\sigma_k)\ln P(\sigma_k)+\gamma\sum_{k=1}^{N}p(\sigma_k) \ . \qquad (10)$$

A special feature of this function is that the structure of the efficiency function includes the logarithm of the subjective probability:

$$\eta_p=-\sum_{k=1}^{N}(\alpha\ln P(\sigma_k)+\beta\varepsilon(\sigma_k))p(\sigma_k). \qquad (11)$$

The complexity of decision making could be characterized by the uncertainties or the pilots' incapacity to make decisions, which is increasing while getting closer to the minimum decision altitude, H^*_{Dmi}. To make decisions, the pilots must overcome their "entropic barrier", H_p. The rate of incapacity could be defined with the norm of entropy:

$$\overline{H}_p=\frac{H_p}{\ln N} \quad . \qquad (12)$$

Before application of this described method, the human way of thinking, the working of brain must be modelled, too.
From control theory point of view, the most important behaviour of human brain is the memory, namely learning, memorizing and remembering (Receiving, Storing and Recalling). Generally, human beings are learning all the time, storing information and then recalling it when it is required (Davidmann, 1998). After investigation of the way of human thinking, including recognition, information analysis, reasoning, decision support (Rohacs, 2006; 2007) we have characterized the human way of thinking by the following behaviours:

- syntactic and semantic processing of the sensed information,
- working on the basis of the large net of small and simplified articles (neurons),
- using the complex system oriented approach,
- making parallel thinking and activity,
- learning (synthesis of the new knowledge),
- model-formation and using the models (including verbal models applied in learning processes and complex mathematical representation),
- long-term memory,
- tacit knowledge (took in practice),
- intentional thinking (goal and wish),
- intuition (subconscious thinking),
- creativity (finding the contexts),
- innovativity (making originally new minds, things),
- unexpected values can be appeared,
- jumping from quantity to quality.

As it can be seen, the human way of thinking and decision-making is a very complex stochastic process, contains some chaotic effects.

Principally, there are not enough information about the physical, systematic, intellectual, psychophysiology, etc. characteristics of the subjective analysis, about the way of thinking and making decision of subjects-operators like pilots. Only limited information available about the time effects, possible damping the non-linear oscillations, long term memory, etc. making the decision system chaotic. it is really, there are not enough information for exact modelling, but the enough for understanding the chaotic character of thinking and detecting the "oscillation" processes, namely changing between the accepting and rejection of the right solution in decision making (Basar E. 1990; Freeman, 1992; Dartnell, 2005).

Professor Kasyanov introduced a special chaotic model (Kasyanov, 2007) based on the modified Lorenz attractor (Stogatz, 1994) for modelling the endogenous dynamics of the described process.

$$\begin{aligned}\frac{dX}{dt} &= aY - bZ - hX^2 + f(t);\\ \frac{dY}{dt} &= -Y - XZ + cX - mY^2; \qquad (41)\\ \frac{dZ}{dt} &= XY - dZ - nZ^2.\end{aligned}$$

where *a, b, c, d, h, m, n* are the constants while *f* takes into account the disturbance. (In case of $h=m=n=0$ and $f(t)=0$ the model turns into the classic form of Lorenz attractor.)

Principally there are not strong arguments explaining the use of Lorenz attractor for modelling the human way of decision making (human thinking) (Dartnell, 2010; Krakovska, 2009), but the results of application it by estimated constants from real flight measurements are close to real situations (Kasyanov, 2007), real processes. Of course, this approach requires further investigation.

The pilots' subjective decision had been investigated in PPLANE project, too (Rohacs et al, 2011). It was applied to study the landing the small aircraft. According to the flight operational manuals and airworthiness requirements, limitations (minimum and maximum)are defined for velocity, descent angle and the decision altitude, that minimum altitude, at which the pilots must make final decision on following the landing or break it and go around (for making a return to start the landing again).

From the results of the developed model, we can conclude that in case of a problem at the final approach, common airliner pilots require about three times more time to decide than those having more practices.

The decision process of less-skilled pilots was studied, too (Rohacs et al., 2011). The descent velocity of a small aircraft is calculated to be about 100 km/h for airliner common pilots, and 75 Km/h for those of less-skilled.

In this case, the airport can be designed with a runway about 250 - 300 m and a protected zone under the approach (to overfly the altitude of 100 m) of about 1500 m. These characteristics enable to place small airports close / closer to the city centre.

7. Pilot load model monitoring

The central element of the pilots duty is the situation awareness. According to Endsley (1995b), situation awareness provides "the primary basis for subsequent decision making and performance in the operation of complex, dynamic systems..." Endsley (1995a) developed a model of situation awareness in dynamic systems generally, which is still a very widely - probably most - used representation of the operators decision process. This model was improved and adapted to investigation the situation awareness in future aircraft and air traffic controls (Rohacs, Rohacs and Jankovics, 2015). In such highly automated future systems the role of operators will change from active control to passive monitoring or better to say supervising the system.

The results of investigations applied to studying the less-skilled pilots' works (Rohacs et al. 2011) had been improved to general application for describing and investigating the operator loads. The figure 13 shows the model developed for air traffic controllers (ATCOs) (Rohacs, Rohacs and Jankovics, 2015). By use of this approach, the pilots' loads can be classified as

- task load that is defined by the flight plan and influenced by the weather condition, air traffic complexity, air traffic management,

- information load induced by quality and quantity of available and supplied information (on aircraft operation, traffic complexity, weather condition) supporting the pilots that might be not harmonized and even conflicting and contradictory;
- workload depends on task load and real air traffic conditions, its complexity, real (not predicted) traffic and weather situations, etc.;
- mental load takes into account the human subjective behaviours including e.g. knowledge, practice, physical, psychological conditions) that is always associated with workload.

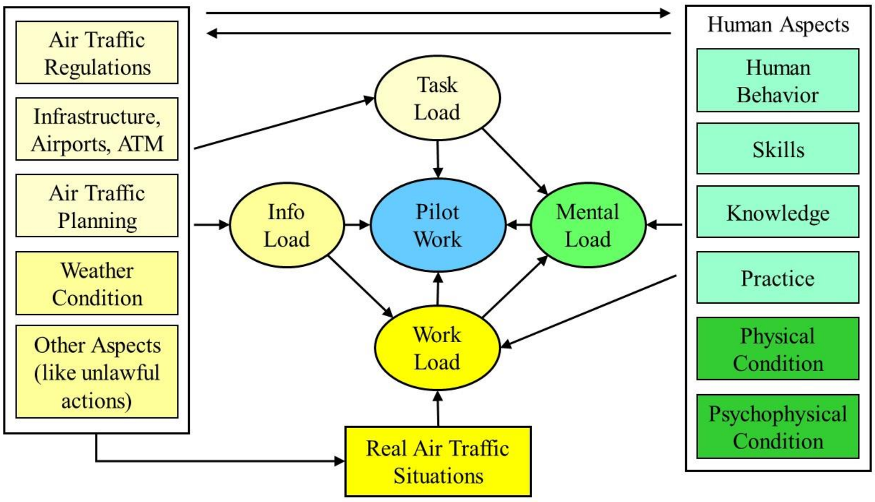


Fig. 13. Load model of the operator-supervisors

Principally, the loads are well investigated except the information load. That is appearing as a new types of load because availability of lot of information from many different sources. The information load may confuse the operators and put them into difficulty to evaluate the right and required information (Ruff, 2002). The loads

A concept on load monitoring and management has developed and tested (Rohacs, Rohacs, and Jankovics, I. 2010; Kale, et al., 2017; Tekbas, Kale, 2017; Jankovics, Tekbas and Kale, 2017). This system uses the collected available data on flight tasks, air traffic, aircraft condition, flight phases, weather condition, etc. and measures data pilot work and mental (psycho-physiological) conditions. There were developed and tested several micro sensors that might be integrated into the working environment (Korody, 2007; nagy, Szabo Rohacs, 2012; Jankovics, Nagy, Rohacs 2014; Jankovics, Tekbas and Kale, 2017; Bos et al., 2017). The central processor of the systems determines the values of loads. The applied merits are based on well know and applied methods as NASA Task Load Index (TLX) (Hart, Staveland, 1998) or Situation Awareness Rating Technique (SART) (Traylor, 1990) and new rating methods like Automation Thrust Index (SATI) (Dehn, 2008) or identifying the key human performance (Lee, et al., 2015). The created improved, integrated and generalized method results to values of information, task work and mental loads values between the zero and one. These values can be displayed on central screen of the operators-pilots. The first simple management may cause alert in case of high level of single loads or combination of loads.

8. Pilot decision support system

With the aspects above, a new concept was developed to improve the pilot working environment and decision support. Of course, the supporting systems includes all the possible methods that may help in reaching the better flight performance and better stability, flight dynamics and control characteristics of the aircraft controlled by less-skilled pilots. So, the design the aircraft with adjustable or changeable control systems (as adjustable position of center of gravity or controllable changes in deflection angles and deflection singular speed of the conventional control surfaces, as well as the creating the integrated controls (described by point 5.) one of the very powerful element of the pilot support system.

The recommended pilot decision support system is based on the (i) environment, (ii) technology and (iii) solution (software) developments.

The vision on future cockpit is a good example for future pilots supporting concept (Rohacs et al., 2011) containing the following solutions:

- the developed cockpit could contain up to 6 colour displays for the following tasks :
  - digital reproduction of the basic flight instruments,
  - coloured 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;
- flight advisory system with
  - day – night visualization of the aircraft surroundings,
  - artificial vision 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,
  - 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.

The developing pilots support system (Figure 14.) has ground and on board parts. Its on board central processing unit collects and analyses the available data 8including information provided by cooperating other aircraft and ground system) and measurements for supporting the load management, situation awareness and decision support. The results are displayed on the pilot's screens. The display is divided for six parts (see fig. 14). On the bottom, the four types of loads are presented in forms of coloured lines (left side). In central part, the tasks are displayed. The right bottom, the advises are given in text form. The upper side the screen is contains the more than 180-degree view of ahead and side of the aircraft. The view on left and right sides (at list partly) are shown as synthetic vision pictures. The central view is the real view but the head up display shows the recommended flight path (in predicted tunnel forms) and gives some other recommendations, measured information. For example the ground sensed information on the wind, wind shear under the landing trajectory.

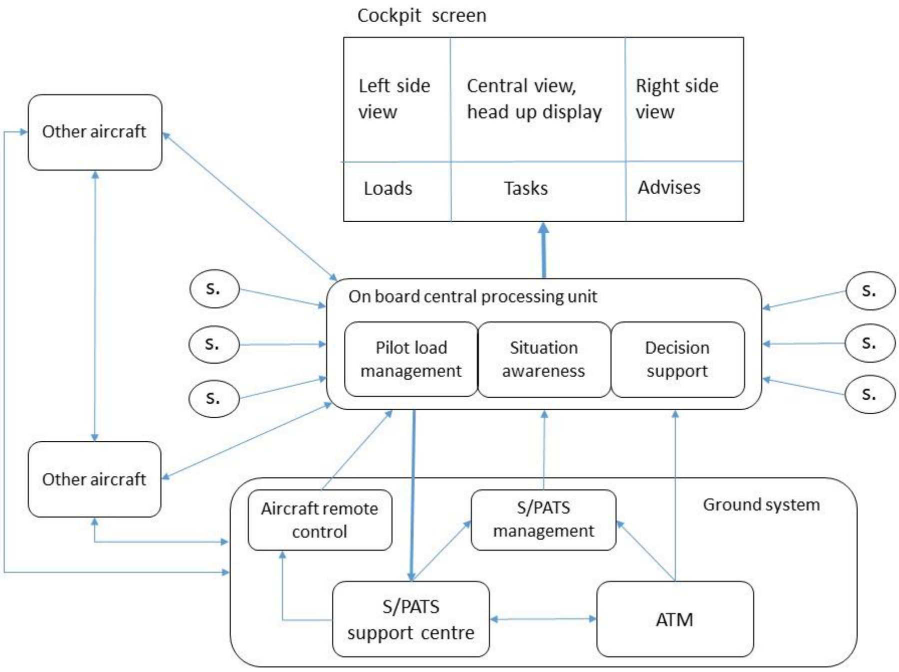


Fig. 14. Functional model of the pilot decision support system (s. – sensors)

The small / personal air transport should have a ground support centre, too. It collects and evaluates the available data provided by ATM, cooperating small aircraft and other services (like weather prediction). It has two important sections. One determines the recommended flight trajectories depending on the traffic conditions, and conflict detection and resolution. It may shows – for example - the ranking (prioritized) landing of different aircraft. Each aircraft may have on individual supported trajectory. The other task of the ground supporting system is the remote control centre. The remote control might be initiated by the ground or the on-board sub-systems in case of identified emergency situations.

9. Conclusions

There are many international and national projects, as EPATS, PPlane, SAT-Rdmp, Esposa, NASA SATS, etc. have developed a new small aircraft and new small / personal air transportation systems for last two decades. The new small aircraft will be operated by the less-skilled pilots, pilots having limited practice. Therefore, the investigation and solving the safety problems, as well as developing the pilot supporting systems are in first group of important tasks to be solved.

This paper overviewed the actions and summarize the results (i) safety aspects analysis of the small / personal aircraft, air transport system, (ii) introduced the methods of subjective analysis to investigation and modelling the pilot decision process, (iii) created an improved pilot load model and load management, and (iv) defined the developing (less-skilled) pilot supporting system.

The paper described mainly the results of those projects in which the authors were involved. Even so, the results are rather general. The Department of Aeronautics, Naval Architecture and Railway Vehicles utilizes the developing methods of safety aspects investigation simulation technologies (Schweighofer, J. (et al., 2015), studying and developing the decision making (Simongati, 2010; Bicsak, 2015) and developing the operator support systems (Tekbas, Kale, 2017) in wide range of possible applications.

The safety analysis has shown that, the small air transportation system nearly as safe as the airliners services, so long as taking into account facts, the small aircraft are controlled by the single pilot and the flight distances are much shorter. However, the personal pilots are involved into (make) accidents (related to the flight hours or flight distances) about 3 times more than the commercial pilots. So, the less-skilled pilots owning and renting the aircraft and having less practices, less flight hours, may generate problems in the future S/PATS.

The European projects had analysed the safety and connecting security aspect of S/PATS and there were developed a series of recommendation for developing, design, production and operation of small aircraft. For example special (self and remote) security checking system was developed.

The investigation of the situation awareness and decision process of the pilots had leaded to introduction of methods of subjective analysis into the modelling and designing systems for the (less-skilled) pilot subjective decision process. By using this approach, the requirements for the small aircraft landing process had been derived.

The study the pilot loads including the information, tasks, work and mental loads results to developing a new improved operator (pilots, ATCOs) models and load management systems introduced by this paper, too.

Finally the vision on and developing (less-skilled) pilot support system was specified. The system deals with cooperating aircraft and has ground and on-board parts. The ground part includes a traffic management system might be applied at the small airports for control the small aircraft motion in airport areas; and a special remote control centre for controlling the aircraft motion in case of emergency situation. The on-board part operates the load management, situation awareness and decision support sub-systems. The system is contains a special screen in which the important supporting information including predicted trajectory, available information on weather (wind) condition in airport regions, traffic situation, etc. are shown. The system elements (like required micro sensors built in working environment, control elements, software, rule of managing, etc. are developed and tested in flight simulators and simulators of the ATCOs working environments.

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