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Faculty of Transportation Sciences
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University of Žilina
Faculty of Operation and Economics
Of Transport and Communications
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Brno University of Technology
Faculty of Mechanical Engineering
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In cooperation with
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New Trends in Civil Aviation 2011

Foreword

The thirteen editions of the International Conference New Trends in Civil Aviation 2011 (Nové trendy v civilním letectví 2011) is held in Prague at the Czech technical University in Prague, Faculty of Transportation Sciences, Department of Air Transport under the patronage of the Dean of the Faculty of Transportation Sciences, Prof. Dr. Ing. Miroslav Svítek, and is organized in close collaboration with partner universities: Brno University of Technology, Faculty of Mechanical Engineering, Institute of Aerospace Engineering and the University of Žilina, Faculty of Operation and Economics of Transport and Communications, Department of Air Transport and Czech Aeronautical Society. The conference chain follows original International Colloquium established in 1999 by distinguished late colleagues, Prof. Ing. Ludvík Kulčák, CSc. a Prof. Ing. BohuslavSedláček, CSc.

The scope of the conference arises from the name itself. It is in compliance with contemporary as well as mid-term strategies of R&D and innovations of aerospace, space and air transportation of European Union in the horizon up to 2020. They cover topics as follows:

Reduction of emissions in air transport
Aircraft propulsion systems and alternative fuels
Aircraft design
Air traffic management
Safety and security aspects of air transportation
Environmental efficiency of aviation

Main purpose of the conference is to give an opportunity to young professionals, Ph.D. students to present results of their research and get together with distinguished and experienced professionals from academia, research, industry and civil aviation institutions as a unique forum for exchange of knowledge and experience.

Presented papers and their professional and scientific level is reviewed by the Scientific Committee of the conference and best presented papers will be offered for publication in reviewed magazines Transactions of Transportation Sciences, Czech Aerospace Proceedings and ActaPolytechnica.

Acknowledgements

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Ergonomic Methods Applicable in the Development of New Small Aircrafts.

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***Abstract*—The development of new aircraft belongs among the most demanding and complex engineering disciplines. Designers must take into account a huge number of requests from different areas, like aerodynamics, aeroelasticity, flight mechanics, strength, material, construction of frame, systems, mechanisms, power units, electrical engineering, automation, software, manufacturing etc. . Highly specialized experts, technicians and engineers may easily forget the fact that the designed product is built for people and people will not only use the product, but they will also have to build, operate, maintain and repair the aircraft. This paper deals with small aircraft engineering with focus on human factors and ergonomics. The goal is to introduce methods that can help to improve safety, functionality, value and comfort of new aircraft design. The introduced ergonomic analyses can be used to analyze aircraft's interior (cockpit, crew and passengers compartment) and also aircraft's manufacturing, inspection, maintenance and repair. Thanks to the consistent application of ergonomic principles in the development, people should not be longer constrained by thestructure, but the structure should bedesigned and built to meet humanneeds and capabilities. The introduced ergonomic recommendation are based on information collected from existing standards, survey among pilots of small aircrafts and DHM (Digital Human Modeling) analyses and simulations. The DHM simulation has proved to be an essential tool for testing and comparing of the various options and searching for a compromise amongoften opposite requirements.**

Keywords- ergonomic, human factor, aircraft cockpit design, digital human modeling .

I. INTRODUCTION

The aircraft structureeven of small airplanes is a very complex product. But still the most complex element on board of the aircraft is itself human. Despite this fact the human factor is not taken into account early enough and thoroughly enough in the small aircrafts development. There have been observed ergonomic problems even with drone planes encountered by ground staff.

The properly mastered ergonomicduring design is a key factor of safe operation and leads to prevention of errors and mistakes, both in normal and emergency situations. USAF medical report states that the ergonomic design deficiencies are a contributing factor in a significant percentage of accidents (Gregory F. Zehner [1]).Therefore there is necessary to understand the human's needs and find his limits. The structure should be designed with respect to it's usersize and capabilities (pilots, passengers, mechanics and other ground staff). Obviously the safety is a key but the ergonomic design leads also to decrease of human stress and fatigue and also helps to increase comfort, utility value, quality, user's satisfaction and prestige on market.

There were collected information from existing standardsand methods, several small aircraft cockpits dimensions were measured, and there was proceeded a survey among pilotswho evaluated the ergonomic issues they have been encountering. The collected data were analyzed and evaluated by simulation in DHM software (Tecnomatix Jack, Siemens PLM Software). The digital simulations and analyses helped to find a set of ergonomic recommendation and methods intended for the human centered design of the new small aircrafts.

II. ERGONOMIC PROBLEMS OF CURRENT SMALL AIRCRAFTS

There have been observed several ergonomic issues of current small aircraft cockpits like constrained space, awkward location and design of drivers and controls, insufficient internal and external view etc.. The design often does not takeinto account the full range of population size. The larger pilots have problems with lack of space for their knees under the dash and/orlack of space above and around head leading to awkward postures and unpleasant headphones strikes to canopy or shade.

The aircraft's seats (pedals) in this category have often none or insufficient range ofmotion and do not meet population range requirements. There are situation during operation when pilot's body (e.g. legs) is colliding with control stick. Some of the controls are located outside comfort reach zone. There are also smaller pilots in population which may encounter a problem with brakes maximum reach or with insufficient external view. The boarding on the small aircrafts is also very often uncomfortable especially for older persons. The standard basic design methods are based on two-dimensional templates and drawings (e,g, SAE J826 (ISO 300725), which represents the outline of the legs and torso of 95 percentile male. There are several otherstandards e.g. dealing with eye position in the population (eyellipse), sitting height(SAEJ941 and J1052) etc. .

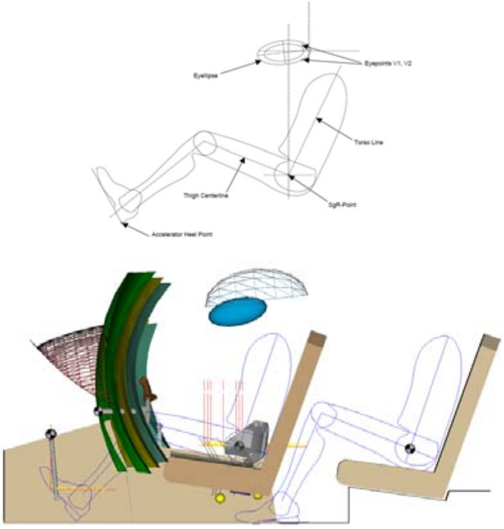


Figure 1. SAE J826 template, SgRP, eyelipse, reach zones

There are several deficiencies in the current design methods. The current methods mostly use population size range 5 - 95 male percentile and anthropometric data are based on Anglo-Saxon population. This approach means a trouble for a certain percentage of pilots. The aircraft are operated all around the world, and the anthropometric dimensions vary considerably. This is concerning not only the category of small aircrafts but also the category of general aviation. The research conducted by Buckle, P.W. [3] for aircrafts Boeing 737-200, 747, 757 and Lockheed TriStar has shown that the ergonomic design issues significantly decrease a range of potential pilot recruits with appropriate anthropometric parameters and the requirement for functional eye height while sitting excludes 73% of the British female population (19-65 years) and 13% of British male population (19-65 years).

The demographic profile has been also changing significantly. The population has been growing (height and width). Buckle P.W. [3] in his study noted that in the last thirty years the size of a young adult was increasing in average by one cm every ten years. A similar study of the Czech population showed that over the last 100 years the average height of human has increased by 12cm.

The new aircraft cabin design should respectthese trends and take into account not only current but also future population size within a lifecycle of the aircraft. Therefore the introduced ergonomic recommendation were created based on the population size ranging from 5 percentile of female to 99 percentile of male and are based on the most recent anthropometric data.

The other probable causes of the current ergonomic issues are in the traditional methods used in the development of the small aircrafts. For many years, the aircraft cabins were designed only based on percentile of population. The consequence of this approach is that a significant number of pilots encounter difficulties in operation and work in the airplane (Zehner, GF [4]). The percentile approach takes into account only the size of the population. But the pilots are not only small or large but they also have different proportions. Two people with same height in e.g. 5 percentile may significantly vary in proportions - one can be slim, the other overweight. There can be also two 95 percentile persons, when one of them may have a normal torso lengthand long legs and the second one may have a long torso and normal legs. The variation in proportions in the same percentilewill lead to different seating postures and the posture will affect visibility,reach, and space requirements. Therefore there were considered several variables of the human body parts in the digital simulations during the research and the ergonomic recommendation formation.

Zehner, GF [4] in his study noticed another possible issue, inappropriate application of anthropometric data in cockpits design. This issue occurred most often in determining eye position and sitting height. The anthropometric data are based on measurement in sitting position withback straight and fully upright with gaze horizontally forward. In fact, the pilot adopt such posture very rarely if ever. Therefore during the digital simulation there were created postures as similar as possible to the real pilot seating postures and the fundament cockpit dimensions were set based on the postures in different situations.

III. The Pro-Active Approach to Ergonomics and DHM Simulations

Currently the most common approach to ergonomics is a reactive approach. The product is designed with consideration of some basic standards and possible ergonomic and functional problems are often discovered not soon as the physical mockupis tested or in the worse case during prototype flighttests (DiClemmente P. [2]). The testing of the physical prototype and any changes in the late development stage is significantly time-consuming and expensive. The best opportunity to optimize the product isin the early design stage. But in this phase the structure conceptexists mostly only as CAD model. In order to support key decisions, the engineers must have an exact image not onlyhow the design looks like but also how the future people will be accommodated and how will be interacting with the product.

The basic idea of this work is to find and solve the potential functional and ergonomic problemsin the digital model, in advance they would occur in the real world. This pro-active approach can be used in practice thanks to a rapid DHM (Digital Human Modeling) software development, where 3D CAD model is extended with biomechanicallyaccurate digital human models and digital tools for human activity and performance analyses.

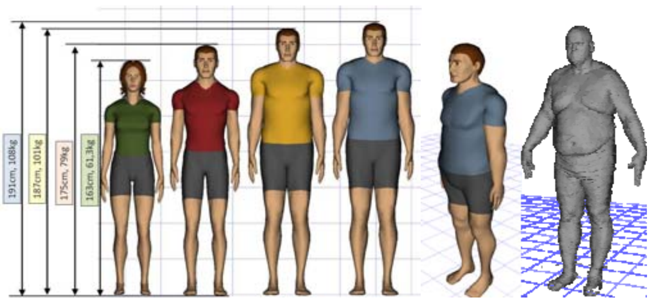


Figure 2. Selected Digital Human Models in software Tecnomatix Jack

The human – machine interaction was evaluated by digital human model in a digital mockup of several small aircrafts. Based on the analyses there were determined a set of recommendation which should help to ensure the proper accommodation of current population, correct reach, visibility and other ergonomic tasks in early design stage.

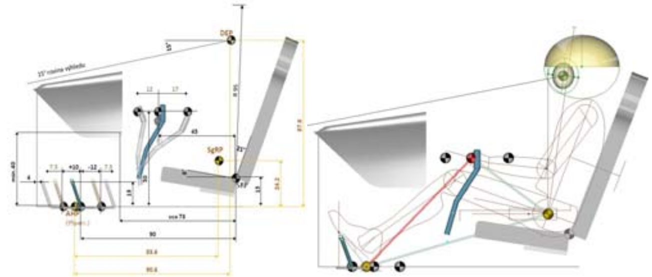


Figure 3. *Reference dimension for small aircraft (UL2) with fixed seat and adjustable pedals*

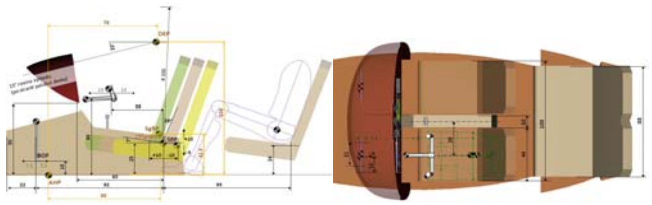


Figure 4. Reference dimension for small aircraft with adjustable seats and/or adjustable pedals

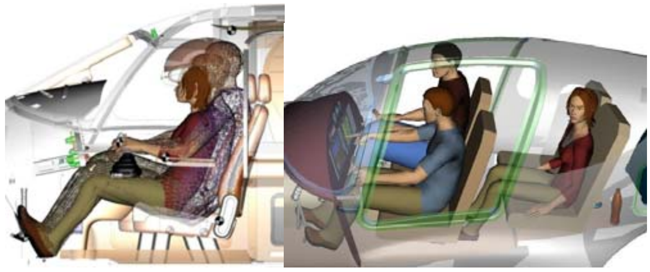
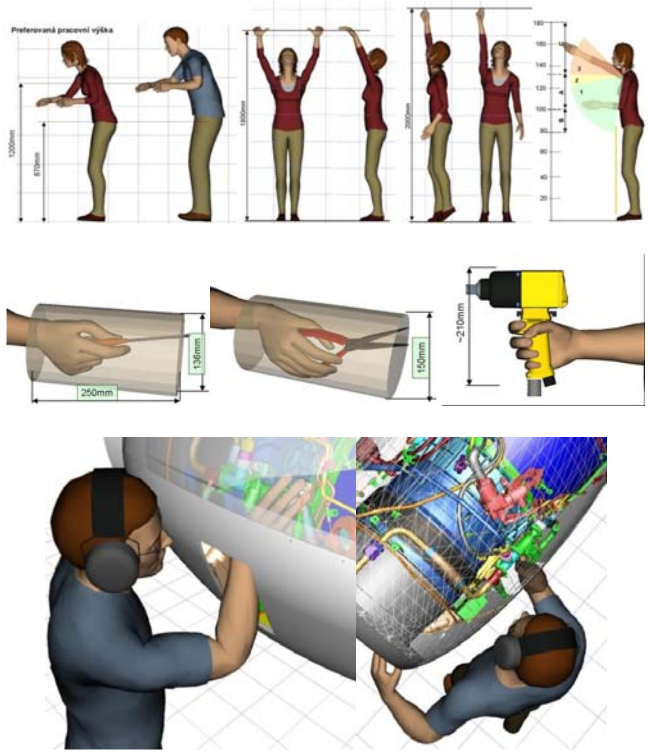


Figure 5. Human models in the selected population range in different postures

IV. Human Centered Design in Aircrafts Manufacturing, Maintenance and Inspection

The aircrafts maintenance costs represent a significant portion of total operating costs. Even more important the maintenance and inspection tasks have a significant impact on safety. The ergonomic of the manual tasks have impact on quality and so safety. The second part of the work has focused on the human factor and ergonomic in the area of manufacturing, maintenance and inspection and there were determined a set of recommendations which should help to ensure feasibility and quality of manual tasks when designing the new small aircraft structures. These methods focus on how to ensure sufficient access, space reach, visibility etc. for easy and fast maintenance. The third part of the work deals with recommended ergonomic methods and analyses to assess biomechanical and muscular –skeletal load, postures and limits in the typical manual tasks.



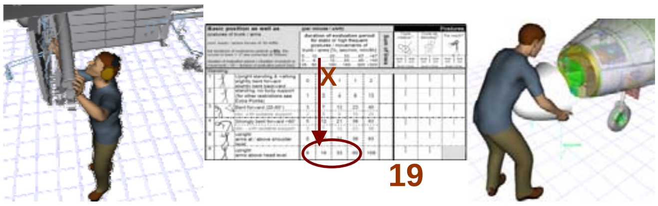


Figure 6. Examples of the DHM analyses of manual tasks in manufacturing, maintenance and inspection of the aircrafts

RESUME

The digital human simulation in design has proved to be an effective tool for creation the human centered products and processes and to implement the needs of future users. It is possible to literally populate the 3D CAD model with the digital humans and to evaluate their requirements and demands.

The following future research should be focused on the implementation and application of the Virtual Reality toolssuch as Motion Capture suit, Cybergloves and Head Mounted Display so the engineers, human factor specialists and pilots would be able to test and evaluate the future productsproperties even in more detail in the early design stage.

Figure 7. Virtual reality tool – Head mounted display, cyber gloves, motion capture suit for human factor analyses in digital mockup

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Aircraft Selection for Small and Medium - Sized Companies

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***Abstract*—This paper discusses the selection of suitable aircraft construction for small and medium-sized companiesin Slovak republic and possibility of using less expensive aircraft with a simple structure. It highlights their advantages over the airplane. Aircraft design is divided into two groups, which are compared in terms of purpose and economic factors.**

Keywords - helicopter; helicopter design; operational use of thehelicopter; analysis

Air transport is a major leader not only in sphere of passenger transport, post and load, but also in other technical and economic sectors. For that reason is air transport building into a position of important competitor in these sectors. Because the greater parts of the surface of Slovak republic are mountainousareas with hardly accessible places, the utilization of an aircraft, especially helicopters, is necessary in the most of the situation.

Construction and aerodynamic facilities of the helicopter enable variously maneuvers such as hovering, reversing, vertical flying and landing on small runways, which present a big advantage in compare with an airplane.

Diversity of the helicopters construction enablesuse of helicopter in areas such as passenger transport, transport load and post, search and rescue and a different aerial works.

THE PURPOSE IN USING OF THE HELICOPTER

1. *Personnel purpose*

The small personnel helicopter presents a competition to an automobile in area of the personnel transport these days, because of its comparable price and operating costs.

2. *Search and rescue*

The diversity of helicopters using is within the search and rescue very large. The helicopters provide the assistance in cases of mass casualties and traffic accidents; helicopters are an integral part of mountain rescue service, where operates in the mountains, forests and hardly accessible places; they are used for people and property rescue; provide urgent pre – hospital care, transport; allow transport of patients in critical condition; they are used for the transport of the medical supplies; to ensure medical care of sport and other mass events; evacuation; etc.

3. *Agricultural purpose*

Helicopters are also used in agricultural sector. They play a main role in dusting and spraying the agricultural areas, but they also make hardly accessible areas in the mountains accessible, where the using of heavy machinery would cause the disturbance of ecologic environment. It´s about conveying timber, transplanting trees, liming of forest fires, bypass streams, etc.

4. *Transport purpose*

Transport helicopters are used for the transport of the goods and more people and also for transport – assembly works.

5. *Aerial works*

Construction and assembly flights:

- construction poles and power lines,
- installation of air conditioning
- assembly and disassembly of advertising spaces,
- construction of cableways and lifts,
- installation equipment on the poles, buildings, reservoirs or observation towers
- transport loads, etc.

Controlling, measuring and scanning:

- thermographic scanning,
- chemical and radiation research,
- controlling electrical wiring and distribution plants,
- controlling pipelines,
- security service,
- geophysical and geological measurement,
- control of possible gas leak,
- control of buffer zones,

- control of pipelines system,

Other aerial works:

- transporting atypical goods,
- assembling construction,
- bypass streams,
- creating air turbulence,
- filming and photographing,
- concreting,
- air conveying timber,
- liming of forest fires,
- dusting and spraying the agricultural areas, etc.

Before the analysis of suitable helicopters construction for small and medium – sized companies' measurement in Slovak republic, we divided helicopters construction into two groups – "Universal construction" and "Special construction".

"UNIVERSAL CONSTRUCTION"

This group includes helicopters, which construction enables the modification for a various using of helicopter.

Example of "Universal construction"

- Mi – 2

Passenger version

Figure 1. Passenger version. *[Source:* http://www.aviationmarine.co.uk/heliwing/products/mi2_vers.htm]

This version provides a place for 9 people and allows a quick converting into the transport version with the load capacity of 700 kilograms.

Search and rescue version

Figure 2. Search an rescue version. *[Source: http://www.aviationmarine.co.uk/heliwing/products/mi2_vers.htm]*

Search and rescue version offers a place for transport of two patients and one medical personnel, but available is also version with place for four patients. The typical version contains stretcher, equipment necessary for the treatment and administration of first aid during the patient transport, one place for medical personnel and other medical necessary equipment.

Transport version

Figure 3. Transport version. *[Source: http://www.aviationmarine.co.uk/heliwing/products/mi2_vers.htm]*

Helicopter Mi – 2 is easily convertible into one of two transport versions, namely version with the load of 700 kilograms and version called "flying crane" with the load of 800 kilograms. The helicopter has safety nets and ropes to avoid a load displacement. This construction enables the installation of electronic equipment for lifting loads weighing 120 kilograms.

Agricultural version

Figure 4. Agricultural version. *[Source: http://www.aviationmarine.co.uk/heliwing/products/mi2_vers.htm]*

Agricultural version is available in four primary versions assigned for specific activities. (spraying, dusting and liming). The maximum capacity of trays is 1200 liters.

"SPECIAL CONSTUCTION"

This group includes helicopters, which construction does not enable the modification for a various using of helicopter such as helicopters in group "Universal construction".

Example of "Special construction"

- Robinson R22

Figure 5. Robinson R22. R 2 2 *[Source: http://www.airliners.net/photo/Mountain-Flyers/Robinson-R-22-Beta/1888601/&sid=e99fc4cace1122764dfa24fa5bdfa803]*

This one engine helicopter of small construction is designed to carry persons and for the training. Because of small construction and low performance, they are not used in search and rescue or in transport of loads sections.

- Robinson R44

Figure 6. Robinson R44. *R 4 4 [Source: http://www.robinsonheli.com/rhc_r44_raven_series.html#]*

Robinson R44 is four seats helicopter and thanks to this capacity is suitable for members of companies and families transport. It can be also use in a large spectrum of aerial works.

- Robinson R66

Figure 7. Robinson R66. R 6 6 *[Source: http://www.robinsonheli.com/rhc_r66_turbine.html#]*

The biggest helicopter in this group is Robinson R66. It´s a five-seat upgraded version of Robinson R44 and can be also used in a large spectrum of aerial works.

THE ANALYSIS

We addressed for the analysis 26 small and medium – sized companies in Slovak republic in the form of the questionnaires. We asked questions such as:

- "Do you plan to buy an aircraft?(airplane or helicopter)"
- "Reason for buying an aircraft(airplane or helicopter)"
- "Investment amount of purchase?"
- "Investment amount in service?"

QUESTIONNARIES EVALUATION

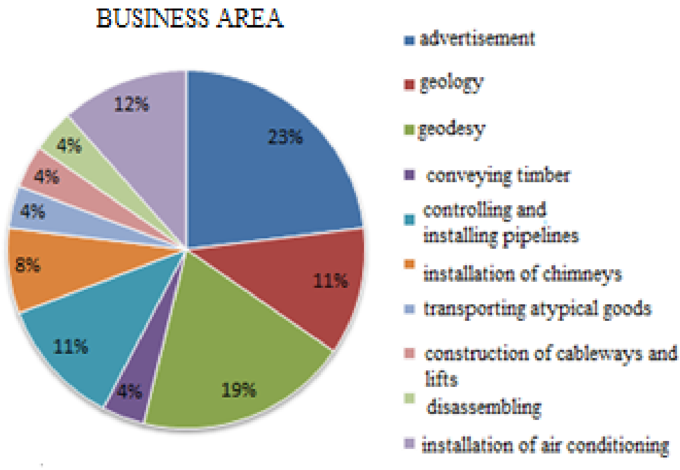

Figure 8. Companies bussines area.

Fig. 8 presents addressed companies' business areas. We focused on areas such as advertising, geology, geodesy, conveying timber, controlling and installing pipelines, etc.

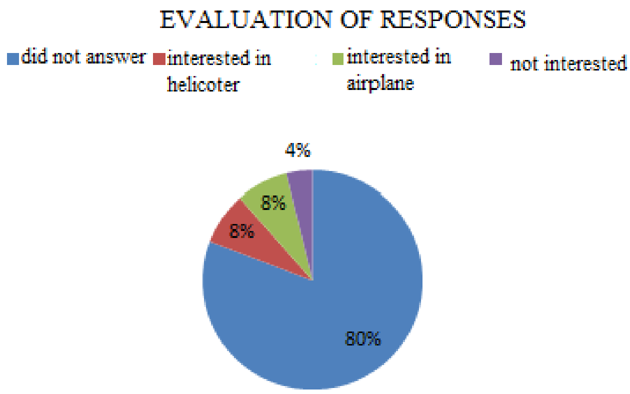

Figure 9. Evaluation of responses.

As shown in Fig. 9, we received responses from 20% addressed companies. From these responses 4% of companies are not interested in buying an aircraft, 8% are interested in buying a helicopter and 8% in buying an airplane. We focused in the analysis on those 8% companies, which are interested in buying a helicopter.

TABLE I. QUESTIONNARIES EVALUATION

Addressed companies	Business area	Airplane/Helicopter	The reason for buying	The price [EUR]
Company No. 1	Advertisement	Not interested	-	-
Company No. 2	Advertisement	Helicopter	Documentation	150 000
Company No. 3	Geodesy	Airplane	Geology research and monitoring	200 000
Company No. 4	controlling electrical wiring and distribution plants	Airplane	Personnel transport	80 000
Company No. 5	construction of cableways and lifts	Helicopter	Controlling and maintenance	250 000

Based on the companies' requirements from Table II., we selected two type of helicopters, namely Robinson R22 and Robinson R44.

TABLE II. MENTIONED SOLUTIONS

Type of helicopter	The price	Operation cost
Robinson R22	184 140 EUR	83,89 EUR/flying hour
Robinson R44	244 160 EUR	126,50 EUR/flying hour

THE SOLUTION FOR COMPANY NO.2

For documenting of advertisements fields is one of the best solutions the helicopter from Robinson American Company – Robinson R22. Robinson R22 isa single-engine two-seat light utility helicopter,suitable for light aerial works, monitoring, controlling objects and so on. Helicopters offer in general advantages as hovering, reversing, vertical flying and landing on small runways. Robinson R22 is equipped with a glassed cabin that allows a great view not only for pilot, but also for second passenger and it´s simple and light construction allows landing and take – off from small areas. The difference between the price and planning investment in purchase is offset by low operating costs.

THE SOLUTION FOR COMPANY NO.3

For geologic research and monitoring is a better alternative for Company No.3 Robinson R44. Helicopter offers a wider range of benefits as airplane, for which they were interested in. For the needs of geologic research and monitoring is the helicopters ability to hover in the air, reverse and dexterity a big plus. That´s the reason, why we suggested helicopter Robinson R44 for Company No.3. Robinson R44 is a single-engine four-seat light utility helicopter, suitable for light aerial works, monitoring and controlling objects. Helicopter is equipped, same as its smaller brother Robinson R22, with a glassed cabin that allows a great view not only for pilot, but also for other passengers. The difference between the price and planning investment in purchase is offset by low operating costs.

THE SOLUTION FOR COMPANY NO.4

For personnel transport is the best solution for Company No.3 a single-engine two-seat light utility helicopter Robinson R22 with small price and operating costs. As we mentioned before, this type of helicopter features a big rival to automobile in the personnel transport sector. The difference between the price and planning investment in purchase is offset by low operating costs. The price of the Robinson R22 meets the requirements of the Company No.4.

CONCLUSIONS

The analysis shows, that for needs of small and medium – sized companies in Slovak republic, is the most suitable solution, light utility helicopter with a quite small operating costs, such as helicopters from "Robinson family".For these companies is using the helicopter better alternative than using airplanes, because of their advantages and price availability.

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Future European Seaplane Traffic and Operations

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After the creation of the first aircrafts in the early 20th century, the lack of suitable aircraft infrastructure (airports) led to the development of seaplane designs. However, improvements on seaplane design stagnated since the aftermath of World War II due to the introduction of new efficient aircraft designs and suitable landplane infrastructure. Most seaplane designs operating today face with common weaknesses that makes the seaplane market very unreliable to investors. The main objective of this document is to propose advance ideas in order to improve seaplane traffic and operations in Europe. A market analysis, seaplane operations and technical solutions will be discussed in this paper in order to analyze the strengths and weaknesses that seaplanes stand today. Propose solutions that would improve seaplane traffic and operations for the near future will be analyzed and discussed. The main technical solutions for a near future design will be conducted into the floating device in which it will be utilized a trimaran boat hull technology to improve hydrodynamic performance and retractable floats to reduce aerodynamic drag. Preliminary results show that retractable floats reduce aerodynamic drag around 5% compared to the floats at an extended position. Based on the literature review on trimaran technology, it shows that boats have an improvement in water stability, hydrodynamic drag and greater buoyancy reserve as compared to monohull vessels. Further studies on the trimaran technology will be conducted theoretically and with the aid of a CAD model extended research on computational fluid dynamics, structural and hydrodynamics will be conducted.

Keywords: *Seaplane Design, Aircraft Traffic,Operations*

I. INTRODUCTION

Since the creation of the world's first successful airplane done by the Wright Brothers in 1903 [1], the idea for improving and exploring the world of aeronautics have been expanding rapidly throughout the 20th century. With the lack of suitable landplane infrastructure and the availability of vast motor boats, the idea of creating a seaplane could not be held. The first motor seaplane flight was conducted in 1910 by a French engineer Henry Fabre

[2], and since then, much research on seaplane aviation was widely conducted. However, in the mid-1950's, with the introduction of improve aircraft designs and the construction of suitable landplane infrastructure, the use of seaplane traffic and operations drastically drop [3].

For over the next 60 years, the main important role that seaplanes had were to conduct fire fighter operations as water bombers, such as the Beriev BE-200 [4]; they are commonly used in the private sector, in which most seaplanes are just a small landplane adapted with floats, such as the Cessna 185 [5]; and finally as a tourist attraction.

The objective of this paper is to introduce ideas in which the seaplane traffic can improve and expand throughout Europe, focusing on the strengths seaplanes possess, and improving its weaknesses. First a market analysis will be conducted in order to make a clear view where seaplanes stand in today's aeronautical market. A **SWOT** (**S**trengths, **W**eaknesses, **O**pportunities, and **T**hreats) analysis will be conducted in order recognize the important factors of seaplane operations. Finally, some technical solutions will be proposed, in which a more efficient seaplane design will be elaborate in order to reduce costs in manufacturing, maintenance, operation, and water/air traffic. Preliminary experimental results are presented to prove the use of the technical ideas analyzed for an advanced seaplane design.

II. MARKET ANALYSIS

Air transportation has increased rapidly in the last decade, compared to other types of transportation such as trains, buses, or cars. This is the same case in the United Kingdom [6]. Figure 1 shows this increment in air travel in the UK from 1996-2006.

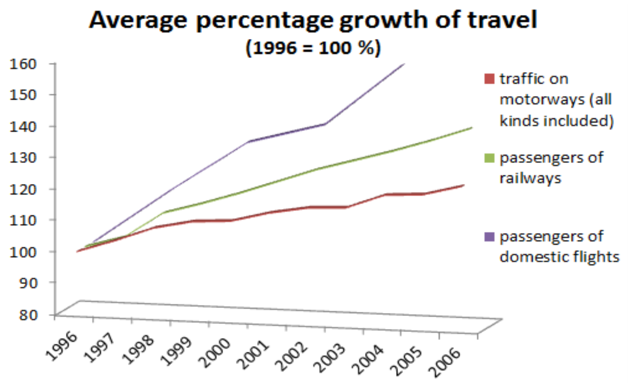

Figure 1: Average Percentage Growth of Travel in the UK [6]

However, this is not the case for seaplanes. Seaplanes do not have a wide market due that most seaplanes existing today are approaching its final operating life. The creation of new seaplane concepts and designs are expensive and the industry is not interested due to its market unreliability.

Most existing seaplanes operate in North America (around 10,000 registered), where most of them are own privately; also a large number of seaplanes operate as water bombers, people and cargo transportation, fly by fishing, and bear viewing expeditions [7]. In Europe, seaplanes are scarce, however there is a great potential for growth due to its large bodies of water destinations and islands scattered throughout. The proliferation of forest fires in the Mediterranean also relies on the use of water bombers, and other seaplanes.

Some other important aspects that seaplanes have to face are operational issues, pilots, regulations, certifications, infrastructure, technical issues, and future development for seaplane transport system. Probably one of the best European seaplane projects created is FUSETRA (Future Seaplane Traffic), which aims to investigate the current seaplane situation by evaluating the current strengths and weaknesses. An online survey created by FUSETRA is accessible to worldwide seaplane operators in order to discuss some of the important points in which seaplanes need to be improved, strength and discussed [8, 9].

A. Operations

As explained by an experienced seaplane pilot, the greatest difficulty for the new seaplane operator is to convince the authorities that there should be no rigid rule as to the exact landing and maneuvering areas for safe seaplane operations [10]. Most problems faced today by seaplanes are of social issues, regulations, operations and infrastructure, rather than technological issues. However, if there is no technological advancement that proves that seaplanes are safe, and have both water and air capabilities, both the market and the authorities will not be convinced that seaplanes can operate as safe and efficient as a boat does on water or an aircraft does on the air.

B. Certification, Regulations and Pilots

Seaplanes have to face with both aviation and boat regulations. Some of these regulations are not well established in Europe, especially in the United Kingdom. Seaports are another main issue. Suitable seaports will require extra fund and costs either by the government or the private sector in which they are not reliable to pay, because seaplanes are not a mayor investment in the transportation sector.

The general situation, when summarizing all results about the comments on the availability of pilots, is not alarming. Almost three quarter of the participants do not characterize the situation as critical. Dividing up the continents shows that in North America the availability of pilots is unproblematic for over 85%, while for two-thirds of the European participants it is critical and challenging for the remaining one-third. In Asia and Australia the situation is generally characterized as challenging.

III. SWOT ANALYSIS

The aim of this SWOT analysis is to recognize the key internal and external factors that are important to seaplane operations [11].

Strengths and weaknesses of seaplane operations are here analyzed under the light of the "European Aeronautics: a vision for 2020" document [12], where the concept of sustainability is introduced and made the kernel of the aviation future. In vision 2020 aeronautics must satisfy constantly rising demands for lower costs, better service quality, the highest safety and environmental standards and an air transport system that is seamlessly integrated with other transport network.

A. Strengths

One of the major deterrents facing the seaplane market today is the opposition by environmental authorities on the perceived impact of seaplane. The main argument is based on the noise impact of seaplane landing, taxiing and taking off, which is known to exceed the ambient noise level. Additionally, there is a belief that noise, landing and take-off all impact on wildlife. Moreover, as mentioned before, also worldwide the greatest obstacle facing seaplanes is considered to be the opposition of environmental authorities. In Europe this was also agreed by 20% of operators [13].

Only few studies have been completed to assess the seaplane environmental impact anywhere in the world and in many cases these are independent studies carried out by private seaplane operators [14[15]. The most inclusive and unbiased is probably an investigation conducted by US Army corps of Engineers (USACE) [16]. The outcomes were:

1. Seaplanes compare favourably to boats, since they do not discharge oil or engine exhaust into the water.
2. Seaplanes do not disturb sediments or marine life due to their insignificant wake.
3. Noise at takeoff and landing is the same as a motorised boat, but only lasts around 40 seconds.
4. Seaplanes and cars compare in *direct* environmental impact, but seaplanes are better considering *indirect* impact.
5. There is no evidence to suggest that seaplanes should be restricted to locations where motorised boats are permitted.

It is true that carbon emission generated from seaplane exceed the emission produced by boats. However, consideration should be given to the fact that the number of boat movements within any given area greatly outweighs seaplane movements in this area. Attention should also be drawn to the fact that seaplanes do not discharge sewage or oily bilge water and are not treated with toxic anti-fouling paints unlike boats. Seaplane exhaust are emitted into the air, much above the water giving low water impact, and currently used seaplane fuel does not contain the flammable and volatile compound MBTE (Methyl Tertiary-Butyl Ether), which is found in boats. Moreover, seaplane propellers are located away from the water, giving no disturbance on sediments or marine life, and they are near negligible polluters in regard of foul water and waste from chemical toilettes. Evidently, a further study validated that floatplanes generate no more than a three inch wake without any shoreline erosion effects [17].

B. Weaknesses

Seaplanes today are "endangered species" and although they posses undoubted potential, the lack of ability to unlock this potential is due to numerous problems. These are of a various nature and involve different aspects of seaplane/amphibian's environment. Certainly, the design aspect is a major impediment on seaplane advancement and is linked to many other areas. This situation has resulted in a scarcity of modern and cost-efficient seaplanes. The lack of innovative designs and use of today's technology then force seaplanes to VFR (Visual Flight Rules) and make them not suitable in adverse weather conditions or rough waters. In addition, some environmental issues could, in the near future, change what is currently a strength factor into a weakness. As stated before, vision 2020 aims to reduce polluting emissions by 50% for CO2 (Carbon dioxide) and by 80% regarding Nox (Nitrogen oxide). Alternative fuels and new generation engines, together with better aerodynamic performances, must be considered in order to keep these values as low as possible and match the suggested targets by the year 2020.

Finally, but equally important, the limited amount of seaplane bases and missing standard infrastructure equipment is surely a weak point that limits the seaplane market. It means that refueling and regular maintenance are factors which need serious consideration.

C. Opportunities

There is huge room for improvements in seaplane operations and many opportunities that can be exploited in such market. While demand is difficult to forecast without a detailed market research and an overview of current trends, something that is not available to fledgling industries, it can be presumed that demand should arise if the industry can offer a different service from large commercial airlines, either in terms of savings, convenience or novelty. Following is a list of the main features that may be considered as reliable new opportunities for seaplane:

- Easy usability among places with lots of islands and area/s with (many) resource/s of water.
- Faster service compared to ferries when connecting mainland-islands or island-island (e.g. Greece, UK, Ireland, etc) and the possibility to fly directly from major inland cities catering also specific groups of commuters in their daily journeys [18].
- Unconventional experience from transport (especially for tourists).
- Transport with quick dispatching.
- Avionics systems (lighten the burdens on the pilot, help making correct decisions and reduce human error, night flight). In fact, seaplanes are limited to daytime VFR. Then the way to eliminate this disadvantage is by adding advance cockpit technology, or the used of advance gear such as GPS (Global Positioning System), radar, laser altimeters, gyros, advance sensors, among other gear.
- Larger seaplanes with better range, more seats and less affected by weather/water conditions.
- Efficient, safe, comfortable infrastructures [19] (seaports, docking facilities, accessibility…).
- Air freight services: cargos travel by air because it is more competitive.
- Modifications of existing planes with innovative new design. Based on the market research and the technological review, the creation of a new seaplane design will require time, manufacturing costs, regulation and certification, and social acceptance.
- Investments in new technology, materials and new seaplanes/amphibians advance design. When new advance design is involved, it should be consulted with operators, due to future equipment plans, and maritime authority regulations should be considered in advance of the design process. However, it may be expected that new solutions that lower drag when airborne, maintenance times and costs, and enhance competitiveness in cost/seat/miles ratio will be always looked forward by operators.
- Add value to the air transport market by opening up more locations to air travel and in doing so make it more convenient, while reducing the congestion on airfields and offering significant time savings to passengers.

D. Threats

For seaplanes to really take off there are a number of barriers that must first be overcome. This paragraph highlights the major threats that seaplane operation is facing today and the fundamental issues that need to be addressed:

- Possibly difficult accessibility of airport (to replace automobile and railway means of transport is very hard in this case because of difficult approach of airports).
- Public perception of light aircraft safety may impact on the acceptability of seaplane transportation. However, it should be noted that in the UK there has not been a single reported accident according to their air accidents investigation branch (AAIB) [20], though this is in part due to the fact that there have been historically very few seaplane operated in the UK. [21].
- Acceptance from population and environmental activists.
- Fly time limitations. Alleviation on this regulation is needed so as to better meet the requirements of seaplane operations thus making them more financially sustainable without any subsequent of flight safety standards.
- Lack of a minimum level of training and acceptability of Dock Operating Crew so as to be multifunctional with regard to, assisting in the arrival and departure of aircraft on pontoons or piers, passenger handling, as well as manning the requirements of Rescue and Fire Fighting activities.
- Certification process for new seaplanes.
- General regulations: government regulation and control includes both aviation authority regulations and naval authority regulations. Nowadays there is not a set of unified regulations throughout Europe and these can also be sometimes in conflict.
- Corrosion resistance.
- Seaplanes are still too much depended on the weather conditions.

IV. TECHNICAL SOLUTIONS

Many proposed ideas were analyzed for possible technical solutions that will aim to reduce costs on research, manufacturing and operation of an advance seaplane design. The complexity and high costs of some ideas narrow the search for technical aspects that can be researched and experimented for the near future. It was decided to use retractable floats which will reduce aerodynamic drag and the use of trimaran boat hull technology that will increase hydrodynamic performance of the seaplane.

In order to conduct an efficient seaplane design which will reduce the amount of time and costs on the main design, existing certified aircrafts will be configured into a seaplane configuration by adding a floating device. Therefore, the main research will be conducted into the floating device. Using a certified aircraft will decrease the time in air regulations, and research on air performance. The aircrafts must have common similarities that are essential for the aircraft to be converted into a seaplane. They must have high wing configuration and have the capability of Short Takeoff and Landing (STOL).

The first technical investigation was conducted into adapting retractable floats. The floats will form a single component embodied to the hull and fuselage when retracted, as shown in figure 2. This will reduce the drag form interference factor added by the floats and boat hull [22].

The use of retractable floats gave a decrease in drag of around 5% compared to the floats in an extended position shown in Table 1.

The seaplane in the retracted position improve the flight performance in which less thrust is generated, a greater turn radius for steady level turn was observed, higher absolute and service ceiling values were obtained, and better speed performance is given in each of the flight segments (takeoff, climb, descent, and landing). In general, retractable floats gave a great improvement in thrust and level turn, especially at high speeds.

Since the addition of extra components will increase the weight of the seaplane, this will imply in reducing the weight for fuel or payload, reducing range or the mission requirements design of that of the original aircraft design.

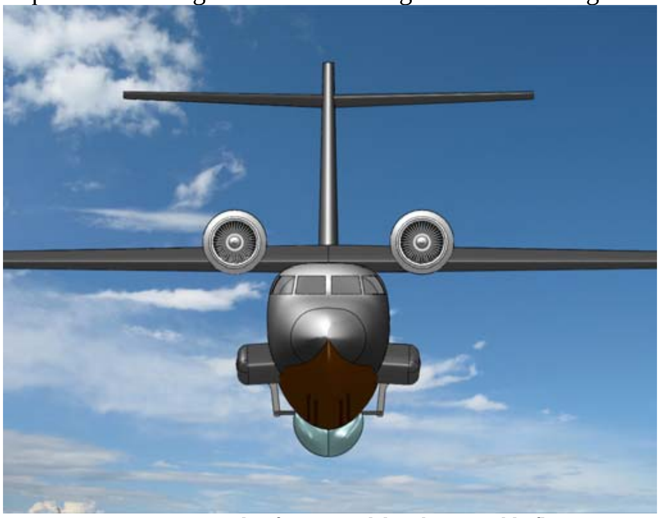

Figure 2: Example of CAD model with retractable floats

Table 1: Flat Plate Drag Area Breakdown for typical aircraft and seaplane configuration with floats on extended and retracted position

Flat Plate Drag Area Breakdown [m²]	Aircraft	Seaplane [Extended]	Seaplane [Retracted]
Fuselage	0.205	0.205	0.205
Wing	0.319	0.319	0.319
Horizontal Tail	0.078	0.078	0.078
Vertical Tail	0.055	0.055	0.055
Subtotal	1.279	1.279	1.279
Boat Hull	0	0.107	0.078
Floats	0	0.071	0.049
Strutting	0	0.037	0.012
Total	1.279	1.494	1.419
C_d	0.037	0.043	0.041
C_d Increment	0	0.0062	0.0041
Drag [N]	5724.63	6682.83	6346.82
Drag Increase		14.34%	9.80%

Since the addition of extra components will increase the weight of the seaplane, this will imply in reducing the weight for fuel or payload, reducing range or the mission requirements design of that of the original aircraft design. With the introduction of composite materials (GLARE)[1], this increase in weight can be reduced to almost 50% as compared to other materials. Then, with the use of these composite materials and the use of retractable floats, an aerodynamic flight performance comparing the original typical aircraft and the seaplane configuration is shown in Table 2.

Table 2: Total Time [hr] and Range [km] of the Aircraft and Seaplane

	Aircraft		Seaplane	
	Max Fuel	Max Payload	Max Fuel	Max Payload
Gross Weight [kg]	6600	6600	6600	6600
Max Fuel [kg]	1320	-	1320	-
Max Payload [kg]	-	1710	-	1710
Empty Weight [kg]	3960	3960	4221	4221
Total Fuel [kg]	1320	930	1320	669
OEW [kg]	5280	4890	5541	4890
Payload [kg]	1320	1710	1059	1710
Fuel Flight [kg]	1017.63	627.63	1011.27	360.27
Time Flight [hr]	2.55	1.57	2.54	0.9
Distan Flight [km]	969.52	597.96	963.45	343.23
Total Time [hr]	**3.14**	**2.17**	**3.16**	**1.53**
Range [km]	**1109.61**	**738.05**	**1104.06**	**483.84**

[1] Glass Laminate Aluminium Reinforced Epoxy

Studies on the floating device were also conducted by adapting trimaran boat hull technology in the seaplane design. A trimaran is a ship with 1 main hull, and two outriggers or floats at the side as shown in Figure 3.

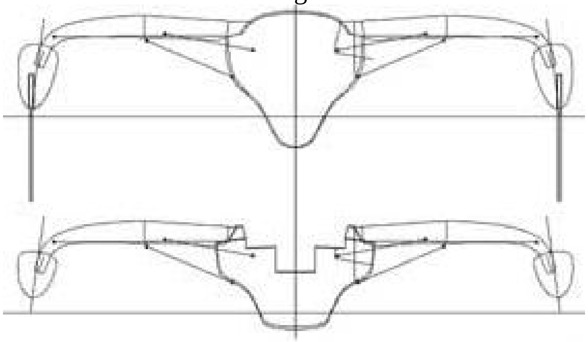

Figure 3: Trimaran main hull and outriggers [23]

The trimaran possesses some advantages over other types of boat hull designs [23]:

- Low wave resistance at high speed due to its slender ship hulls
- Superior stability attributable to suitable layout of the side floats. A trimaran can keep a high speed under high sea conditions.
- The wave interference between the main hull and the outriggers can produce a beneficial wave interference optimizing the speed and engine power required correlation
- In case of an emergency the all float structure remains floating even when the hull or the outriggers are severely damaged.
- Less hydrodynamic drag due to the slender bodies and low wetted surface areas

Trimarans are superior in terms of stability because the arrangement of the hulls is such that individual centers of buoyancies have a righting moment about the centre of gravity that helps in stabilizing the vessel as shown in Figure 4 [24]. This gives the boat or in this case the seaplane, more roll stability, better water maneuverability, and better water performance at docking and even for high waves.

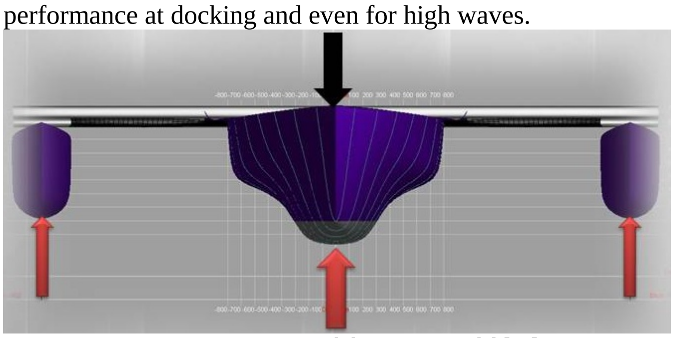

Figure 4: Trimaran Stability-Beam Model [24]

Another important aspect to analyze is wave performance. Seaplanes must have the ability to perform in any weather and water conditions. When a wave passes through a conventional float, when it reaches the bow produces a lift force which pushes the stern down, as the wave passes through the body of the float, the center of buoyancy changes along with the wave, when the wave reaches the stern the lift force push the bow down and as a result, at high speeds during rough water conditions a dangerous pitch effect could cause the bow to be submerged and capsize violently. For the outriggers; when the peak of the wave moves towards stern, the lack of buoyancy on this section to the shape, negates the lift force which produces the pitching effect, therefore the outriggers are capable to operate in a wider range of rough water conditions than the conventional floats. Past studies conducted on trimaran shows that wave resistance of trimarans is significantly lower compared to an equivalent catamaran (or is equal to a low percentage of it) as shown in Figure 5 [25]. Therefore, trimaran has superior seagoing performance.

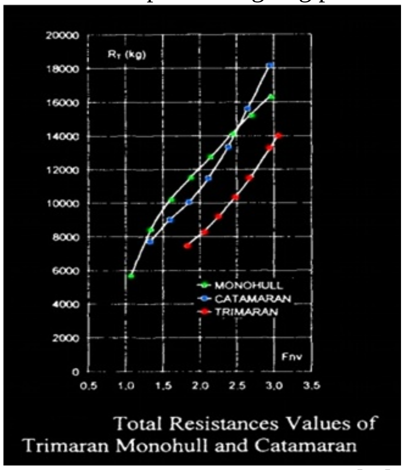

Figure 5: Resistance comparison curves [24]

However, due to time constraints, further studies of the trimaran technology will be performed first in a theoretical manner in order to calculate optimum design values of the main hull and floats.

Finally, a CAD (**C**omputer **A**ided **D**esign) model representation was elaborate to calculate the dimensions, observe the mechanism of the retractable floats, and show the location of the boat hull. In the near future, with the aid of this CAD model, it will be conducted CFD (**C**omputational **F**luid **D**ynamics), structural, FEMA (**F**inite **E**lement **M**ethod **A**nalysis) and hydrodynamic analysis of the seaplane design.

V. CONCLUSION

The following figure shown Figure 6 in CAD model representing the seaplane design elaborated with the results and the dimensions obtained. It shows a boat hull mounted on the bottom section of the fuselage with two retractable floats mounted on the undercarriage of the original aircraft design and the extended position of the floats to form a trimaran hull. It was assumed the boat hull to be of a half cylindrical shape, and the floats to be a cylindrical shape for calculations. However in Figure 6 it shows different shapes for the boat hull and floats in order to fit the idea of the retractable floats and boat hull as shown from the example in Figure 2. It is shown the boat hull and the floats at the retracted position, where the floats are fitted as one component to the boat hull, as well as the boat hull to the fuselage, reducing drag interference.

In conclusion, based on the preliminary results obtained, the use of retracting floats has an increase in drag of around 10%, compared to the increase in drag in the extended position of around 15%. This 5% decrease in drag shows better results in aerodynamic flight performance, especially at high speeds. The absolute ceiling and service ceiling was reduced to almost 300 m. The descent and descent angles are also affected by the


Figure 6: Seaplane CAD Model showing Trimaran Hull

use of extended float position. The reduction in weight caused by the increase of the extra components is the major influence for the flight performance. However, most of the weight of these components is dependent on the material and the design.

The use of composite materials reduces the total weight added by the extra components up to 50% less. Composites will also help the floating device against corrosion, and this type of material will have enough structural strength for the seaplane to operate on water.

Since this project is in its preliminary design stage, more extend research, calculations and work will be done on hydrodynamics, structures, and stability and control. Experimentation conducting the use of trimaran hull will be done and final CFD simulations and FEMA will also be conducted with the aid of the CAD model. Wind tunnel testing will be elaborate to prove the theoretical results using retracted floats.

Final comments will also be to conduct more studies on future long term ideas. Advance new seaplane designs could be made, based on the increase of the market. Amphibian aircraft will also be considered, since the ability of landing on land makes an aircraft more reliable and have a better acceptance in the market. Investment in new technologies and material should be done as well. Larger seaplanes with better ranges should also be considered. Efficient, safe and comfortable seaports and docking facilities should also be analyzed to improve seaplane market. Finally more unified seaplane regulations should exist, especially in Europe; this will help the seaplane market be more practical and have a better acceptance in the aircraft society.

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Lessons to Be Learned from EGNOS for Better Galileo Implementation

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***Abstract* — This paper deals with problems that come out during the EGNOS implementation processes in Europe. We have to avoid of repeating these mistakes during the Galileo implementation.**

The essentials parts of technology improvements of EGNOS implementation (e.g. background technology, core technology, user-place, operation procedures) were analyzed one by another to identify major problems.

The goal of the paper is to heighten the awareness of these issues, to learn the lessons from this "bed practice" and promote the need for core technology development and testing, setting up the user-place, implementing operation procedures for future Galileo based approach right now.

Those who wish to get ready for the day when Galileo's Open Service will become available and doors to the development of new markets will become open, will find out, that the promoted Galileo testbeds offer unique opportunities for developing competitive products and testing clever innovations.

Keywords – EGNOS; APV SBAS; RNAV GNSS approach; Galileo Approach; GNSS avionics; avionics implementation; Galileo testbed

I. Introduction

One of the mostly used space technologies in every-day life are satellite- based navigation systems commonly named as a Global Navigation Satellite System (GNSS). The whole world is relying or has to relay on the pioneer's, US's, military Global Position System (NAVSTAR GPS).

The world is never monopolar. There is well known endeavour of other countries (regions) to develop their own, independent GNSS system. Russia's GLONASS, Chine's BEIDOU, India's IRNSS, Japanese Quasi-Zenith and finally, in Europe mostly mentioned, Europe's Galileo.

Let's talk about aerospace related GNSS applications. Navigation is needed in all flight phases, in departure, en-route flight, approach, landing and ground operations. GNSS can play a role in each of them. The most critical approach and landing phase is being taken into consideration within this paper.

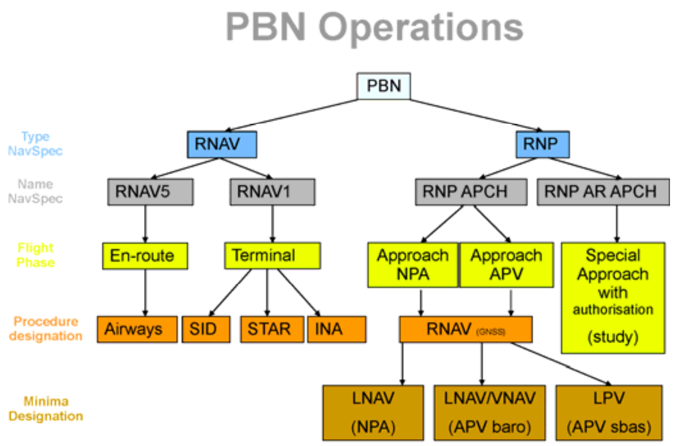

Figure 1. Performance Based Navigation sorting tree

II. Essential parts of technology improvements

When we want to achieve new goals, to achieve new, improved technology we need four essential elements. Particularly in aviation, they are as follows.

A. *Background technology*

Technology for technology - something what is really necessary for new improvements but, basically, it wasn't developed for this particular reason. Technology that has global impact and aviation is just one of the users. This kind of background technology is sort of technology enablers, sort of the basis for developing new dedicated systems.

When we talk about GNSS approach the background technology are, naturally, GNSS satellites and all related support equipment as a ground control unit, control stations, monitoring stations, etc.

B. *Core technology*

The new dedicated system builds on the basis of background technology. We can say the core technology is kind of technology interpreter.

We can’t just come and take needed output from the background system. Many times, we do not fully understand this output, we can’t read it, we can’t interpret it explicitly. There is a need for translation function - the unit that transform parameters of background system to the parameters we understand, the parameters we want to use.

Based on this we can say there can’t be core technology without the background one.

In our intentions the core technology are onboard GNSS receivers, navigation computers and antennas.

C. *User-place*

New technology must be made for somebody. Technology for using, not for decline. It needs procedures for setting up a user-place, a playground, for new technologies. It has no sense to have new core technologies and has no place thus no chance to use them.

The user-place in our intentions is airport, to be more concrete the publicized GNSS approach procedures.

D. *Operation procedures*

Once the user-place (the playground) is set, the game rules must be set as well. These procedures must be set within the concrete margins, to prevent the system and other users against damage, hazardous situations, to maintain safety level, long lasting smooth operation and effectiveness.

Operation procedures for GNSS approach must be set within the operators Standard Operation Procedures (SOP) in hand-to-hand with crew training.

On top of all these elements, there are standardization and certification criteria.

III. The Wind of Change

The goal in mid-term perspective in aerospace navigation is using GNSS, respectively Galileo as a primary navigation mean in all flight phases in Europe.

The European Commission or better say each of us is investing large amount of EUROs in development brand new navigation technology - GALILEO that will serve as the background technology in automotive, marine, airspace and even space applications.

Because of the investment we must expect, naturally, the strong push of the European Commission to "foster the development of EGNOS and GALILEO downstream applications, and to achieve the quickest, deepest, broadest development of applications across all domains so to reap maximum benefit from the EU’s infrastructure." as is mentioned in Commission’s "Action Plan on Global Navigation Satellite System (GNSS) Applications" (COM(2010)308) [4].

Galileo full operation phase is the sound of the future but there is no time to lose. We should learn the lessons from EGNOS implementation to avoid duplicating the mistakes.

Analyzing the essentials parts of technology improvements within EGNOS implementation one by another we come to the following results:

A. *Background technology*

Background technology is not a problem topic, it is there and available for use in safety- critical applications esp. aviation. EGNOS (European Geostationary Navigation Overlay Service) is the European Satellite Based Augmentation Service (SBAS) that complements the US Global Positioning System (GPS). The most important and beneficial application of EGNOS in aviation is increasing position accuracy allowing the aircraft to perform approaches with vertical guidance (APV approaches to LPV minima) with no need of ground navigation aids infrastructure hand to hand with improving the integrity information.

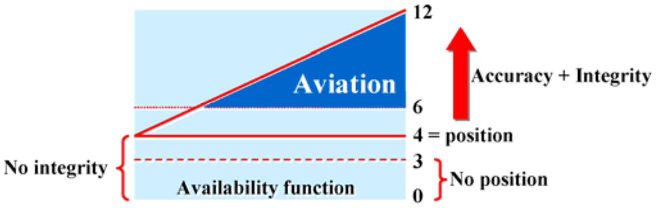

Figure 2. GPS without augmentation – min. 6 satellites needed

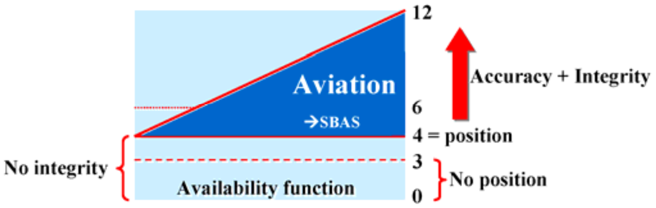

Figure 3. GPS with augmentation – min. 4 satellites needed

On the 2nd of March the EGNOS Safety-of-Life Service (SoL) was officially made available for the safety-critical task.

A marketing department of European Commission is promoting: "EGNOS is there, let’s use it". In fact, it is easier to be said than to be done! [4]

B. *Core technology*

Onboard GNSS receivers, navigation computers and antennas are already certified to being used within the EGNOS. To say it more precisely, the GPS WAAS certified avionic with minor changes is allowed to be used within the EGNOS with no influence on performance and safety.

The complete solution consists of:

- SBAS enabled receiver that implements the MOPS DO-229 [5] with navigation weighted solution and message processing (equivalent to Class 3 GPS/WAAS receiver requirement,
- Certified Flight Management System (FMS) and Automatic Flight Control System (AFCS) software according to ETSOs C144,C145 or C146
- SBAS-compatible antenna compliant with TSO-190

- Airworthiness certificate according to AMC-20- 27 [6] (note: EASA AMC 20-28 is planned for release in Q4 2011)

90% of the fleet of the biggest Czech (no named) private aircraft operator is equipped with such an avionic. The Czech private (no named) bizz jet operator has none of its aircraft equipped for APV SBAS approach but planning to extend this up to 13% of the fleet.

Therefore, finally, we can see, this is not the EGNOS implementation bottleneck topic as well.

C. User-place

What is really a problem topic is the user-place. Thanks to the background technology, an ANSPs are now enabled to implement EGNOS based operations, in particular LPV procedures. In fact, there are just few LPV procedures certified at the airports around the Europe.

Pau Pyrénées in southern France has become Europe's first airport to use the new EGNOS Safety-of-Life Service, to guide aircraft in for landing using only this highly accurate space navigation signal. Le Bourget Airport follows its forerunner and certified LPV procedure on the 2nd of June 2011, just on time before the Paris Air Show opened its gate in June. DSNA (French ANSP) wants to certify up to 14 LPV procedures at the French airports within 2011 [2].

In contrast to this, in the USA, there are 2442 certified LPVs serving 1254 Airports. 1526 LPVs to non- ILS Runways and 916 LPVs to ILS runways, 997 LPVs to Non-ILS Airports and 257 to ILS Airports.

What is more a few already certified airports in Europe are, mostly, ILS equipped as well and ILS minima are, naturally, lower than LPV ones. The highest added value of APV SBAS approach is on the smaller airports, which are not equipped with precision instrument landing systems. None of such an airport has been certified yet.

Another point is navigation fees. The ANSP's doesn't distinguish conventional instrument landing approach fees from APV SBAS fees in spite of the fact that technology and installation cost of the first are much higher than the latter.

We can see that users segment crawls far behind the system development in the Europe.

It is fact, that the situation is nowadays controlled by European GNSS Agency and EUROCONTROL but isn't it too late? GNSS Agency run 3 projects (HEDGE, GIANT 2, ACCEPTA) from which the latter is most important in our case aimed to accelerate the EGNOS adoption in the aviation sector, with a wide-scale real- life adoption of the EGNOS-enabled LPV approaches throughout European airports. EUROCONTROL has launched three projects (NATS with Aurigny, ATI w. Beluga, Mielec Project) with the objective to stimulate the introduction of APV operations based on EGNOS and thus to gain experience in the implementation of such procedures. In the latter, the Czech ANS is participating.

D. Operation procedures

It is up to aircraft operators whether they implement operation procedures for APV SBAS approach within their Standard operation procedures or not.

Being certified for APV SBAS approach is not only the question of competitive benefit and prestige while it could broaden number of served destinations, especially in poor weather conditions and increase overall safety, but also question of cost efficiency.

Air Nostrum estimated overall cost of small regional jet APV SBAS upgrade in amount of approx. 60 thousands Euro. Including avionic replacement, certification cost, crew training and installation downtime.

Is it worth doing that? Here comes the second big issue while in nowadays Europe it is definitely not because of lack of the abowementioned user-place.

IV. SOUND OF THE FUTURE

To avoid this "EGNOS worst practice" being repeated, there is a need for core technology development and testing, setting up the user-place, implementing operation procedures for future Galileo based approach right now. "Whether Galileo will be fully operable" is not the question better is to ask "WHEN?"

A. Background technology

In the Europe, there is the unique opportunity to learn the lessons from the previous implementing process of European EGNOS system.

Galileo background technology is under control of European Commission in cooperation with ESA. The launch of its first two satellites is planned on late October this year (2011) with planned full system operability since 2016.

B. Core technology

As we can see in EGNOS chapter Core Technology, there is low share of the global GNSS applications market allocated by European industry. As the GPS WAAS avionic is allowed to be used within the EGNOS there is subtle, if any, motivation for European corporation to produced EGNOS dedicated systems. For example, the European division of american avionics developing and producing corporation - Honeywell, does not have in their pipe- lines development of EGNOS avionics. The situation is even more dramatic when deliberate over Galileo avionics.

There could be doubt: "How could be core technologies developed when background technology is not presented yet?" Fortunately, it could be done using a simple trick - building up of testing areas.

Galileo testing polygons, sites, or even regions, dependant on the area that is covered by electromagnetic signal from nearby transmitters. Transmitters are permanently installed in various positions around the periphery of the area, beaming Galileo-conformable signals into it. This signal has got similar characteristics as the signal emitted by the Galileo satellite altered by transition through the Earth atmosphere and by reflection superposition. Receivers receive same signal as if it comes from the satellite some 23thousand kilometres above the Earth.

The transmitters - Galileo pseudollites are produced by the European organization, which is involved in Galileo programme from the very beginning.

C. User-place

By building up such a facilities we would be able to testing and promoting innovative receiver technologies, applications and procedures of the future system today. All this, could be done until Galileo is going to be fully operable.

Testing area somewhere around the airport would help us to test new Galileo avionic, defining new approach procedures, standardization criteria and developing new guidance documentation. Best solution is to choose airport with higher level of precision approach systems (e.g. ILS with CAT II minima) being able to correlated data acquiring from Galileo receivers with those from conventional approach systems. Choosing APV SBAS certified airport would bring added value on top.

This was understood in Germany few years ago where were built 5 testbeds under the GATE program. One of the installations is dedicated to aviation research and is built on Braunschweig airport by TU Braunschweig.

V. CONCLUSION

The limited use of applications based on EGNOS and GALILEO leads to critical dependencies on GPS-based applications. The EU would be exposed to the potential non-availability of the GPS signal, which is beyond the EU's control.

Despite Europe's investment in its GNSS infrastructure and the availability of EGNOS, European industry has only a low share of the global GNSS applications market compared with what it is capable of achieving in other sectors of high-technology. Europe will therefore be missing a huge opportunity if it does not take an appropriate share of the economic benefit expected from GNSS applications.

We can see the strong demand on European innovative technologies in this sector on the one side, but it must be taken into consideration that there is neither innovation nor industry production possible without research & development on the other hand. Innovative products have to be hazard free and safe in all, especially, critical operating conditions and environments what has to be proven not only by virtual but also real hard testing. Testing facilities have been always significantly assisting engineers in developing future's technologies that day and Galileo testbed is no exception.

The Czech Republic has potential becoming the leader in CE Europe region. Choosing appropriate airport which will be upgraded to Galileo testing airport under the abowementioned recommendations could significantly stimulate the European GNSS market and, what is more important, stimulate the Czech's R&D and industry.

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Analyse and Use of Meteorological Aircraft Derived Data

Automatic weather reports from commercial aircraft via mode S radars

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Abstract **— this paper is cursory introduction to problematic of Aircraft Derived Data (ADD), especially meteorological ADD which can be gained from commercial aircraft via mode S radars. Czech Republic is one of the European countries where the system of Air Traffic Control Radar Beacon System (ATCRBS) was quite well developed. This innovation brings benefits to many involved subjects. ADD mean source of information not only about the current flight (identification, position, speed, heading, vertical rate, altitude, track and turn data, next waypoint …) but they can also provide such information like weather condition and many others (complete list of data stored in BDS register of mode S transponders can be found in [1]. This thesis will focus just meteorological ADD and will provide uncomplicated report about possibilities of using this technology in Czech Republic. To incorporate processed met – ADD to ATM systems which are used by air traffic controllers that could bring many advantages. Some ADD are already in use. The best practices could be implementation of Downlik Aircraft Parameters (DAPs) to ATM system. ANS CZ has been using DAPs in its ATM system since year 2010. Met – ADD can be next step for improvement of current systems used in aviation in the Czech Republic.**

Keywords – aircraft derived data, meteorological observation, BDS registers, wind, mode S radar, GICB,

I. Introduction

Using of meteorological ADD is nothing brand new in aviation. Since 80s met – ADD have been used for detecting hazardous meteorological effects in the atmosphere quite often in the USA and Canada. World Meteorological Organization (WMO) uses these data even in numerical models of weather forecast. I was proved that ADD increase accuracy of forecast significantly. This technology is used quite commonly throughout the world, not only in the USA but in other part of the world as well (Canada, Australia, Pacific and Asia region). AMDAR (Aircraft Meteorological Data Relay) is the name of that program. Data are obtained from the aircraft via ADS – B (Automatic Dependent Surveillance Broadcast) or ACARS (Aircraft Communication and Addressing Reporting Systems). The reason for that (using ADS – B or ACARS) is clear. There´s no mode S ATCRBS developed at such level like in the Europe. However program based on ADS – B and ACARS is running within Europe too. It is called EUMETNET-AMDAR (E-AMDAR).

Project E-AMDAR currently provides around 35000 observations daily from 360 aircraft. For comparison at this research in cooperation with ANS CZ and CSSOFT there were more than 150000 observations provided by more than 500 aircraft per particular day. These data were provided by MSSR radars Praha and Písek within their sphere.

As mentioned in the beginning of this thesis, mode S ATCRBS is well developed in the specific parts of the Europe. Czech Republic is the eastern part of this area. That is why it was started to collect and analyze ADD from commercial aircraft flying through FIR Prague last year. To aim ADD via mode S ATCRBS contains inconsiderable advantages. Further details about that could be seen in paragraphs below.

In the following text the readers can learn about the history of met-reporting, basic principles of aiming ADD from the aircraft. In section IV: are described the particular data which are subject of this research. Some statistical outputs, reports can be found in this paper too (see section VI and VII). There are also some proposed ways how could be these data enforced in ATM branch and aviation at all.

II. History of Met-Reporting from aircraft

Routine meteorological observations from aircraft have been taken since the days of World War I. In 1919, pilots of piston-engine aircraft were paid for flying with aerometeorograph strapped to the aircraft wing struts. The observations were recorded on a cylindrical chart that was retrieved after the aircraft landed; the temperature, pressure, and relative humidity were then read out from the chart and disseminated as "APOBs"–airplane observations. Pilots were required to reach an altitude of at least 13500 ft (4100 m) in order to be paid and were given a 10% bonus for each 1000 ft (300 m) above that. At these altitudes, pilots sometimes blacked out from lack of oxygen making this a very dangerous enterprise. By 1937, the U. S. Government funded 30 regularly scheduled civilian and military aircraft "soundings" per day in the USA, but by 1940, these were replaced by soundings made by the newly developed radiosondes. The middle of the last century was the time when comparison of data from radiosonde with collocated aircraft soundings started.

The aircraft observations were made not only by aerometeorograph but there were also voice pilot reports (PIREPs) too. These were suitably encoded and have been used in Numerical Weather Prediction (NWP) models for nearly four decades. Automated aircraft reports first became available in 1979 and have increased dramatically in the 1990's.

Observations from aerometeorograph meant “off-line” reports. It means data were available after landing and not during the flight. Only voice PIREP was kind of “on-line” report. New perspective of automated met – reports raised alongside development of ACARS and ADS – B and mode S radar as well.

III. How are Data Measured On Board Aircraft

The basic meteorological measurements on board modern aircraft are made by:

(1) Pitot-static head for static and total air pressure;
(2) Immersion thermometer probe for total air temperature; and
(3) Inertial reference platform for normal, longitudinal and lateral acceleration of aircraft

Other measurements include:

(1) Relative humidity, measured on some aircraft using a solid state sensor exposed in a standard temperature sensor housing;
(2) Aircraft pitch (angle of attack), measured by flow angle sensor and used to correct static pressure; and
(3) Sensors with which some aircraft are equipped to measure the presence of ice on the flying surfaces.

Data from the sensor are processed usually in the Air Data Computer (ADC) or Inertial Reference Unit (IRU). If the aircraft are equipped with Global Positioning System (GPS) navigation systems, they can provide position and wind vector information with greater precision than the typical IRU. It can also provide an independent, highly accurate time reference.

ADC outputs include:

(1) Pressure altitude derived from static pressure; and
(2) Static air temperature derived from total air temperature and Mach number, where the Mach number itself is computed using static and total pressure measurements;

IRU outputs include:

(1) Present position-latitude;
(2) Present position-longitude;
(3) Wind speed (derived from computed wind vectors using airspeed from the ADC corrected for Mach number and temperature);
(4) Wind direction (from computed wind vectors);
(5) Normal or vertical acceleration; and
(6) Roll angle.

Where relative humidity sensor data is available and/or turbulence reported, additional processing is required, usually carried out in the Aircraft Condition Monitoring System (ACMS). Other data needed for attaching to the measured and processed meteorological data are available from other aircraft systems. These include:

(1) Time (UTC);
(2) Tail number; and
(3) Flight number.

For detailed description of data processing (pressure altitude, static air temperature, wind speed and direction, relative humidity, turbulence, icing) on board of aircraft, see [3, chapter 2.5 Measurement accuracy]

IV. Basic Principles of Data Aiming via Mode S

A. Mode S in Europe

Mode S Elementary Surveillance (ELS) and today even Mode S Enhanced Surveillance (EHS) are being deployed within core area of Europe because the current SSR systems have reached the limit of their operational capability. EHS builds upon the concept of ELS and consists of the extraction of specific aircraft parameters. Although ADS – B can be used as replacement for SSR (secondary surveillance radar) in remote low traffic density airspace (parts of Australia, Alaska), it is not expected that ADS – B will be used as a sole surveillance means in high density traffic areas like the core area of Europe.

It was decided to use mode S ATCRBS to obtain ADD from aircraft. In Czech Republic, there are 2 mode S radars in use at the moment:

- Praha – type RSM 970, range 170 NM (314,8 km),
- Písek, type RSM 970, range 160 NM (296,3 km) and
- Buchtův Kopec (type RSM 970, range 210 NM (388,9 km)become mode S radar soon.

B. Mode S Transponder Registers

Mode S-Specific Services protocols make use of the set of 255 data registers contained in every mode S transponder. Each of these 56-bit BDS (Comm-B designated subfields) registers may be loaded with specific aircraft derived information available on avionics buses; the data may then be extracted by an interrogation from an external mode S sensor. In addition, the transponder can transmit the contents of certain registers spontaneously with specified repetition rates.

The current specification for mode S defines the contents for many of the 255 transponder registers. Note that some registers are still reserved for further used. It is not clearly decided what they will be used for and the specification of these registers must be done at first. A sample of the defined transponder registers is shown in Table 1 below.

TABLE I. SAMPLE OF MODE S TRABNSPONDER REGISTER DEFINITIONS

No of BDS register (hexadecimal)	Register Contents
05_{16}	Airborne Position (latitude/longitude/altitude)
08_{16}, 20_{16}	Aircraft Flight Identification
09_{16}	Airborne Velocity (horizontal and vertical)
10_{16}, 18_{16} … $1C_{16}$	Transponder and Avionics Static Configuration
17_{16}	Transponder and Avionics Dynamic Configuration
30_{16}	ACAS Resolution Advisory Data
40_{16}	Vertical Intent (FMS Data)
41_{16}, 42_{16}	Next Waypoint Details
44_{16}	**Routine Meteorological Data**
45_{16}	**Hazardous Meteorological Data**
50_{16}	Track and Turn Data

(Note: the European mandate for "elementary surveillance" requires support of registers 10_{16}, 17_{16}, 20_{16}, and 30_{16}.. Support for "enhanced surveillance" adds the requirement for registers 40_{16}, 50_{16}, and 60_{16}.)

C. Interogation/Respose Protocol

Mode S ground sensors perform their normal surveillance function via an interrogation/response protocol. The sensor transmits an interrogation (uplink) on 1030 MHz containing a sensor identification code, the desired 24-bit aircraft address and a data selector (either ATCRBS mode 3/A identity code or mode C altitude). The mode S transponder of the aircraft with the indicated 24-bit aircraft address responds with a 56-bit message (downlink) on 1090 MHz. The response message contains the selected information (identity code or altitude) and the identification code of the sensor whose interrogation caused this response. A 24-bit error detection algorithm (using the aircraft's address) is applied as a part of both the uplink and downlink message processing – downlink processing also incorporates an error correction algorithm. If the transponder fails to respond to the interrogation or the response cannot be decoded, then the sensor will retry the interrogation. Range information is derived from the time delay between the interrogation and the response. Azimuth information is derived from the ground sensor's boresight antenna azimuth and signal monopulse processing. A data validity time tag is appended at the receiving sensor.

An extension to the basic mode S surveillance protocol is termed "Ground-Initiated Comm-B" (GICB). In the GICB protocol, the standard mode S surveillance uplink is extended to incorporate a transponder register number. If the mode S transponder is equipped to handle Comm-B communications (configured to level 2 or higher), it will respond with an extended downlink message (112 bits) that includes the 56-bit contents of the desired register. Surveillance range and azimuth determination, error checking, etc. are all done in exactly the same manner as for standard mode S surveillance. The mode S sensor can use either standard surveillance or GICB interrogations each antenna scan, depending on whether or not one or more transponder registers are to be extracted. The Mode S sensor and transponder act as a modem with latency measured in fractions of a second.

Mode S GICB protocol forms the basis of the European mandated ELS and EHS functions. Extraction of the meteorological register data for the air-to-ground application would also use the mode S GICB protocol.

In addition, mode S transponder can also generate a downlink transmission spontaneously under certain condition. This transmission is called "squitter". (Squitter differentiates from a normal mode S downlink transmission by bits in message called "downlink format" (DF) value.). This protocol won´t be ruminated more in this paper.

V. METOEOROLOGICAL BDS – REGISTER FORMATS

In this section may be found description of meteorological registers of mode S transponders. Register 44_{16} contains routine meteorological information (Table 2), while register 45_{16} contains information about meteorological hazards (Table 3). The format of the contents of these registers is specified in [2].

TABLE II. ICAO ROUTINE METEOROLOGICALDATA FORMAT (44_{16})

Data Field	No of bits	Range	LSB
Source/FOM Naviagrional "figure of merit" inferred from data-source	**4**	0 = none 1=INS 2=GNSS 3=DME/DME 4=VOR/DME 5 … 15 = reserved	
Wind Data Status	**1**	0=no data 1=current data	
Wind Speed	**9**	0 … 511 knots	1 kt
Wind Direction	**9**	-180 … 180 degrees true	180/256 degrees
Static Air Temp.Status	**1**	0=no data 1=current data	
Air Temperature	**10**	-128 … 128 degrees C	0,25 degrees C
Static Air Pressure Status	**1**	0=no data 1=current data	
Static Pressure	**11**	0 … 2048 hPa	1 hPa
Turbulence Status	**1**	0=no data 1=current data	
Turbulence Metric	**2**	00=none 01=light 10=moderate 11=severe	
Humidity Status	**1**	0=no data 1=current data	
Humidity	**6**	0 … 100 percent	100/64 %
	∑ 56 bits	Minimum update register rate: 1 second	

Table 3 below describes the format of mode S transponder register 45_{16} from the current ICAO specification. Note that each of the subfields in the register has a status bit to indicate whether the particular subfield data is current. The air temperature and pressure fields are duplicated from the routine meteorological report (register 44_{16} specified above). This is done to allow a single mode S register extraction (using either the GICB protocol or the extended squitter protocol (not described in this document) to provide the required meteorological data in most cases. Minimum update rate of items in these registers was specified to 1 second.

TABLE III. ICAO HAZARDOUS METEOROLOGICALDATA FORMAT (45_{16})

Data Field	No of bits	Range	LSB
Turbulence Status	**1**	0=no data 1=current data	
Turbulence Metric	**2**	00=none 01=light 10=moderate 11=severe	
Wind Shear Status	**1**	0=no data 1=current data	
Wind Shear Metric	**2**	00=none 01=light 10=moderate 11=severe	
Microburst Status	**1**	0=no data 1=current data	
Microburst Metric	**2**	00=none 01=light 10=moderate 11=severe	
Icing Status	**1**	0=no data 1=current data	
Icing Metric	**2**	00=none 01=light 10=moderate 11=severe	
Wake Vortex Status	**1**	0=no data 1=current data	
Wake Vortex Metric	**2**	00=none 01=light 10=moderate 11=severe	
Static Air Temp.Status	**1**	0=no data 1=current data	
Air Temperature	**10**	-128 … 128 degrees C	0,25 degrees C
Static Air Pressure Status	**1**	0=no data 1=current data	
Static Pressure	**11**	0 … 2048 hPa	1 hPa
Radio Height Status	**1**	0=no data 1=current data	
Radio Height	**12**	0 … 65535 feet	16 ft
Reserved	**5**	---	
	∑ 56 bits	Minimum update register rate: 1 second	

There must be mentioned that the current ICAO specification (according to Annex 10) includes some differences comparing with the meteorological data defined in ICAO Annex 3 defined by Meteorological Information Data Link Study Group (METLINKSG). These disproportions were identified and reviewed during ICAO meeting in Brisbane (May 2005). Proposed modification of the mode S meteorological data registers (44_{16} and 45_{16}) is the result of the meeting. These updated formats are still being revised within ICAO and will be incorporated into future drafts of the ICAO Mode S documentation when approved. Now it is already few years after creating of the proposals of the new formats but changes were still not applied. Also the research is still based on formats stated in this paper.

The main differences and proposals of new register formats are described in depth in [6].

VI. SO FAR ACCOMPLISHED RESEARCH

A. *Prerequisities for Research*

a) Selection of specific items to collect from registers

Before starting collecting data from BDS registers 44_{16} and 45_{16} it was very important to decide which items are interested and important for further use. It was decided that almost all data from register 44_{16} will be collected (only humidity was excluded from particular first step of this research). From register 45_{16} was decided to collect all hazardous effects. Excluded were only items which are duplicate to register 44_{16}.

b) Creating of software which recalculates raw data from registers to particular value

In company CS-SOFT was created program which was installed to server in IATCC Jeneč (ANS CZ) where are gathered all incoming responses from the transponders of aircraft. This software produces as output text file which contains already enumerated values of requested data from registers.

c) Setup of radar bracon

At this step was very important to setup optimal interval of radar interrogations for specific register. That was done with the respect of the maximum capacity of registers in each interrogation. (Note that existing mode S sensors with rotating antennas can extract about 4-6 transponder registers per aircraft per antenna scan. This register extraction limit results from the fraction of the antenna scan time that a given aircraft lies within the sensor's antenna beam.). Actually in Czech Republic are radars set to interrogate for 3 registers in each rotation of antenna. And furthermore once in 30 seconds radar interrogates for 4 registers.

d) Activation of data collecting

After doing all steps named in a) – c) process of data collection could be started. It was done in May 2010. To the end of May was testing operation. (First 2 weeks served for ensuring that all parameters were properly adjusted and for eliminating initial software bugs). Regular operation of data collecting has been started since June 2010 and is running till now.

e) Collected data repository

Data saved in output files were step by step stored to the local off-line database for further work. Each sounding stored to database consists not only from meteorological aircraft derived data such as wind condition, temperature, pressure and hazardous meteorological effects but it was also supplemented with other data which serve as unique identifier of each sounding. This identifier consists of timestamp, position (altitude, longitude, latitude), SIC (System Identification Code) and SAC (System Area Code) of radar, raw content of each register (hexadecimal), aircraft identifier and source. If the data were not available in register, to database was stored value "NULL". In reality it appears very often that not all items are filled in register (see section *B.)* The operational database is MySQL server 5.1. During the data collecting was created further software tool serving like the database query browser.

B. Statistical interpretation of collected data

In the beginning there were few clear explicit questions which had to be answered. Are there any data gained from registers at all? If yes, are these data true?

Preliminary results (after few days of data collecting) showed up that data from register 44_{16} (routine met – data) are profusely represented. Contrary data from register 45_{16} (hazardous met – data) are represented very rarely (see Fig. 1 and 2).

DAT	AID	CFL	WID (LAT)	LEN (LON)	ICE	TUR	WSH	MBS	WTC
2010-06-01 05:33:41.0	DLH1KV	340,25	49,66432501	14,64532549	medium	medium		none	none
2010-06-01 08:47:51.0	SSF9571	400,25	48,13480358	16,05503521			none		
2010-06-02 11:03:02.0	KRP16E	310	47,79998171	15,18150203		low	high		
2010-06-03 05:56:29.0	CSA588	200,25	51,22482208	13,47863356	none	high	low	none	none
2010-06-03 18:28:39.0	DLH83U	380	50,70200343	14,51172622		high	medium		none
2010-06-04 11:57:44.0	DLH3289	320	50,36974285	11,11967725		high			
2010-06-05 03:31:17.0	CSA658	200	49,1288914	16,55035577			none		
2010-06-07 08:09:43.0	KRP15E	300,25	49,52156487	11,92005065	low	high			none
2010-06-07 08:10:37.0	KRP15E	300,25	49,56995808	11,81483106			none		
2010-06-08 17:16:14.0	CIM3527	321,75	51,74796492	14,15172827	low	low	high		light
2010-06-10 04:43:17.0	DLH1HP	250	47,76920274	13,6632629		low		medium	
2010-06-10 05:55:31.0	CSA516	160	51,33014638	13,98597711	none	none	high	medium	
2010-06-10 17:47:19.0	DLH6NH	303,5	48,05468404	14,2278919		high			
2010-06-13 09:52:10.0	DLH3256	300,25	48,22671363	14,11109363	high	medium			none
2010-06-13 10:38:14.0	GMA640	380,75	51,09433905	13,89179772	medium		medium		light
2010-06-14 15:32:53.0	AZA4DR	160,5	49,75415951	10,13017665		high	none	low	light
2010-06-15 10:27:11.0	CSA37A	210	49,25200338	18,05898013	medium	low			none
2010-06-15 14:24:49.0	DLH7FP	380,25	48,10168346	16,07036605		high			none
2010-06-16 13:59:39.0	DLH1CJ	340	49,0038541	17,23178285		high		low	none
2010-06-17 12:27:07.0	VJS264	400	48,49002964	11,84543277		medium		none	
2010-06-17 14:58:25.0	MJSTA	390,25	51,89501499	12,81631495		medium			
2010-06-18 05:52:23.0	DLH1KV	320	50,33186151	11,19916426	none	high		medium	light
2010-06-19 11:33:24.0	DLH3257	177,75	48,06190828	13,44982076	medium	none	medium		none
2010-06-21 17:03:52.0	DLH24T	186,25	48,66035448	16,66148211	high	low	medium		none
2010-06-23 16:27:08.0	CIM4547	330	51,12393673	11,51323678		high			
2010-06-23 19:16:29.0	LOT38T	165,5	50,91492779	16,02682809	high	none	low	high	none
2010-06-26 05:52:51.0	CSA572	240,25	51,62534004	12,16772932	medium	low		low	
2010-06-26 08:05:58.0	XPE290	430	49,02531145	17,03767176		medium		medium	none
2010-06-27 10:14:02.0	DLH5YF	183,75	49,10490938	12,37778708	medium	low		low	
2010-06-27 15:32:38.0	ESQ077	309,5	48,14277666	15,79481155	low	low	none		none
2010-06-28 09:07:34.0	TCMSB	399,75	49,57090613	10,54552807		none			
2010-06-29 07:24:52.0	ADR103	210,5	47,7620066	12,69261214		low	high		
2010-06-30 13:03:36.0	HBVWN	430	49,18164983	17,34158061			none		
2010-06-30 13:14:40.0	DLH2NH	194,25	48,19340251	12,58439007	high	high	high	medium	

DAT	AID	CFL	WID (LAT)	LEN (LON)	ICE	TUR	WSH	MBS	WTC
2010-07-02 16:49:44.0	CSA967	194,75	48,92844722	16,98750281	high	low		low	medium
2010-07-03 11:00:26.0	CSA734	200	49,11524809	13,13446797		medium		low	none
2010-07-04 22:39:07.0	JBR501	220	47,99778512	16,30166226					none
2010-07-06 11:00:26.0	SAS2684	390	52,01853252	11,82254791		medium			
2010-07-06 18:43:48.0	ISK3078	220,25	51,46600293	11,65340228					none
2010-07-12 12:51:18.0	ISK3048	220,25	50,60651074	11,76729155					none
2010-07-13 14:18:15.0	DLH1CJ	340	50,499676	10,84375196	high		medium		
2010-07-14 14:36:21.0	URHBD	320	48,20340563	16,83945937	low	medium	high	none	none
2010-07-14 14:38:58.0	HBJFZ	400,25	49,60465174	11,16062685		none	none		
2010-07-15 20:02:56.0	CSA836	63,75	49,95780333	14,29469819		low		none	none
2010-07-17 11:17:08.0	BZH902N	289,5	49,96957108	12,29242562		low	high		
2010-07-19 19:54:12.0	CSA836	209,75	49,01384886	15,29464203	none	low	low	low	none
2010-07-20 20:42:17.0	ADR511	330	48,50092399	15,54651951			none		
2010-07-22 13:14:16.0	CSA791	200	49,01508571	16,80465217		high	high	high	medium
2010-07-23 10:18:53.0	OYVGA	380,25	48,03873524	15,17279492		high	high	high	light
2010-07-23 11:03:40.0	VJS259	400	47,60968067	15,27194843	low				none
2010-07-26 09:29:46.0	DLH8JK	181,25	48,85264566	11,43231339	none	low	low		
2010-07-26 18:40:15.0	CSA520	101,75	50,08851916	13,60591101		high		high	none
2010-07-28 10:23:00.0	CSA962	170,25	48,67790996	17,20977848		high	high	high	
2010-07-28 18:37:12.0	CSA545	39,5	50,18410371	14,46379593		medium			none
2010-07-29 06:01:40.0	DLH6TY	260	49,93175895	11,93721248		high			
2010-07-29 07:19:40.0	NJE870Y	330	47,86365018	13,61120632			medium		light

Column descrition:

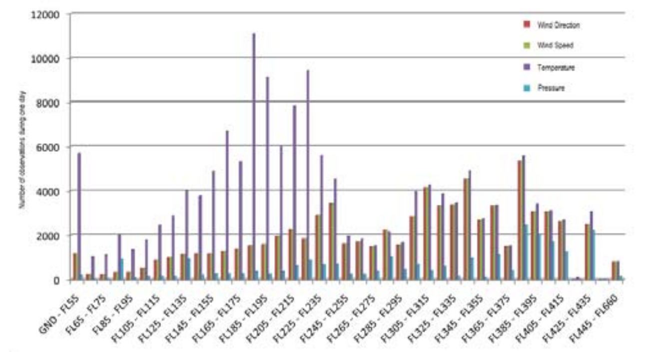
- DAT – date and time of observation
- AID – aircraft identification
- CFL – cleared flight level – altitude of observation
- WID / LEN – position (coordinates), latitude and longitude
- ICE – icinig
- TUR – turbulence
- WSH – windshear
- MBS – microburst
- WTC – wake turbulence

Figure 1. Collected hazardous data in June and July 2010 register 45_{16}

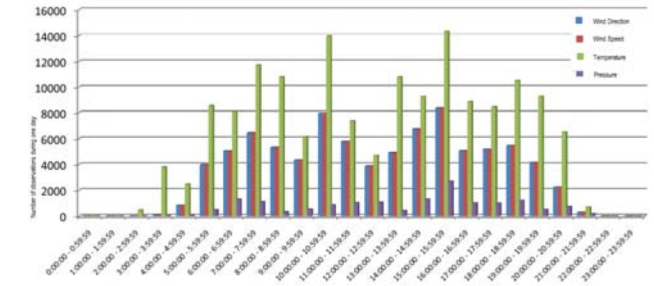
There could be offered several possibilities why are these hazardous data so seldom covered. First, there were no hazardous effects in the atmosphere but after few months (especially after thunderstorm period) this theory was rejected. Another explanation could be that aircraft are not equipped for providing such information. But after discussion with specialists for transponders this theory was discarded too (in fact there were only several packet of ten soundings in register 45_{16} as could be seen in graphic below.

Very different situation dominates in case of register 44_{16} (routine reports). There is amount of provided data incomparable higher. There were created two statistics:

- spread out of observations during the daytime
- spread out of observations within specific altitude



Average spread out of data within specific altitude



Average spread out of data during daytime

Figure 2.Statistical output

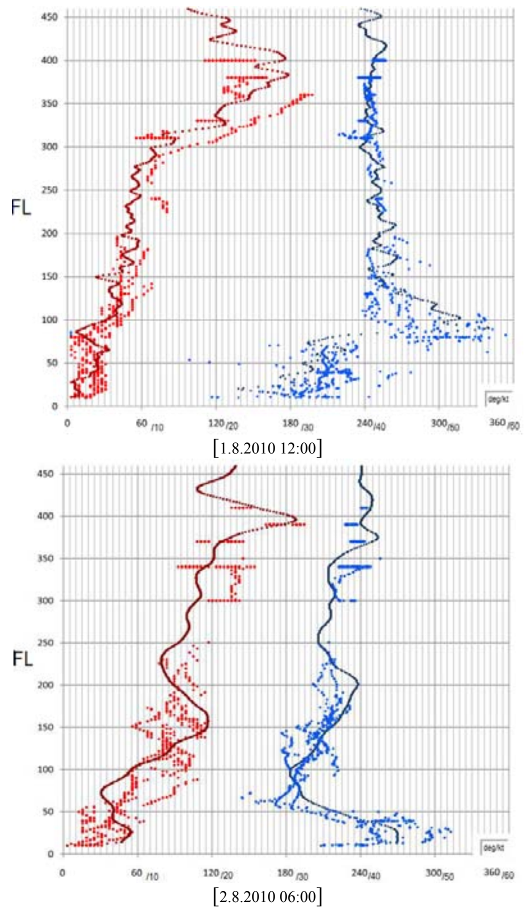
The answer for the second question (*Are collected data true?*) request more complex point of view. Collected data had to be verified (see paragraph *c*).

C. Comparison of collected meteo data with official published data of CHMI (Czech Hyydrometeorlogical Institute)

For verification of data collected from register 44_{16} (routine met – data) were used data provided by Czech Hydro Meteorological Institute (CHMI). Data of CHMI comes from radiosonde (see figure 3). Radiosonde of CHMI provides information about wind speed and direction, air pressure, temperature and humidity. Data from CHMI radiosonde was the source of data for comparison with collected met - ADD. CHMI is doing measurement every 6 hours (0:00, 6:00, 12:00, and 18:00 UTC). The radiosonde starts every times approximately 30 - 40 minutes before nominal time (that means time around 21:25, 4:25, 10:25, and 16:25 local time during summer period in Prague). The probe takes usually one and half hour till the radiosonde climb to altitude of 30 km or

Figure 3.Start of radiosonde / Radiosonde RS92 used by CHMI

above in the atmosphere. The aircraft provide data from its cruise altitudes (max FL410 = 12,5 km, above only solely cases). In the graph below is sample of observation from radiosonde compared with met – ADD (from the same time period and area – cca 100km around Prague. To see example of comparison look at figure 4. There are selected two comparisons of data from 1.8.2010 12:00 UTC and 2.8.2010 06:00 UTC.



Legend:

- Dark red line – wind speed (knots) from radiosonde
- Dark blue line – wind direction (degrees) from radiosonde
- Red dots – wind speed from aircraft derived data
- Blue dots – wind direction from aircraft derived data

Figure 4.Comparison meteo data (radiosonde vs. aircraft)

VII. Conclusion and Contribution

Till now were analysed data from June till half December 2010. It is obvious that data from BDS register 44_{16} are very numerous and valid. The most often item in observations is temperature. Very often is also wind direction and speed. Static air pressure is reported from time to time. At the beginning was decided not to deal with humidity but after several discussions with specialist from CHMI was also humidity add to processed items because specialists from CHMI evinced interest in this item. The collection of humidity values from BDS register was started in August 2011 but regrettably, from the first view to stored data, it is evident that almost no one aircraft provides this item.

Just now there are further analyses of wind data in progress. It is also preparing further and closer cooperation with airliners which are flying through airspace of Czech Republic. The request is to set their transponders to state of provision these data in BDS registers 44_{16} and 45_{16}. It is not compulsory to provide data from met – registers. That´s why many airliner's transponders have blocked these registers (e.g. Travel Service). Benefits of this will be of course provision of more met – data.. Local airliners such as Czech airlines, Job air, Air Silesia and most other European airliners such as Lufthansa (Germany), Farner (Switzerland), Gama (UK) , Intersky and Vista Jet (Austria), Lot (Poland), Netjests (Portugal), Scandinavian (Sweden) and many others provide meteorological ADD.

Implementation of these processed data into present ATM systems can bring some prominent advantages. If there will be data from BDS register 45_{16} (hazardous effect) available or more numerous it will be very useful. It is possible then to depicture reported dangerous meteorological data into radar screen for air traffic controllers and they can very easily inform other aircraft in the vicinity about the effects. Jet streams will be very precisely located in the atmosphere and that can save many tons of the fuel and save a lot of time for both passengers and crew too if the aircraft will use or avoid these streams.

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Recent Changes of Rules for Parachutists

Requirements for Medical Fitness

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***Abstract*—In terms of the Czech Air Law, parachutists are regarded as pilots of sports flying devices. Consequently, they are subject to specific requirements concerning their medical fitness. Several controversial legislative changes made in the last few years are discussed.**

Keywords - parachutist; medical fitness; licensing; legislative requirements

Motto: Parachutist = madman leaving a fully functional aircraft in flight.

I. Introduction

Skydiving represents a rather specific activity, which cannot be considered as "flying" in the conventional meaning. Notwithstanding the fact that parachutists land without taking off, several differences can be found even in comparison with the most similar activities, i.e. paragliding and hang-gliding.

II. Main Traits of Skydiving

A. One-way movement

Any parachute is designed for descending in the air. Regardless of its gliding ratio, which may attack the parameters of some paragliders, a parachute is not meant for climbing.

B. Limited time in the air

The consequence of the aforementioned. The time from leaving the aircraft to landing rarely exceeds several minutes, even in disciplines such as CRW, including early opening of the parachute. A further consequence is a limited range of parachutists who are supposed to land in a very confined space – ideally at a designated point.

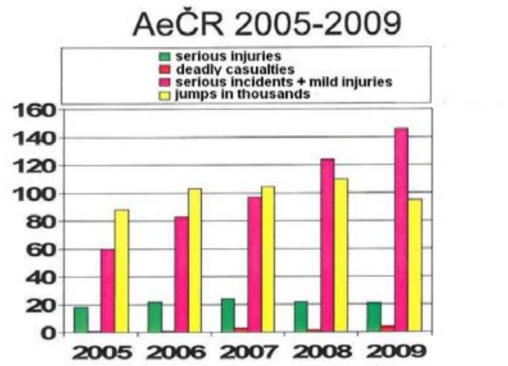
C. Limited risks

The limited time in the air significantly reduces the probability of sudden occurrence of any unfavorable health condition during descent. The limited range reduces the probability of causing any emergency outside the airfield perimeter.

III. Accident Statistics

According to the Para Committee of the Aeroclub of the Czech Republic, in the year 2008 in 44 countries 918 436 skydivers had made 5 770 169 jumps, with 70 casualties. This means 1 deadly accident on 13 121 parachutists and on 82 431 jumps.

The situation in the Czech Republic can be seen in the following graph.



IV. Legal Provisions

The Czech Air Law, Act No. 49/1997 Coll., defines the category of "sports flying devices", comprising ultralight aircraft (airplanes, helicopters, gliders and autogyros), paragliders and propelled paragliders, hanggliders and propelled hanggliders, and sports parachutes.

The users of such devices are regarded as pilots and are subject inter alia to comply with medical requirements for class 2.

Originally all such pilots (including skydivers) were forced to be assessed by aeromedical examiners, authorised by the Civil Aviation Authority of the Czech Republic.

A. *Amendment 225/2006 Coll.*

Three categories of sports flying devices were relieved from the obligatory assessment by aeromedical examiners, probably on ground of their lower risk rate.

These are single-seat paragliders, hang-gliders and parachutes. Double-seat paragliders, hanggliders and parachutes, as well as propelled paragliders and hang-gliders underwent no change.

The pilots of the above mentioned single-seat “soft” flying devices were to be assessed by their general practitioners. As these were not commonly aware of aviatic regulatons, the Ministry of Health had issued a guideline recommending the use of normatives regulating the medical fitness of automobile drivers, with increased attention to the state of the skeletal system (particularly the vertebral column and joints of lower extremities).

Simultaneously the validity period of such medical certificates had been prolonged from original 2 years to 60 years of age, which is also identical with the initial period for drivers of automobiles under 3500 kg.

This amendment was efficient from 1st July 2006.

B. *Amendment 301/2009 Coll.*

The parachutists have been exempt from the above mentioned exemption as from 1st January 2010.

Consequently they are again subject to assessment by aeromedical examiners in periods of 5/2 years in the age under 30/30-60, respectively.

Meanwhile, the pilots of paragliders and hang-gliders (single-seat, unpropelled) remain in the alleviated medical assessment regime.

V. DISCUSSION

Nowadays, a global trend can be seen in the direction of liberalization of strict regulations, especially in the field of recreational and sports activities. It can be assumed that the use of sports flying devices is not as demanding as flying with “adult” aircraft and therefore allows inter alia milder medical requirements. Further, it can be argued that the assessment of medical fitness for the use of “flying bags”, such as a paraglider or a parachute, does not deserve the attention of a specialized aeromedical examiner.

Furthermore the accident statistics of these devices show that a medical incapacitation in flight is a very exceptionally cause of serious incidents, let alone accidents

On the other side these activities *are* aviation and it would be rather negligent to say “every holder of a driver´s license is fit for flying”.

A. *Similarities and Differences*

All three discussed types of sports flying devices have the form of a simple lightweight apparatus, which is attached on the pilot instead of the pilot sitting inside.

In common with other types of flying vehicles the most frequented causes of incidents and accidents are pilot faults and errors, and more often than in “adult” aviation violation of rules can be seen.

Due to the characteristics and performance of these devices, even in case of an accident the damage usually is limited to the pilot and device itself.

The main difference between skydiving and gliding is in the flight profile, essentially “vertical” for the parachute and “horizontal” for the gliders. This fact further restricts the potential of causing damages to others.

To be honest, new types of “fast” parachutes and disciplines (swooping) tend to disrupt this sharp border. One of the consequences is the increasing number of accidents in the landing phase on fully functional parachutes.

Other significant difference lies in the motivation and preparation of the users. While the users of gliders have to pass through a lengthy course and usually intend to continue flying for a longer time, a huge percentage of “parachutists” only want to try something exciting and content themselves with a weekend course with 1-3 jumps.

B. *Objectionable Legislative Issues*

The original legislative solution may be regarded as “conservative” - any human being flying in the air with the aid of some object has to be medically assessed as a pilot.

The amendment of 2006 was “liberal” - flying activities with limited risks need not be too strictly regulated. It was “ultra-liberal” in fact, due to the incredible longevity of the medical certificate.

The amendment of 2009 seems rather “ambiguous”- it conserves the liberalization for the slightly riskier types of flying devices and returns to restriction for all types of parachute users.

C. *Suggestions de Lege Ferenda*

If the law-giver really intends to have a liberal arrangement for some categories of aviators, it would be preferable to at least:

1. Shorten the period of validity of medical certificates for glider users according to other aviator categories.

In case of assessment by general practitioners the Ministry of Health should issue a normative in the Collection of Laws, implementing the ICAO requirements for Class 2 medical fitness.

If any, then the “weekend parachutists” should be assessed by general practitioners with limited validity of the certificates.

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L 13 Main Spar Fatigue

Aging Aeroplanes Fatigue Issue

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***Abstract*—This paper presents most important information concerning the problem of main spar fatigue cracking occurred in L-13 "BLANIK" glider. It reviews the L-13 type design certification and fatigue evaluation history. The basic methods of fatigue evaluation in aeroplane structure are explained. The paper also focuses on the recent fatal accident caused by main spare fatigue in 2010. Mandatory actions required by Civil Aviation Authorities as a result of this accident are reviewed. There are introduced some examples of existing solutions for continuing airworthiness and best practices for dealing with fatigue issues in aging aeroplanes structures.**

Keywords-L-13, fatigue, safe-life, damage tolerrant, fail-safe, Fatigue Management Program,

I. Introduction

L 13 Blanik is one of the most numerous and widely used glider in the world. It is designed for basic and continued pilot training, cross-country and aerobatics training. Total production was in excess of 3000. L 13 was developed more than 50 years ago in 1950´s. As there was most experience with design of metal structures in that time, there is no surprise that L 13 is designed as all-metal flush riveted sailplane with fabric covered control surfaces. During development the designers were forced to evaluate the fatigue facilities of designed structure. As a result, operating limits and design service life were determined based both on knowledge about fatigue and computing technology in those days. As a result of L-13 recent fatal accident in Austria the calculation of fatigue service life were questioned which caused that almost whole L-13 fleet all over the world is grounded now. The operators' attention is focused on proposal of acceptable solution, which would guarantee further safety operation of this very popular glider. Since time of L-13 development more than 50 years ago there has been a rapid advancement in computer technologies and also in Non Destructive Testing (NDT). This fact can be used e.g. for reassessment of structure design or implementation of NDT, which could return L-13 Blanik back to skies.

II. L-13 Type Certificate Data

Since 1959 the type L-13 "BLANIK" has been certified by Civil Aviation Authorities (CAAs) in many countries around the world. Excluding the Europe countries, it has been certified in USA, Canada, Brazil, Australia, New Zealand and many others. In Europe the European Aviation Safety Agency (EASA) is responsible for type certification of all aeronautical products registered with CAAs of European Union (EU) member states. In Type Certificate Data Sheet (TCDS) No.: EASA.A.024 [3] basic data related to the type design fatigue issue can be found.

A. All variants

- Type Certificate Holder: Aircraft Industries a.s., Czech Republic
- Airworthiness Category: Acrobatic
- Lifetime limitations: Refer to Maintenance Manual

B. L-13 "BLANÍK"

- CAA CZ Type Certification Date: May 29, 1959
- Certification Basis: Bauvorschriften für Segelflugzeuge (BSV) issued August 1939 and BCAR, Section E, issued June 16, 1966
- Airworthiness Requirements: see Certification Basis

C. L-13 A"BLANÍK"

- CAA CZ Type Certification Date: December 16, 1981
- Certification Basis: BCAR, Section E, issued June 6, 1966
- Airworthiness Requirements: see Certification Basis

D. L-13 AC"BLANÍK"

- CAA CZ Type Certification Date: July 15, 1999
- Certification Basis: CRI-A-01, issue 2, issued August 31, 1998
- Airworthiness Requirements: BCAR, Section E, issued June 6, 1966

III. Fatigue Evaluation Methods

Reference [2] fatigue is defined as the process of progressive localized permanent structural change occurring in a material subjected to conditions that produce fluctuating

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stresses and strains at some point or points, which may result in cracks or complete fracture after a sufficient number of fluctuations.

Parallel to the development of various aeroplane structures in past years different approaches to manage fatigue in those structures were used to ensure safety operation throughout the whole service life. The main three fatigue evaluation methods for normal, utility and aerobatic category aeroplanes as requested by current certification requirements [2] and [1] are:

A. Safe-Life Evaluation

The safe-Life of the structure is that number of events, such as flights, landings, or flight hours in service, during which there is a low probability the strength will degrade below its design ultimate value due to fatigue. The safe-life is a point in the airplane's operational life when the operator must replace, modify, or take the structure out of service to prevent it from developing fatigue cracks that can degrade the strength below its design ultimate value.

B. Fail-Safe Evaluation

Fail-safe is the attribute of the structure that permits it to retain its required residual strength for a period of unrepaired use after the failure or partial failure of a principal structural element.

C. Damage Tolerance Evaluation

Damage tolerance is the attribute of the structure that permits it to retain its required residual strength for a period of use after the structure has sustained a given level of fatigue, corrosion, accidental or discrete source damage.

IV. L-13 FATIGUE EVALUATION

Since certification in 1959 L-13 "BLANIK" fatigue life has been the focus of much attention. This attention has been mainly related to those parts susceptible to fatigue cracking that could contribute to catastrophic failure of an airplane, called fatigue critical structure [1]. In L-13 type design these structure includes:

- Wing spar lower cap and cap splice critical area, Fig. 1 and Fig 2
- Lower flange of the wing centre section, Fig. 3

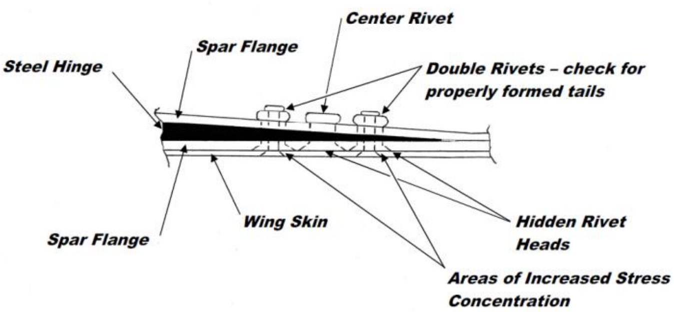

Figure 1. Wing spar lower cap and cap splice critical area

Figure 2. Wing spar lower cap and cap splice critical area

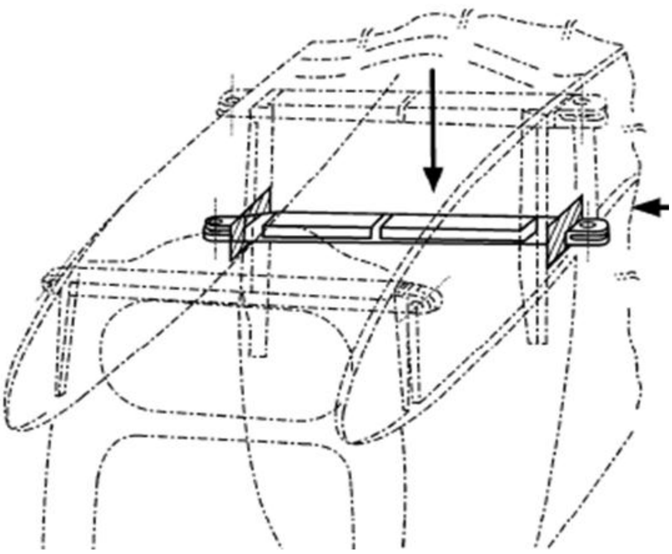

Figure 3. Lower flange of the wing centre section

A. Type Certificate Holder

The fatigue evaluation of L-13 type design was originally made by method of Safe-life. The service life of glider has been based on evaluation of above stated fatigue critical structure. The original service life stated in Maintenance Manual was 2700 Flight Hours (FH). As the experience with L-13 operation raised, the Type Certificate Holder (TCH) has been issuing a lot of instructions in form of Information and Mandatory Service Bulletins to adjust the service life in accordance with the most recent knowledge. Following are the main Service Bulletins including L-13 and L-13A variants:

- In 1976, Mandatory Bulletin L13/042 was issued to set the service life at 3000 FH, 15,000 take-offs, or 25 years, whichever occurs first. If the 25 year criterion is met first, this bulletin authorizes life limits up to 3000 FH or 15,000 take-offs if the aircraft is in a condition for safe operation. Acceptability is dependent upon the aviation authority.
- In 1977, Mandatory Bulletin L13/045 was issued to supersede Bulletin L13/042 and revise the service life of the L13 and the conditions of its applicability. This bulletin set the service life to 3750 FH based on average operating conditions in Czechoslovak aero clubs. It also stated conditions for possible further increases in the service life if specific flight operating procedures are applied.

- In 1978, Information Bulletin L13/050 was issued to potentially increase the L13 service life by 3750 hours for average operating conditions specified in Mandatory Bulletin L13/045 or by the value of the service life specified for the average operating conditions indicated by the operator to the manufacturer. This increase is hinged on replacement of the complete wing, the lower flange of the wing centre section, and the wing-to fuselage connecting pins.
- In 1985, Mandatory Bulletin L13/059 was issued to cancel all data concerning service life from Mandatory Bulletins L13/042 and L13/045. It set the service life at 3750 FH only if defined operating conditions are met. It also states the detailed statistical values which operator must provide to TCH in order to further increases in service life.
- In 1986, Information Bulletin L13/060 set the service life to 4900 FH if defined service conditions are met. This Bulletin applies only to L-13 operated for whole service time in Czechoslovak aero clubs. Service life extension is based on inspections which will be performed on first 6 gliders after reaching 4000 FH, 4500 FH and 4900 FH in service.
- In 1995 Information Bulletin L13/068 allows the operator to modify L-13 to L-13 A in nearest Overhaul (OH) and thus increase the service life by 6000 FH
- In 1995 Information Bulletin L13/070 set the service life from 3750 FH to 4500 for all L-13 only if operating conditions specified in Information Bulletin L13/060 are met.
- In 2005 Information Bulletin L13/104b set conditions for increasing service life to 5000 FH or more. It cancelled Information Bulletins L13/060 and L13/070 and applies only to L-13 operated for whole service time in Czechoslovak aero clubs.

The approved service life extensions as described in SBs are dependent on one or more of these three types of actions:

- Limitation to operating conditions, in average:
  - Number of take-offs is max 4,8 per 1 flight hour
  - The ratio of winch launches to the number of aerotow launches is 5:1
  - Crew: 65% solo : 35% dual
  - Aerobatic flight time is 2% maximum of total flight time
- Mandatory inspections
  - All inspections required by above mentioned SBs are only visual inspections
- Modification/part replacement (e.g. IB L13/068)

All of the above mentioned principles of fatigue evaluation presume the operators to be honest and careful in the recording of flight hours and landings completed. All of the limitations to operating conditions as takeoffs to flight hours ratio, winch launches to aerotow launches ratio, solo to dual ratio and especially max of aerobatic flight time, which are stated in Maintenance Manual, have to be strictly observed. The operator is also responsible that operational loads will remain below designed load spectra for various missions, especially for aerobatics. Max G-loads are stated in Flight Manual. As a result, without responsibly operators' approach to what is mentioned above, a fatigue evaluation cannot ensure a safe operation no matter how advanced it is, resulting in higher probability of catastrophic failure.

B. Gliding Federation of Australia (GFA)

The GFA is responsible for glider certification in Australia as delegated by Civil Aviation Safety Authority (CASA). GFA have been developing an extensive maintenance program for the L13 since 1976. In the 1980s, they established a total hours lifetime limit for the L13, and have subsequently published a pair of Airworthiness Directives (Ads)

1) GFA-AD-369

GFA-AD-369 published on 27 October 1989 identifies critical structural fatigue areas. These areas are: bottom spar cap and bottom carry through member. The critical areas of Blanik gliders must not exceed the following service limits unless they have been inspected / modified to this AD

- 5000 hours total flight time
- 18000 total launches (Whichever occurs first irrespective of launch method)

Requirements for continued service are as follows:

a) Fuselage Replacing lower carry trough member by new component or serviceable spare part at or before reaching service limits each fuselage can return to serviceable to operate until the lower carry through member accumulates 5000 hours total flight time or 18000 launches (Whichever occurs first irrespective of launch method)

b) Wings There are 3 options available to Blanik operators when each wing reaches service limits:

- Total wing structure replacement
  - Using new factory supplied wings or serviceable wings from another Blanik with complete service records the Blanik can return to service able to operate until either wing accumulates 5000 hours total flight time or 18000 launches (Whichever occurs first irrespective of launch method)
- Major wing spar modification
  - Blanik gliders modified fully to GFA-AD-160 can continue in service for: 12000 hours total flight time or 50000 launches
- Recurring 500 hour main spar eddy current inspection
  - Three double rivets are removed from the bottom spar cap of each wing. Each hole is inspected for cracks using high frequency eddy current (ET) method. Holes are lightly reamed and installed

Hi-lok fasteners. On completion wings can operate for additional 500 hours time in service following each recurring, successful eddy current inspection

2) GFA-AD-160

In 1984 D.J. Llewellyn designed a modification scheme, introduced in GFA-AD-369. Gliders so modified have received Supplemental Type Certificate 96-1 and were designated L-13-A1 in Australia.

Both GFA-AD-369 and GFA-AD-160 are not approved by CAAs outside of Australia and New Zealand. Getting them approved by EASA would involve huge amount of engineering and substantiation work. It was made clear by EASA that for any service life increase there has to be depth analysis of all structure and according testing.

V. Recent Fatigue Accident

The main reversal with L 13 type design fatigue evaluation came after fatal accident which occurred to an L-13 Blanik, reg. OE-0935 on June 12, 2010 in Austria. In this accident the main spar of the right wing failed near the root due to positive load resulting in detachment of the right wing from the aircraft. The preliminary investigation has revealed that the fracture may have been due to fatigue. The glider was manufactured in 1972 and it had time since new of 2318 hours and cycles since new of 5151.

A. L-13 Airworthiness in Europe

EASA respond to this fatal accident by issuing the Emergency AD (AD). Accomplishment of EASA AD is mandatory for each aeroplane registered in EU member state to which an AD applies. EASA ADs were issued in following order:

- EASA AD 2010-0119-E, 18 June 2010
  - Prohibited further aerobatic flights.
  - Required immediate inspection of the main spar at the root of the wing to detect fatigue cracking.
  - If any cracks detected, no further flights were permitted.
  - Required review of the operation conditions and their submitting to TCH.
  - To accomplish the requested action of the EASA AD 2010-0119-E Aircraft Industries a.s. issued Mandatory Bulletin No. L13/109a “Checking of the connection of the bottom wing suspension with spar cap – review of the operation conditions”.
- EASA AD 2010-0122-E, 23 June 2010
  - Retained the requirements of AD 2010-0119-E, which was superseded, and extended the applicability to L-13 A BLANÍK sailplanes.
- EASA AD 2010-0160-E, 30 July 2010
  - EASA concluded that the inspection method described in Mandatory Bulletin No. L13/109a might not be sufficient for detecting the crack.
  - TCH indicates that it is extremely important to remain within the flight limitations specified in the Aircraft Industries a.s. Mandatory Bulletin No. L13/109a.
  - Further required operating records review to determine whether the sailplane had been operated within the limitations.
  - If any ratio was exceeded or if the sailplane records were missing or incomplete, no further flights were permitted.
- EASA AD 2010-0185-E, 03 September 2010
  - Further analysis indicated that the OE-0935 accident occurred before the sailplane wing main spar reached its theoretical estimated fatigue safe life limit.
  - Prohibits any further operations of L-13 and L-13 A BLANÍK sailplanes.
- EASA AD 2011-0135, 20 July 2011
  - Since issuance of AD 2010-0185-E, it has been determined that Model L-13 A BLANÍK sailplanes have a wing installed which is structurally less sensitive to fatigue than the wing installed on Model L-13 BLANÍK sailplanes. It is known that some L-13 BLANÍK sailplanes have been modified in service to conform to the L-13 A BLANÍK type design, although the design status of their wing structure is uncertain. Thus, it is necessary to identify the design of wing critical parts installed on the sailplane. TCH issued Mandatory Bulletin L13/112a which contains instructions to enable identification of L-13 BLANÍK sailplanes that have a reinforced wing structure in conformity with the L-13 A BLANÍK type design. For the reasons described above, this new AD retains the flight prohibition requirement of AD 2010-0185-E, which is superseded, and allows sailplanes to return to flight, under certain operating limitations, provided certain actions are successfully accomplished, as described in Aircraft Industries Mandatory Bulletin L13/112a, and depending on the sailplane usage ratio.

With the cooperation of TCH and the Aero Club of Czech Republic, the CAA Czech Republic developed an exemption from EASA AD 2010-0185-E allowing certain L-13s to fly in the Czech Republic until April 2011. This exemption was reasoned in accordance with EC 216/2008, Article 14(4) exemption. This step was done to allow L-13 to fly until the alternate method of compliance (AMOC) to AD 2010-0185-E prepared by TCH would be approved by EASA. Unfortunately the development of notified inspection method in cooperation with Aeronautical Research and Test Institute is delayed and still not approved.

B. L 13 Airworthiness outside of Europe

The EASA ADs were adopted by CAAs of the states outside EU which is a common practice. As a result L 13 and L 13 A were grounded e.g. in USA, Canada, Argentine, South Africa, Australia, New Zealand and many others. In Australia, the L-13-A1 was exempted from EASA 2010-0185-E thus allowed further operation of this modified variant.

VI. Continuing Airworthiness possibilities

Regarding the accident in Austria the investigators made two very important conclusions after inspecting the fracture surfaces on fatigue critical structure.

- fatigue contributed to the accident
- similar failure is likely to occur on other gliders in L-13 fleet

The second conclusion would be correct only in case the operation of OE-0935 involved in the accident was in accordance with the operating conditions limitations from Mandatory Bulletin L13/059 stated in Maintenance Manual.

As the two above mentioned conclusions were made by investigators, the L-13 type design should be considered as type design that has a demonstrated risk of catastrophic failure due to fatigue. After such a finding, the responsible CAAs may require

- Initial short term actions including operating limitations, immediate inspections or fleet grounding, which was accomplished by ADs issued so far
- Long-term permanent solution to mitigate the demonstrated risk.

A. Fatigue Mangement Program (FMP)

The best way to comply with the requirement for permanent solution to mitigate the demonstrated risk of catastrophic failure due to fatigue is to develop a FMP. The best guidance on developing FMP provides document Advisory Circular (AC) No.: 91-82A issued by FAA. The EASA or CAAs can then mandate the FMP by AD or they may also approve the FMP as an alternative method of compliance (AMOC) to an AD.

The FMP can be developer typically by TCH or applicant for Supplemental Type Certificate (STC). Any FMP proposed by an applicant to address a demonstrated risk should include each of the following components [1]:

1) Damage-Tolerance Based Inspections or Replacement/Modification of the Structural Elements Directly Related to the Unsafe Condition

a) Damage-Tolerance Based Inspections: The applicant should complete a damage-tolerance evaluation. A thorough damage-tolerance evaluation will identify the crack location, scenario, critical crack size, the detectable crack size, inspection threshold, and the inspection interval (in number of flights or flight hours time in service) during which the crack grows from the detectable crack size to the critical crack size. The applicant must understand that damage-tolerance based inspections may not provide a permanent solution, if cracks are expected to continue to develop in the fleet.

a) Replacement/Modification: The applicant should be aware that by strengthening the location where the fatigue cracking occurred, the load path may change and transfer load to surrounding structure, creating a new fatigue location. The applicant should establish the time in service for each replacement/modification to minimize the probability of having a crack initiate in the structure. An applicant must demonstrate compliance to the applicable regulations and establish a safe-life limit or develop a damage-tolerance based inspection program for both the modified or replaced structure and existing surrounding structure it affects.

2) Inspections of Other Fatigue Critical Structure The purpose of this component is to proactively inspect for indications that may be precursors to an unsafe condition. The most likely areas are those where it is determined fatigue cracking may be expected to occur prior to their surrounding areas. These areas typically include the most fatigue sensitive details of joints, cutouts, run-outs and other discontinuities where local peak stresses are higher than the surrounding areas due to local geometry. The inspection requirements (e.g., where to look, how to look, how often to look, and when to start looking) may be service history or damage-tolerance based

If the airplane model has instructions for continued airworthiness (ICA), the applicant should add the FMP to the existing Airworthiness Limitations Section (ALS) of the ICA to meet requirements for FMP documentation.

B. Approved and proposed solutions and their applicability

1) Modification ADxC-DC-39-001

Aircraft Design and Certification Ltd. (AD&C) developed a spar modification displayed in Fig. 4. EASA certified the AD&C spar modification as STC 10035295 on 14 June 2011, and approved this STC as an AMOC with EASA-AD-2010-0185-E. Gliders with this modification are now allowed to fly in Europe. This STC can be considered as a *Replacement/modification* according to above mentioned FMP principles.

The modification consists of an additional root rib bracket, addition and replacement of several highly loaded rivets, and an additional girder plate attached to the spar at the lower wing root. The use of Hi-Lok fasteners ensures superior fatigue resistance and easier inspections in the affected areas.

Specific NDT inspections are mandatory during the structural modification and in increments thereafter. The NDT inspections are made possible by definition and usage of a reference normal, a part taken from an original aircraft structure in which realistic cracks have been incorporated. With this approach AD&C was able to define a method that has a relative small undetectable crack size and helps to define the longer-inspection intervals.

The approved life of the modified Blanik is reinstalled to the EASA approved 3750h it had before modification. AD&C has designed the modification for at least 6000h against the so called Kosmos spectra which contains 12% of aerobatic use. However since AD&C is unable (at this stage) to address the remainder of the airplane in the same depth, the approved usable time of the airplane is unchanged. AD&C is considering a further program for a general life time extension, pending on market response.

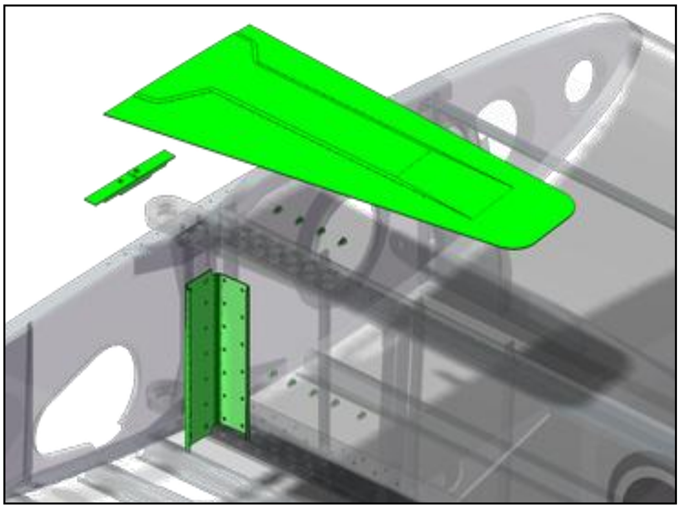

Figure 4. Modification ADxC-DC-39-001

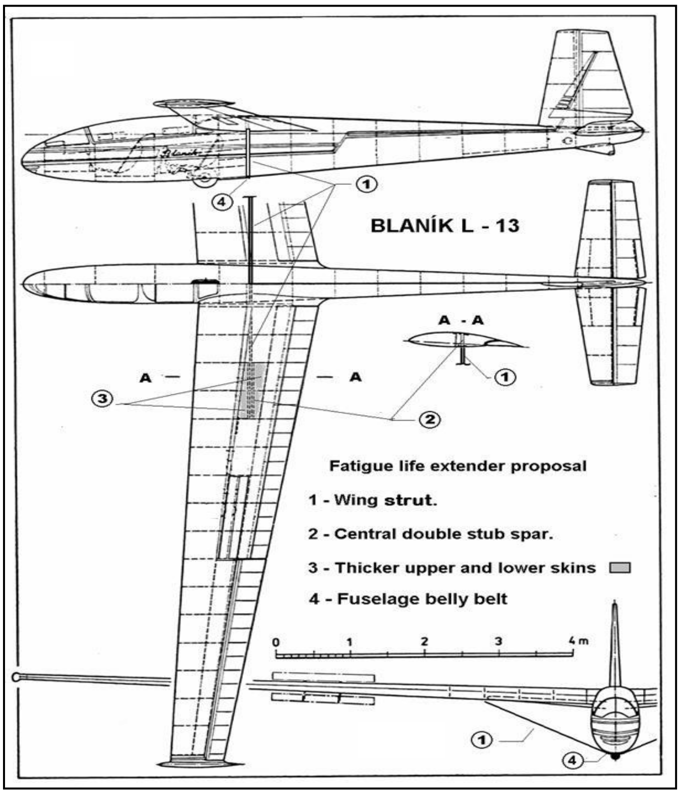

Figure 5. Fail Safe Fatigue Life Extender Proposal

2) Fail Safe Fatigue Life Extender Proposal

Francisco Leme Galvão, Brazilian aeronautical engineer, introduced solution consisting of wing external struts joining both wings to fuselage as shown in Fig. 5 that will act as fail-safe elements

A possible applicant for design change should understand that according to FMP principles if cracks are expected to continue to develop in the fleet, a fail-safe modification might not provide a solution to the demonstrated risk. In this case, the CAAs will probably require the fleet-wide replacement or modification of the structure.

VII. Conclusion

Based on the recent investigation L-13 type design is considered to have a demonstrated risk of catastrophic failure due to fatigue. This finding should be now addressed by complex solution that will ensure further safety operation. Although there is a lot of experience with operating L-13 in past 50 years all over the world, the fatigue is still very complicated issue and there is no simple way of mitigating the risk. The most recent knowledge from aerodynamic, fracture mechanics, Non Destructive Testing and other related disciplines should be utilized to review the fatigue evaluation process and develop clearly defined conditions for continuing airworthiness as required by CAAs. A required development is very timely and financially consuming and there is question, if such investment would be profitable for TCH or any other Design Approval Holder. Only future research can show, whether one of the most popular gliders on world is still perspective or it will be forced to yield to its modern composite successors.

Acknowledgment

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Contributions and Risks of the Biofuels in Aviation

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***Abstract* - The article is dealing with the solution of the using biofuels to drive aviation turbo-jet engines (ATJE) run of the laboratories of small-size jet engines (SSJEs) of the Department of Aviation Engineering, Faculty of Aeronautics, Technical University Košice. The aim of the experiments was to assess the possibilities of using various contributions of Fatty Acid Methyl Ester (FAME) biofuels mixed with kerosene and to analyze the changes in parameters and operational characteristics of the experimental SSJE in the contribution then are the findings regarding the influences of using alternative fuel exerted upon the selected parts of the SSJE. On the basis of the experiments, the conclusion is providing possibilities and limitations of using this type of alternative fuel to drive jet engines.**

Keywords-FAME, kerosene Jet A-1, small-size aviation jet engine, rubber sealing, low temperatures

I. INTRODUCTION

Manufacturers of aviation engines in the world apart form designing and producing more and more perfect, saver and efficient turbo-jet aviation engines (TJAEs) are also refocusing their attention to the use of non-traditional fuels to propel their power plants. The trend has been set by a gradual drop in the stocks of classical, fossil fuels available as well as the steady rise in the prices of aviation fuels, reaching as high as the ones typical for its alternative counterparts.

Governments in many countries pay more attention to the use of non-traditional and reusable sources of energy. In some of them, use of alternative fuel helps cover the substantial part of public transport fuel demands. Based on the prognoses of experts and in the light of its evident economic benefits, the trend is considered to be fixed. However, the idea of alternative fuels is by far least modern. The idea is not as new as it might see. It was as early as in 1893 that Rudolf Diesel designed his diesel-engine propelled by oil gained from oily grains.

The Slovak republic (SR), similarly to other countries of the European Union (EU) has signed the Brussels Directives committing itself to increase the share of biofuels on the total fuel consumption. The figure should represent 5 as much as %. Increasing the share of biofuels in SR is contained in the National program for the development of biofuels, which, among others, is trying to create legislative conditions for meeting the indicative target se for Slovakia by the European Parliament Directives 2003/30/ES on Support for using biofuels and other kinds of recyclable fuel in transport.

II. PROJEKT „BIOPAL“

Research into the possible use of an experimental mixture, i.e. the classical kerosene known as Jet A-1 and the methyl ester of the oily acids of FATE has become the objective of the Project „BIOPAL“ (Biofuel for Aviation), conducted by lecturers, PhD. and Bachelor-degree students. The entire project run on the basis of the resources available at the Department of Aviation Engineering, Faculty of Aeronautics, Technical University, Košice, (KLI LF TUKE), is divided into three independent tasks. The basic target of the project is to find out, by experiments, the technical potentials for reliable operation of the MPM-20 small-size turbo-jet engine (Fig. 1) when using various concentration of the Jet A-1 kerosene and the FAME-Fuel mixture. The second part was to monitor the long-time effects of the mixture on the rubber sealing. The third part of the experiments was oriented at the investigation of the changes in the behavior of the mixture at low temperatures [2].

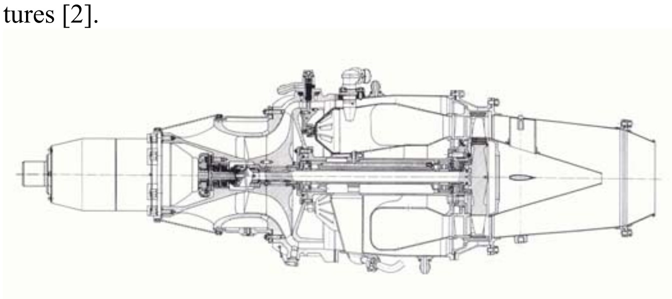
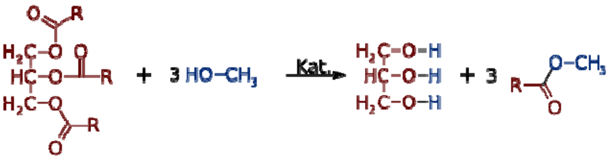


Figure 1. The experimental jet engine MPM-20

III. PROPERTIES OF THE FAME-BIOFUEL

The beginnings of the 90s saw the appearance of the biofuel 1.st generation. It was an ecological alternative to fuels on the basis of methyl esters of unsaturated oil acids based on vegetable (of the ones called FAME). The manufacturers were focused on making the clean FAME, following some treatment by additives to be usable in diesel-engines.

A fatty acid methyl ester (FAME) can be created by an alkali catalyzed reaction between fats or fatty acids and methanol. The molecules in biodiesel are primarily FAMEs, usually obtained from vegetable oils by transesterification.



(1)

Using vegetable oil fuel of local resources has been a rather positive idea. Massive exploitation of the clean FAME, however, was hindered by the rather negative experiences form its practical application. The vegetable oil fuel was unable to achieve the performance parameters of fuels based on crude oil. FAME also proved difficult to run through filters at lower temperatures (with the point of coagulation at -8°C), very low caloric value and the consequently loss of performance. Furthermore, this biofuel proved detrimental in damaging frictional parts of the engine, making it unsuitable for most of the diesel engines in use. Higher, (as much as double) fuel consumption turned into the most evident proof of its inefficiency.

The FAME biofuel of 2.nd generation is still the only alternative fuel frequently used for diesel engines. Some of its parameters even surpass those of the crude-oil-based counterparts, especially in terms of the wear of the mechanical components of the fuel system and the engine as well. As any of the alternative fuels, it also has its pros and cons. It is manufactured through refinery process called as esterification, when methanol is mixed with natrium hydroxide and then with oil pressed from local vegetables, sunflower, etc. or soy beans. It is then added or treated by de-aromatized and de-sulphurized crude-oil additives in order to maintain its neutral decomposition feature. The biofuel is a propellant agent at which maintains its crude oil characteristics while becoming environmental-friendly, both in term of the engine and the living environment as well. It is therefore considered as a great progress in the field of alternative fuels, also thanks to its indisputable qualities when compared to its 1.st generation predecessor. The basic component, methyl ester of oily acids, manufactured by PALMA-TUMYS j.s.c. is a clean, oily, yellow liquid. Its ignition point is at about 150°C, a property more suitable for storage than those classical ones. It is also known for its high lubrication features (more greasy than oil) thereby lowering wear of the internal parts of engines and giving longer life to injection nozzles. Important for those engines were lubrication is performed directly bay the fuel.

The Biofuel poses no special requirements in terms of its storage. It can be kept in the very same tanks and barrels as oil. Thanks to its improved combustibility, it produces less exhaust gases, sulphur and CO and carbon-hydroxides at all. With its decomposition period of 21 days, this fuel is more suitable for the environment selectable to contamination of soil - agriculture and forestry, water-works and reservoirs, etc. It is also considered as a cleaning agent, capable of relieving carbon, thereby extending service – life both to the engines and filters.

Before transition to biofuel, it is recommended to clean the entire fuel delivery system from water and sediments. Sudden transitions with preparations result in clogging the filters and damaging the fuel supply system (stoppages of shifting parts, nozzles). Storage of biofuel also requires clean depots area with no water contact. Long-term storage is not to be recommended as it results in the decomposition of the solution into its vegetable components, while making it aggressive to rubber parts, easy to oxidize and to produce sediments and acidosis products. It is also more vulnerable to bacteria when compared to standard oil.

IV. JET A-1 KEROSENE AND THE FAME-FUEL AS TJAE PROPELLANTS

The experiments were facilitated by the laboratory of small size jet engines built at the Department of Aviation Engineering, FA, TUKE, i.e. on the MPM-20 turbo-jet engine manufactured converted from the TS-20 turbo starter [3, 4]. Additional sensors attached to it were to record the basic thermo-dynamical parameters of the engine along with other selected data characteristic for its operation. The sensor signals were fed, via a transfer element, is processed in real time applying the program known as lab view producing graphical and tabloid outputs. The entire process of experimental testing was recorded on a video camera. Each concentration of the Jet A-1 and FAME a minimum of three measurements were made to exclude random failure [1]. Based on the measurements and evaluations performed one can conclude the following:

1. In view of the relatively small difference between the heating values of the tow fuels (Jet A-1: 43,292 $MJ.kg^{-1}$, and FAME 39 $MJ.kg^{-1}$), no fundamental changes in the thermodynamic parameters have occurred (Fig. 2);

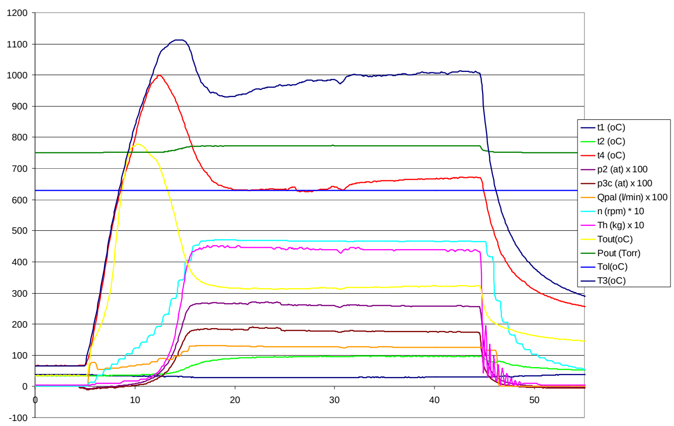


Figure 2. The change of the main parameters of the MPM-20 during the test

2. The higher was the proportion of the FAME (ρ_{FAME} = 882 $kg.m^{-3}$) in the mixture made with the Jet A-1 kerosene ($\rho_{Jet\ A\text{-}1}$ = 810 $kg.m^{-3}$), the higher was the density of the mixture, resulting in lower quality of fuel atomization when passing through the fuel nozzles in the combustion chamber making it more difficult to ignite the fuel mixture;

3. Reliable starting-up can be performed with cold engine at ambient temperature of t_H = 20°C only to 40% proportion of FAME in the mixture with Jet A-1. Higher concentrations (45% and 50%) resulted in difficulties with starting the MPM-

20, only following a preheating as a result of an earlier start-up. The results of measurements correspond to those attained in the United States made public on the Internet;

4. In view of the different density between the two mixture components, imperfect mixing and sedimentation of the more weighty FAME in the lower parts of the aircraft fuel tanks making it more difficult for the turbojet engines to start-up.

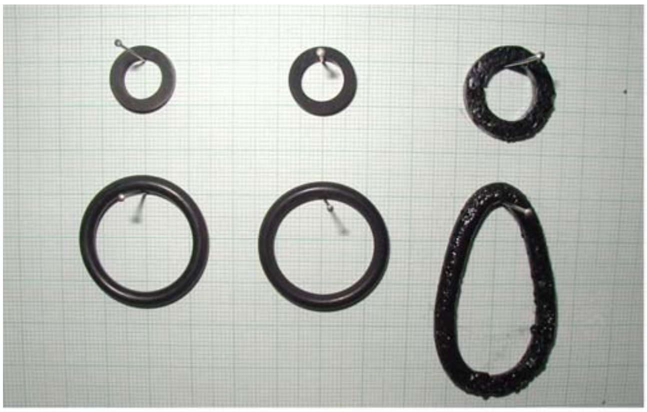
V. THE JET A-1 AND FAME MIXTURE AND RUBBER SEALING

The extent, to which the various Jet A-1 and FAME mixtures affect rubber sealing, was tested on typical rubber packing sealing rings of circular and square cross-section. The long-term (6 month) monitoring of the sample sealing withstanding various concentrations of the Jet A-1 and FAME mix has ended with his following results [5]:

1. Rising concentration of the FAME in the mixture with Jet A-1 lead to more intensive fermentation resulting in increasing the volume of rubber sealing.

2. Rising concentration of the FAME in the mixture lead to deterioration of the strength of the rubber sealing.

3. Rising concentration of the FAME and extending the period of exposure, leads to decomposition of the rubber sealing surface structures (Fig. 3).



0% FAME 0% JET A-1 | 0% FAME 100% JET A-1 | 80% FAME 20% JET A-1

Figure 3. Influence of the different concentration Jet A-1 and FAME on rubber sealing.

VI. PECULARITIES OF IN THE BEHAVIOUR OF THE JET A-1 AND FAME MIXTURE AT LOW TEMPERATURES

One of the limiting factors to use FAME for aviation engines is the temperature of congealing. The experiments conducted have unambiguously proven that the lower the temperature the higher the rate of change in the density of the Jet A-1 and FAME mixture. The higher the proportion of the FAME in the mixture, the process is more intensive. The tested FAME and kerosene Jet A-1 mixture is not fit for use in turbojet engines for aircraft provided that special additives extending the range of congealing temperature are added. The mixtures subject to testing are considered suitable only for stationary engines, e.g. power stations driven by aviation turbo-jet engines operating under conditions above freezing point.

Figure 4. FAME at -8°C (left) and at 15°C (right)

VII. CONCLUSION

The experiment conducted at the Department of Aviation Engineering, Faculty of Aeronautics, Technical University Košice, have made it evident that the idea to use of the alternative FAME as part of the mixture with kerosene Jet A-1 is a viable one. However, there are certain limitations to the use of the mixture, set by inherent properties of the FAME that are to be respected or treated using special additives. The facts, that will need to be subjected to further research by the fuel manufacturers themselves.

ACKNOWLEDGMENT

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Possible Mitigations of Aviation Impact on Global Atmosphere

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***Abstract*— The document dissertates about possibilities to mitigate aviation impact on global atmosphere. And warns before most obvious problems connected with every of the possibilities**

Keywords-aviation, EU ETS, atmospehere, radiative forcing, envinronment

I. Introduction

For year 2005 was, according to IPCC Climate Change 2007: Working Group I: The Physical Science Basis, the total radiative forcing (RF) due to human activity estimated to be 1,6 Wm-2. Aviation is producing less than 2 % of CO2 emissions but total impact of aviation on global RF is estimated to be around 0,078 Wm-2 (according to figure 1, including AIC) what represents about 4,9 %. Nevertheless that there exists large variety of uncertainness among estimations it is obvious that aviation is great contributor to global RF and has serious impact on global atmosphere. Therefore there shall be made serious attempts to mitigate the aviation impacts. In present day we see 3 possible ways how to achieve mitigation. These 3 alternatives are: a)avoiding of future growth of aviation b) Alternative fuel and new plane construction technologies c) law regulation.

II. Avoiding of dotore growth of aviation

Avoiding of future growth of aviation as whole would lead, in combination with innovation of worldwide fleet , in significant decrease of emissions and RF addition would be smaller than today. Avoiding of future growth is but something what we shall avoid. Only thing which can vindicate avoiding the growth of aviation would be if external costs of growth would be higher than positive external cost which are produced by the growth. It must be goal for every interested side to decrease global impacts of aviation on global atmosphere without avoiding of aviation growth, at least to time where positive and negative external costs of growing aviation would be equal. All efforts must be made with regards on sustainable growth. All policies and laws must be made with respect to not disadvantage one transport against other. Not well considered policies can lead in fact to decreasing aviation, but in end not in decreasing of environmental impacts because passengers will use another transport which can be even less environmental friendlier than aviation.

III. Alternativ fuel and new plane construnction technologies

One of most important goal of today aeronautical engineering is decreasing of fuel consumption. Decreasing fuel consumption leads to decreasing of emissions. Every year is average emission on one passenger per 1km decreasing, thanks to modernization of worldwide fleet of airliners. But with present day engines we are very near the final frontier of emissions mitigation. New more significant decreasing of emissions will be possible only with completely new fuel or construction elements.

There is no alternative fuel in present day which could substitute classic jet fuel. There exist varieties of fuels synthesized from various sources coal natural gas methane or coke. Problem of most of these fuels is that there is large amount of CO_2 emitted during synthetysation and so these fuels are not better alternative for RF mitigation because when we add the emissions produced during synthetisation, burning one kg of synthetic fuel produces more emissions than standard jet fuel. Very similar situation is connected with the liquid hydrogen. Liquid hydrogen relative emissions are strongly dependant on source from which is hydrogen produced. If produced with use of electricity produced in coal power plant hydrogen has more relative emissions than classic jet fuel. Hydrogen produced with nuclear energy or renewable sources has lesser relative CO_2emissions than classic jet fuel, but produces large amount of water vapor which can has the worst influence than CO_2itself. Another problem connected with hydrogen is its poor volumetric heat of combustion, what represent problem that for same amount of energy we have to have much larger amount of the fuel. It makes great problem with the fuel infrastructure and the fuel supply chain. Aircraft

design need to be complexly revised to find place where to store such as great volume of fuel.
The only alternative, which research enables for present day use, and which is producing less CO_2, than classic jet fuel are fuels manufactured from renewable sources. These fuels are called bio fuel, despite that there exist wide variety of these fuels with different characteristics. Every kind of bio fuel has some specific problem which prevents its nowadays usage. For example, one of most important of these biofuels, Fischer–Tropsch Synthesis, is during burning producing large amount of NO_X , alcohols are producing organic compound which are potentially health risk for areas near airports. And for every alternative fuel is important to enhance the production with a devices which captures CO_2 and preventing its spread during production. These additional devices and procedures make alternative fuel production more expensive than today classical jet fuel.

IV. LAW REGUALTION

Law regulations itself can not mitigate any emissions on their own. Regulations and policies only shall persuade airlines to reduce amount of emissions. Airlines can be prevailed to reduce emissions only by giving them a reason to do so. Reason may be negative or positive. We can fine everyone who won´t reduce emissions or we can reward everyone who do so. Law regulation and policies, such as Kyoto protocol, are political decisions made by government of interested countries. The regulation shall be as much global as possible, because not keeping on emissions reduction principles carries with market advantage. The countries which agreed to reduce emissions force airlines to reduce emissions what carries additional costs for these airlines, and these airlines suffer market disadvantage against airlines from countries which don´t force to reduce emissions. Law regulation and policies shall stimulate air operators to find best combination of procedures and innovation to achieve the goal of reduction emissions.
For Europe air operators is crucial implementing aviation in **EU ETS**. EU ETS is European system of CO_2 emissions allowance trading. Theoretically it enables every interested subject to trade with allowance and to make profit for selling own unused allowances, or decreasing own costs by buying less amount of allowances. EU ETS was established primarily for trading between large industrial facilities such as power plants, factories and refineries. Implementing aviation in EU ETS is scheduled from 2012. So far EU ETS worked well for industrial operators and it helps to reduction of production of CO_2. But including aviation in this scheme brings new challenges.
Negative impact on involving aviation, such as increasing costs connected with keeping records about emissions and implementing of new emission saving procedure, are unavoidable as well as so called carbon leakage. This problems I discussed in my article form last year of this conference. Same situation was in other industries implemented in EU ETS and it is compulsory evil which can not be avoided.
What is fundamental problem connected with aviation emissions is fact that CO_2 emission are only small part of addition of aviation to RF. New problems such as contrails and cirrus clouds creation, they are only connected to aeronautics and LOSU of many of these problems is very low and without any chance to better on few years horizon.
As clearly visible from figure one, there are three factors - production of ozone connected with emissions of NO_x in upper part troposphere, linear contrails and induced cloudiness. EU ETS is, from this point of view, possible negative instrument and there is a large risk of negative impacts of this policy on environment. For example, if airliner will change fuel for alternative fuel with smaller CO_2 emissions and higher NO_x , they will be rewarded for CO_2 reduction but in fact total RF may be worst than in case with the classical fuel. The same is the problem of the optimal flight level. Flight level is optimal for lowest fuel consumption in higher flight levels but in these flight levels is higher risk of production of contrail. For example a airplane will flight higher so it will burn less fuel and produce less CO_2, EU ETS will benefit it, the spared allowances can be traded, but because of fact of contrails and its addition to RF, impact on environment will be worst. There is strong need to prepare usable strategy on using of airspace with combination with impact of different flight levels on RF.
Choosing optimal flight level for flight in order to make lowest possible RF is very complex issue. RF depends on meteorological situation - specially on fact if the atmosphere is in danger of creation of contrails. There exist two basic types of contrails - aerodynamic contrails and exhaust contrails. Both need another conditions to appear. So when we are choosing right FL we have to avoid conditions for both contrails. Another variable, which is needed to be factor into, is daytime. Because negative impacts of contrails and induced cloudiness is much higher during night. It is because during night there is no positive impact of cloudiness on solar radiation and sustain only negative impact on long wave radiation, which is partially prevented by cloudiness from exiting atmosphere.

V. CONCLUSION

In present time is best way how to mitigate emissions the way by implementing right law regulation or policies. The polices chose in frame of EU to mitigate emission of greenhouse gases are, in my opinion, not the right for aviation. Aviation has many special characteristics and unusualness connected with pollutions emitted in higher levels of troposphere. EU ETS is device which works well for decreasing of emissions of CO_2, but may not work well for decreasing of global RF from aviation. And decreasing of the RF shall be the main goal of all policies fighting against risk of global warming. In present time there is no technical solution which would solve problematic of aviation RF at all. The only possible way is small implementing of various different methods of lowering the RF. First step to be made is changing of EU ETS for aviation because in today state it is not working as it was intended.

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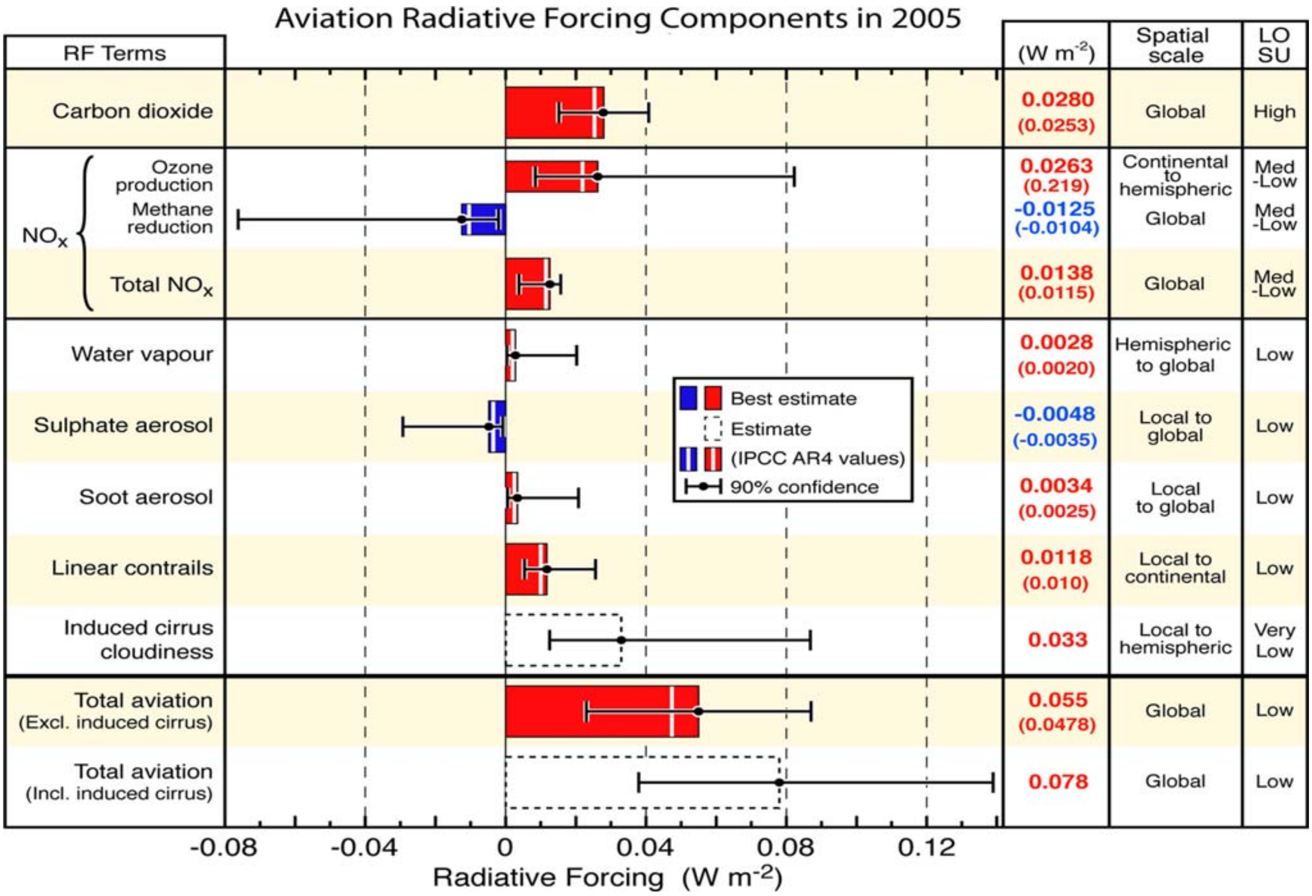

Figure 1 show bet estimates for aviation RF with 90% border of confidence Reproduced from [2]

Basic Problems for Driving Process

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***Abstract* - Human society needs still more intensive exploitation of all kinds of transportation facilities. This need lasts already several decades and will be much more imperative in future. Mobility is one of most strict requirements for survival, besides the energy and food resources, health care and security. The requirements on transportation systems concern not only the quantitative and qualitative aspects of transportation activities, but still more also the aspects of their reliability and safety. This concerns not only the transported subjects or goods, but also the environment. In spite of the fact significant progress was made in recent years as concerns the transportation systems automation, the fully automatic transportation system in use is still for-seen in the considerably far future. Analyzing the reliability and safety of transportation, one finds that the activity of human being is the weakest point. The technical reliability of almost all the transportation tools has improved quite a lot in recent years, however the human subject interacting with them has not changed too much, as concerns his/her reliability and safety of the respective necessary interaction. Therefore there is a hard necessity to improve it and the possibilities how to increase it will stay still more in the focus of our interest. In this contribution the overview of related problems is made, the challenges for further research and development in this area are discussed and the outline of the vision of with respect to human interaction reliability optimized transportation systems is presented.**

Keywords - human, flight training, simulator, transport

I. INTRODUCTION

Artificial systems can interact with human beings on the basis of:

- human control of system operation
- human use of system operation
- human society interaction with system operation

In the case of interaction between an artificial system and various members of human society forming its environment, interaction reliability and predictability can also be of very great importance. This is especially true in situations when the artificial system suddenly changes its behavior, and when it interacts with a large and heterogeneous part of human society. In order to estimate this environmental reaction, we need a deep understanding not only of the individual behavior of a human subject exposed to interaction with the varying properties of a particular artificial system, but also of any social factors that may exist or may be activated in the relevant part of human society. Such studies are evidently of great importance for general safety, but they are very difficult and time-consuming and require access to large special databases storing the results of many measurements of human subject interaction reliability markers. The main reasons for this unacceptable situation are as follows:

- increasing complexity of the systems,
- increasing demands on the operator's ability,
- increasing demands on his/her level of continuous, long-term attention,
- the increasing demands on the speed of his/her reactions.

The losses resulting from artificial system operation faults are proportional to their power, significance and value. In the case of many modern transportation systems (large planes, fast trains, large ships, trucks), large power plants, major financial systems, security and defense systems, and also major medical care systems, the losses resulting from malfunction can be catastrophic. Therefore, alongside the continuing interest in minimizing the probability of technical failures in any artificial system (at an acceptable cost), considerable interest has also been shown in recent years in the reliability of system operator activity. Studies demonstrate that human error accounts of the losses incurred by artificial system malfunctions. The demands on a human operator of an artificial system can be categorized as follows:

- demands on attention level and attention span,
- demands on the speed of the operator's reactions,
- demands on the correctness of the operator's decisions.

The safety of the operator - system interaction is to be considered as the probability that it will be resistant to any disturbing influences. General conditions causing decrease in attention include:

- extreme length of service without a break,
- physical and mental exhaustion,
- a monotonous scene, which the operator has to observe for a long time,
- extreme temperature in which the operator has to serve (too high or too low),

- extreme humidity in which the operator has to serve (too high or too low),
- extreme air pressure,
- air smell, dust density, etc.

Situations leading the operator to concentrate on problems other than his/her main task can likewise cause attention to drop. If the task is also monotonous, this can lead to a micro-sleep.

II Methodology of the study

In order to detect a decrease in attention, we need to select a set of significant parameters which can be used for identifying attention decrease and the onset of micro-sleep.

- Such parameters include:
- electro-magnetic activity of the brain,
- frequency of breath,
- frequency of heart beats,
- eye movements,
- skin resistance,
- facial grimaces, etc.

All these parameters have their specific advantages and also disadvantages. We have chosen EEG activity as the dominant significant parameter, because this is probably the only parameter from which almost immediate and reliable information about brain function can be analyzed (similar information can be of course be obtained from magnetic measurements of brain activity, but this would be technically much more difficult).

III Motivation

The need to minimize these losses is the dominant motivation for activity in this area. Let us restrict here to the car-driver and vehicle interaction. The progress in this respect could be reached by combination of the following 5 main approaches, which needs an very interdisciplinary approach:

- Improvement of the training the drivers with respect to their higher resistance to disturbing factors causing decrease of their attention,
- Improvement of the interior of the car cockpit with respect to minimizing the influence of disturbing factors causing the decrease of drivers attention and enrichment of the car equipments by new active and passive tools improving the driving safety,
- Development of micro-sleep warning systems and their installation in car cockpit,
- Improvement of the traffic control systems with respect to wide scale detection of risky and aggressive driving and of its punishment,
- Investigation of the influence of various drugs (including alcohol, nicotine etc) on human subject driving activity and development of new pharmatics improving the human attention.

As concerns the drivers training, much can be reached by the use of traditional methods, especially if they are completed by the systematic use of advanced driving simulators. However, the progressive training methods based on the use of simulators equipped by bio-feedback tools, if the training is carried out in satisfactory number of repetitions and being controlled by skilled neurologist or psychologist can lead to significantly improved resistance against both the fatigue and number of disturbing factors influencing the driver during his/her driving activity. Such enhanced state of the particular person resistance against fatigue can last considerably long, probably up to few years. In this period, the threat that his/her attention level falls down below acceptable level when driving is much less.

IV Experiment

Standard Operational Procedures (SOP) by flight crew - PC-flight simulator at the Department of Air Transport, VŠB - Technical University of Ostrava

A. First step – simulator

The experiment was divided into two days. The flight crew consisted of two pilots who changed positions in the pilot flying (PF) and pilot not flying (PNF). It also was carrying a notebook available with the software Flight Instructor, with whom had the opportunity to not only monitor the entire course of the flight, but also change the weather or simulating a fault. The auditor was in the cabin and flight crew assessed the activity in relation to compliance with standard operating procedures and guidelines for ATC. Any deviations from standard operating procedures, or ATC instructions recorded in the appropriate forms. Graphic output of the experiment - Fig. 1., Tab. 1.

B. Second step - Study of the effectiveness of flight training - Questionnaire

- Access of flight training instructors? (marking 1-5/ 1 is the best, and coments…),
- His theoretical knowledge? (marking 1-5/ 1 is the best, and coments…),
- How can he motivate? (marking 1-5/ 1 is the best, and coments…),
- How can he use a student´s errors? (marking 1-5/ 1 is the best, and coments…),
- Chat was the instructor´s preparation before the flight? (marking 1-5/ 1 is the best, and coments…),
- What was the analysis after the flight? (marking 1-5/ 1 is the best, and coments…),
- Comfort on the board? (marking 1-5/ 1 is the best, and coments…),
- Approach training center to the students-pilots? (marking 1-5/ 1 is the best, and coments…),
- All training (theory and practice) in English? (Yes/No), and coments…

Result

Simulators should be an integral part of flight training. Flight simulator no substitute for real flight in the resolution of adverse conditions on board. After evaluating all the questionnaires are returned to me, is evident what is most important for pilots. Even, if all during training was replaced by several instructors, mainly to agree that it is important to them on-board comfort and patience during the training instructor. It would also welcome more hours spent in a flight simulator and an individual approach to individual pupils.

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Category errors	Numerical evaluation	Color designation
Immaterial errors	1	GREEN
Serious errors	3	YELLOW
Very serious errors	5	RED
Errors directly lead to an accident	7	BLACK

Table 1. Category errors

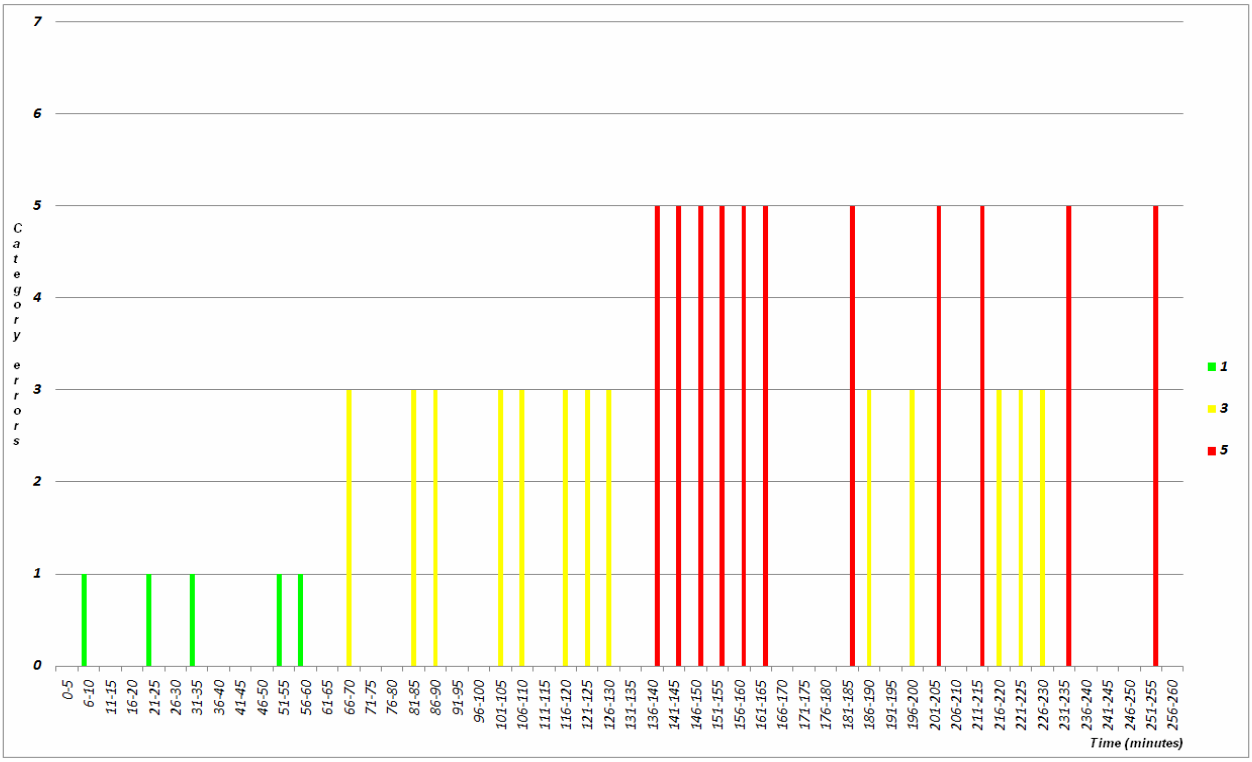

Figure 1. Experiment graph - Flight time/Category errors

Optimization of Passenger Boarding

Creating optimal boarding method for small turboprop aircraft

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***Abstract*—This article deals with passenger boarding problem. It discusses the issue of optimal boarding pattern and compares various boarding methods analyzing their advantages and drawbacks. Focus is on segment of small turboprop aircraft. The paper describes ten boarding scenarios for ATR 42 which were simulated using software tool. Finally, some of them were simulated in real conditions. The most optimal scenario is assessed.**

Keywords – passenger boarding; boarding scenarios; simulations

I. INTRODUCTION

Time is money. Every single airline is aware of this well known fact. Time is a critical value. Especially time spent on the ground during handling procedure. This period does not allow an airline to generate any revenues. Revenues can be generated only when the aircraft is in the air. Thereforeis reducing of non-productive period spent on the apron one of the biggest challenges which airlines are facing in these days when the market is oversaturated withcompetition.

Reducing stay on the ground means possibility of adding additional frequency for an aircraft flying on short or medium-haul routes. Consequences of this step are obvious. From marketing point of view, more frequencies means more attractive schedule, more attractive schedule means competitive advantage. From economic point of view, more frequencies means more passengers, more passengers means more revenues.

One of possibilities how to cut off turnaround time is partial shorteningof duration of each particular process.Those processes which take most of turnaround time are considered to be critical. Besides baggage handling processes, aircraft cleaning and refueling is one of the most critical process passenger boarding.Hence this paper discusses issue of passenger boarding problem as a critical process during aircraft ground handling with aim to find the optimal passenger boarding method in a segment of small turboprop aircraft. To realize this goal,this paper uses two types of simulations (first computer and then real ones) for assessing the most optimal method.

II. PASSENGER BOARDING ISSUE

Airlines use various systems to get passengers on board. When boarding, passengers are usually divided into groups. These groups are called to be boarded in predefined order. After call in a certain moment, the group leaves gate and goes on board. In most cases, the first group called is passengers from first of business class. After, passenger requiring special assistance and those with reduced mobility are board. Finally, passengers from economy class are called. These passengers can form one group only, but more commonly they are divided into more groups. Division into these groups depends on used scenario.

Narrow-body jets are generally boarded through front doors (low cost carriers use also rear doors to speed up the boarding process). From this point of view, it is logical to board passengers sitting in the rear part first, then those having seats in the middle part of cabin and finally passengers with seats in the front part. Reverse system seems to be ineffective. This statement comes from assumption that aisle congestions are reduced when passengers are board from back to front.

Scenarios developed recently can save lot of time. Boarding from window to an aisle can prevent situation when passenger seated on an aisle seat has to stand and allow passenger sitting next to the window to take his seat.

Within the framework of [1] the interference model was defined.They made the assumption that the minimization of interferences is equivalent to the minimization of total boarding time. Two types of interferences was defined, *seat interference* and *aisle interference*. Seat interference occurs when a window or middle seat passenger boards later than the middle and/or aisle seat passenger that sits on the same side and same row of the aircraft. Let us explain it on ATR 42 example. Passenger D on Fig. 1 is seated on his seat. When the passenger C with seat next to the passenger D boards the aircraft, passenger D must get out of his seat to allow passenger C access.

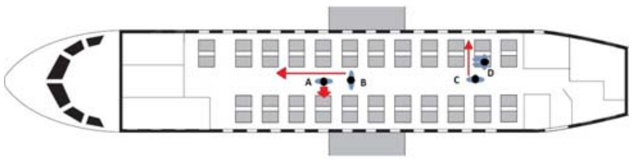

Figure 1. Interference model

By aisle interference is meant the situation when a passenger B is boarding the aircraft and has to wait for the passengersA in front of him to take his seat and to stow his luggage. After passenger A is seated, passenger B canproceed to his seat located further in the cabin. Aisle interference can occur within one group, or between two consecutive groups.

According to this model, we can reduce boarding time by reducing the number of interferences.

Nowadays, airlines use traditional systems that are easy to understand for the passengers and do not cause them any kind of stress. Moreover, traditional network carriers practice assigning particular seat to each passenger (seating). Low cost carriers, on the other hand, do not practice seating. They claim that when they avoid seating, the whole procedure can be finished earlier.

III. AIRCRAFT BOARDING PATTERNS

Boarding possibilities have been modified and adjusted to ATR 42 aircraft. The orientation on small turboprop aircraft segment has been chosen due to following reason. The aim of this research has been to find optimal boarding method, i.e. that one which takes the least time possible. Describing the problem by theoretical concept only would not be enough to assess which one is optimal. Some kind of verification has been needed. Simulations have been chosen for this purpose. To ensure as realistic results as possible, two kinds of simulations have taken place. One of them have been real simulations with real aircraft and real people at real airport. The only aircraft that has been available to be used within these simulations was ATR 42-500 of Czech Airlines.That is the reason why all the scenarios are illustrated at ATR 42 aircraft example.

Let us have a closer look at turboprop boarding singularities. The main difference in boarding procedure between jet and turboprop aircraft is that boarding the turboprops is executed through rear doors, instead of front one when boarding jet aircraft. The reason is very simple; ATR does not have a front door. Another difference is that small turboprop aircraft has just two seat rows at each side of aisle, i.e. one row counts four, not six seats. Finally, passenger group size is smaller than in single aisle jet aircraft.

Czech Airlines offer their services in two classes; business and economy. As real simulations have been executed with aircraft of this airline, all created scenarios consider with passengers of both classes. Business passengers have their seats at the rear part of an aircraft; economy class is in the front part. There is a curtain to divide both cabin partsinside the aircraft. As capacity of an aircraft is 46 seats, all scenarios count with 8 business passengers and 38 passengers in economy class.

As it was mentioned above, there are plenty of scenarios possible, every type can be modified or combined with the others. Within this paper there have been ten boarding scenarios created. Some of them are combination or modification of previous ones.

Business passengers are called as a first group in all cases. It is one of the benefits that airline offer to this high yielding passenger segment. Once business passengers are seated, other passengers are called. Depending on scenario, these passengers are divided into various numbers of groups.

A. Boarding without seating

The first method is the simplest. All passengers are called at the same time, but business passengers have advantage of priority boarding.

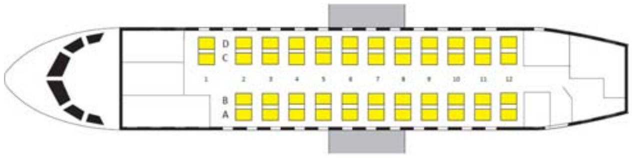

Figure 2. Boarding without seating

Not every airline assigns seats in the aircraft to passengers. They say that this is the way how to cut down the boarding time. As passengersdo not have assigned particular seat, they are trying to take the best seat available (according to their preferences). This makes the process very quick. This is typical for low cost carriers and as they do not use turboprop aircraft, this scenario is not used in this segment.

B. Random boarding

Hence every passenger will have assigned his own seat. Also, each passenger will belong to particular boarding group. First, business passengers are called. Second, all economy class passengers are called as they form one group and are seated randomly.

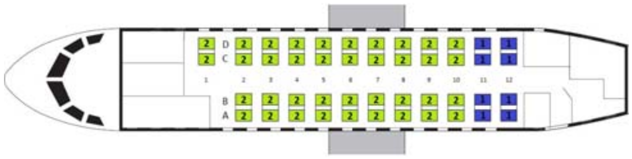

Figure 3. Random boarding

This method utilizes all the aisle length. That means that more passengers can store their luggage into the bins at the same time. Another advantage is low number of calls that airport employee has to do in the gate. The disadvantage is relatively high number of any kind of interference. This scenario is very common.

C. Front to back zone boarding

In this scenario we have one more group in compare with the previous one. Passengers in economy class are divided into two groups (zones). First group consists of passengers seated in the front part of an aircraft, the second one are passengers in the rear half of cabin. The boarding is executed from front to back (excluding business passengers).

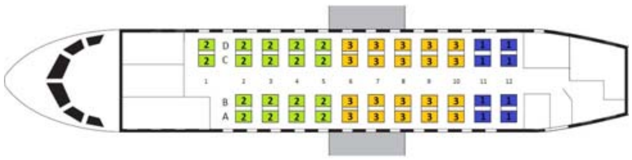

Figure 4. Front to back zone boarding

This scenario can be modified depending on number of rows belonging to each group. Single aisle jet aircraft with capacity from 120 to 150 seats use from to six groups with usually five rows in one group. In this case we are talking about back to front boarding because of usage of rear cabin door.

Main drawback of this pattern is fact that in one moment only a one part of aisle is used by passenger to store a hand baggage. Also, many interferences occurs. In spite of mentioned drawback, this scenario is widely spread in real operation. It is considered to be intuitive and therefore effective. This feature is its biggest advantage. As intuitive it is also considered by passengers.

D. Front to back row boarding

This is the scenario with the highest number of boarding groups. The group is formed from passengers seated in one row. Even business passengers are divided into two boarding groups.

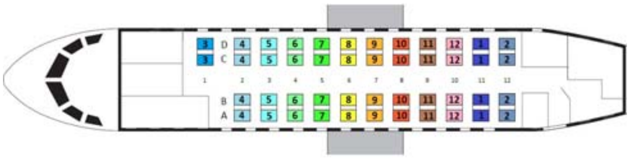

Figure 5. Front to back zone boarding

This pattern is one of the modifications of the previous one. That means exactly the same drawbacks as in a previous case. Passengers belongings to the same group are trying to store their baggage at the same place and at the same time. The rest of an aisle is unused. The aisle is (most likely) still blocked by passengers of the previous group at the moment when the next group is called. This can cause long queue of non-active passengers throughout the aisle. This disadvantage is more apparent when considering aircraft with six seats per row. In this case this scenario belongs to less effective ones. There is a assumption that this intuitive model could work better in a segment of small aircraft with four seats per row.

This procedure is used at the Žilina airport with one difference; the business passengers are boarded at the end of the whole process. The reason is that there is a special departure gate for those travelers at this airport. Business passengers can comfortably wait with their drinks in this lounge.[a]

E. Rotating zone boarding

This is another modification of back to front boarding model. In this case there is a modification in such a way, that the name back to front is debatable. That is the why this designation is left out from the scenario name.

After business passengers are seated, the aircraft is filled by the second group from the front, but the third group is seated in the rear cabin part. The other groups are also rotating from front to back.

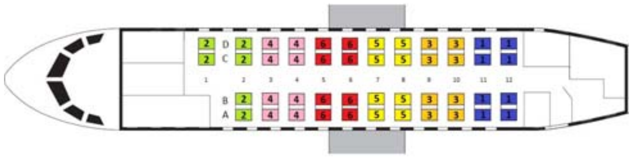

Figure 6. Rotating zone boarding

This modification solves the problem of non-active passengers queuing in the aisle. The passengers are seated in two cabin parts simultaneously instead of queuing in blocked aisle. This adjusting reduces aisle interferences, but does not solve seat interferences.

F. Outside-in boarding

The pattern that resolves seat interferences is called outside-in. Passengers in economy class are divided into two groups. The first is composed of those seating at the window seats. The second one, of those having assigned aisle seats.

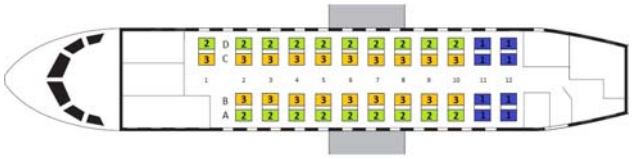

Figure 7. Outside-in boarding

This scenario looks as a pretty good idea. It completely eliminates seat interferences (except four interferences possible in a business class section). Another advantage is usage of the whole aisle length for stowing hand baggage. Look at the disadvantage - aisle interferences, but those occur every time the whole aisle length is used.

G. Letter boarding

Letter boarding is a modification of outside-in scenario. Both economy class groups are cut in halves. The groups are formed from passengers seating on the seats with the same letter, i.e. in the row in longitudinal direction.

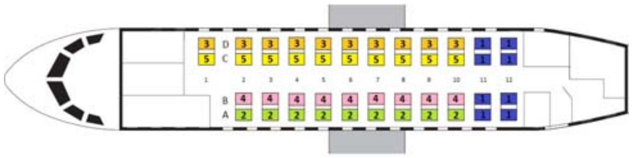

Figure 8. Letter boarding

This method is more effective than the previous one, due to smaller group size. The smaller the group is, the fewer interferences occurs.

H. Reverse pyramid boarding

This pattern combines two scenarios; outside-in with front to back. The economy class passengers are divided into three groups. The order of groups seems like building the pyramid from its peak. After business passengers are boarded, group

[a] At bigger airports there are special business lounges somewhere in the terminal. The business passengers are obliged to leave them and get to the gate prior the boarding procedure is started. They must wait in the overcrowd gate with other passengers. For that reason they are board first; to avoid waiting in such a conditions.

(2)is boardedin the front and at the window seats, group (3) is boarded at the rest of windows seats and at the front aisle seats and finally the core of pyramid – group (4) is seated at the rest of aisle seats.

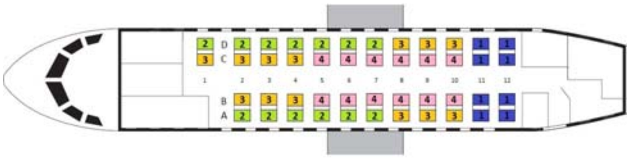

Figure 9. Reverse pyramid boarding

Application of this method is more apparent in the segment of aircraft with six seats per row and more rows. This pattern solves both interferences. Aisle interferences are solved by implementing features of front to back system and the seat ones by implementing outside-in features.

I. Block boarding

Block boarding is another combination of outside-in and front to back systems. The seats are divided into five boarding groups. First call goes to business passengers, the second one for those economy passengers with window seats in the front part of an aircraft. Next, front aisle seats are filled, then window rear seats and finally rear aisle seats.

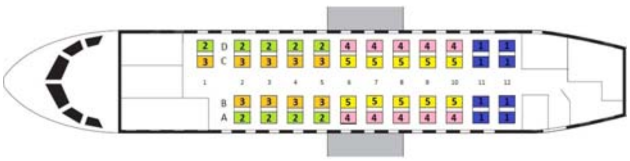

Figure 10. Block boarding

This method does not use the whole length of an aisle, but is more apparent than building of reverse pyramid.

J. Seat boarding

The dream of each passenger is an individual care. In this case, the dream comes true. Every single traveler is called individually. Planned passenger calling with outside-in features to eliminate seat interferences and front to back features to cut down aisle interferences leads to reducing the boarding time to minimum.

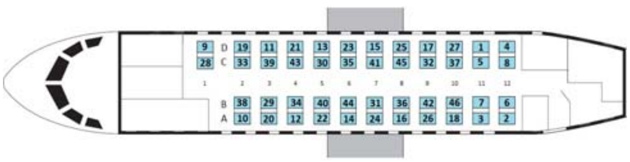

Figure 11. Seat boarding

All studies and simulations confirmed one conclusion. This is the best way how to optimize passenger boarding. Nevertheless there is not a single airline which would implement this pattern. Let us take a look why. First, the model is technically difficult to execute (in terms of number of gate calls – onecall every few seconds). The passenger must be focused for the whole boarding process; language barrier can be problem also. The main drawback is from the point of view of passenger groups which desires to board together. It is impossible to imagine three years old child who is boarding on its own. For this reason this model will not be considered anymore. This one is optimal, but technically difficult and unacceptable to passengers.

IV. BOARDING SIMULATIONS

As mentioned above, within the paper there have been two types of simulation executed to assess which from *A – I* scenarios is the most optimal.

A. Computer simulations

First simulations executed are virtual simulations. To realize this kind of simulation, model from Arizona State University has been used. Menkes H. L. van den Briel, J. Rene Villalobos and Gary L. Hogg created interference model within [1] and then created reverse pyramid boarding pattern in the cooperation with America West Airlines within [2]. This group of researchers produced very accurate simulation tool which production composed of two phases. In the first one, where authors utilized their mathematical skills, analytical model was created. This model described passenger movement throughout the aisle to his assigned seat through mathematical equations. In the second phase, analytical model was filled with input data which was gained by monitoring real boarding process of America West Airlines. Values like passenger speed inside the aircraft, duration of each type of interference and duration of stowing hand baggage inside the overhead bins were gained and incorporated in the model. Thanks to this data collection from real operation, this model is considered to be accurate enough.

The created model works with Airbus A320 with 23 rows, one aisle and six seats per row, i.e. with capacity of 150 passengers. The model was built in simulation tool ProModel which collects following data: (1) total length of boarding, (2) number of seat interferences and (3) number of aisle interferences. As simulation tool ProModel is in its full version very expensive solution, for the purposes of this paper version ProModel Student has been used. This version does not allow changing graphical layout of model, but its functionality stays unchanged. For this reason the model was adjusted to correspond with ATR 42-500layout like it is shown on Fig. 12.

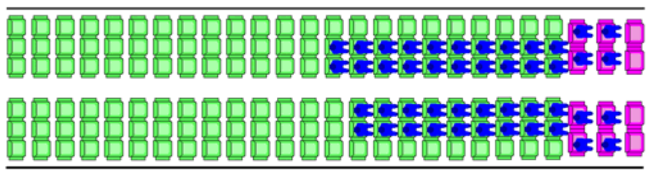

Figure 12. Simulation model layout adjusted for ATR 42

Hence, for the simulation was not used the full capacity of 150 passengers, but 46 only.

Each scenario (except for*Seat boarding*; because the software model does not support such a high number of boarding groups)was simulated 150 times, i.e. 1350 simulations were executed.

TABLE I. COMPUTER SIMULATIONS RESULTS

	Boarding length (min:sec)			Seat interferences			Aisle interferences		
	Average	*Maximum*	*Minimum*	*Average*	*Maximum*	*Minimum*	*Average*	*Maximum*	*Minimum*
Boarding without seating	7:41	10:33	5:33	11,2	17	6	14,3	22	8
Random boarding	7:46	10:59	6:08	11,4	17	5	15,1	23	7
Front to back zone boarding	7:55	11:10	5:52	11,8	19	5	14,5	22	9
Front to back row boarding	8:09	10:28	6:12	11,9	18	6	14,1	19	9
Rotating zone boarding	8:21	11:18	6:11	11,2	17	4	15,1	23	9
Outside-in boarding	7:20	10:17	5:18	2,2	4	0	13,6	22	4
Letter boarding	7:21	10:01	5:33	2,1	4	0	13,1	21	6
Reverse pyramid boarding	7:18	9:52	4:48	2,1	4	0	12,9	19	7
Block boarding	7:24	9:40	5:27	2,0	4	0	13,0	22	6

Results are shown in Table I. For each of nine simulated scenarios there is calculated average, minimum and maximum value for every date category (boarding length, seat and aisle interference).

At the very beginning of interpreting the results it must be noticed that time differences among average boarding lengths of all scenarios is very low. The time difference between the lowest and the fastest scenario is in average 63 seconds.

According to average boarding length all scenarios can be divided into three groups. First group consist of scenarios with the worst results. These patterns are modifications of front to back system (*front to back zone boarding*, *front to back row boarding* and *rotating zone boarding*). In the second group we can find scenarios with random seating – *boarding without seating* and *random boarding*. The only difference between these two methods is whether they do seating or not. Time difference between them was 5 seconds only. We can conclude that in the small aircraft segment there is no reason why to implement boarding without seating as a time saving is negligible. Finally, the third and the fastest group in terms of average boarding times consists of scenarios implementing outside-in features (outside-in, letter boarding, block boarding and reverse pyramid boarding). According the virtual simulations, the most optimal scenario is reverse pyramid pattern.

Now look at the maximum and minimum simulation times. The fastest boarding time is 4 minutes and 48 seconds which has been achieved with reverse pyramid method. On the other hand, the slowest time has achieved rotating zone pattern with value of more than 11 minutes. Time difference between this two values is six a half minutes, which is significant reflecting average boarding times.

B. Real simulations

The second type of simulations was simulations with real aircraft and real people. These simulations were executed at the Žilina airport in two days in March 2011 during the turnaround of ATR 42-500 of Czech Airlines on route Prague – Žilina – Prague.

Due to limited time of aircraft availability not every scenario was simulated. Four methods have been chosen. Two of them are currently used in real operation. Another two patterns achieve good results in a simulations and researches. First couple of scenarios is *random boarding* and *front to back zone boarding*. The other couple is *letter boarding* and *reverse pyramid boarding*.

Let us spend a few words about methodology. The measurement must be the same as in virtual simulation. That means that boarding starts when the first passenger enters into the aircraft and ends when the last passenger is seated.

As pseudo-passengers were used students of Air Transport Department from University of Žilina. Their role was to act as realistic as possible. Each was equipped with one piece of hand baggage and coat or jacket or any other outfit to stow into the overhead bins which caused the aisle interference. Every student and every piece of hand baggage came through the security check to declare required security level. Everyone got their own *boarding pass* where were clearly stated three basic facts: (1) number of simulation, (2) assigned seat and (3) boarding group. The passengers were not aware which scenario is currently simulated to avoid “right” behavior.

At the simulations participated 95 pseudo-passengers, 50 during the first day and 47 during the second one. Only two of them participated in both days. The aim of this step was to avoid getting “right” behavior. Each of four scenarios has been simulated three times, i.e. together twelve simulations have been realized.

Results can be seen in Table II.

TABLE II. REAL SIMULATIONS RESULTS (MIN:SEC)

Simulation No.	**Random boarding**	**Front to back boarding**	**Letter boarding**	**Reverse pyramid boarding**
1	4:55	4:51	4:25	4:50
2	4:40	4:20	4:45	4:15
3	4:45	4:22	4:35	4:10
Average	**4:46**	**4:31**	**4:35**	**4:25**

The real simulations result differs from virtual ones in term of quantity. In real conditions the boarding process was faster by approximately three minutes. The reason may be simple; the students do all the activities faster than average passenger. What is important is that both virtual and real simulation has determined the same scenario as an optimal. Also in this case has been the fastest way how to board 46 passengers into ATR 42 the *reverse pyramid* method. The order of other scenarios is different in compare with the order of computer simulations. *Letter boarding* has been beaten by *front to back zone* *boarding*which has achieved the worst results in virtual simulations among four scenarios simulated in real conditions. Widely used *random boarding* was the slowest one.

Closer look at Table II says that the differences among simulated scenarios are very low, a tens of seconds. Hence, the order of patterns is not important. What is important is how much time can be saved. That leads to the conclusionthat in the small turboprop aircraft segment it does not matter what type of scenario an airline uses.

V. CONCLUSION

Lots of possibilities exist in an effort to cut off the boarding time. Airline can choose any of various boarding scenarios to adjust enplaning procedure to its will. However, in spite of fact that there are systems which are more effective than those currently used, only a few airlines found courage to put them into practice. Let us discuss why it is so.

Airlines use scenarios that are passenger friendly. They use simple and intuitive scenarios from passenger point of view. Random boarding and back to front boarding definitely belong to this group. Also outside-in or a letter boarding can be considered as simple ones. But they are definitely not passenger friendly. Imagine family with two children traveling by air transport with seats assigned side by side. All passengers are ready to board. The first group is called and six years old boy is obliged to go with the strange group of other travelers. His parents and younger sister must wait for call of their boarding group.

This is solution that may discourage passengers from using services of particular airline. However, this issue can be solved relatively easily. Passengers travelling in group are called right after business passengers. In fact, this is what airlines do in practice.

In the segment of small turboprop aircraft with capacity up to 50 passengers it really does not matter what scenario an airline uses because saved time is negligible. Considering bigger aircraft, single aisle jet with capacity up to 200 passengers, there is space for saving of tens of minutes. This is significant reduction which can help to shorten turnaround time. The non-optimal scenario can extend the boarding time by more than half of time of the optimal one, e.g. optimal pattern takes 20 minutes meanwhile non-optimal one 30 minutes.

Right now, it is an airline turn. They all have chance to cut off their boarding time by implementing one of optimal scenarios.

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Safety of the Czech Republic Civil Aviation

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Abstract*— This article deals with the safety of the Civil Aviation in the Czech Republic. Safety is one of the more important attributes of air traffic. Air transport is one of the safest forms of travel. ÚZPLN – AAII (Air Accidents Investigation Institute) of the Czech Republic is an independent institution working with international standards. It aims at constant improvement of traffic safety in civil aviation. The overall number of occurrence reports from air carriers and from the Air Navigation Services of the Czech Republic shows a steady state condition on a long-term basis and corresponds to the distribution of air traffic and the traveling trends over the Czech Republic. An important indicator is reporting of occurrences that affected, or might have affected, flight safety. In recent years, reports of glare crew low-flying aircraft laser beam. These cases have been reported not only in the Czech Republic, but also at other international airports around the world. From 2009 there are realise the safety campaigns iniciated by Civil Aviation Authority of the Czech Republic.

Keywords- safety; accident; civil aviation; laser beam; safety campaigns***)***

I. Background

Safety is one of the more important attributes of air traffic. Air transport is one of the safest forms of travel. Nevertheless, it is essential to continuously improve that level of safety for the benefit of European citizens. The European Aviation Safety Agency (EASA) is the centre piece of the European Union's strategy for aviation safety. The Agency develops common safety and environmental rules at European level. Also, it monitors the implementation of standards through inspections of the Member States and provides the necessary technical expertise, training and research. The Agency works hand in hand with national authorities which continue to carry out many operational tasks, such as certification of individual aircraft or pilot licensing.

The Agency had access to accident and statistical information collected by the International Civil Aviation Organisation (ICAO). States are required, according to ICAO Annex 13 'Aircraft accident and incident investigation', to report to ICAO information on accidents and serious incidents to aircraft with a MTOM over 2 250 kg.

II. AAII of the Czech Republic

A. ÚZPLN

ÚZPLN (Ústav pro odborné zjišťování příčin leteckých nehod) – AAII (Air Accidents Investigation Institute) of the Czech Republic is an independent institution working with international standards. It aims at constant improvement of traffic safety in civil aviation.

B. Legislation

As based on requirements stipulated by the E.U. and competent international civil aviation organizations, the Government of the Czech Republic decided at its 6th meeting on February 11, 2002 on amending Act no. 49/1997 Coll., on aviation and on amendments to Act no. 455/1991 Coll., on entrepreneurship (The Trades Licensing Act) as amended. A part of the amendment included the establishment of an independent institution that would determine the causes of aircraft accidents and incidents in a professional manner, introduce precautions and thus significantly contribute to increase the safety in civil air aviation. The activities resulted in Act no. 258/2002 Coll., which amends Act no. 49/1997 Coll., on civil aviation and on changes and amendments to Act no. 455/1991 Coll., on entrepreneurship (The Trades Licensing Act) as amended, and which, among others, established the ÚZPLN (Ústav pro odborně technické zjišťování příčin leteckých nehod). The headquarters of the Institute is Prague.

The position of ÚZPLN was supported by the Decree of the Government of the Czech Republic no. 1006 of October 14, 2002, which approved its Articles of Association and appointed its Director. Article 6.3 of the Articles of Association obliges the AAII Director to present the Government through the mediation of the Minister of Transport with an annual report on its activities in the past calendar year. ÚZPLN commenced its activities on January 1, 2003.

The basis of AAII activities is the fulfillment of the 94/56/EC Council Directive and requirements of ICAO – International Civil Aviation Organization. These requirements are stipulated in Annex 13 to the Civil Aviation Convention. The main task of AAII is to compile and analyze information concerning air accidents, determine their causes and draw up conclusions and safety recommendations for their prevention.

Identify applicable sponsor/s here. *(sponsors)*

Professional ascertainments of causes and conclusions or recommendations must not assess or pass judgment with regard to guilt or liability.

III. Safety of the Czech Republic Civil Aviation

Much like in the previous years, there were no fatal accidents or accidents with injuries related to aircrafts with maximum take-off mass exceeding 5 700 kg in the Czech Republic in 2010.

In 2010, only two accidents occurred in the traffic of aircrafts with the maximum take-off mass exceeding 2 250 kg but under 5 700 kg, which did not result in injuries. This aircraft category also experiences a steady state condition on a long-term basis as regards low number of occurrences and their consequences.

In 2010, AAII received reports on 85 accidents related to aircraft with maximum take-off mass of 2 250 kg or less, used for aerial work, recreational and sport related flying including parachuting. A total of seven people were killed in accidents within the territory of the Czech Republic in 2010. As regards the year-on-year comparison, the drop in the number of fatalities is positive.

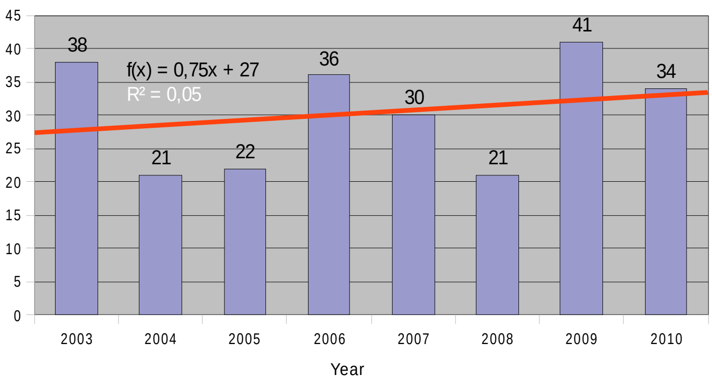
In 2010, AAII received reports on 85 accidents related to aircraft with maximum take-off mass of 2 250 kg or less, used for aerial work, recreational and sport related flying including parachuting. A total of seven people were killed in accidents within the territory of the Czech Republic in 2010. As regards the year-on-year comparison, the drop in the number of fatalities is positive. Within the above number, 34 accidents occurred to airplanes, helicopters and gliders. One accident was related to balloon flying.

On February 14, 2010, an airplane had an accident in the territory of the Federal Republic of Germany in which two persons of Czech nationality died.

TABLE I. Accidents of the aeroplanes to 5700kg MTOM of the Czech Republic

Accidents								
Year	***2003***	***2004***	***2005***	***2006***	***2007***	***2008***	***2009***	***2010***
No.	38	21	22	36	30	21	41	34

Figure 1. Accidents of the Aeroplanes to 5700kg MTOM in the Czech *Republic*



The number of reports of occurrences significant for the traffic shows a slightly increasing trend on a long-term basis. In 2010, AAII, in conformity with the adopted legal regulations on obligatory reporting of occurrences in civil aviation, collected and analyzed a total of 676 reports from aircraft operators or pilots, providers of air services and entities from other fields of aviation in the Czech Republic, and also reports received from abroad.

The overall number of occurrence reports from air carriers and from the Air Navigation Services of the Czech Republic shows a steady state condition on a long-term basis and corresponds to the distribution of air traffic and the traveling trends over the Czech Republic.

A positive feature is that the number of fatalities in accidents decreased.

TABLE II. Occurences of the civil aviation in the Czech Republic

Occurences								
Year	***2003***	***2004***	***2005***	***2006***	***2007***	***2008***	***2009***	***2010***
No.	540	557	634	683	623	763	686	764

Figure 2. Occurences of the Civil Aviation in the Czech *Republic*

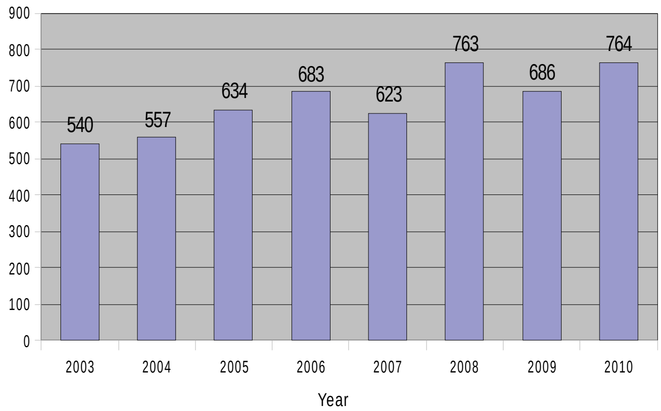
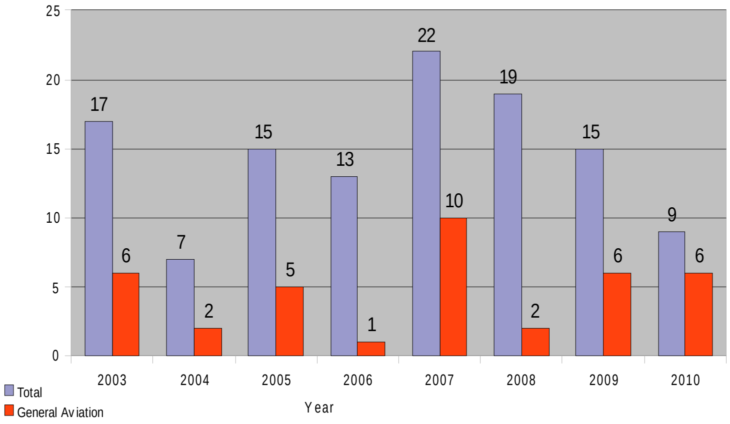


TABLE III. Fatalities of the civil aviation in the Czech Republic

Fatalities								
Year	***2003***	***2004***	***2005***	***2006***	***2007***	***2008***	***2009***	***2010***
Total	17	7	15	13	22	19	15	9
General Aviation	6	2	5	1	10	2	6	6

Within the framework of the European region, the year of 2009 was one of the safest years in air traffic in the past decade. However, this safety trend has not witnessed any improvement in recreational and sport related flying in the Czech Republic, in particular in sport flying devices regarding air accidents with fatal injuries.

Figure 3. Fatalities of the Civil Aviation in the Czech *Republic*



An important indicator is reporting of occurrences that affected, or might have affected, flight safety.

IV. Laser Beams

In recent years, reports of glare crew low-flying aircraft laser beam, especially in the stages approach to landing and takeoff, thus in the phase of maximum psychological strain crew. These cases have been reported not only in the Czech Republic, but also at other international airports around the world.

The operators from Czech Republic reported several cases of deliberate exposure of the cockpits laser beam from the ground from unknown sources, during 2009. These events are resolved by the Ministry of Transport, Ministry of Industry and Ministry of the Interior.

There was committed on the territory of Czech Republic 9 in 2009 and for 34 laser attacks on low-flying aircraft in 2010. 98% of attacks were committed at Prague International Airport, the remaining 2% to other international airports in the country.

During 2010, were recorded 65 reports of aircraft laser beam attacks. These are events in the Czech Republic and abroad, of domestic and foreign operators. On 9th December 2010 changed the law 49/1997 Coll. Where this issue has been adjusted, however, until 1st February 2011 came into force an amendment to the Act, which defines the actions and specifies the amount of punishment.[1]

In § 37 the amendment to the Law on Civil Aviation there are a newly-defined protection zones with the prohibition of laser devices. The use of laser radiation sources in these protected areas is possible according to § 40 only with the approval of the Civil Aviation Authority of the Czech Republic, which allows the device only if they are not impede air traffic or threaten its security.

In § 90, paragraph f) of the Act, is defined as the amount of penalty for breach of the protection zone for laser facility of up to 5 000 000 CZK.[6]

Most of these attacks takes place at night when the glare crew reaches the highest level. The eye in this case is adapted to darkness, and any sharp light source immediately cause glare, which can be as painful. Other associated effects are loss of orientation and coordination. The human eye can be excluded from activities within several minutes or hours depending on the length of exposure to the eye laser radiation and its intensity [1].

According to available statistics prepared by the Civil Aviation Authority of the Czech Republic, were in all cases so far registered in the Czech Republic to a dangerous glare laser beam of pilots without damage of their sight. Laser attack so far has not led to the emergence of a tragic event, but it can be assumed that with increasing number of attacks can cause such an event.

V. Safety Campaigns

It follows from the conclusions of the ÚZPLN commissions that the causes of fatal accidents resulted from human failure in the above-mentioned accidents. Technical causes played less important role.

In 2009-2010 was realised by Civil Aviation Authority of the Czech Republic the first safety campaign called „Přemýšlej doletíš“ ["Think twice…and you will land safely"] based on presentations and materials divided into three basic groups:

- phraseology
- human factor and its impact on flying
- meteorology, emergency procedures, flying techniques, airplanes, aerospace

Other safety campaign conducted in 2010-2011 under the title "Doletiš?" was based on a videos aimed at nine thematic areas:

- lack of discipline
- check list
- alcohol
- weather
- technical condition
- performances
- aerodrome
- training

The third and most recent safety campaign called “Doletíš” and designed for the years 2011-2012. Here is yet prepared video material under the name „Myslete na Ikara“("Think of Icarus") approaching basic principle of the coherence and philosophy of the civil aviation system.

The potential positive impact of safety campaigns can be expected to operate up to civil aviation in the coming years. One can only hope that these measures will reverse the negative trend in accidents in the last two years.

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Implementation of the Most Modern Knowledge about High Performance Canopies into the Present Regulations

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Abstract— **High performance canopies have nowadays absolutely different flight characteristics and technical parameters in comparison with oldschool profiles. The currently valid regulations used by FAI (Federal Aeronautical Institution), USPA (United States Parachute Association) and other authorities don´t solve the problem of proper educating and licensing of high perfomance canopy pilots. In the last couple of years many skydivers have died under a fully functional parachute. Main goal of my project is increasing safety at the airports and avoiding serious injuries or death. This paper presents results from testing one of the smallest and fastest skydiving parachutes Icarus Extreme FX 66 and the beginning of testing the new prototype Daedalus JVX 66.**

Keywords-component; Airport safety, Skydiving fatalities, Canopy piloting, High performance canopies

I. Introduction

High performance canopy piloting or so called swooping is one of the most dangerous disciplines in modern skydiving. The canopy pilot deployes parachute after exiting plane around 5000 ft, flyes to an initiation point over the swoop course, then turns into a rotating dive that dramatically increases the canopy's speed. The canopy pilot stops the canopy's rotation on the proper course heading, while at the correct altitude allowing canopy to recover from the dive and level out with maximum speed more than 150 km/h before entering the course.

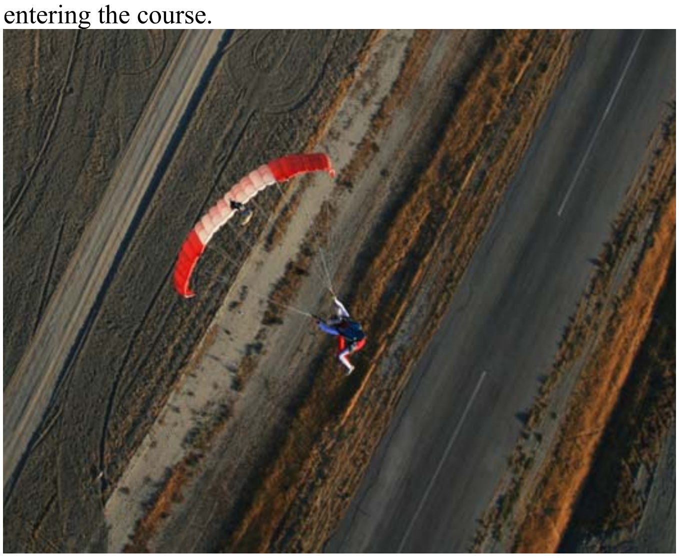

Figure 1. Speeding up turn over Perris Valley drozone, CA.

Many skydivers with a C license (200+ jumps), which allows them to choose a proper parachute to fly at their own discretion, have misjudged their skills and the flight characteristics of those high performance wings and this situation is happening again and again. Unfortunatelly the consequesnces of flying on higher speeds and loosing the control or going too low with the speeding up turn cause very serious injuries, sometimes even death.
Canopy piloting is known as an official skydiving discipline under FAI (The World Air Sports Federation) since 2003, when the first test World Cup took place at Perris Valley in California.
In Czech republic there is no proper education program for new canopy pilots and the system of licensing allows low level experience skydivers to choose their canopy without making sure they know, what is this all about. The situation would be comparable to pilots with Professional pilot license who would start practising flying aerobatics without any briefing or ground lessons.

II. Current Status

In the last couple of years many skydivers have died under a fully functional parachute, the reason wasn't a malfunction of the parachute or equipment failure, the majority of all fatal incidents was human factor, the most popular factor in the field of aviation sports. While flying at 100km/h and more you can easily do a mistake, when you don't know how to use all the controls you have and you initiate your turn slightly lower than usually, or experience some emergency downwind landing or have to do a presize maneuver to avoid the traffic. Main goal of my project is controlling the process of education of high performance canopy pilots and increasing safety at the airports and avoiding serious injuries or death.

III. Research design

First of all I dealed with the analysis of accidents. More than 80% of all the incidents were caused by human failure, less than 10% was equipment failure, mostly caused by a bad maintenance. That is something that can be changed by using the right flying techniques and regular inspection.
I have established a cooperation with one of the biggest parachute canopy manufacturers Icarus canopies and NZ Aerosports and I am trying to follow their great experience in this field. In the first part of my research in 2010 I was testing one of the smallest and fastest parachutes on the world, the Icarus Extreme FX 66. The name stands for Elliptical Xbraced Tri-cell, size of 66 ft^2. This wing was built specifically for radical maneuverability. It is for experienced pilots only.

Figure 2. FX 66 and JFX 79

In the beginning of 2011 I get a new prototype Daedalos JVX 66 and started testing the flight characteristics and differences between those two wings.
The Daedalos JVX is a 27-cell elliptical cross braced Tri-cell with upgrades like a new nose modification, improved trim, longer lines, no stabilizers and HMA lines are standard. The JVX is slim, sleek and fast with less drag. First off, the JVX has no stabilizers. Stabilizers on small high performance canopies don't due much except flap in the wind causing added parasite drag. The Daedalus Project first dealt with the issue of reducing drag on the wing tips by developing ram-air stabilizers. [1]


Figure 3. Daedalos JVX 66

During all the test flights I was wearing an electronic altimeter, recording the altitude of deployment, maximum vertical speed, and speed curve for all the.flight time. I was working on different flying techniques in order to increase the highest speed and learn how to control the wing properly.

IV. Results

During 2010 I did more than 600 test flight on a canopy Icarus Extreme FX66. The maximum vertical speed reached during the research was 143 km/h while flying the Icarus Extreme FX 66 at a wing loading of 1.9 lb. $ft^{-2.}$
Loss of altitude for a 270° speeding up turn was average of 190m.
In the 2011 I started testing the new prototype Daedalus JVX 66, till now I have done almost 100 test flights. I started dealing with a problem with my equipment, altimeters recording the speed flying on a parachute starts were getting confused during some test flights and calculated the flight of the parachute as freefall due to higher speed and so didn't measure the exact highest speed reached. My opinion is around 160km/h, that has to be confirmed during the next part of my testing. Loss of altitude for a 270° speeding up turn was average of 210m.
In August 2011 I was even testing the flight charecteristics flying at airports with higher elevation. The highest elevation I have tried was while talking taking part at the Mountain Gravity boogie at the airport Ambri in Switzerland with elevation 3000ft. Surprisingly, the flight characteritics didn't show very big differences compared to flying on dropzones with elevation at the sea level.
Next results should be available at the end of 2011 after more test flights on the Daedalus JVX 66 and adjusting the equipment for flying parachute on higher speeds.

V. Conclusion

This paper includes description and explanation of new profiles of high performance canopies and their characteristics, including prototypes, that have been made and flown especially for the Czech Technical University research in cooperation with one of the biggest parachute canopy manufacturers Icarus canopies and NZ Aerosports. Results from the research showed, that todays high performance wings can create super high speeds and manouveravability.

Figure 4. Final part of the swoop showing the high speed

Modernisation of training courses currently used in compliance with the regulations V-PARA 1,2 and proposal of new system of licensing is needed to ensure safety of performing canopy piloting in the Czech Republic and all over the world.

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Airport Collaborative Decision Making

Pre-departure Sequence Manager Tool

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Abstract

This paper is focused on the planning tool for airport traffic in the frame of collaborative decision making process. The planning tool design and its development that are described in this paper are concerning the departure traffic and it is mainly connected to the Prague Airport.

Keyword: collaborative decision making, pre-departure sequence manager, departure manager, arrival manager

I. INTRODUCTION

The airport collaborative decision making concept (A-CDM or CDM) is based on simple idea of information sharing. Today's airport key players already possess well developed sophisticated systems using modern technologies; however, they are not connected or compatible with each other. Thus, the need for their linkage is enormous. Since 2002, The European Organization for the Safety of Air Navigation (EUROCONTROL) is the main driver of this initiative and provides support (implementation manual, best practices, etc.) to the airports partners. The objective is to integrate the airports into the European ATM network that would lead to sharing the most of operational data.

On 25th August 2011, the Prague airport became the next A-CDM airport in Europe. The A-CDM procedures including pre-departure sequencing have been tuned for more than one year there and still there is a challenge of adverse weather conditions as deicing or thunderstorms.

II. A-CDM COMPONENTS

The core of the A-CDM process is presented by airport database where the operational data from all airport partners such as ground handling companies, air navigation services provider, airline operators and airport operator are collected. Therefore, every airport partner has complete picture about situational awareness even under adverse conditions.

The basic level of A-CDM that is information sharing may be enhanced by the component of pre-departure sequencing including start up and pushback for all flights. It means to use the information for better runway capacity planning, involving waiting times at the departure holding points before take-off, reduced apron and taxiway congestion and support the air traffic controllers' work. According to the agreed definition, the pre-departure sequence is the order that aircraft are planned to depart from their stands taking into account partners preferences. It should not be confused with the take off order where aircraft are organized at the holding point of a runway.

III. PRE-DEPARTURE SEQUENCE MANAGER

The whole process is based on a prediction of the off-block time. The prediction is made by ground handling staff and expresses the readiness of aircraft by manually inserting the value that is called the Target Off-Block Time (TOBT). This value is essential for the calculation of take-off time (TTOT); respectively time when aircraft can depart from their stands/parking positions and that is made through the provision of a Target Start-up Approval Time (TSAT) taking into account operational constraints. The table "Tab.1" summarizes considerable constraints for regular departure manager (DMAN) where those used for pre-departure sequence manager are marked.

TABLE 1 Operational Constraint

Type of constraint	Used in pre-departure sequence tool
Type of stand (nose-in /open)	YES
Taxi time	YES
Runway buffer	-
Line-up time	-
De-icing procedures	YES
EOBT	YES
Slot regulation (CTOT)	YES
Wake vortex category	YES*)
SID	-
SID separation	-
Runway in use	YES
Runway capacity	-
Runway occupancy time	-
Airport closure (runway inspection)	YES
Entry points to the runway	YES
Minimum departure interval	YES
Visibility condition	-
Landing strategy	-

*) Wake vortex category is considered only for push back times dataset, not for the aircraft separation.

IV. MIXED MODE TRAFFIC

The capacity gain from automated order optimization was estimated to be about 10% for a departures-only runway and about 5% for a runway with 50% arrivals [3]. To achieve optimal runway use for mixed mode operations, effective co-ordination with arrival manager (AMAN) must take place to support an equitable distribution of delay between arriving and departing traffic.

In case any AMAN has not been implemented, the minimum departure interval may cope with the mixed operations partially in the way of setting the interval at:

- Lower value for departure-only peak hour
- Higher value for runway mixed mode operations.

However, the experience from Prague airport where the minimum departure interval is the only enabler how to cope with mixed mode operations appears that the prediction of arriving traffic with no support of automatic tool is not sufficient and time consuming method. The example of mixed mode operations of 18 August 2011 where departure peak period within 1200 – 1300 is complemented by arriving traffic is displayed in Fig. 1.

The recommendation found in [2] states that even if only in embryo, there is a need for an “arrivals” module in the DMAN planning, like installed in the EUROCONTROL/DLR DMAN. The simple arrival module that shall be based on the quantity and density of arriving traffic is under development for Prague airport as well. It is supposed to have several testing sessions that will provide the data for further analysis.

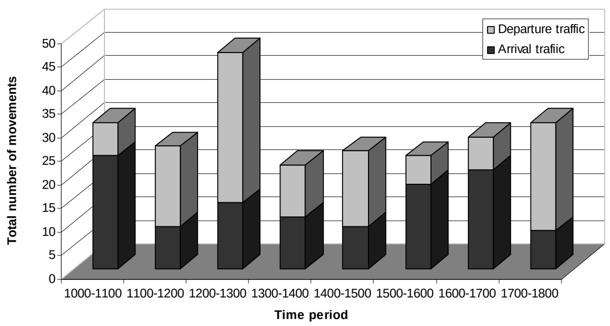

FIGURE 1 Mixed mode operations at Prague Airport

V. TRAFFIC ANALYSIS

Several operational characteristics were defined to monitor and analyze the effectiveness of the whole A-CDM process. Among the quantitative characteristics, the taxi time’s reduction is considered as the most desired one. The initial data from Prague airport point to the average reduction of half minute per one departure. In addition, there are some specific quantitative characteristics that may be measured for the evaluation of pre-departure sequence such as:

- Magnitude of changes in sequence order
- Magnitude of TSAT change
- TOBT and TSAT variance for one flight
- TOBT and TSAT average variance for the sequence
- Total sequence duration.

As the pre-departure sequence calculation is based on the variable taxi times defined by statistical estimation, the qualitative characteristics are assessed, too. The quality of taxi times used in dataset is essential (1).

$$|\,(ATOT - ASAT) - (TTOT - TSAT)\,| \quad (1)$$

ATOT stands for the actual take off time (the time when take off action is input in the system by the air traffic controller) and ASAT for the actual start-up time (the time when the clearance delivery dispatcher issues the clearance).

All characteristics regarding the pre-departure sequence may discover the effect of optimization function on the sequence stability.

VI. CONCLUSION

Concerning the Prague airport, the first step in the A-CDM implementation was done, however, the further enhancements and possibly future developments involving the adverse weather conditions are needed. It comprises the inclusion of the deicing procedures into the calculation of pre-departure sequence tool and its tuning where the sequence stability appears as the main demand.

In order to get more accurate input operational data, possible linkage to other systems such as the surveillance system, arrival/departure managers or electronic flight strips for tower operations may be the subject of the future enhancements of the A-CDM. According to the decision of the A-CDM/DMAN/A-SMGCS Links Expert Panel that was founded under the Airport CDM Procedures Group, the further work will continue under SESAR development phase because at the most airports the A-SMGCS (Advanced Surface Movement Guidance and Control System) and DMAN is still under implementation.

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Aerodynamic Analysis of Propeller with Variable-Twist Blades

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Abstract— **This paper presents the aerodynamic analysis of propeller with variable-twist blades, i.e. propeller whose blades can be twisted so that the propeller works each time with optimal circulation distribution along the blade. Method for computing propeller performance and optimal blade twist is described. Efficiency of variable-twist and standard constant-speed propeller with the same blade chord distribution is compared for typical propeller for sport aircraft. Possibility of increasing of efficiency by using variable-twist propeller is analyzed.**

Keywords-propeller aerodynamics, blade element theory, smart structures, active structures, variable-twist blades

I. NOMENCLATURE

c_T	thrust coefficient
c_P	power coefficient
D	propeller diameter
n_s	propeller revolutions per second
P	power
r	radial coordinate
R	propeller radius
T	thrust
U	radial component of velocity
V	axial component of velocity
Γ	circulation
η	efficiency
λ	advance ratio
μ	drag-to-lift ratio
Ω	angular velocity

II. INTRODUCTION

The state of art of the development of smart and morphing structures makes possible design rotors with variable-twist blades. Research is focused mainly on variable-twist rotor blades helicopters. They provide increase of helicopter performance and reduction of noise and vibrations. Twist is controlled ether by piezoelectric actuators in the blade structure or by active trailing-edge flap. Using of variable-twist propeller blades can bring improvement of propeller efficiency. However variable twist itself brings also many problems with design and structure analysis. So contribution of variable-twist to propeller performance should be analyzed before the structural problems are solved. This work compares efficiency of variable-twist propeller and variable-pitch (also called constant-speed propeller).

III. DEFINITION OF DIMENSIONLESS QUANTITIES

All computations were performed using dimensionless quantities. Dimensionless dimensions are defined by using propeller radius R.

$$\bar{r} = r / R \tag{1}$$

Dimensionless velocities are defined by using propeller blade tip radial velocity $R\Omega$.

$$\bar{U} = U / (R\Omega) \tag{2}$$

$$\bar{V} = V / (R\Omega) \tag{3}$$

Dimensionless circulation is defined by Eq. (4).

$$\bar{\Gamma} = \Gamma / (4\pi R^2 \Omega) \tag{4}$$

Propeller thrust and power consumption are defined by thrust and power coefficients c_T and c_P.

$$c_T = T / (\rho n_s^{\,2} D^4) \tag{5}$$

$$c_P = P / (\rho n_s^{\,3} D^5) \tag{6}$$

Propeller advance ratio is defined by Eq. (7).

$$\lambda = V / (n_s D) \tag{7}$$

Propeller efficiency can be expressed by Eq. (8).

$$\eta = \lambda c_T / c_P \tag{8}$$

Thrust and power coefficients can be expressed by Eq. 9 and 10 (Eq. (1.13) and (1.14) in Ref. 7).

$$c_T = \pi^3 \int_0^1 \bar{\Gamma}\left(\bar{U}_1 - \mu \bar{V}_1\right) d\bar{r} \tag{9}$$

$$c_P = \pi^4 \int_0^1 \bar{\Gamma}\left(\bar{V}_1 + \mu \bar{U}_1\right) \bar{r}\, d\bar{r} \tag{10}$$

IV. Methodology Description

Similar methods are used for aerodynamic analysis of constant-speed and variable-twist propeller. Both of them consist of two steps. Aerodynamic design of propeller is done in the first step. Both propellers have the same design point:

power coefficient $c_P = 0.05$

advance ratio $\lambda = 1$

number of blades $N = 3$

These are approximate conditions for the propeller of sports plane during cruise. Airfoils from NACA16-series were used on propeller. Mathematical model of airfoil aerodynamic characteristics was taken from Ref. 8. This model was also used for aerodynamic analysis of the propeller. Procedure for propeller design layout used in this step is described in chapter VI.

Aerodynamic analysis is performed during the second step. It consists of numeric iterative procedure for computing blade pitch (for constant-speed propeller) and blade twist (for variable-twist propeller). The same code was used for computing of performance (i.e. propeller efficiency) in both cases, so that the results are comparable. The analysis was performed for values of power coefficient corresponding to 25%, 50%, 75%, 100%, 125%, and 150% of nominal engine power (i.e. $c_p = 0.0125$, 0.025, 0.0375, 0.05, 0.0625 and 0.075) and for advance ratio in the range from 0.5 to 3.0.

A. Constant-Speed Propeller

Blades of constant-speed propeller can change their pitch in respect to propeller hub. Their twist can't be changed. Iterative procedure for computation of pitch of propeller blades for given conditions (i.e. advance ratio and power coefficient) during computation of propeller performance was developed.

B. Variable-Twist Propeller

Blades of variable-twist propeller can change both their pitch and twist. Optimal circulation distribution can be obtained for any condition (i.e. advance ratio and power coefficient). Iterative procedure was used for computation of optimal circulation. Optimal twist of propeller blades was computed from the optimal circulation distribution according to Goldstein (see [10], [11] and [12]).

V. Computation of Propeller Performance

Helicoidal vortex model was used for computation of propeller performance. Each propeller blade was divided into 20 sections and induced velocity was numerically computed for each section. Thrust and power coefficients were obtained by numerical integration of equations (9) and (10). Efficiency was evaluated by using equation. (8).

Ref. 8 was used for verification of this method. In comparison with the results in Ref. 8, power and thrust coefficients are in good agreement with experimental results. Efficiency is higher that the measured one due to combination of errors from both thrust and power coefficients.

VI. Propeller Design Layout

Betz condition[9] and Goldstein's optimal circulation distribution[10] was used for design layout of the propeller. Circulation distribution was computed numerically by the method described in Ref. 11, which gives identical results as Goldstein's method (comparison can be seen in fig. 1). Blade twist and chord were then computed from circulation distribution and from the design lift and drag coefficients.

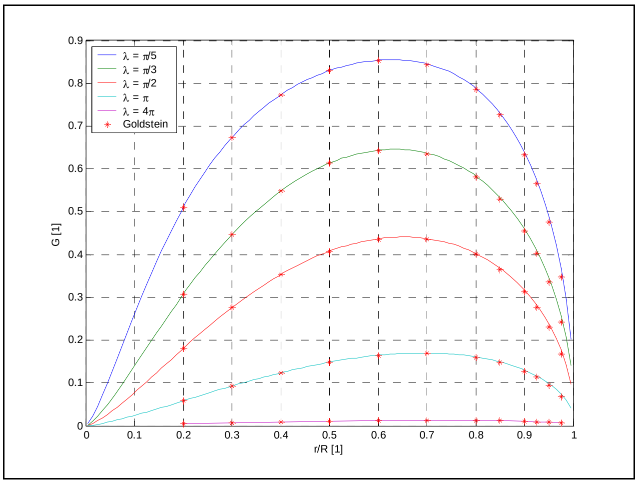

Figure 1. Comparison of Goldstein factor G computed numerically by using blade theory (solid lines) and tabulated values according to [12].

VII. Computation of Optimal Twist of Propeller Blades

Method for computation of optimal twist of propeller blades is based on modified method for propeller design layout. So that at each flight condition the propeller works with optimal lift distribution and maximum possible efficiency. In this case, optimal circulation is computed for given advance ratio and power coefficient. Lift coefficient is computed from circulation and chord at each blade section. This procedure has to be repeated several times due to the dependence of power coefficient c_P on drag-to-lift ratio μ (see Eq. (10)). Then angle of attack and consequently optimal blade twist are computed.

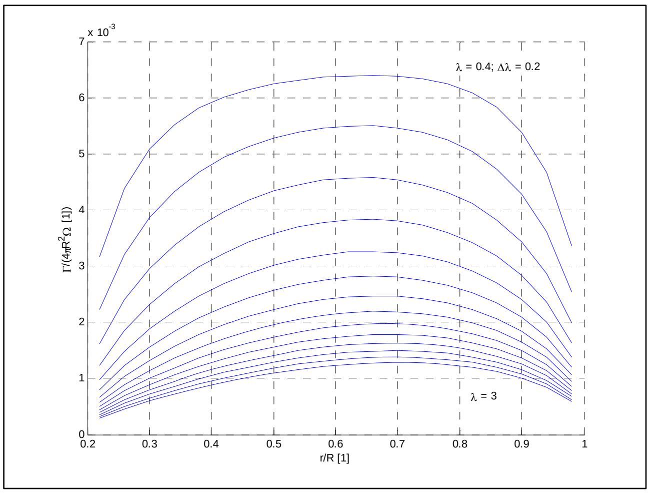

Figure 2. Computed optimal circulaton distribution on the propeller for various advance ratios λ.

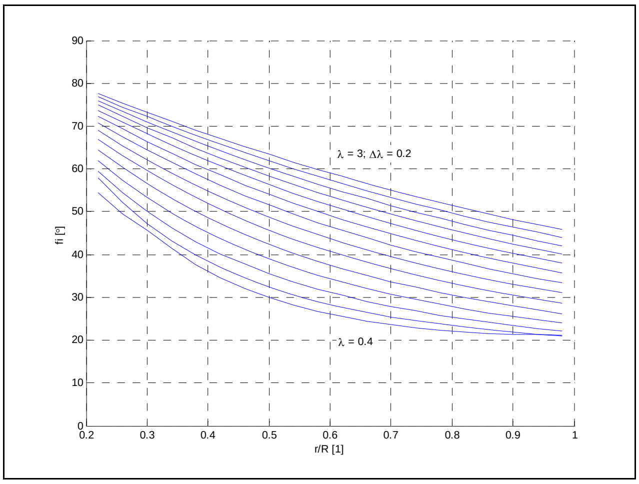

Figure 3. Computed optimal twist of propeller blades for various advance ratios.

VIII. Results

Dependence of propeller efficiency on power consumption expressed with respect to design power coefficient is shown in Figs. 1 and 2. It can be seen that efficiency at higher advance ratios drops faster for constant-speed propeller that for variable-pitch propeller. Efficiencies of constant-speed and variable pitch propeller working at 25%, 100%, and 150% of design power coefficient are compared in Figs. 6 to 8.

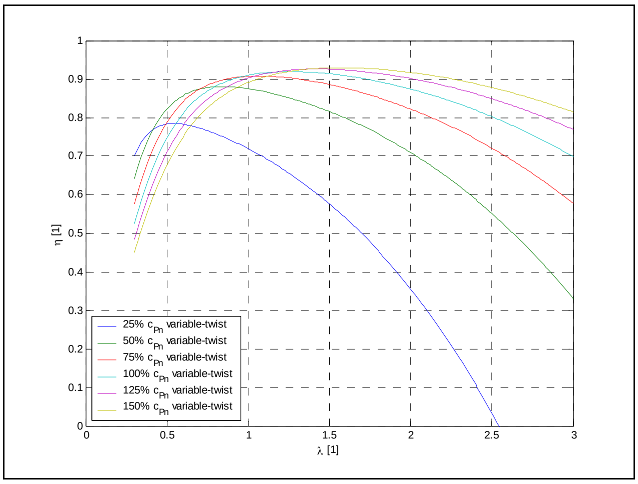

Figure 4. Computed efficiency of variable-twist propeller for various values of power coefficient c_P with respect to propeller design power coefficient c_{Pn}.

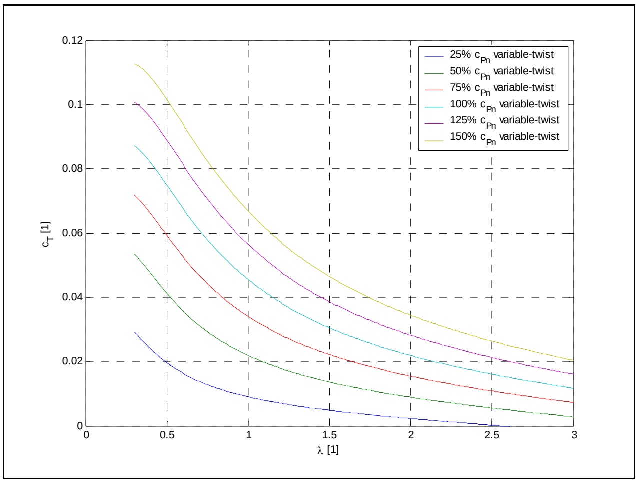

Figure 5. Computed thrust coefficient of variable-twist propeller for various values of power coefficient c_P with respect to propeller design power coefficient c_{Pn}.

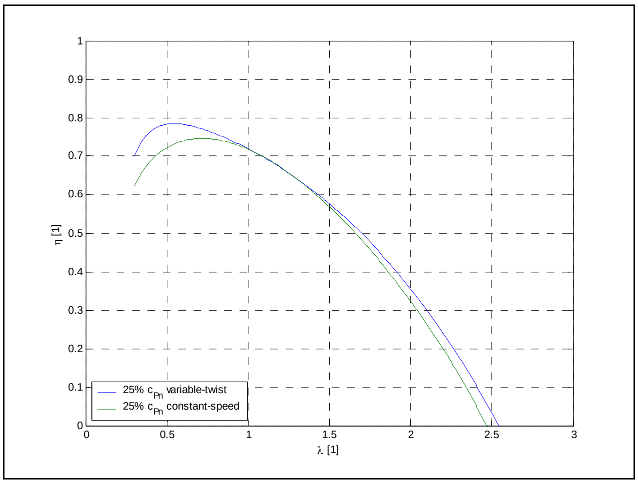

Figure 6. Comparison of the efficiency of constant-speed and variable-twist propeller for 25% of design power coeffficient.

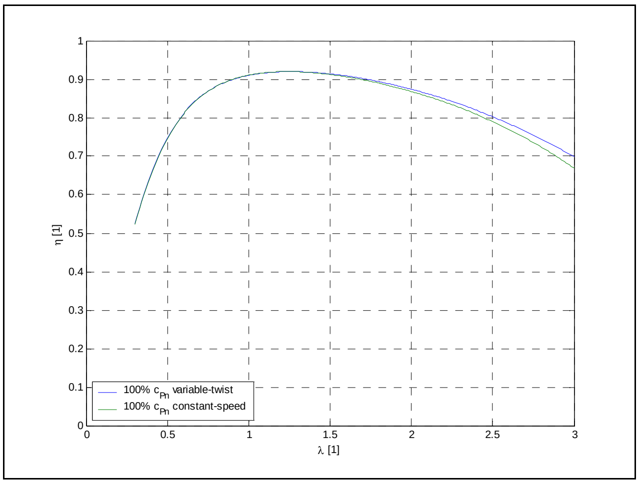

Figure 7. Comparison of the efficiency of constant-speed and variable-twist propeller for power coefficient equal to design power coeffficient.

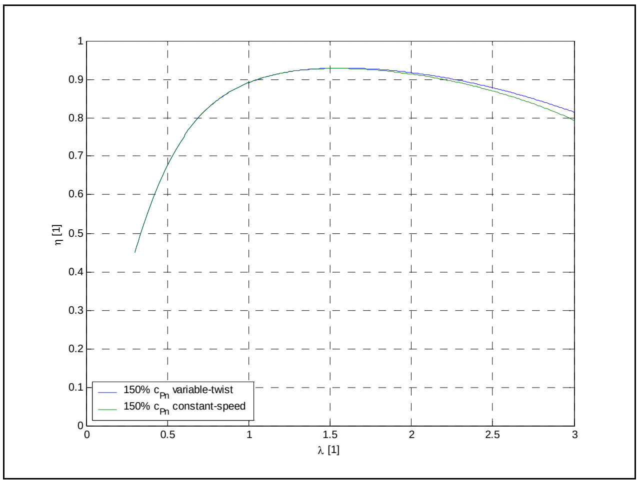

Figure 8. Comparison of the efficiency of constant-speed and variable-twist propeller for 150% of design power coeffficient.

IX. CONCLUSION

Aerodynamic analysis of both constant-speed and variable-twist propeller was performed. Numerical code in Matlab was developed for both cases. It was shown that variable-twist propeller does not bring increase of efficiency round the design point of the propeller, but considerable increase of efficiency can be obtained at higher speeds and low power loadings. Propeller with variable-pitch blades can be used in wider range of operating conditions compared with constant-speed propeller.

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Modification ABL B737-800

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The article discusses the issue of the exchange of the steel brakes for the carbon brakes. It tries to capture all relevant aspects that should be taken in consideration while evaluating the advantages of the modification. The modification is logically divided into four main parts - Maintenance practises, Enviromental benefits, Fuel burn cost savings, Steel / Carbon comparison.

Key words : Carbon brakes, Steel brakes, Modification ALS, Brakes, B737, B737/800, Fuel saveing, Maintenance practises, Aircraft landing system, Cost per brake landing, Goodrich, Messier Bugatti, Honeywell, Economical rate of investment, Landings per overhull

Modification ALS B737-800

It was the autumn of 2010 when the company Travel Service a.s. asked ULD FD CVUT for a favor to elaborate a project that would solve the problem of modification ALS (Aircraft Landing System) for the airplane B737- 800. The considered alternation was based on the change of steel brakes made by Honeywell for the carbon ones. The actual offers were proposed to Travel Service a.s. by the companies Goodrich and Messier – Bugatti. The reason that evoked considering the change of the brake system was primarily better physical characteristics of carbon brakes compared to the steel ones. In the first place it was all about higher heat rate which can be reduced by carbon brakes much better than by steel ones and as a result the weight of the vehicle is reduced.

This can bring a lot of benefits that will be described later in the chapters. The main advantage of using steel brakes over the carbon brakes was the existing knowledge about this type of brakes and experience in the cost of repair. In the case of transition to the carbon brakes it would be necessary to allow for initial investment which would be expensive. Travel Service a.s. did not want to use its own employees to conduct the survey of expediency of individual offers. Therefore the company request ULD FD CVUT for working out this project. On the other hand Travel Service a.s. offered a help with gaining the essential information either from the brake manufacturers or their own statistics.

The expediency of this modification was to be reviewed in 4 main areas. These include the economic return of this replacement, the operating aspects – fuel costs and the evaluation of difficulty of service, and definitely the impact on the environment.

To estimate the final economic return, we had to individually calculate all the aspects that affect the total financial balance of this modification.

The Initial Investments

As it has been mentioned earlier in the text, the biggest disadvantages of transition to the carbon brakes are the initial investments that are inevitable to accomplish and that are expensive. The initial costs include the purchase of brakes and wheels. These will need to be changed as well because the design of steel and carbon brakes is not the same.

The other costs that are included are the costs for pre-supplying. The both companies who offered the supply were familiar with these costs, hence they propose so called "initial program". The main idea of this program is that it shows a certain amount of airplanes equipped with new brakes and wheels, so that the initial costs can be reduced as much as possible.

The proposals of these companies vary in the numbers of airplanes for which the initial program might be used and the equipment for which it would refer to.

Operating Aspects

In the case of transition of the airplanes of Travel Service a.s. to carbon brakes it would lead to a relevant saving of weight and as a consequence a perceptible fuel saving, too.

Indeed the amount of savings would be in a sequence of years laden by extensive, hardly identifiable uncertainty as far as fuel is concerned. Definitely the weight of individual components of the brake system has to be guaranteed by the producer. Otherwise the fuel savings would decrease, which would be undesirable.

Other factors that are variable and that affect the amount of savings are LPY – the average number of landings per year and an average flight length. These factors are different in every company. They are affected by the sequence of the flights that the individual airline operator is focusing on or whether the operator targets more for charter flights, scheduled air move and so on. All the factors share the final savings formation.

Although the main advantage of saving the weight is in fuel saving, there are other operating benefits which this modification might return. This can include a better variability in flight planning, such as a plane staying a few more minutes in the air due to a lighter construction (we can carry more fuel per flight). Therefore, the flight can be more optimized by choosing a different alternative airport. Another possibility might be the fact that during the departure the plane is limited by its MTOW (Maximum Take off Weight) and not by a tank volume. Then the saved weight makes it possible to increase flying range at the maximum payload.

In the case the distance of a flight is not variable, the benefit to the consumer is that more weight can be carried by the plane, such as extra baggage, or extra fuel may be carried if the price is cheaper at the place of departure than in the place of arrival.

MAINTENANCE

The costs for service depend on a few aspects. The most important aspect is the price of individual components. For carbon brakes the price is much higher than for steel ones. A huge financial problem as far as brake service is considered represents the exchange of heat sink (it is a part of a brake where the mechanical energy is converted to heat energy) and heat stack (a heat sink equivalent).

Within the service the steel brakes have a designing advantage. The heat sink at carbon brakes is changed as a unit, at steel brakes is heat stack constructed modularly (it is composed of individual brake segments), which allows an exchange of worn out components only. Hence we used for our calculations so called overhaul heat stack. Basically this overhaul represented regular overhaul of a steel brake. The proportion of components exchange in overhaul was estimated pursuant to the bills of Travel Service that were made out for brake overhaul and statistical details by Honeywell. This fact makes the rapid decrease of costs of service to the steel brakes possible.

The producers of carbon brakes try to compensate for this disadvantage by a system of discounts applied for change of the heat sink. This system is realized by CPAL (Cost per Aircraft Landing) or CPBL (Cost per Brake Landing) program. CPAL and CPBL program consists in payments of a certain amount for individual landings. After the total brake wear the heat sink is exchanged for free. That technically means that the longer lifetime the heat sink will have, the more expensive his exchange will be.

The next aspect affecting the service costs was lifetime of components. Operating life of a brake is based on an operating life of a heat sink (heat stack). Other components are exchanged depending on the actual wearing condition also called "on condition" except for a few pieces of gaskets which have a permanent operating life. We had the real data about operating life of individual components only for steel brakes.

Hence we started from the statistics from a couple of last years of the company Travel Service and from the statistics supplied by Honeywell. On the strength of these statistics we were able to accurately define the operating life of individual parts of steel brakes.

An unknown variable for us was the operating life for carbon brakes. The operating life guaranteed by manufacturers was a lot higher than a declared one but it was twice as long as the steel brakes have. At first glance this might appear as a large advantage within the service. Eventually it only increases the costs for one heat sink. Goodrich and Messier – Bugatti supplied the information about the average operation life of the brakes. These details were made by practitioners who live or fly to more southerly areas than Travel Service a.s. flies to, so it was not necessary to use defrosting systems that are highly hazardous for carbon brakes and can badly damage them. It is not possible to estimate the operating life more correctly without the accurate statistics from other practitioners from middle and east Europe. Therefore we worked on our calculations with the minimal guaranteed values.

THE IMPACT ON ENVIRONMENT

We can sum up the ecological impact of modification ALS into two main points. The first one is calculating the fuel savings and thereby emissions that would originate by its combustion. Also, from these sample assumptions it was possible to derive the final amount of "saved" emissions. Another step was a recycling of the used heat sinks. A practitioner sells individual components with expired operation life to a vendor. There is an exception, the responsibility for storage and liquidation is up to a practitioner in case that heat sink is damaged by a corrosion or a by mechanical destruction.

Other minor problem is brake dust that might have an impact on our health and technical state of the components. The carbon brakes produce smaller amount of the dust and its color is not so visible.

SUMMARY

The project of modification ALS B737/800 is a very complex problem. Therefore it requires a special approach. A corporation interested in its realization must consider every single indicated aspect so that the required savings can be achieved. The accurate calculation of economic return really depends on choosing the input variables (LPY, LPO, etc.). Because we are talking about a statistic data it is up to an airline if it does or does not have access to data with required accuracy.

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The Comparison of Modern Equipment for Environmental Flight Laboratory

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Abstract—**This article describes chosen devices for environmental flight laboratory which will measure water vapor volume in the atmosphere during flight. It deals with their detail technical parameters and it also provides readers with their comparison for mentioned flight lab. In addition to this comparison there is also briefly description how these gas analyzers work. The purpose of measuring water vapor volume is monitoring of this compound as a greenhouse gas whose abundance causes climate change. There is no doubt that flight measuring represents more flexible, efficient and precise data gathering than for example meteorological balloons or other methods.**

Keywords-environmental flight laboratory; water vapour; sensors; devices; measuring; differential absorbtion; real-time data

I. INTRODUCTION

The progress of civilization has brought many positive impacts on the quality of our lives. On the other hand it produces constantly bigger and bigger constraints on the environment. Especially the pollution of atmosphere has been reaching the limits which lead to climate change. The Department of Air Transport at the University of Zilina within the frame of the Centre of Excellence for air transport is currently conducting a project regarding flight laboratory equipment capable for measuring water vapour content of atmosphere during flight. Water vapour is also a product of combustion in the aircraft power plants and represents one of the most significant active trace gases which cause greenhouse effects.

The one of main tasks is survey of current gas analysers which are available on the market and then to find the most appropriate one which meets given requirements for flight measuring of water vapour volume. This basic topic is analysed in the following sections.

II. THE REVIEW OF WATER VAPOUR ANALYSERS

The newest analyzers use DIAL technology (differential absorption LIDAR (light detection and ranging)) for gathering of composition of certain gas. The technique of measurement relies on the unique "fingerprint" absorption spectrum of each molecule. An absorption measurement is made with laser light, at a peak of absorption (lambda-on) and at a trough (lambda-off), giving a differential signal. The differential nature of the signal simplifies the measurement process.

A pulsed laser beam is sent out into the atmosphere (figure 1) and small proportions of the light are backscattered by particles along the beam path to a sensitive detector (right side of figure 2). In this sense dust particles and aerosols are being used as reflectors, albeit rather weak ones. The laser light is in short pulses and time resolution of the backscattered light (along with the speed of light) gives range resolution as in a simple LIDAR. For concentration measurement the DIAL system relies on a differential return from two closely spaced wavelengths, only one of which is absorbed strongly by the target gas. The size of the differential return signal at different distances along the laser beam path indicates concentration [1].

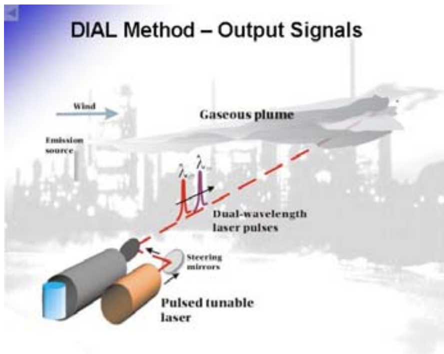

Figure 1. Principle of DIAL technology [1]

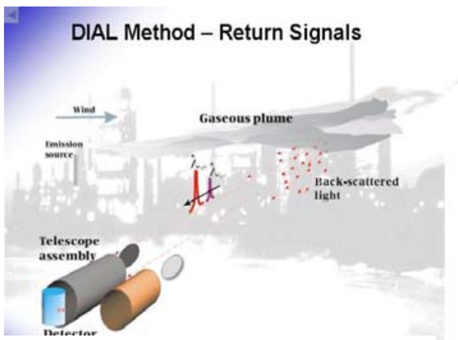

Figure 2. Principle of DIAL technology [1]

A. WVSS-II

There are many products and solutions regarding measurement of air quality on the world market. However most of them are designed for utilisation in ground conditions such as measurement of air quality in industrial centres. The American company Spectrasensors developed a device capable of gathering information related to the volume of water vapour in all altitudes up to FL 400. This product (shown in figure 3) called WVSS-II (water vapour sensing system) is also based on DIAL technology. Comprehensive system of water vapour monitoring in atmosphere has been used in the USA for two years. It based on cooperation between agencies, airline companies and transmission systems too. The transmission systems are responsible for data gathering from onboard sensors located in airliners.

The process begins by measuring of water vapour volume which WVSS-II ensures. This measured data including pressure and temperature values are sent via ACARS (Aircraft Communications Addressing and Reporting System) to ground stations of ARINC (Aeronautical Radio, Inc.). They next continue to Gathering centre where other data from meteorological balloons and satellites are also processed. According to this obtained information the American national weather service (NWS) makes out more frequently updated weather forecasts. NWS provides this hot information about weather situation with relevant air traffic centres.

Figure 3. Principle of DIAL technology [2]

1) Why is WVSS-II so effective

Accurate weather forecasting needs measurements of water vapour, wind, temperature and pressure at all levels of the atmosphere. Weather satellites provide broad coverage of atmospheric information for regional and international forecasting. But their data, whether derived from infrared or visual imaging, cannot reveal the detailed changes in water vapour in the vertical dimension. Traditional radiosonde weather balloons provide a vertical profile of observed data. But they are limited by the low number of locations that launch balloons at the required twelve hour intervals, and by the recurring cost of operations. By contrast a fleet of aircraft equipped with the Water Vapour Sensor System (WVSS-II) can provide thousands of times the number of vertical profiles accurately, automatically, and at a fraction of the operational cost.

Continuous, real time information captured and communicated by 2500 aircraft ascending to high altitudes and descending to their destinations can more reliably update weather observations and dramatically increase severe weather prediction capabilities. Data collected and transmitted by crisscrossing aircraft at various altitudes provide a more efficient tool for collecting the observations necessary for accurate weather modelling. Climate models also benefit by answering more questions about the role of water vapour in Climate Change research and Climate Services [2].

There are two possible variants of WVSS-II utilisation in our project. The first one would use gathered data directly onboard of aircraft. A measured data would be depicted by means of RS-232 output directly on operator's display. The second one would be able to send measured data by means of VHDL (very high frequency data link) to ground stations for meteorological purposes. The significant advantage of this device is that it has certification for exploitation in many airliners and in the aircraft of general aviation.

B. AQM Sentry FTIR

AQM Sentry FTIR is product of American company CEREXMS which is a leader in real time multi-gas detection systems. Although it is primarily designed for ground exploitation and has no certification for flight laboratory, this device is in compliance with most requirements related to utilisation in the flight laboratory. This system is based on product called Open-Path AirSentry FTIR which is the most reliable for monitoring industrial facilities, accidental releases, and hazardous waste site emissions. The analyser is provided with a library of nearly 400 compounds such as H_2O, NO_x, CO, CO_2 and others.

It could be noted this system is not usable for flight observations because it is static and requires a retro-reflector for air quality measurement of open space. On the other hand AQM Sentry FTIR (shown in figure 4) is coupled with a multi-pass cell (shown in figure 5) and therefore it is suitable for fixed installation and installation on board aircraft or a mobile van.

Figure 4. AQM Sentry FTIR [3]

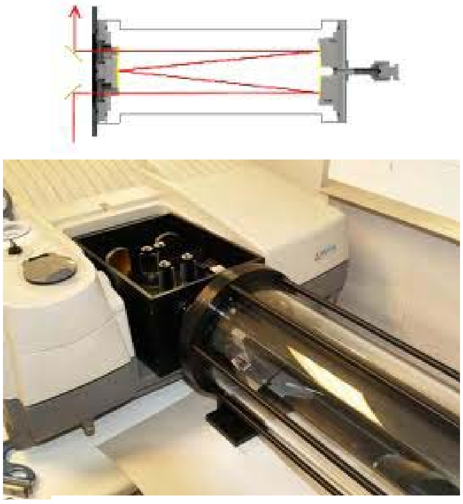

Figure 5. Multi-pass cell [3]

The mentioned device could be used on board of aircraft in the following way; the central box with the multi-pass cell will be located in the space for baggage or in the interior. However one of the problems is how to lead air from the outside to the multi-pass cell. Cerexms does not offer necessary accessories therefore utilisation of Spectrasensor`s air sampler with hoses (shown in figure 3) offers a good solution.

During flight the air will flow continuously from the air sampler mounted on the fuselage through hoses to the multi-pass cell where the air composition will be measured by means of a laser beam. The data required will be continuously depicted in real time on the monitor by the operator. Although this device allows measure various compounds precisely and in real time, the main problem is its certification, dimensions and input voltage 240 V AC.

C. Licor 7500

This device (figure 6) of American company LICOR allows precise and fast in-situ measurements of H_2O and also CO_2. The technology is based on the same principle as in case of WVSS-II or AQM Sentry FTIR. Sensor Licor7500 consists of open measuring part and optical framework. This optical framework allows passing only in one way. Detector measures the absorption of infrared radiation in 4,26 ηm and 2,59 ηm wave lengths which are typical for H_2O and CO_2. The measuring part is creating of zephyr glasses in both sides. This cover is extremely resistant against scratching and bursting. Data outputs is carried out by simple interface which is compatible with Windows system.

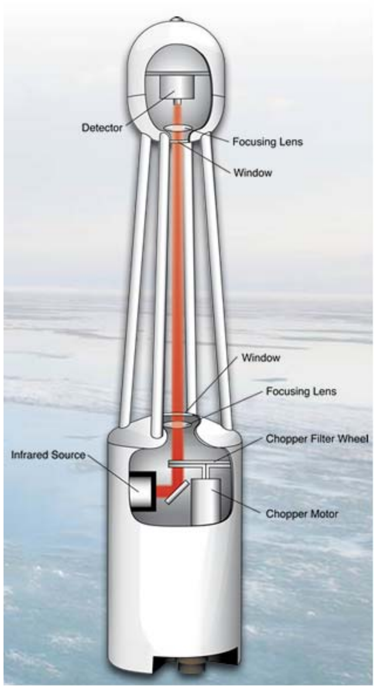

Figure 6. Licor 7500 sensor [4]

D. Particle Volume Monitor – PVM- 100A

The next chosen device for water vapour volume measuring is also American product of Gerber Scientific Company. In addition to H_2O measuring it is also able to measure size of droplets in a cloud. For the purpose of anti-icing the whole device is heated. The next reason is avoiding a condensation on the lens. PVM-100A enables high frequency of measurement up to 5000 Hz which allows gathering data in turbulent streams. By contrast the sensitivity of device is decreasing when bigger droplets are measured. This equipment is also based on DIAL technology. The main difference between PVM-100A and for example WVSS-II is in the place of measurement conducting. The eye of device (figure 7) is located outside, it means that laser beam is scattered external in contrast to WVSS-II where the measured air is led through the hoses to the central box where by means of laser beam the detection is carried out.

Figure 7. PVM-100A [5]

E. King Probe

The last device is product of PMS, Inc which is situated in the USA. King Probe uses different method for water vapour volume measurement. It operates under the principle that liquid water can be calculated from measurements of the amount of heat released when vaporised. A heated cylinder is exposed to the airstream and intercepts on coming droplets. The electronics maintain this sensor at a constant temperature (approximately 130 ^{o}C) and monitor the power required to regulate the temperature as droplets vaporise. This power is directly related to the amount of heat taken away by convection plus the heat of vaporisation. The convective heat losses are known empirically and vary with airspeed, temperature and pressure. The liquid water volume is calculated from power loss found from the difference between total and convective power losses.

King probe consists of a heated metal cylinder, covered with isolated copper wire. The wire is part of a Wheatson resistance bridge. The bridge keeps the wire resistance (i.e., its temperature) constant by automatically adjusting the electrical power. The changing power P (constant wire temperature and resistance) is a measure of the changing water vapour volume. IF TAS (true air speed) and temperature of air are known then the water vapour volume can be derived from the P-measurement.

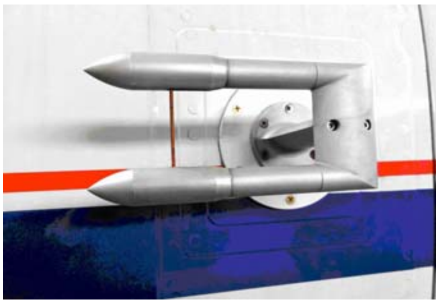

Figure 8. King Probe [5]

E. Final comparison of chosen devices

The following table offers the comparison of several parameters and prices. Diamond DA42 MPP Guardian will be used as a platform for the flight laboratory. Following this fact, because of bigger dimensions the devices Licor 7500, PVM-100A and King Probe are not suitable for that type of aircraft. The installation of these devices would require new aerodynamic calculations therefore these three ones are used only on bigger aircraft such as ATR-42 in the case of SAFIRE agency. Finally, WVSS-II was chosen because of its weight, dimensions, certification for flight utilisation and accuracy. The data in the table are taken from official websites of manufacturers (see references) and prices are obtained by request via email.

TABLE I. THE COMPARISON OF CHOSEN GAS ANALYSERS

	WVSS	**AQM Sentry FTIR**	**LiCor 7500**	**PVM-100A**	**King Probe**
Price [EURO]	24 300	83 700	27 940	12 600	7 150
Dimen-sions [mm]	254x138x 92[1]	622x470x 254[2]	350x300x 150[3]	535x57[4]	395x76[5]
Weight [kg]	3,43	68	5,2	7,3	4
Op. tempera-ture [°C]	-65 to 50	-29 to 40	-25 to 50	-70 to 40	-70 to 45
Sensibili-ty [g.m^{-3}][6]	0,038-45,16	0,484-109,41	0,002-42	0,002-10	0,05-3
Power supply	28 VDC	220 VAC	30 VDC	28 VDC	28 VDC
Accuracy [%]	±5	±8	±3	±8	±15
Output	RS-232	RS-232	RS-232	RS-232	RS-232
Designed for flight purposes	yes	no	no	yes	yes

CONSLUSION

The monitoring of water vapour volume in the atmosphere by means of flight laboratory is very comprehensive and difficult task. For this reason the aircraft DA42 MPP Guardian is the best choice from the price, technical parameters and certification point of view. Mainly the issue of certification represents significant cost item. Therefore it is a good solution to buy an aircraft which has at least EASA certificate. Concretely Guardian has EASA TCDS-A513 certification and its construction is special designed for carrying of various devices such as cameras, laser scanners or mentioned gas analysers.

The ambition of our environmental flight laboratory is flexible monitoring of water vapour volume everywhere where it is necessary and it also wants to contribute for qualitative weather forecast within given region.

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[1] Dimensions of central box, external sensor's dimensions: 136,35 mm x 80,89 mm x 19,98 mm

[2] Dimensions of central box, an external air sampler is necessary for aeronautical utilisation (for example the air sampler of WVSS-II), multi-pass cell's dimensions: Ø 100 mm – 1000 mm

[3] Dimensions of central box, external sensor's dimensions: Ø 65 mm – 300 mm

[4] Central box and external sensor is located in one body

[5] Central box and external sensor is located in one body

[6] The data are converted to grams of H_2O in the one cubical meter of air in the ISA conditions

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2016: Cleared to Land on RWY 24L!

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Abstract **- To assure further development of air transport, it is necessary to increase the runway capacity at Prague / Ruzyne airport, that services about 93 % of all Czech travellers. Since the 1990s, the number of passengers and flights handled at Prague / Ruzyne has been significantly growing. In the last ten years alone, the volume of transport has tripled. At the beginning of 2006, a new Terminal 2 launched its operations. This step enabled increase in the terminal passenger handling capacity and the current layout of two terminals together with planned Pied D has a perspective to handle 21 million passengers in 2020. The runway system of the airport, quite to the contrary, has virtually not changed since the 1960s despite the sharp increase in the amount of handled passengers and serviced flights. Thus at peak times, the system does not suffice and without an extension will become the main obstacle to the expected growth of civil aviation in the Czech Republic.**

Keywords- Runway; capacity; airport development; Prague Airport.

I. INTRODUCTION

Similarly to other airports in Europe, the capacity bottleneck of Prague / Ruzyně airport is the runway system. However the airport has three RWYs, only one of them, 06/24 is fully operational. The second RWY, 13/31 can be used for departures of turboprops only due to environmental reasons. The third RWY, 04/22, shortest and oldest one and limited due to noise, too, is closed for departures and arrivals at all and the airport operator uses its surface for long-term parking of the aircraft.

II. CURRENT STATUS

The runway system has been the capacity bottleneck since 2004. It is used at the maximum of the operational capacity at peak times and the Airport Slot Co-ordination is unable to accommodate all requests of aircraft operators. The growing popularity of Prague / Ruzyně Airport amongst passengers and airlines already causes increase of delays at peak times and will soon escalate in stagnation of the airport's performance. In light of the above, it is necessary to note that each minute of delay at Prague / Ruzyně airport immediately affects other European or world airports by cumulated delays. [2].

Airport Slot Co-ordination capacity

Arrivals: 3 ARR/5 min. and 33 ARR/60 min.

Departures: 3 DEP/5 min. and 33 DEP/60 min.

Global: 46 MVT/60 min.

Capacity in Low Visibility Operations

The following hourly traffic rates of RWY 24 are anticipated in the time periods of Low Visibility Operations.

RVR from 600 m to 350 m: 17 or less arrivals

RVR less than 350 m: 14 or less arrivals

RWY System Preference: current situation

In the typical operational day, RWY 06/24 is used for most of the arriving and departing air traffic. Whenever conditions permit, RWY 24 is preferred to RWY 06.

Use of RWY 13/31 is limited due to noise. In the typical day, RWY 13 is used for departures of turboprop aircraft bound to the south and east, in order to reduce the traffic load on 06/24.

III. AIRPORT CAPACITY / DELAY REDUCTION PLAN

Table 1. Capacity Action Plan [3]

Action Description	2010	2011	2012	2013	2014	2016
Airport Collaborative Decision Making (CDM)	X	X	X	X	X	X
TMA optimization		X	X	X	X	X
Creation of two turn-offs for RWY 06/24			X	X	X	X
Period 5 min for airport slot coordination	X	X	X	X	X	X
RWY 06R/24L						X
Resulting Global Maximum Capacity Objective / Forecast	**46**	**46**	**48**	**48**	**48**	**60+**
Yearly Planned capacity increase	**0%**	**0%**	**4,4%**	**0%**	**0%**	**25%**
Expected delays reduction	=	=	=	=	↓	↓

Legend:
= No major delays reduction expected
↓ Expected reduction in delays

New turn-offs for RWY06/24

Figure 1. Positioning of the new Turn-offs

TWY J: 2075 m from THR 06

TWY W: 1550 m from THR 24

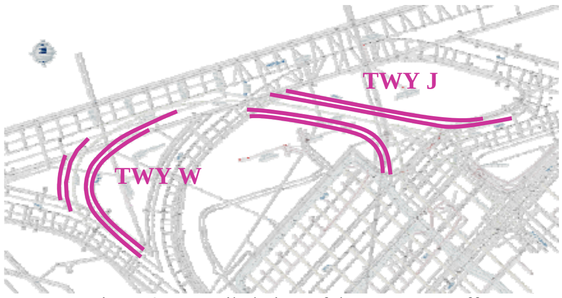

Figure 2. Detailed view of the new Turn-offs

IV. RWY 06R/24L

Background

The RWY 06R/24L is the only way how to remove the capacity bottleneck of the airport and bring the ultimate capacity solution for the future. The concept of a second, parallel, runway at Prague airport is not a new one. The plan to build the parallel runway in due course was already in place when the current main runway RWY 06/24 (originally RWY 07/25) was built in 1961 - 1963. At the beginning of the 70s, the plan was made part of the land use planning documentation of the capital city of Prague, including Guiding Land Use Plan and Land Use Plan of the Capital City of Prague.

While during the first year of operations of the main runway RWY 06/24, Prague Airport serviced 1 million passengers on 45 thousand take-offs and landings, in the year 2008, there were 12,6 million serviced passengers on 179 thousand take-offs and landings. Despite the fact that the number of serviced passengers grew more than 12 times the amount and the number of aircraft movements about four times the amount since 1963, the airport runway system has remained virtually the same.

The airport expects to see the numbers of serviced passengers and dispatched flights to grow also in the future. See the traffic forecast attached.

Location

The new runway will replace the runway 04/22 that has for a long time been out of operation and used only for parking of aircraft. The runway will be parallel with the existing RWY 06/24 at the distance of 1,525 meters to allow for independent operations of both runways.

Technical parameters

Construction Length of the Runway: 3,550 m

Construction Width of the Runway: 45 m

Construction Width including shoulders: 75 m

Runway Stripe: 3,670 m x 300 m

Operational Status

Both RWY 06R and RWY 24L precision approach CAT II/III

Proposed layout

Figure 3. Layout of the RWY06R/24L

A video sequence describing the layout as well as the future RWY operational concept is available at: http://www.paralelnidraha.cz/en/site/o_letisti/paralelni_draha.htm [2].

Schedule

Start of building the runway: 2013 - 2014;

End of the runway building: 2015 - 2016;

Runway ready for operations: 2015 - 2016;

Capacity benefit: 2016+.

RWY OPS Concept 2016+

In the typical operational day, RWY 06L/24R will be used for departures. RWY 06R/24L will serve for all arrivals and further, for departures of aircraft from APRON SOUTH, i.e. mostly flights of the General Aviation. RWZ 06R/24L will not be used for arrivals and departures at night 22.00 – 06:00 local time.

The RWY 13/31 will not be used in the typical operational day. Use of the 13/31 will be limited to the cases of maintenance, exceptional situations or strong crosswinds on 06/24.

Modes of operation

Table 2. Modes of operation

RWY Operations mode	% time / year
DEP RWY 24R – ARR RWY 24L	67
DEP RWY 24R – ARR RWY 24R (maintenance 06R/24L 2 weeks)	3
DEP RWY 31 – ARR RWY 24L (maintenance 06L/24R 2 weeks)	3
DEP RWY 06L – ARR RWY 06R	22
DEP RWY 06L – ARR RWY 13	1
DEP RWY 13 – ARR RWY 06R	1
DEP RWY 31 – ARR RWY 31 (extreme weather conditons)	1
DEP RWY 13 – ARR RWY 13 (extreme weather conditons)	1

Traffic distribution in % / year – daytime

The image bellow takes standard operations, maintenance periods and adverse weather into account.

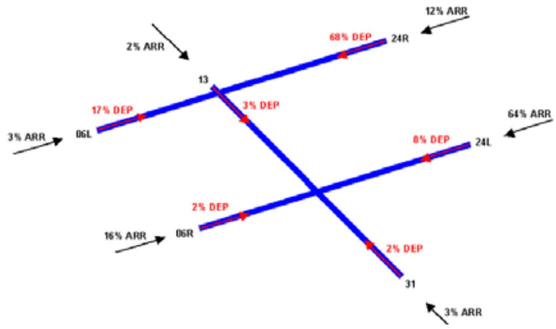

Figure 4. Proposed traffic distribution

References

[1] L. Kurzweil, Optimalizace času obsazení vzletové a přistávací dráhy, Faculty of transportation sciences, Czech Technical University in Prague, 2010, pp. 101 - 119.

[2] Parallel runway, 2011. http://www.prg.aero/en/prague-airport/parallel-runway/

[3] Local Single Sky Implementation, EUROCONTROL, 2011

CRED: Calculation of RWY Exit Distance

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***Abstract*–The CRED is a new application for computing optimal distances of the RWY Turn-offs.**

Keywords- Runway; Taxiway; Exit; Turn-off; capacity; optimization; airport development; Prague Airport.

I. INTRODUCTION

A RWY system is the capacity bottleneck at many airports around the world, especially in Europe, where a development of the RWY Systems is tough. Lack of land for expansion of airports, high investment costs, bureaucratic approval processes, public opposition, court cases. All these reasons cause many years of delay to airside development projects and on the top of that, several projects are stopped at all.

It is clear that those few RWY projects, which successfully passed the approval process, must bring maximal operational benefit to particular airport. The main goal is to reach the highest possible capacity through a RWY occupancy time reduced to a minimum. In technical language, all this means that amongst all measures for the capacity enhancement, the RWY turn-offs must be placed in the right distance from the threshold for the fleet mix operating at the airport. This task is not easy because every aircraft type has different performance and its requirements vary landing to landing with actual weight and configuration. To make the task even more complicated, the braking distance alias the right position of RWY turn-off depends on many RWY technical parameters, RWY surface conditions, weather, airline's operational procedures and pilot's performance.

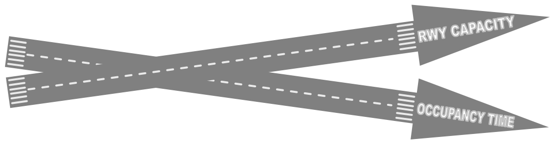

Figure 1. *Optimally placed Turn-offs bring shorter occupancy time thus higher RWY capacity*

Now the sophisticated calculation tool for computing the optimal distance of the turn-off is available. The name is CRED (Calculation of RWY Exit Distance) and it was developed 2009 – 2011 at Czech Technical University in Prague, Faculty of Transportation Sciences in close co-operation with LetištěPraha, a.s., the operator of Prague Ruzyně Airport, the largest airport in the Czech Republic and holder of the IATA Eagle Award 2011 for an outstanding performance in customer satisfaction, cost-efficiency and continuous improvements of the airport.

The new application CRED is based on the self-developed Segment model of aircraft landing and landing roll [1], that allows to to calculate the RWY speed profile for the particular aircraft movement, thus the optimal distance of the RWY turn-off while all imaginable variables are taken into account.

The pilot reference of the application CRED is the optimization of RWY turn-offs of the new parallel RWY 06R/24L at Prague Ruzyně Airport.

II. CURRENT STATUS

The runway system has been the capacity bottleneck since 2004. It is used at the maximum of the operational capacity at peak times and the Airport Slot Co-ordination is unable to accommodate all requests of aircraft operators. The growing popularity of Prague / Ruzyně Airport amongst passengers and airlines already causes increase of delays at peak times and will soon escalate in stagnation of the airport's performance. In light of the above, it is necessary to note that each minute of delay at Prague/Ruzyně airport immediately affects other European or world airports by cumulated delays.[2].

III. THE SEGMENT MODEL OF AIRCRAFT LANDING AND LANDING ROLL

During the development project, the technique of landing, landing roll and vacating the RWY has been studied and described in detail. With reference to all findings, the „Segment model of aircraft landing and landing roll" has been developed. It uses mathematical equations to compute speed profile, times and distances for 4 defined segments of the RWY movement: Landing, Stabilization, De-celeration and Turn-off.

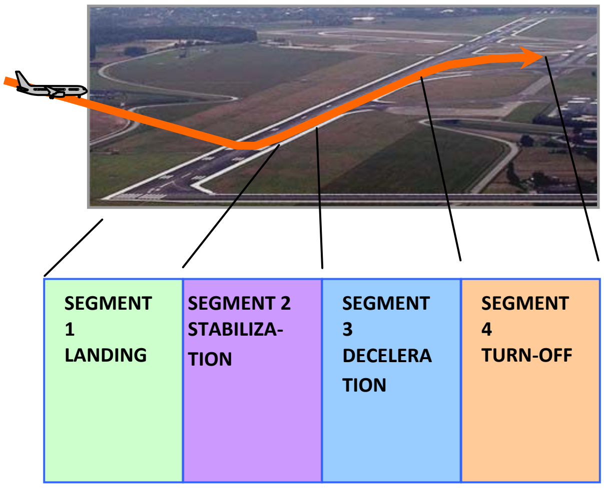

Figure 2. *The Segment model of aircraft landing and landing roll*

IV. THE WAY FROM THE SEGMENT MODEL TO THE CRED APPLICATION

The main capability of the Segment model of aircraft landing and landing roll is to calculate the speed profile of an aircraft on a RWY. Further, if the design speed of particular RWY turn-off is known, the optimal RWY turn-off distance can be calculated using several equations. These thoughts gave birth to the CRED, the application for the calculation of RWY Exit (turn-off) Distance.

Since the RWY performance varies significantly amongst aircraft types, it was a necessity to develop an aircraft database in the CRED. The database is now ready and contains reference speeds, approach speeds, flaps settings and other variables for the most common types and versions of commercial aircraft. At present, the database contains technical information about 23 aircraft types and sub-versions.

To summarize, the CRED application profits from the three inputs, the Segment model, the set of equations and the Aircraft Performance Database.

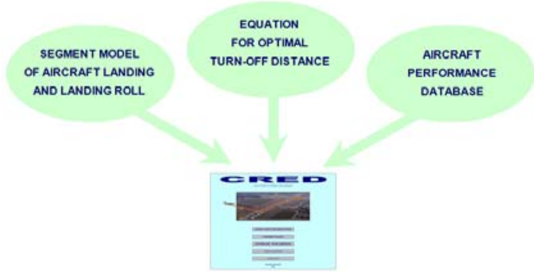

Figure 3. *The roots of the CRED application*

V. THE CRED SOFTWARE APPLICATION

In order to allow practical use of the Segment model, an excel application CRED for computing the optimal distance of a turn-off TWY from a RWY threshold has been developed. Its main function is to compute the distance that an aircraft requires for de-celeration to defined turn-off speed, which means the optimum distance of the turn-off TWY.

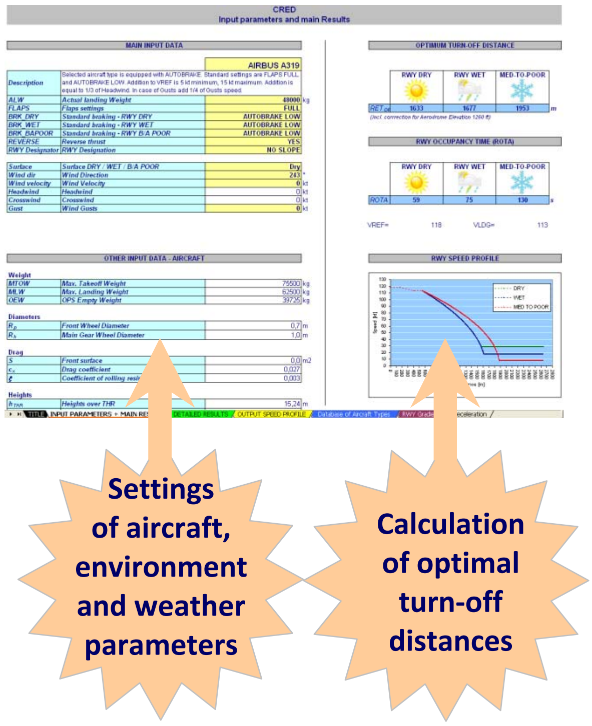

Figure 4. *The CRED user Interface*

The application has a straightforward graphical user interface and is ready to be used by users without any training. User siply chooses the aircraft type from a roll-down menu, sets actual configuration of an aircraft, sets RWY and weather conditions and results are displayed automatically.

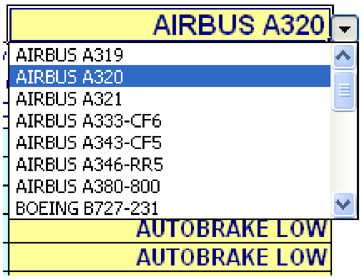

Figure 5. *The Roll-down menu with aircraft types*

VI. 4. CRED Input Data

One of the valuable parts of the application CRED is the database of 23 aircraft types. The technical data about particular aircraft types has been extracted from manufacturer's manuals. The most important aircraft technical and performance data are:

- Minimum, common and maximum landing weights,
- reference speeds for particular landing weights and flaps settings,
- rules for computation of the approach speed,
- common turn-off speed from the RWY dry / wet / contaminated for various design types of the turn-offs (90 degrees perpendicular, high-speed turn-off),
- standard procedures for landing, landing roll and vacating the RWY,
- performance of brakes, autobrake, reverse thrust of engines in $m.s^{-2}$.

The aim was to obtain a dataset for as many aircraft types as possible. At present, the following reliable and verified aircraft data are included in the CRED database:

- ATR 42 / 72
- A 319 / 320 / 321
- A 330-300
- B 737-300 / 737-400 / 737-500 / 737-600 / 737-700 / 737-800 / 737-900 / 737-900ER / 737-BBJ
- B 757-200
- B 767-300
- B 777-200

Thereafter, reliable data about the airport, RWY and weather are required:

- Dimensions and altitude of the RWY,
- longitudinal slope, broken down by 1/10 lengths of the RWY,
- technical parameters of the turn-off TWY,
- wind direction and speed, wind gusts.

VII. 5. The Pilot Project: RWY 06R/24L of Prague Ruzyně Airport

The runway system of Prague Airport is the capacity bottleneck of the airport since 2004. It is used at the maximum of the operational capacity at peak times and the Airport Slot Co-ordination is unable to accommodate all requests of aircraft operators. The growing popularity of Prague Airport amongst passengers and airlines already causes increase of delays at peak times and will soon escalate in stagnation of the airport's performance. In light of the above, it is necessary to note that each minute of delay at Prague Airport immediately affects other European or world airports by cumulated delays.

However Prague Airport has three RWYs, only one of them, 06/24 is fully operational. The second RWY, 13/31 can be used for departures of turboprops only due to environmental reasons and the third RWY, 04/22, shortest and oldest one and limited due to noise, too, is closed for departures and arrivals at all and the airport operator uses its surface for long-term parking of the aircraft.

The construction of the new RWY is the only way how to remove the capacity bottleneck described above. The concept of a parallel runway at Prague Airport is not a new one. The plan to build the parallel runway in due course was already in place when the current main RWY 06/24 (originally RWY 07/25) was built in 1961 - 1963. At the beginning of the 70s, the plan was made part of the land use planning documentation of the capital city of Prague, including Guiding Land Use Plan and Land Use Plan of the Capital City of Prague.

Figure 6. *The visualisation of the new parallel RWY*

While during the first year of operations of the main runway RWY 06/24 of Prague Airport serviced 1 million passengers on 45 thousand take-offs and landings, in the year 2010, there were more than 12 million serviced passengers on almost 160 thousand take-offs and landings. The airport expects to see the numbers of serviced passengers and dispatched flights to grow also in the future. More than 21 million of passengers are expected in 2020 [2].

Technical parameters of the parallel RWY

Construction dimensions of the Runway: 3,550 m x 45 m

Construction Width including shoulders: 75 m

Runway Strip: 3,670 m x 300 m

Operational Status: Precision approach CAT II/III

The new runway will replace the runway 04/22 that has for a long time been out of operation and used only for parking of the aircraft. The runway will be parallel with the existing RWY 06/24 at the distance of 1,525 meters to allow for independent operations of both runways.

The CRED pilot application

The RWY 06R/24L will be equipped with three high speed turn-offs for aech direction. The CRED application was employed to calculate the optimal distances of each turn-off from the RWY threshold. All importantvaribles were taken into account, incl. RWY elevation and longitudinal slopes. All results of the CRED calculation are displayed in the graphs below.

The RWY Turn-off distance calculation for RWY 06R

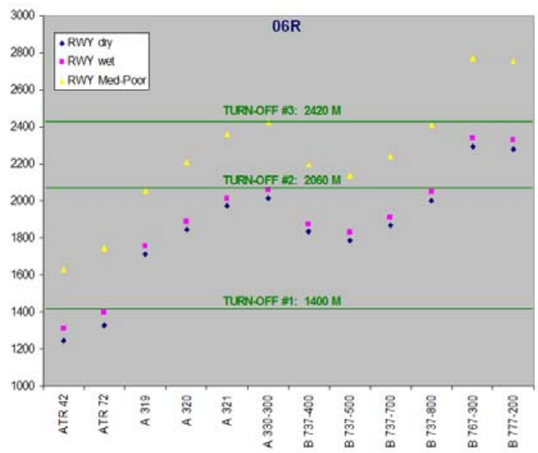

Figure 7. *The RWY Turn-off distance calculation for RWY 06R*

The RWY Turn-off distance calculation for RWY 24L

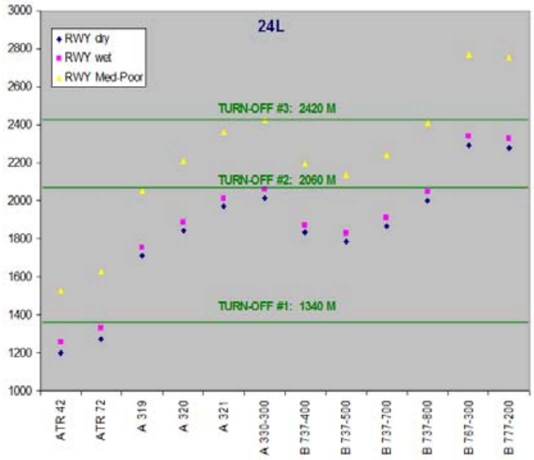

Figure 8. *The RWY Turn-off distance calculation for RWY 24L*

VIII. 6. Conclusions from analyses describing the impact of key factors on the turn-off distance

The optimal distance of a RWY turn-off is influenced by a plethora of factors and parameters. The project performed following analyses to evaluate the impact of all key factors: 1) RWY surface conditions, 2) De-celeration procedure, 3) Actual landing weight, 4) Flaps setting, 5) Wind speed and direction, 6) Wind gusts.

The following conclusions have arisen from the analyses:

Analysis 1) RWY surface condition

An aerodrome operator must ensure effective RWY operations during dry and wet surface conditions. The braking action Medium to Poor significantly increases the braking distance; hence, it should be avoided by good-quality winter surface maintenance.

Analysis 2) De-celeration procedure

From the perspective of capacity and effectiveness of the RWY operations, the better option is the higher autobrake setting. However, aircraft operators prefer the autobrake setting with lower de-celeration speed, as it brings lower wear of brakes and reverse thrust and saves maintenance costs.

Analysis 3) Actual landing weight

When drafting the turn-off distances, aerodrome operator must take not only the traffic mix as an input data into account, but determine the common landing weights as well, based on the traffic characteristics of the airport. Different values can be expected for full-service flights, another for low-cost flights and completely different for unscheduled charter flights.

Analysis 4) Flaps setting

Flaps setting influences the braking distance in the same way as the landing weight, because both mentioned variables are fundamentally important for computing the reference speed vREF and the approach speed vAPP. The higher flap setting, the lower approach speed and consequently the shorter braking distance.

Analysis 5) Wind speed and direction

Due to operational safety reasons, landing with headwind is always preferred compared with tailwind landing. The analysis no. 5 showed, that there is also another reason why the headwind landing should be prioritized, and the reason is capacity. The headwind ensures lower ground speed during the landing, hence the shorter braking distance and in case of properly placed turn-off TWY, shorter RWY occupancy time and higher RWY capacity.

Analysis 6) Wind gusts

Efficient RWY operations during high wind gusts can be achieved by construction of three or more rapid exit TWYs in a row (however those high investments must be justified by the costs – benefits analysis). The turn-off TWY no. 2 will then be a backup for the turn-off TWY no. 1 and aircraft will use it every time it misses the no. 1 due to the wind gusts and higher landing speed. Similarly, the turn-off TWY no. 3 will be a backup for no. 2 etc. When the separation between turn-offs is not higher than ca. 400 m, the impact on the RWY Occupancy Time is not significant and can be accepted.

7 Conclusions

- ✈ **The Segment model of aircraft landing and landing roll incl. detailed description of the landing procedure, speeds, times and distances was developed,**
- ✈ **The CRED software application is now available to the industry,**
- ✈ **Six analyses were performed to describe the impact of key factors on the turn-off distance,**
- ✈ **Optimal turn-off distances for the RWY 06R/24L at Prague Ruzyně Airport was calculated.**

References

[1] L. Kurzweil, Optimalizace času obsazení vzletové a přistávací dráhy, Faculty of transportation sciences, Czech Technical University in Prague, 2010, pp. 101 - 119.

[2] Parallel runway, 2011. http://www.prg.aero/en/prague-airport/parallel-runway/

Application of UAVs to Search People in the Terrain

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***Abstract* – The article is focused on the application of UAVs for searching people in the terrain with new possibilities of the other UAVs, methods and use of bio-information of the lost or wanted person.**

Keywords-component; unmanned aerial vehicle, search and rescue, biosignals

I. INTRODUCTION

In everyday life are constant demands for searching people (lost children, sick or wanted people, etc.) mainly in the rugged terrain. Currently used for these purposes, mainly video and infracamera. The article is focused on the application of UAVs for searching people in the terrain with new possibilities of the other UAVs, methods and use of bio-information of the lost or wanted person.

II. UAVS AND THEIR APPLICATION FOR THE PEOPLE SEARCHING IN THE TERRAIN

UAVs are surrounded by great interest in the last few years. The development of modern aviation technology, advanced computer technologies and the deployment mainly positional satellite systems has led to demands for resources to monitor difficult reach places in a terrain and search any person.

What is the unmanned vehicle and its use to monitor people?

Unmanned aerial vehicles are flying machines with own power and motor unit. The most important fact is absence of flight crew, pilots on a board. They can be operated by a pilot/operator from the ground or they can fly by themselves by automatic system.

The control can be used by several types of systems:

- remote-controlled plane/vehicle with a pilot on the ground
- autonomously controlled plane/vehicle with predefined parameters

Unmanned vehicle, often also called a UAV (Unmanned Aerial Vehicle) is nowadays mainly used in the military sector. Military UAV serves as a reconnaissance aircraft, which are sent into dangerous areas or inaccessible terrain. In addition, aircraft are used as fighting machines, which are capable to carry homing missile or bomb to attack. In the civil sector, they are used for sighting and monitoring during the day and night, photographic works, or one of the newest applications for monitoring the traffic situation. Direct using for searching people are not common.

There are many different types of UAVs with different dimensions. They can be very small, like several centimeters to a size which is comparable with piloted airplanes. It all depends on the equipment and devices which are used. These vehicles are now produced in many different ways as shape, size, weight, and in different uses.

Classification of UAV:
1st observational
2nd reconnaissance
3rd combat
4th target practice
5th bait (decoy for military use)
6th logistics (specifically designed for logistics purposes
7th mentors
8th commercial
9th research and development

Another possible division by Table I.

TABLE I.

Abbr.	Category Name	Weight (kg)	Range (m)	Altitude (m)	End. (hr)
μ	*Micro*	≤5	≤10	250	1
mini	*Mini*	≤25/30/150	≤10	150/250/300	≤2
CR	*Close Range*	25-150	10-30	3000	2-4
SR	*Short Range*	50-250	30-70	3000	3-6
MR	*Medium Range*	150-500	70-200	5000	6-10
MRE	*Multi Role Endurance*	500-1500	≥500	8000	10-18
LADP	*Low Alt Deep Penetration*	250-2500	≥250	50-9000	0,5-1
LALE	*Low Alt.Long*	15-25	≥500	3000	≥24

	Endurance				
MALE	*Medium Alt.Long Endurance*	1000-1500	≥500	5/8000	24-48
HALE	*High Alt.Long Endurance*	2500-5000	≥2000	20000	24-48
Strato	*Stratospheric*	≥2500	≥2000	≥20000	≥48
EXO	*Exo/ Stratospheric*	-	-	≥30500	-
UCAV	*Unmanned sign AV*	≥1000	+/- 1500	12000	+/-2
LET	*Lethal*	-	300	4000	3-4
DEC	*Decoys*	150-500	0-500	50-5000	≤4

The most famous type of UAV, and probably the most deployed is military Predator, which is used for combat actions in Iraq and Afghanistan. In Figure I is a structural design of UAVs, different dimensions and weight.

FIG. I. Design of UAVs

In the civil sector UAVs are mostly based as RC models. These are classical or heavily developed, such as hexacopter which is an aircraft with vertical take-off. Hexacopter is popular due to its stability and the possibility of remain motionless in one place. This feature is very useful for taking photos, when it is necessary to minimize movement for better image quality. UAVs with similar properties are shown to be suitable for use to search people in the terrain.

III. REQUIREMENTS FOR UAV TO SEARCH PEOPLE IN THE TERRAIN

Flying vehicle for searching people in the terrain should be dimensionally (range up to 2m), the smallest weight (up to 10kg total weight), user-friendly control, endurance flight approx 1 hour and hovering around 30 seconds duration. On the other hand we need sufficient number of sensors, which ensures fast retrieval searched persons.

IV. SUITABLE SIGNAL SELECTION TO SEARCH PEOPLE

In our case, we will focus on the use of UAVs to search people for general use. Specifically, we will look into the possibility of detection and scanning the manifestations of the human body.

From the large number of biological signals that the body produces, we must select those which are possible to scan with the the current (or near future) techniques. Due to the requirement for remote (contactless) scan is necessary to exclude a large number of biological signals, biochemical signals and for the other signals will try to choose specific options for their capture. We will build on the manifestations of the human body.

As biological signals, we can identify all the signals, whose existence can be observed in alive organisms. This may be a waveform of electric voltage, variable magnetic field, changes in chemical concentration, mechanical movements, sounds, temperature changes, etc. We can register native signals as a result of spontaneous activity of the biological system evoked signals as a result of any intentional stimuli.

Despite the wide spectrum of physical nature (in terms of quality and quantity) of biosignal, we can observe and investigate many common features.

Origin of the biosignals:

As mentioned, biosignal can be any physical quantity that varies with time and in some way reflects (carries information) of occurring actions in the body, which is in the interest of our attention. Then we can analyze their use for searching people.

Electric biosignals

Electric biosignals are generated by nerve and muscle cells. They are the result of electrochemical processes inside cells and between cells. If the nerve or muscle cell has a stronger incentive than the threshold stimulation, the cell generates an action potential. The total action potential represents the flow of ions through the cell membrane can be measured using intracellular microelectrodes. Action potentials of excited cells are transferred to adjacent cells and can create electric fields in the corresponding biological tissue.

Changes in extracellular potentials can be scanned by electrodes on the surface of the body or organism as a time course of biosignal. This group includes the signals in Tab. II, which is listed suitability for use to search for current technology with parameters fitted to UAVs.

TABLE II.

Signal	Characteristic	Amplitude level (mV)	Frequency range (Hz)	Measura bility	Usable
EKG	Electrocardiography – heart's electrical activity	0,5 -5	0,5	Surface	No
EMG	Electromyography - electrical activity of	0,5 – 10/0,05 - 5	0,01 – 10 000/0,01	Surface/ injection	No

	skeletal muscles		– 10 000		
EEG	Electroencephalography – activity of brain's neurons	0,005 – 0,3	0,1 - 100	Surface	No
ECoG	Electrocorticography – activity from the cerebral cortex	0,005 – 10	0,1 - 100	Surface	Yes
EP	Evoked potential – electrical potential recorded from the nervous system	0,0001 – 0,02	Jednotky Hz	Surface	No
ENG	Electroneurography	0,005 - 10	0,01 - 1000	Injection	Yes
EOG	Electrooculography – measuring the resting potential of the retina	0,01 - 5	0,05 - 100	Surface	No
EGG	Electrogastrograph - electrical signals of stomach muscles	0,1 – 10/0,01 – 0,5	0,01 – 5/ 0,01 – 5	surface/ nitro gastric	No
ERG	Electroretinography – activity of the retina	0,005 - 1	0,2 - 50	Surface	No
fEKG	Fetal electrocardiography – heart's electrical activity	0,01 – 0,02	0,01 - 250	surface	No

Magnetic biosignals

Many organs in the body like heart, brain, and some others, generate magnetic fields. Sensing these fields provide information that is associated with specific physiological activity, but not included in other biosignal. Biosignal measurement of these is very difficult because it is the level of magnetic field intensity which is lower than the geomagnetic field. This group can include magnetic biosignals in Tab. III.

TABLE III.

Signal	**Characteristic**	**Amplitude level (mV)**	**Frequency range (Hz)**	**Measura bility**	**Usable**
MOG	Magnetooculography – activity of the retina	10	0,1 - 100	magnetic	No
MKG	Magnetocardiography - potential of cardiac muscle cells	50 - 70	0,05 - 100	magnetic	No
MMG	Magnetomyograpgy– electrical activity of skeletal muscles	10 - 90	0 - 20000	magnetic	Yes
MEG	Magnetoencephalography – activity of brain's neurons	1 -2	0,5 - 1	magnetic	No

Impedance biosignals

Tissue impedance is not significant information about their composition, perfusion, blood volume, nervous and endocrine activity, etc. The impedance biosignal is obtained from surface or injection electrodes during application of low currents (20 μ A to 2 mA) at frequencies of 50 kHz to 1MHz. This impedance measurement is usually done with four electrodes - two source and two are measuring. The method is called as the impedance pletysmography or geography.

Acoustic biosignals

Many physiological phenomena are guided or self-generate acoustic signals, or acoustic noise. Measuring these signals provides additional information in assessing the function of major organs. Blood formed a typical acoustic signals when flows to heart valves or to blood vessels. The sounds are also generated in the digestive tract and joints. This group includes the signals in Tab. IV.

TABLE IV.

Signal	**Characteristic**	**Dynamic range(dB)**	**Frequency range (Hz)**	**Measur ability**	**Usable**
Fonocardio graphy	Heart sounds	to 80	5 - 2000	Magnetic	Yes
Foniatric signal	Information about the heart, blood circulation and respiration	to 80	440 – 10 000	Magnetic	Yes

Chemical biosignals

For chemical biosignals consider the results of chemical measurements made on alive tissues. It is the determination of the concentration of various ions (K, Ca) within cells, but also their surroundings by means of special ion-sensitive electrodes. Significant are the partial pressures of oxygen and carbon dioxide (pO_2 pCO_2) in blood or respiratory system.

Mechanical biosignals

Each mechanical biosignal has its origin in some of the mechanical functions or activities of the biological system - the body. These signals are derived from movement, pressure. mechanical stress or flow. Biosignal measurement of these involves require various sensors. A typical example indirect way of measuring is blood pressure, fonocardiography, cardiography, etc.. This group includes biosignals in Tab. V.

TABLE. V

Signal	**Characteristic**	**Range**
NIBP	Blood pressure	The upper limit to 300mmHg 0 mmHg corresponds to atmospheric pressure
	Cardiac output	The volume of blood circulation to the heart per unit time
	Volume of tissue	To assess blood flow to the tissues
	Respiratory frequency	Respiratory frequency is usually measured indirectly from modulation of other biosignal such as ECG or concentration of CO2 in exhaled air

Optical biosignals

Optical biosignals are the result of observation of the optical properties of biological system - the body - whether they are the essence of the system or are induced at measurements. It is known that blood oxygenation, oxygen saturation, can be assessed by measuring the direct and reflected light (different wavelengths) after passing through tissues. The method is called oximetry.

Heat biosignals

Heat biosignals carry information about the body's core temperature or temperature distribution on the surface of the body. Measured temperatures are an expression of physical and biochemical processes in organisms. Measurement is usually a contact method using various types of thermometers. Another kind of signals is from the infrared rays that are captured in a 2D format for non-contact thermal imaging camera. This is currently most used method for finding people in the terrain with a visual method.

Radiological biosignals

These signals are the interaction of ionizing radiation with biological structures. At all applied wavelengths and energy levels, carry information about the internal anatomical structures of the body. They are captured by special sensors and then processed and displayed in 2D and sometimes in 3D format. They are very important in the diagnosis.

Ultrasonic biosignals

These signals are created from interaction of ultrasonic wave with the tissues of the body. They carry information of the acoustic impedances of biological structures and their anatomical changes. They are sensed by probes with piezoelectric converters, processed and displayed in 2D or 3D format. A special form of ultrasound are Doppler signals, which carry information of the size, direction and character of blood flow in major blood vessels or the cavities of the heart.

From the amount of information and technical capabilities of existing sensors (their weight, dimensions, performance requirements), it is possible to evaluate that except currently used methods (visual and thermal) can be gradually introduce scanning of acoustic, mechanical and ultrasonic biosignals. Gradually transfer of information on the ground could be considered a radiological biosignal.

V. Conclusion

The basic condition for the use of UAVs to search people in the terrain is suitable carrier and suitable sensors. The way of the development of media, computing, sensors and navigation enable to successfully deploy UAVs to search for people in the terrain in the near term.

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Creating Safety in Current Civil Aviation

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Abstract*—This paper focuses on developing safety in civil aviation. It gives general overview of measuring safety and possible safety indicators. For modern era of aviation safety it is specific that it is ultra-safe. Therefore it is very hard to measure safety level in traditional way by lagging indicators like accident rate. It is very vital for improving safety to be able to measure it especially after major operational changes in company. Only accident rate is not good enough to label company as safe. Proactive safety is mostly based on establishing safety culture and creating leading indicators. Leading indicators are important because it gives information about current safety level even during casual everyday operationswithout encountering undesirable outcomes.It is supposed toprovide signals or early warnings to prevent failure.*This work was supported by the Grant Agency of the Czech Technical University in Prague, grant No. SGS10/221/OHK2/2T/16.**

Keywords-safety; safety culture; measuring safety;safety indicators; proactivity

I. INTRODUCTION

Safety must be developed systematically with obvious goal to prevent accidents. That is possible by supporting safety awareness. Creating safety-operation company is nowadays best achievable by implementing safety culture standards. These standards are mainly represented by employees' perceptions, attitudes and beliefs about risk and safety. Other important task of safety department in civil aviation is to measure outcomes of safety and effects of undertaken safety precautions. Proactive methods are best to further increase safety level in current ultra-safe civil aviation environment.

II. SAFETY

Safety is a very much publicized topic, yet nobody is certain how to define it with utter precision and complexity. There are many definitions of safety, but generally safety is a term that represents operations without unacceptable risks, which might lead into accident. Safety is implemented to guarantee that company operations will be done without injury or property damage. On the other hand it is possible to perceive safety is elimination of technical breakdowns and human errors.

Most of safety definitions state, that safe is a company without accidents or incidents. But it is highly superficial to designate aviation company as safe just because of spotless history. "It would be ludicrous to advocate that Valuejet operations were safe before the accident into the Everglades[1]and then unsafe afterwards. The colloquial term often used to describe this phenomenon is 'an accident waiting to happen'." [1] Air transport is one of the safest industries that as [2]states "reaches the mythical barrier of one disastrous accident[2]per 10 million events". So it is very obvious that measuring safety in traditional way is getting useless. This topic is discussed further in chapter VI.yet the definition should take that into account as well.

The best definition of safety operation is that safe operation is the one when unacceptable risks are avoided. Equally when some operation is safe the risk of operation is acceptable,nevertheless acceptable operation is not totally risk-free. The goal is to manage risks so it is in acceptable or tolerable region of Safety risk tolerability matrix. Therefore very essential task of safety department is to identify, manage and mitigate risks 'as low as reasonably practicable' (ALARP). The best requisite to do so is to follow Safety Management Manual [3]published by ICAO.

Even though safety according to public should be the first priority; SMM[3] itself states that it is "just another organizational process that allows aviation organizations to achieve their business objectives through the delivery of their services". Companies doing business in aviation, as anywhere else, are established primarily for the purpose of making a profit. Therefore it is necessary that civil aviation authorities create such rules, which keep safety at the highest level, but on the other hand, give companies space to carry on business. That is the reason why ALARP approach is used, regardless of public opinion, and risks are not fully mitigated.

"Safety is the state in which the possibility of harm to persons or of property damage is reduced to, and maintained at or below, an acceptable level through a continuing process of hazard identification and safety risk management." [3]

[1]ValuJet flight 592 – 11. 5. 1996 - http://en.wikipedia.org/wiki/ValuJet_Flight_592
[2]A disastrous accident is an accident causing human death, and/or loss of property, and/or important consequences on the environment or on the system's economic viability.

III. SAFETY CULTURE

Safety should be perceived systematically, as a continuous process that never ends. It is a system characteristic that is very difficult to measure. Mostly people notice it only when an accident occurs, in a situation where the safety fails. In this case systematic approach means to create safety structures across the company and primarily develop safety culture.

Safety culture is according to UK Health and Safety Commission [4] "product of individual and group values, attitudes, competencies, and patterns of behavior that determine the commitment to, and the style and proficiency of, an organization's safety programs".

In general safety culture is an attitude inside company to safety. Safety attitude (culture) is widespread all over the company. Apart from ordinary worker or safety staff it depends very much on management commitment to safety. Because safety culture is only one part of corporate culture it can be influenced by such seemingly unrelated changes as downsizing or organizational restructuring. Therefore it is very crucial to be able to measure level of safety culture and most importantly monitor changes.

To measure safety culture it is necessary to identify those attitudes (efforts) that are essential to building safety. Apart from the effort to enhance safety by each and every single employee; it is very crucial to involve management and develop reliable communication links. In that case it is safety climate that is measured, because it is present state of safety culture. This survey gives just a snap shot of current level of safety culture (safety climate), therefore it is important to repeat it regularly, especially after operational changes.

Quite easily observable and measurable by survey is the way how people treat information about safety. "Organizations with a positive safety culture treat safety information in the following way:

- Information is actively sought
- Messengers are trained
- Responsibility is shared
- Dissemination is rewarded
- Failure leads to inquiries and reforms
- New ideas are welcomed" [5]

IV. EVOLUTION OF SAFETY THINKING

Aviation safety passed a long way from the dawning of air transport and it achieved many victories. Nowadays improving safety is not that much dependent on technology or equipment because it is mostly standardized and required by regulations. Yet it is still the main goal to completely eliminate technical failures and human errors. Even though the progress was so immense, one of the first information in[3] is that "failures and operational errors will occur in aviation, in spite of the best and most accomplished efforts to prevent them. No human activity or human-made system can be guaranteed to be absolutely free from hazards and operational errors."

Provided that we know that failure or human error is inevitable it is the best starting point to improve regulations, processes or whole systems. It is therefore main task of safety department to find those operations or systems that are prone to failures and errors.

A. Reactive approach

Traditional approach of safety management is to primarily focus on accident investigation, analysis and then introduction of new safety regulations. This approach is based on building safety after some major accident or incident has happened. Naturally it was the best possible way to build safety in prehistoric times of aviation. Accident investigation provided many useful crucial lessons and it is still very necessary resource of information after accident to investigate the causation and circumstances to avoid it next time.

But are we still in position to willingly wait for accident to increase safety level? This is commonly known as learning by trial and error and it is not desirable to be dependent on increasing safety this way.In modern era of aviation safety it is essential to be able to proactively predict possible failures and errors and provide such strong defenses to prevent potential accident.

B. Proactive approach

Proactive approach is according to [6] aimed to "detect and identify potentially unsafe conditions in their developmental phases. And, more importantly report, how and when managers should take appropriate proactive corrective actions based on leading safety indicators that fall well outside of the traditional historical metrics of incident and accident reporting."

Proactivity is mostly needed when there is already developed system that is starting to suffer from operation deviations or as SMM[3] calls it a 'practical drift.' These deviations from rules, procedures or performance could eventually lead to accident. Therefore information about system safety should be scrutinized and available to supervisor and especially top management. It is very pivotal to provide right tools to be able to meaningfully measure safety level in order to "be used to identify, in advance, the strengths and weaknesses within an organization that influence the likelihood of accident occurring." [7]

V. INDICATORS

Avoiding accidents is best possible by reducing possibility of such situation. Therefore management or safety department itself should have precise information about system condition and possible threats. Indicators are supposed to be used as signals or early warnings to prevent failure, yet it is possible mainly by leading (proactive) safety indicators.

Safety indicators properties according to [8] are that:

- indicators provide numerical values (such as number or a ratio),
- indicators are updated at regular intervals,
- indicators only cover some selected determinants of overall safety or risk, in order to have a manageable set of indicators.

A. *Lagging indicators*

Lagging indicators are also known as traditional or reactive indicators. It is safety outcome, mostly emerging when safety efforts has failed. That is why it is not possible to use those indicators to prevent failure, because it is activated right on account of failure. Lagging indicators are the launching point to start reactive procedures. Efforts of safety investigators have shifted from monitoring accidents to incidents and eventually to casual operational errors. “Lagging safety indicators show when a desired safety outcome has failed.”[7]

Example of safety performance lagging indicators from [9]:

- Accident rate: number of accidents per 100 000 flight hours
- Incident (serious incident) rate: number of incidents per 100 000 flight hours
- Deviations rate: number of reported deviations, disturbances per year

B. Leading indicators

Leading indicators are those that are possible to measure during casual operations without encountering undesirable outcomes. It is the best way to measure current safety level of company prior to accident or incident. Proactive indicators are also very important to discover prospective latent conditions that might breach safety defences and prevent subsequent aftermaths.

These indicators advert to real commonplace operations and indicate status by observation, audits or surveys (questionnaires).

Example of safety performance leading indicators from [9]:

- External audits (by authorities)
- Internal audits (company level)
- Emergency
- Competence, training and experience
- Workload
- Maintenance
- Economy/investments

VI. MEASURING SAFETY

“Traditionally, organizations have assessed their safety performance on the basis of ‘lagging indicators’ of safety such as fatalities, or mishap rates. Lagging indicators show when a desired safety outcome has failed or has not been achieved (e.g., number of mishaps). However, as safety has improved and the frequency of mishaps has declined, mishap rates have ceased to be a useful metric of safety performance.” [7]

Even though efforts of increasing safety level are still directed at complete elimination of accidents it is not possible to measure safety level just by accident rate of specific company.

As stated before it is very good way to measure safety by measuring safety culture by audits or surveys. Main topics to measure safety culture are according to [10]: (1) Management commitment, (2) Management actions, (3) Personal commitment to safety, (4) Perceived risk levels, (5) Effect of the required work pace, (6) Beliefs about accident causation, (7) Effect of job-induced stress, (8) Effectiveness of safety communications within organization, (9) Effectiveness of emergency procedures, (10) The importance of safety training and (11) Status of safety people and safety committees within an organization.

When we are able to properly measure safety it is very possible to be able to predict system failures or possible errors and prevent them. In other words measuring safety is very crucial to improve it.

VII. CONCLUSION

Although there is evidence that current air transport is very safe it would be disdainful to stop improving it. Reactive approaches produced incredible progress in the past. Yet safety should be at least one step ahead of the present day. Earlier safety was only about one-time reactive action after accident, which was impulse to improve regulations. Nowadays and especially for the future, safety actions should be perceived as proactive process of risk management that is continuous and ceaseless.

It is the best possible way to be able to increase safety without any other accident, subsequent investigation and learning a lesson. This is possible by implementing proactive approaches and leading indicators that warn us before accident occur.

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The Latest Airplanes Technologies

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In this post we have tried to describe the latest trends in aerodynamics, materials and technologies used, which were applied on the two most advanced airliners Airbus A380 and Boeing 787 "Dreamliner." These technologies provide reduction of noise, emissions, fuel consumption, aircraft weight and increase speed and comfort of travel.

Keywords – aerodynamics, materials, fuel consumption, weight, emissions, speed

I. INTRODUCTION

With the continuous development of aeronautical engineering is to increase the efficiency of current aircraft compared to their predecessors. Currently, emphasis is put on increasing the travel speed of airplanes. Increase in travel speed can overcome the planes delimited by the distance in less time, which is especially appreciated among passengers and operators alike by reducing fuel consumption (assuming an equivalent fuel consumption of the units surveyed with airplane with a lower cruising speed). Aircraft are also the same number of track sections reduces flight hours, allowing more flights to fly to the next inspection, overhaul, or throughout its life. The airplane can also shorter flight time to execute a specified unit of time (eg day) more flights to carry

II. INCREASE OF SPEED

Increasing travel speed is limited. The upper limit for all current aircraft speed becomes equivalent speed of sound. Overcoming the limits cease to apply in relations, characteristics and properties of the wing sections designed to subsonic speeds.

III. CRITICAL MACH NUMBER

For aircraft flying high subsonic speeds, depending on the thickness of its profile and the current value of the pitch will be at a certain speed V_{cr} on top of the wings at a local point of maximum velocity to reach supersonic speed M=1 Speed V_{cr} called critical Mach number, and usually you are flagging it as V_{cr}. When you reach a subsequent increase in speed over the value of M_{cr} starts from the point the maximum speed of formation of local supersonic flow field, which will increase proportionately with increasing airspeed. At the end of the supersonic area then there is the step change. Based on other wind patterns will occur at the step change speed while the step change of pressure, which causes an adverse pressure gradient causing the boundary layer.

Currently, aircraft manufacturers try to reduce the effects caused by exceeding the critical Mach number as increasing slenderness airfoils. This principle uses the M_{cr}, depending on the geometry of the wing and the problem with the effects of excess M_{cr} essentially bypasses the critical Mach numbers by moving to higher values by increasing the relative thinness wings. This principle has its limitations, in particular for reasons of structural strength wings and operating characteristics of the airplane. Narrow wings as the main fuel tank area will accommodate smaller volumes of fuel and thereby reduce the potential range airplane. Another option is to use overcritical (supercritical) airfoils.

IV. USE OF SUPERCRITICAL PROFILES

A. SUPERCRITICAL PROFILES

Specially designed airfoils that exhibit better characteristics and behavior even at speeds higher than the M_{cr}. Supercritical wing sections, the upper surface of the wing-shaped assigned in order to prevent a rapid increase in velocity of air flow on the wing, thereby reducing the effect of shock waves generated. Supercritical profiles generally push the point of shock waves closer to the trailing edge of the wing and reduce the intensity of the shock wave. This leads to a lesser extent, to hit the boundary layer on the lower leaf surface.

Profiles compared to the classical concept of the supercritical profiles differ primarily in:

- larger area of the suction edge
- greater relative thickness
- larger leading edge radius
- deflection center line profile of S-shaped
- large trailing edge angle

Summary of the above findings and principles to define the following characteristics:

Advantages: Increase travel speeds while maintaining the layout and increase the range wing aircraft (that is outside the possible increase in speed thanks to the increased volume of fuel tanks, which generally follows the thicker profile than conventional supercritical profiles).

Disadvantages: The reduction in maximum lift coefficient. Another disadvantage is the increase of tilting moments with supercritical wing profile than the classical concept of the profile (this phenomenon is mainly due to the deflection of the rear supercritical profile).

B. *CURRENT USE OF SUPERCRITICAL AIRCRAFT PROFILES*

Currently, according to available resources using supercritical profiles of aircraft:

- Airbus A380 (cruising speed M 0.89)
- Boeing B777 (cruising speed M 0.84)
- Boeing B787 (cruising speed M 0.85)

To compare the advantages of supercritical profile we cruise speed airplane with conventional profiles concept:

- Boeing B737 (cruising speed M 0.74)
- Airbus A320 (cruising speed M 0.78)
- Tupolev TU154 (maximum rate of 0.77 M)

V. MATERIALS

In the Airbus A380 are used advanced aluminium alloys for the wing and fuselage, along with the extensive application of composite materials in the center wing box's primary structure, wing ribs, and rear fuselage section. The A380 also uses Glare material in the pressurized fuselage's upper and lateral shells. Glare is a laminate incorporating alternate layers of aluminium alloy and glass fibre reinforced adhesive, with its properties optimized by adjusting the number of plies and orientation of the glass tapes. This offers a significant reduction in weight and provides very good fatigue and damage resistance characteristics.

At the 787 composite materials make up to 60 percent of the primary structure including the fuselage and wing. There is no exact value, but the number around 25 to 30 percent lighter is reasonable. Composites have different characteristics than aluminum, but the reduction of weight is important in decreasing of fuel consuption.

VI. RESISTANCE

A. *REDUCTION OF INDUCED RESISTANCE*

Induced resistance can be reduced by appropriate adjustment to the shape of a wing profile so that we can affect some of the phenomena, which is dependent induced resistance. The first option is to increase the Aspect ratio (problems with maintaining sufficient strength of slender wings and short range due to lower volume tanks) and other winglets.

Winglet is specially shaped, generally vertical surfaces, located on the edge of the wing. The task of winglets is a good way to reduce the size and capabilities of the induced current field. It achieves its shape, which operates on the fringe beliefs, easy to collapse and shifts the center of the faith of his edge, then over and under the wing. This greatly reduces the influence wing tips by induced currents. Comparing the fuel consumption of aircraft without winglets, and it was found that the use of winglets and the associated reduction of induced resistance can reduce fuel consumption by 3-5%.

The shape and profile of winglets is proposed to measure the use of a particular type of aircraft. Nevertheless, the winglets can be divided into two basic groups:

- classical (conventional) winglets - vertical corresponding shape formed in the sole of the wingtips

Figure 1. Classical winglet A319 and Boeing 737

- unconventional (known raked) winglets - is a special kind of the end of the wing-like spurs are used in the latest aircraft

Figure 2. Raked winglet Boeing 787

Winglets are used for example on airplanes:

- Airbus A320
- Airbus A380
- Boeing B737NG
- Boeing B777
- Boeing B787

Device similar shape of winglets can be found on the ends of blades for new types of propellers.

B. REDUCE RESISTANCE OF CONTROL SURFACES BY ACTIVE INFLUENCING OF BOUNDARY LAYERS

Airbus has tested in accordance with available resources in developing its A380 aircraft at ways to reduce the resistance of control surfaces using active influence of the boundary layer. This concept is called Airbus' hybrid laminar flow technology. Raincoats, the rising part of the control surfaces are covered with thousands of tiny holes through which a vacuum system sucked aircraft boundary layer on the surfaces of these parts. According to Airbus has been achieved thanks to perfectly wrap around the control surfaces with minimal turbulent accompanied by a reduction in the resistance of these surfaces in air flow around a stream.

VII. POWER UNITS NOISE REDUCTION

A. NOISE GENERATED PARTS-FLOW POWER UNITS BY AIR OR GASES

Noise consists of wrapping and subsequent vibration particulate air moving around (outside) part of the engine. Vibrations caused by particle-noise sound waves.

According to the type of power unit, these components in particular:

- the piston and turboprop engine – propeller
- the jet engine - supercharger (compressor) of outer pass degree and the engine outer overpass of bypass turbojet engine
- regardless of unit type - flow exhaust / effluent gases of the power unit

B. PROPELLER

Particulate air flow around a rapidly rotating propeller blades are formed by sound waves, forming a very strong (> = 100 db) noise. Producer tries to suppress this noise, construction of new low-speed propeller with a large number (up to 7) of blades. Individual blades are compared with classical concepts, very complex shape, which is a perfect wrapping the entire length of blade (wrap different speeds according to orbital speed), thereby reducing noise. Also, slow-speed propeller design has further reduced the noise levels lower pass rates of individual sheets and provide the change in frequency of noise generated by lower values. Greater number of blades ensures adequate transmission performance even at low speed propeller.

C. TRENT 1000 (BOEING 787 ENGINE)

The Trent 1000 family makes extensive use of technology derived from the Trent 8104 demonstrator. In order to fulfill Boeing's requirement for a "more-electric" engine, the Trent 1000 is a bleedless design, with power take-off from the intermediate-pressure spool instead of the high-pressure spool found in other members of the Trent family. A 2.8 m (110 in) diameter swept-back fan, with a smaller diameter hub to help maximize airflow, was specified. The bypass ratio has been increased over previous variants by suitable adjustments to the core flow. A high Pressure Ratio along with Contra-rotating the IP and HP spools improves efficiency and the use of more monolithic parts reduces the parts count to minimize maintenance costs. A tiled combustor is featured.

Figure 3. Modern turbofan engine with a large diameter

Figure 4. end-pass channel for suppressing noise blowers Trent 1000

D. BLOWER EXTERNAL PASS AND EXTERNAL PASS OF BYPASS TURBOJET ENGINE

Airflow around the blades of the blower causes the sound waves, which spread outside the bypass channel and further into outer space. Compared propeller drive, however the frequency of the waves below and the subjective feelings of people have a lower impact. Manufacturers of jet engines are trying to reduce the level of bypass levels in several ways:

- enlarging the diameter of the blower - 20 years ago was a common bypass ratio of turbojet engine equal to the value of 2-3, today's modern two-lane bypass ratio engines reach 10

- modification bypass channel - an appropriate end of the bypass channel can be achieved by decomposition of the sound waves into a bigger space, whilst the direction of airflow from the blower is in the maximum extent possible, be maintained in an ideal direction. Thus the waves spread at any point reach a much lower intensity than was the case in their direction is fired into a small target area. End-pass channel usually reminds blade saws

E. FLOW EXHAUST / EFFLUENT GASES POWERPLANT

Noise also causes the wrapping of hot gases, based on the cylinder internal combustion engine or turbine engine components around the output of the engine. The internal combustion engine silencing carried downstream slowdown in the housing partition system - shock absorbers. Level of jet engine noise affects the shape of the end of engine. The resulting noise is then in this case the engine partially dampened (stripping) current of air rising from the outer by-pass channel.

VIII. RESULT

In this summary, we wanted to show stable development aircraft design in terms of aerodynamics and related changes, which ultimately means the economy and increase operational efficiency, reduced noise power units, or noise, generated due to the shape of the hull and other areas, and ultimately improves the safety and convenience of air transport. However, the technology in civil and also military aviation developed very quickly and each new aircraft will be in comparison to previous types more or less improved.

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Design of the Intelligent Tutorial Dialogue

New progressive methodology of ATC-controller training

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Abstract— **The contribution paper deals with the possibility to design and project the new progressive intelligent communication system between the ATC-controllers and automatic computer pseudo-pilots for training purposes. This tutorial intelligent dialogue would be applied and consequently used in the current air traffic procedure systems and methodology of ATC-controllers' training, aiming to improve and increase the level of their proficiency abilities, accuracy, and in general, overall total ATC-controller cadets' work-scope readiness during training for the ATC-controller profession.**

Keywords-component: ***aeronautical phraseology and terminology, training of ATC-controllers, ATC-controller cadet, pseudo-pilots, text-to-speech synthesis, automatic speech recognition, intelligent dialogue system, air traffic safety.***

Introduction

The presented design of the intelligent tutorial dialogue has been running within the 5-year project called "The Intelligent Technologies to increase Air Traffic Safety", in which the following four subjects participate:
1. University of West Bohemia in Pilsen, Department of Cybernetics
2. CS Soft Company, a.s.
3. SpeechTech Company, a.s.
4. Czech Technical University in Prague, Faculty of Transportation Sciences
The common effort of the above mentioned parties is to increase the air traffic safety by first-quality-trained ATC-controllers, who are one of the key personnel ensuring the high safety level of air transportation.

This project aims to design and develop a complex intelligent communication system between the ATC-controllers and automatic computer pseudo-pilots, including the following-up tests in the real traffic operations.
It is divided into a series of connected blocks and its target intelligent software should be able to:
a) create communication and prescribed aeronautical phraseology English training programs, including the checks of its adherence, correct listening and incorrect phraseology pronunciation identification; the system will also have the function to analyze and evaluate the ATC-controller cadet's progress;

b) make different quality changes of the received signal from an airplane board, such as disturbance, atmospheric interference, accompanying cockpit noise, cross-talks and skipping, etc.; in other words, it will arrange the intentional acoustic degradation of the pseudo-pilot's speech to train the ATC-controller cadet;

c) edit various training scenarios and situations preparing the ATC-controller cadet for the most "real" air traffic reality, by which it would improve his/her ability to correctly identify and recognize the exact situation, to choose the convenient solution and consequently to react in a more fast and calm way; in general it can be said that it makes the cadet's transition from the training program environment into the real ATC workspace much easier.

One of the whole project outputs, apart from the aforementioned ATC-controller simulator, will be also an active intelligent system, supporting air traffic control. This system will be able to convert the spoken speech into the written text, which enables the ATC-controllers to check and verify if they understand correctly a phrase received from pilots. It will work as the so called "cross-check". Its highest application will be to implement these gained pieces of information into the active guidance and controlling processes and their direct usage on the command- and instruction-screens of all the air traffic services units. The deadline for this action is planned at turn of 2015 and 2016 year.

1 The current methodology of ATC-controller training

The current methodology of ATC-controller training is based on the systematic training program – from ab-initio training

tasks, via fine-tuning and regular recurrent training with the ATC simulators.
The airplane role and its guiding as in the real air traffic is performed by a computer and the so called pseudo-pilot, which is a trained person to be an ATC instructor, or more often, the former pilots are used for this role. The ATC-controller cadet tries to control the simulated traffic by verbal instructions and he/she also keeps the communication connection with the airplanes under his/her responsibility at a given time-moment. The pseudo-pilot, usually sitting in the separated room, takes up the role of number of airplanes together.
The main idea of these simulations is to train the ATC cadets' knowledge, abilities and competence; on focus of training, there are commands and instructions from the ATC phrasing and diction, also reactions to typical and atypical flight situations.

The ATC cadet training process is a very expensive activity; in total expenses there are the pseudo-pilots' salary expenses to be taken into account.

Moreover, the described way of training contains a lot of from the non-removable human factor (human performance and limitations), appearing particularly in the pseudo-pilots' reactions and behavior changes, and also in "a higher level of toleration" towards the cadet being-trained. Comparing to the "un-human" computer, the pseudo-pilots do not insist on adhering precise phraseology and correcting possible cadets' errors, they also incline to simulate easier training situations.

The solution of the current training methodology negative aspects is stemming from substituting the right "human" pseudo-pilots with the "un-human computer" ones, which will communicate via the automatic speech recognition and text-to-speech synthesis. Apart from the newly-gained big benefit such as making the cadet training much cheaper, they can also offer a wider situations and content range of training scenarios and syllabi.

2. Design description of new communication training system

The preparation for the widest range of model situations must emphasize especially the verbal communication in the English language. In the operations of international air transportation, there are different nations to meet, which means that the radiotelephony communication English is impacted and to some extent modified a lot by language pattern and pronunciation typical for the mother tongue of the given nation or country. The phonetic vocabulary, in brief the way how to pronounce consonants, vowels, syllables, words and sentences in the appropriate language, affects the understandability of speech so much that it can result in a catastrophe.
In addition to that, in case of working under pressure during the high-intensity traffic or while sorting-out unforeseen situations, the ATC-controllers tend to a "more free" way of communication – due to the effort to solve it quickly and effectively. Pressed by lack of time, they often use words "not fully according to" the aeronautical phraseology; at once their English pronunciation contains more elements from their mother tongue – most often they change the speech rate, the speech pace fluctuates, there are also stress changes in words, etc. All these pronunciation deviations from the required standard have the great potential to change the whole meaning of transmitted and received messages.
History and present have already showed us the importance for the ATC-controllers to have some "aid or tool at disposal" to check actively, fast and without any unnecessary delay what was said actually by the pilot, just to be sure that he/she understands correctly and so he/she knows what the pilot is about to do. With this "checking" procedure, it is possible to directly substitute the situations known as "Say again, please", "Read back" or "Acknowledge" between the pilots and ATC-controllers, because these situations make frequencies much more congested.
The presented new communication training system should give the consistent ATC-controller preparation and training in various situations without any "prejudice in favor"; it should approach the reality of air traffic as much as possible to increase the level of their preparedness, competence, and in general safety of flight operations and air traffic services.

In the practical project realization, communication in the way to the ATC-controller cadet under training will be based on the computer text-to-speech synthesis (TTS).

2.1 Text-To-Speech Synthesis (TTS)

The computer text-to-speech synthesis will generate a speech, respectively the speech of the substituted "human" pseudo-pilots and so there will be no need to use these persons in the training any more. The synthesis itself will work upon software programming in advance, gained from the real air traffic communication. Therefore it will be able to make a dialogue with the cadet to control movements of individual airplanes.
It is necessary to add that in the nowadays systems of ATC training, communication between the pseudo-pilot and cadet runs on the clear frequency, without any interference, disturbance or sources of noise, which unfortunately makes many troubles to the ATC-controllers during the transition into the real traffic workspace. They must get used to this "worse-quality and degraded" communication, they need some additional time to adapt to this style. The TTS application can remove this serious problem, or at least significantly minimize it. Thanks to the information on the speech structure, it is able to deliberately degrade and damage the speech, including

placing atmospheric interference, frequency disturbance, airplane noise background, etc.

2.2 Automatic Speech Recognition (ASR)

The automatic speech recognition will be the foundation for communicating in the way from the cadet under training to the pseudo-pilot, here already fully substituted by the computer one. Utterly independently, it will convert the cadet's instructions to a text form and consequently handle them to the computer pseudo-pilot. The Department of Cybernetics has a lot of experience in this technology. Also, after being combined with the knowledge and know-how of the other subject, SpeechTech Company, the "real-time-working" ASR will arise.

Other possible usage in practice can be the software application for teaching and self-studying aeronautical English, phraseology and terminology.

2.3 Intelligent Dialogue System (IDS)

The intelligent dialogue system as the main intended output of this 5-year project will combine both of the described ways of communication processes in one together interconnected body. The software will carry out the control of airplanes with the help of the required changes in heading, flight level and speed, strictly according to the cadet's instructions. And the cadet's task will be to react to these situations as they unfold further.
The closer to the air traffic reality the designed system will be adjusted, the better and more effective the ATC-cadet training will become.

2.4 Training scenarios

To really achieve the success with this project including its practical implementation, it is also possible to design the specific training scenarios according to the needs of potential software users. The training scenarios can be described as the situational plans of all the individual flight events during the flight phases – from a "no-trouble" flight, via the progress of a standard enroute flight up to landing. To full-fill the main training idea of the simulator, these training scenarios must also contain unexpected situations, abnormal ones and emergencies, asking the ATC-controller for an immediate solution.

2.5 Active "clue" for the ATC-controller = "what I hear, I can verify by reading"

As it has been said, the ATC-controllers often face different "versions" of the aeronautical English. Many times it only depends on the ATC-controller's listening ability and experience to "decode" the pilot's speech, impacted for example with a very strong Chinese accent.
These obstacles can be removed by the last planned element of this project, which is to use the automatic speech recognition, i.e. the ASR, as the active tool for the ATC-controller screens. In practice, it would re-write the real-time pilot's speech, transmitted on the frequency from the airplane board, into the monitor/ radar screen. This application should help the controllers understand the appropriate communication, reduce their workload and it would also prevent from requirements to repeat transmitting.

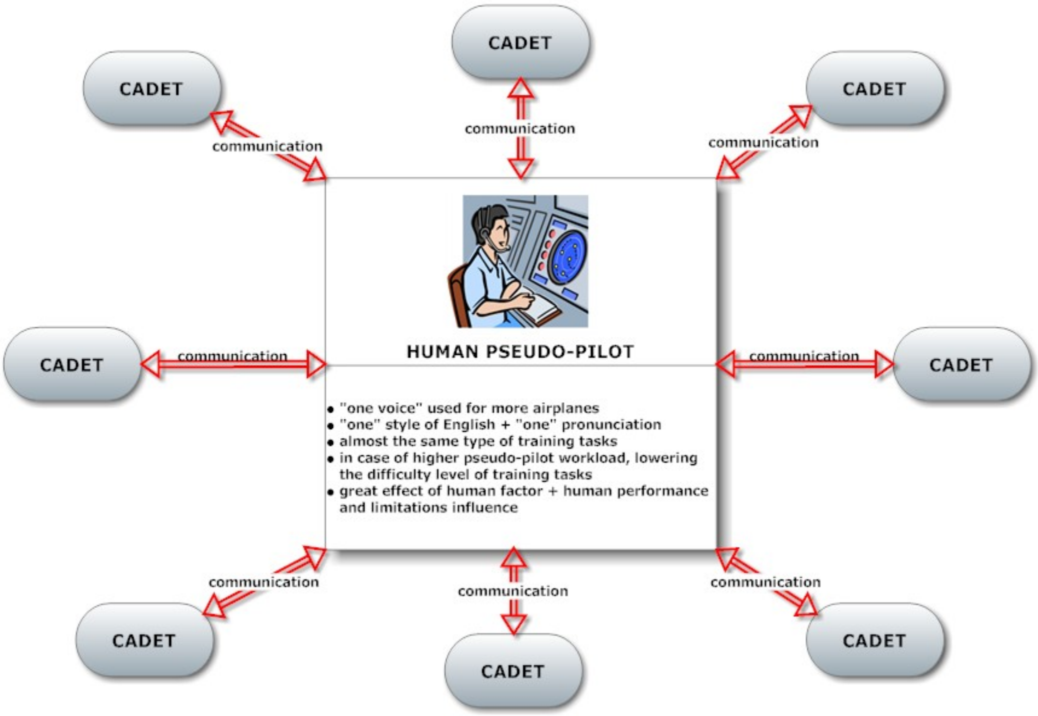

Figure 1. The current methodology of ATC-controller training

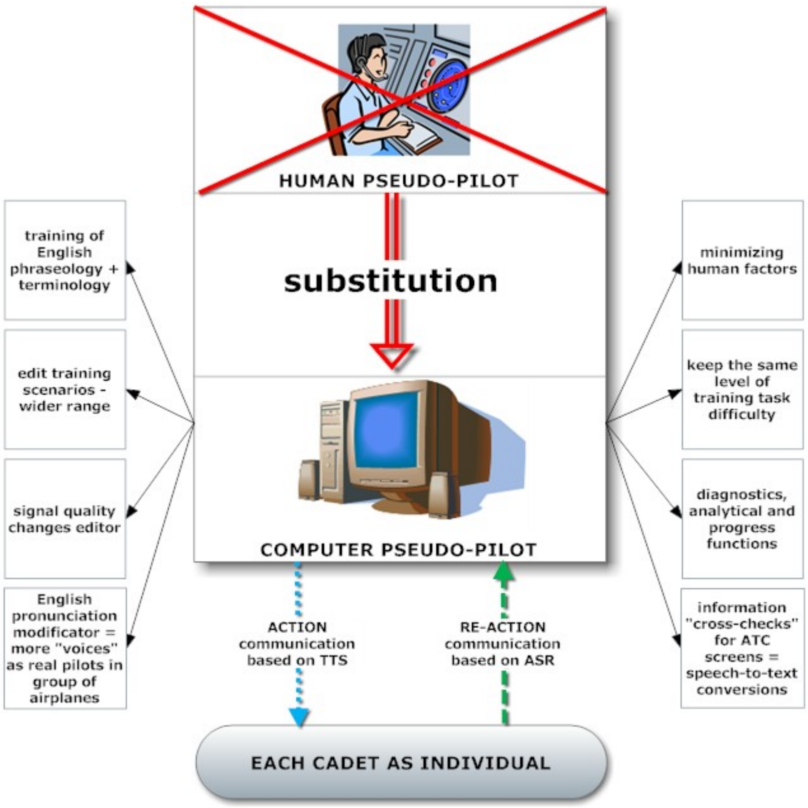

Figure 2. Design description of new communication training system

1090ES ADS-B OUT Implementation and Position Quality Indicators Evolution

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***Abstract*— ADS-B is designed to support numerous surveillance airborne and surface applications. Many of the ADS-B Out and ADS-B In applications demand rigorous operational performance requirements specifications especially as far as the transmitted position quality indicators are concerned. Nevertheless significant redefinitions of these indicators have occurred during the last decade of definition phase and implementation process which make it difficult for correct understanding in all aspects.**

Keywords-component; ADS-B, NUC, NAC, NIC, SIL, SDA, ADS-B-NRA, ADS-B-RAD

I. INTRODUCTION

To be able to use an aircraft in operationally in an ADS-B environment, Airworthiness Approval and Operational Approval is needed to obtain. The current scope of the airworthiness approval is the certification of "ADS-B out" avionics in support of the implementation of the "Enhanced Air Traffic Services in Non-Radar Areas using ADS-B Surveillance" (ADS-B-NRA) application. ADS-B-NRA airworthiness approval achieved through EASA AMC 20-24 ("Acceptable Means of Compliance") material. (Such certification allows apply 5 NM separation in non-radar airspace (NRA) compared to current (80 NM, 50 NM, 30 NM or 10 min) procedural separation.) ADS-B-RAD AMC material is under development by EASA [1].

In line with AMC 20-24, the key avionics requirements are related to:

- ICAO Version 0 (Aircraft Installation complying to transponder standards DO-260/ED-102 and DO-242) as specified in ICAO Annex 10, Volume IV, Chapter 3, (up to and including Amendment 82 to ICAO Annex 10) and Chapter 2 of the Technical Provisions for Mode S Services and Extended Squitter (ICAO Doc 9871) (Equivalent to DO-260)
- ICAO Version 1 (Aircraft Installation complying to DO- 260A and DO-242A) Version 1 ES as specified in Chapter 3 of the Technical Provisions for Mode S Services and Extended Squitter (ICAO Doc 9871) (Equivalent to DO-260A).
- ICAO Version 2 (Aircraft Installation complying to DO- 260B/ED-102A and DO-242B)

First 1090 MHz ADS-B MOPS was published on 13 September 2000 as RTCA DO-260 (and EUROCAE ED-102). 1090 MHz ADS-B/TIS-B MOPS Revision A (a major set of changes to the original DO-260) was published on 10 April 2003 as RTCA DO-260A. Change 1 to DO-260, published 27June 2006 (EUROCAE has not adopted Change 1). Change 1 to DO-260A, published 27 June 2006. Change 2 to DO-260A, published 13 December 2006. 1090 MHz ADS-B/TIS-B MOPS, Revision B was published 2 December 2009 as RTCA DO-260B (and EUROCAE ED-102A).

II. ADS-B OUT AIRBORNE EQUIPAGE MANDATE

The geographic areas with ADS-B Out implementation mandate for airborne equipage:

- Canada's Hudson Bay region (and Minto Sector), (DO-260 or later) segregate airspace between FL 350 to 400, from 18 November 2010.
- Australia (DO-260 or later), FL 290 and above, from 12 December 2013. (From June 2012 for all new airplanes in Australian airspace).
- Europe (EUROCONTROL), forward fit (new aircraft) (DO-260B or later), by 8 January 2015 (preliminary), retrofit (existing aircraft) (DO-260B or later), by 7 December 2017 (preliminary). Aircraft weighing above 12,566 pounds (5,700 kg) or flying more than 250 knots cruising speed, flying IFR as general air traffic (GAT) must be equipped with mode-S transponders compliant with the updated DO260B/ED102A standard, transmitting 1090 MHz extended squitter (ES) position reports. Transponders must be integrated with a global navigation satellite system (GNSS)-based position data source [2].

- USA (FAA) including Gulf of Mexico, (DO-260B or later) after 1 January 2020. In class A, B and C airspace. And above 10,000 ft MSL in Class E airspace (except in Hawaii and Alaska).
- Hong Kong, China - After 31 December 2013 for aircraft flying over PBN routes L642 or M771 between FL290 and FL410. After 31 December 2014 for aircraft flying within Hong Kong FIR between FL290 and FL410. Must meet DO-260 (Version 0), or DO-260A (Version 1).
- Singapore - Implement the use of ADS-B Out after 12 December 2013 within certain parts of the Singapore FIR at FL290 and above. The implementation would require aircraft equipped with avionics compliant with either: Version 0 ES or Version 1 ES. [6]

III. Position Quality Indicators

A. Version 0

NUC (NUC_P, NUC_R) - Navigation Uncertainty Category indicator represents a combined expression of accuracy and integrity requirements through a single parameter. (NUC_P – for position, NUC_R – for velocity.)

B. Version 1

Accuracy and integrity indications for position were separated. NAC (NAC_P, NAC_V), NIC, SIL indicators were defined instead of NUC.

In Change 2 of DO-260A a modification has been made to SIL Subfield Encoding. This change has inserted a dependence on VPL (Vertical Protection Limit) for Surveillance Integrity Level (SIL) encoding (for NIC values >8) when previously SIL was defined in terms of the horizontal integrity limits only. If a VPL cannot be provided for those NIC values (9, 10, and 11) then the SIL subfield must be set to a value of 0.

A similar dependency on VPL exists for NIC Encoding. If a VPL cannot be provided then the NIC parameter cannot be declared higher than 8, even if the horizontal position sensor is reporting an HPL equivalent to a NIC = 9 or a higher value.

It resulted in a situation, when a transmitted SIL value of 0 limits the usefulness of that aircraft's ADS-B Out data set as many applications for ADS-B Out will require a minimum SIL value of 2 or better.

(Similarly, the dependency of NIC on VPL is an artificial limitation on the ADS-B system performance. This would limit the NIC value that can be declared to a maximum value of 8 when the aircraft's true horizontal integrity performance might be a NIC value of 9 or greater.)

For example industry and many ANSPs are evaluating multiple solutions to mitigate Runway Incursion issues, including the use of ADS-B Out data and surface ADS-B In applications on a CDTI. These surface applications will require high value horizontal accuracy and integrity data. The performance and availability of targets for these applications would be limited by the dependence on vertical accuracy and integrity in the transmitted NIC, SIL, NAC_P and NAC_V parameters, even though the vertical data is irrelevant for their operation.

In DO-260B, as a result above discussion, the requirements for the vertical components of NIC, NACp and SIL were removed.

C. Version 2

The quality indicator information: NAC (NAC_P, NAC_V), NIC, SIL, (SIL_{SUPP}), SDA, GVA

One of the most significant change compare to earlier versions was concerned redefining the SIL parameter. The SIL definition for ADS-B transmits of position quality in DO-242A was originally proposed to cover two functions:

(1) the position source (signal-in-space) containment integrity risk level associated with the broadcast of containment integrity as encoded in the NIC parameter, and

(2) the functional integrity of the source position avionics, e.g., GNSS receiver.

Later definitions of SIL included yet more functions, i.e.

(3) SIL could represent the functional integrity of the entire transmit avionics chain from the position source to the ADS-B out transmit function including the broadcast message function of the ADS-B transponder.

Under this earlier definition, the SIL value is the minimum integrity indicator of any of the above functions. The issue is that the SIL parameter has become badly overloaded and the receiver cannot tell which of the above functions the basis of the SIL value transmitted is.

From the viewpoint of the RAD and NRA ADS-B Out Applications, the SIL parameter is inadequate to be used as the basis of received containment integrity. For these applications, the certification basis is that the containment integrity for radar-like surveillance standards needs to be equivalent to that of a RAIM GPS unit, i.e. certified to 10^{-7} per hour level or equivalent to SIL=3 level, whereas the functional integrity of the avionics hardware only needs to be SIL=2 level, i.e. certified to major hazard level or 10^{-5} per hour level. The reason for the difference in integrity requirements is that for radar-like separation standards, a 10^{-7} integrity level in position containment is needed to protect against area-wide failures in position integrity affecting more than one aircraft, whereas the avionics integrity level is only needed to protect against integrity failures affecting a single aircraft. [4]

According DO-260B/ED-102A the position quality parameters interpretation is as follows:

SIL (Source Integrity Level) is used to define the probability of the reported horizontal position exceeding the Integrity containment radius defined by the NIC, without alerting, assuming no avionics faults. I.e. the SIL will address the Signal-in-Space (SIS).

SIL_{SUPP} (Source Integrity Level Supplement). The field that shall define whether the reported SIL probability is based on a per hour probability or a per sample probability. The probability of exceeding the integrity containment radius for

GNSS position sources are based on a per hour basis, as the NIC will be derived from the GNSS Horizontal Protection Level (HPL) which is based on a probability of $1x10^{-7}$ per hour. The probability of exceeding the integrity containment radius for IRU, DME/DME and DME/DME/LOC position sources may be based on a per sample basis.

SDA (System Design Assurance) The parameter indicates the probability of ADS-B system malfunction causing false or misleading information to be transmitted. (The ADS-B system includes the ADS-B transmission equipment, ADS-B processing equipment, position source, and any other equipment that processes the position data transmitted by the ADS-B system.)

NAC (Navigation Accuracy Category), NAC_P for position, NAC_V for velocity. NAC_P provides an indication of position accuracy based on EPU parameter. The Estimated Position Uncertainty (EPU) is a 95% accuracy bound on horizontal position. EPU is defined as the radius of a circle, centered on the reported position, such that the probability of the actual position lying outside the circle is 0.05. When reported by a GPS or GNSS system, EPU is commonly called HFOM (Horizontal Figure of Merit) [7].

GVA (Geometric Vertical Accuracy) The GVA field shall be set by using the VFOM (Vertical Figure of Merit) 95% from the GNSS position source used to report the geometric altitude. (Geometric altitude is defined as the shortest distance from the current aircraft position to the surface of the WGS-84 ellipsoid, known as Height Above Ellipsoid (HAE).

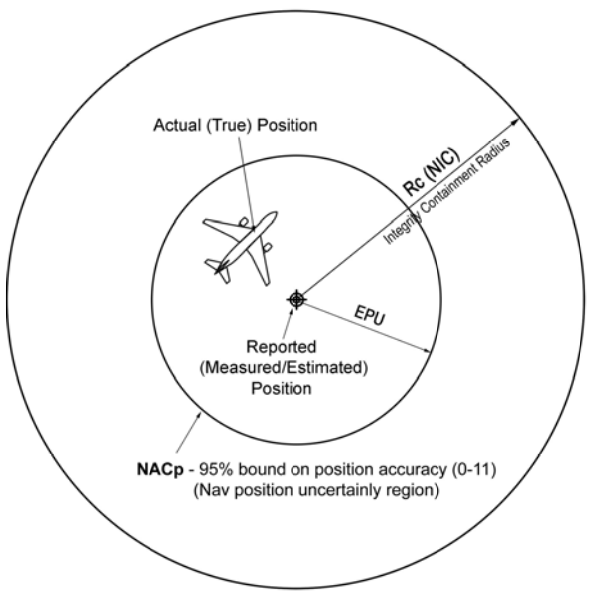

Figure 1. Surveillance position uncertainly regions crresponding NAC, NIC and SIL indicators

IV. POSITION DATA PERFORMANCE REQUIREMENTS

There are specified many surveillance applications both ADS-B ground surveillance applications (such as: ATC surveillance in radar airspace (ADS-B-RAD), ATC surveillance in non-radar areas (ADS-B-NRA), Airport surface surveillance (ADS-B-APT), Aircraft derived data for ground tools (ADS-B-ADD)…) and Airborne surveillance applications (such as: Airborne traffic situation awareness applications, Airborne spacing applications, Airborne separation applications, Airborne self-separation applications, …). For each of above mention applications the minimum performance position requirements specification is essential. For some of them the values of position indicators have been specified yet, for some, especially as far as the airborne surveillance applications are concerned the finalization process is still under way. Note that some inconsistency of specific minimum value (NUC, NAC_P, NIC, SIL indicators) for various applications exists under different documents. According to the DO-303 and DO-318, the following minimum values of position quality parameters must be broadcasted in support of ADS-B-NRA and ADS-B-RAD applications (see TABLE I).

TABLE I. ADS-B OUT APPLICATIONS – MINIMUM PERFORMANCE REQUIREMENTS IN COMPLIANCE WITH DO-303 AND DO-318

	NAC_P	*NAC_V*	*NIC*	*SIL*	*SDA*
ADS-B-NRA 5 NM (EnRoute)	≥ 5	N/A	≥4	≥ 2	≥ 2
ADS-B-NRA 3 NM (EnRoute)	≥ 6	N/A	≥5	≥ 2	≥ 2
ADS-B-RAD 5 NM (EnRoute)	≥ 7	N/A	≥5	≥ 2	≥ 3
ADS-B-RAD 3 NM (Terminal)	≥ 8	N/A	≥6	≥ 2	≥ 3
ADS-B-RAD 2.5 NM (Approach)	≥ 8	N/A	≥7	≥ 2	≥ 3
ADS-B-RAD 2.0 NM (Approach)	≥ 8	N/A	≥7	≥ 2	≥ 3
ADS-B-RAD Independent Parallel Approach	≥ 8	N/A	≥7	≥ 2	≥ 3

V. CONCLUSION

The paper pointed to the complexity of ADS-B implementation process when during the transition period the ANSPs must take into account the fact that they will meet aircrafts which avionics ADS-B installation will be compliant under different standards (see chapter I). That brings difficulties due to usage various parameters and different interpretation of them. It is expected that aircraft installation complying with DO-260/ED-102 and DO-242 will be sufficient airborne equipment standard in some geographical region till at least 2020.

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Emission Reduction Through Continuous Descent Approaches

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The continuous growth of aviation is necessarily accompanied by environmental issues that need to be addressed to achieve sustainable development of the business. One of the challenges is to start reducing air pollution immediately through a method that is already available. Such a method may be the Continuous Descent Approach that reduces emissions by optimizing aircraft descent profiles and minimizing required thrust. This procedure has been verified at Prague airport using data from Airbus A320/321 flights. Although more research needs to be done to precisely evaluate the impact, this article confirms the expected benefits and justifies further work on the topic.

Aviation and Environmental Issues

In the recent years, there has been an increasing concern about the impact of the growing aviation business on the environment. One of the consequences is the aversion of citizens to further development of aviation-related infrastructure and their demands for night curfews, movement limitations and route changes in the vicinity of busy airports. However, aviation is also an important element of both global and local economy. Therefore the challenge is not to restrict the growth of air transport but to make it sustainable.

The two main environmental aspects of aircraft operations are noise and air pollution. While the noise produced by both aircraft and airport operations is more perceptible to an individual, it is mainly confined to an area of several kilometers around the aerodrome. The air pollution, although generally imperceptible to human senses, is ubiquitous and has long-term deteriorating effects on health, nature and climate. According to an Intergovernmental Panel on Climate Change (IPCC) report [1], carbon dioxide (CO_2) emissions from aviation sources contribute approximately 2% to all global greenhouse gas emissions, but together with other aircraft-originated gaseous and solid pollutants account for 3.5% of radiative forcing, which represents the change in energy balance between the Earth and the atmosphere. Although there has been a great advance in modern aircraft fuel efficiency, the relatively slow global fleet renewal and the increasing volume of air traffic call for additional operational measures to mitigate the impact of aviation on the environment.

Aviation Fuel Emissions

About 70% of aircraft emissions are made of CO_2, water (H_2O) is responsible for nearly 30%, the remainder being composed of nitrogen oxides (NOx), carbon monoxide (CO), sulphur oxides (SOx), volatile organic compounds (VOC), particulates and other trace compounds [2]. Aviation fuel like other oil fractions mostly consist of hydrocarbons that combine with oxygen to form CO_2. Given the atomic weights of carbon (12) and oxygen (16), 1kg of burnt fuel produces approximately 3.15kg of CO_2. The amount of pollutants released to the air greatly depends on the phase of flight. In general, the take-off and climb phases, although the most demanding in terms of the engine power required and therefore the fuel flow, are relatively short compared to the cruise phase, which accounts for the greatest proportion of the total fuel consumption. During the approach and landing phases, a relatively low fuel consumption should produce the least emissions. However, with average flight times in Europe being only 60min [3], early speed control and level restrictions and frequent delays at busy airports increase the importance of changes in arrival operational procedures with the view to reducing the environmental burden.

Continuous Descent Approach

A method that is readily available with current aircraft technology is the Continuous Descent Approach (CDA) or Continuous Descent Operations (CDO). There are two different phases of flight between the cruise phase and the landing that may be referred to as CDA:

- Top-of-descent (TOD) point to final approach fix (FAF), hereafter referred to as CDA.
- Final approach fix to landing, hereafter referred to as Continuous Descent Final Approach (CDFA).

CDFA substitutes the traditional way of flying a non-precision instrument approach in vertical steps with a safer constant-angle profile that generally maintains the aircraft higher above the ground and minimizes the need for sudden and repeated power changes, thus reducing both the noise levels and fuel consumption. With most significant airports being equipped with an Instrument Landing System (ILS), continuous final approaches have been the norm for a long time and CDFA is not discussed further in this article.

CDA is a method whereby an aircraft is allowed to descend from its cruise flight level on an optimum profile determined by the aircraft's flight management system (FMS) with the engines at idle thrust. Similarly to CDFA, power changes during the descent are limited and the aircraft does not descend earlier or faster than needed to reach a predetermined point (e.g. FAF) at a selected level (e.g. intermediate approach altitude). Although noise levels are somewhat reduced, a greater part of the descent phase corresponds to relatively high flight levels at which the aircraft are nearly inaudible anyway. Therefore, the noise reduction of CDFA is more significant than in case of CDA. On the other hand, the fuel-saving effect of CDA is more pronounced due to the following two factors:

- Idle, i.e. minimum possible thrust is used.
- Aircraft are not held at low altitudes, where fuel consumption for a given distance or time flown increases.

Most airliners are equipped with FMS and are capable of calculating and following the optimum descent profile if the level difference, ground distance to go and outer air conditions are known. Moreover, pilots already generally fly these optimum paths if not restricted by air traffic control (ATC). Therefore, little change in in-flight procedures is needed. More work needs to be done in terms of ATC as the current airspace organization does not usually allow the aircraft to be cleared directly from its cruise flight level down to the intermediate approach altitude, early descents are frequently required to meet the inter-sector coordination conditions and speed restrictions, delays or track changes are applied at busy airports to accommodate the traffic. At the same time, aircraft descent profiles are currently hardly predictable by ATC. They depend on various factors like the aircraft type, weight, cruise level, wind etc. As a result, CDAs are currently feasible during low traffic intensity periods only when aircraft are "monitored" rather than controlled by ATC.

To justify the investment into improved ATC planning tools and air-to-ground data interchange systems, it is necessary to verify the expected benefits of CDA in practice. During April and May 2011, flight data from a set of CDA and non-CDA arrivals at Prague – Ruzyne airport were collected to assess the differences in the fuel used during a part of the descent.

CONDITIONS

The trial involved Airbus A321 and A320 aircraft, data from A319 flights were also available but the severe prevalence of CDA flights compared to non-CDA flights precluded their use in the evaluation. The data were taken from the Quick Access Recorder (QAR) that records various flight parameters in 1s intervals. To assess the progress of the approach, the following parameters were used:

1. Flight time – to measure the total time of the monitored part of descents and to calculate the total amount of fuel used. The timing started when the aircraft passed an altitude of 16000ft (or the nearest higher or lower value depending on the data available, if the differences of the higher and lower values were equal, the higher value was used) and ended when reaching a stable radio height of 0ft.
2. Barometric altitude – to set a common reference start for all measurements. 16000ft were used to apply the CDA procedure in lower airspace only/terminal area and therefore to limit the impact on other traffic.
3. Radio altimeter height – to set a common reference for landing.
4. Vertical speed – to confirm whether the descent was continuous. Crews were also asked to mark the descent as CDA or non-CDA using the "event" function of QAR. However, some CDA-marked descents contained a record of a positive vertical speed or the altitude-maintaining mode of the autopilot. Such flights were considered non-CDA in the trial.
5. Vertical mode – to confirm that no selected altitude was maintained during the descent except for a period of time just before the final approach, which was unavoidable to capture the glide path of ILS.
6. Aircraft mass – to adjust the results for different masses. The last recorded mass before the landing, rounded to the nearest 100kg, was used.
7. Fuel flow – to calculate the average fuel flow and the total fuel consumption.

LIMITATIONS

The barometric altitude recorded by QAR is related to the standard altimeter setting of 1013hPa and does not take into account current pressure and temperature changes. The actual vertical distance flown by the aircraft might have been different. If so, it would have influenced both CDA and non-CDA flights and therefore no correction was applied. The selected parameters were monitored down to the landing, i.e. including the final approach to avoid an arbitrary division of the two descent phases. All of the flights performed an ILS approach, therefore no additional fuel inefficiency was assumed. While the A321 data proceed from flights from the same direction presumably using the same arrival route, the A320 data include various directions with unequal lengths of the arrival route. The CDA flights should be unbiased by this fact as it is the distance to go, not the distance along the route, that determines TOD. However, the non-CDA flights might have been influenced by some level or speed restrictions applied on some of the arrival routes only.

6 CDA and 20 non-CDA A321 flights and 7 CDA and 3 non-CDA A320 flights were assessed. A greater and more balanced amount of flights should be evaluated to obtain

more accurate results but even such a small sample is indicative of some important trends.

METHOD

For each flight, the time taken to descend from an altitude of 16000ft to a height of 0ft (the elevation of Prague airport is 1247ft) was recorded and the mean fuel flow (FF) of each engine was calculated to find the average consumption during the descent. Using linear regression for each data set (A321/CDA, A321/non-CDA, A320/CDA, A320/non-CDA), the average fuel flow for the mean aircraft type mass was calculated and the values for a corresponding average CDA and non-CDA descent compared. These average values and mean times were used to calculate the total fuel used (FU).

Aircraft	***A321***	***A320***
Mean mass (kg)	70363	57224
CDA average FF (kg/h)	2537	969
Non-CDA average FF (kg/h)	2867	1216
CDA to non-CDA FF ratio	1:1.13	1:1.25
CDA average FU (kg)	537	200
Non-CDA average FU (kg)	670	276
CDA to non-CDA FU ratio	1:1.25	1:1.38
CDA mean time (h)	0.212	0.208
Non-CDA mean time (h)	0.234	0.227
CDA to non-CDA time ratio	1:1.10	1:1.09

CONCLUSION

The results confirm that the there is a reduction in fuel flow both for A320 and A321 (20% and 12% respectively) during the CDA descents. However, the benefit to the environment in terms of emissions is even more significant as CDA descents take about 10% less time than non-CDA ones, therefore the overall reduction in fuel consumption and emissions is 28% for A320 and 20% for A321.

According to [4], with the A320 family average fuel consumption of 5990 kg for a 500-mile sector representative of a slightly longer-than-average European flight, there is a potential to reduce the emissions by 3.5% just by introducing the continuous descent approach method. Such a reduction should be enough to offset the growth of the aviation business in the short term and together with the improvements in technology and changes in procedures during other phases of flight can contribute to a sustainable development of air traffic in the future.

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Practical Usage of Allan Variance in Inertial Sensor Parameters Estimation and Modeling

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***Abstract*—This paper shows a time-domain approach to sensor parameters estimation via Allan VARiance analysis (AVAR). The aim of this paper is not to describe AVAR and its modifications in details, but to show its applicability and suitability for the estimation of inertial sensors parameters and consecutive usage of these parameters in sensors modeling. To prove the suitability of proposed sensor models there was used a composed model for Kalman filter which provided corrected angular rates and accelerations for attitude evaluation.**

Keywords- inertial navigation; sensor modeling; Allan variance analysis; data fusion

I. Introduction

In the field of inertial sensor errors estimation and modeling there exist various known methods using for example PSD (Power Spectral Density) and ACF (Auto Correlation Function) which are straightforward; however, these methods cannot clearly distinguish different characters of noise error sources inside the data without understanding of a sensor model and its state-space representation [1]. Allan VARiance analysis (AVAR) is a time-domain approach to analyse time series of data from noise terms point of view. The AVAR was introduced by D. W. Allan in 1966 in [2]. Originally, it was orientated at the study of oscillator stability; however, after its first publication this kind of analysis was adopted for general noisy data characterization. Because of the close analogies to inertial sensors the AVAR has been also included in IEEE Standard [3, 4, 5, 6]. As described in [7] the AVAR technique provides several significant advantages over the others. Traditional approaches, such as computing the sampled mean and variance from a measured data set, do not reveal the underlying error sources. Although the combined PSD/ACF approach provides a complete description of error sources, the results are difficult to interpret [8].

The AVAR estimates the variance of averaged data in a cluster of a certain length, which is defined by interval τ, moving through the whole data set. The AVAR characterizes Allan deviation that can vary based on the cluster length τ and analysed data set y. A basic equation can be defined as [9]:

$$\sigma_y^2 = f(\tau, y). \tag{1}$$

The AVAR has some modifications and based on the shift of clusters in the data set and corresponding AVAR calculations (for details see [9]) it is possible to distinguish three basic types of AVAR: non-overlapped (original), overlapped, and modified. There also exists another type called dynamic AVAR, for details see [10, 11]. The original non-overlapped AVAR is defined as [9]:

$$\sigma_y^2(\tau) = \frac{1}{2(M-1)} \sum_{i=1}^{M-1} (\bar{y}_{i+1} - \bar{y}_i), \tag{2}$$

where M is the number of clusters in the data set, $M=floor(N/m)$, N denotes the total number of samples in the data set, m – the number of samples in the cluster, τ represents the time length of the cluster, $\tau = m \times T_S$, T_S is the sampling period, $\bar{y}_i, \bar{y}_{i+1}$ are mean values of certain cluster corresponding to i and $i+1$ cluster.

In cases of short intervals τ there is a large number of used clusters which leads to small errors in estimation and large confidence. On the contrary, a small number of clusters in case of long τ leads to large errors in estimation and small confidence. The usage of the overlapped AVAR improves the confidence of the result estimate and its stability mainly in cases of long clusters where M comes close to value 2. However, the applicability and suitability of the overlapped AVAR for long data sets are questionable mainly for its high computational load. The confidence of the AVAR result corresponds to the estimate error defined as [1]:

$$\delta_\sigma(\tau) = \frac{1}{\sqrt{2(N/m-1)}}. \tag{3}$$

The AVAR and its results are related to seven noise terms that can be identified in inertial sensors output and whose estimation can lead to errors suppression in the data [6, 12]. The five basic noise terms correspond to the following random processes: angle/velocity random walk, rate/acceleration random walk, bias instability, quantization noise, and drift rate ramp. Furthermore, this basic set of random processes is extended by the sinusoidal noise and exponentially correlated (Markov) noise [12]. In most cases different noise processes

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appear in different length of time interval τ with different slopes or shapes. Due to this aspect long data set should be measured to be capable to cover all noise terms presented in it.

It can be assumed that if the existing random processes are all statistically independent then AVAR allows easy identification of various random processes based on their influences within the time interval τ. This paper is partially connected to previous our work related to data analysis published in [8]. Generally, the total error can be classified as a sum of individual independent noise errors [6] and the total variance can be expressed as (for abbreviations see Table 1):

$$\sigma_{total}^2 = \sigma_Q^2 + \sigma_{ARW}^2 + \sigma_{BIN}^2 + \sigma_{RRW}^2 + \sigma_{RR}^2. \quad (4)$$

In guidance and navigation applications the integrated velocities and integrated angles are also often used as observables instead of accelerations and angular rates. Therefore, when a quantization noise can be characterized by a white noise in integrated observables [3], it can be done the same way in measured accelerations and angular rates. A white noise can also be applied for the angle/velocity random walk modeling in measured quantities due its random walk effect in integrated observables [1].

Furthermore, the rest of the noise sources have to be considered and included in the model if their influences are not negligible and their shapes are visible in a log-log Allan deviation plot. For this kind of analysis long data (more than 1 hour) should be preferred. Basic mathematical description for the error sources are stated in Table 2.

Based on (4) the total error of terms needed for modeling can be expressed as [13]:

$$e_{total} = e_{BIN} + e_{RRW} + e_{RR}. \quad (5)$$

Individual models based on Table 2 can be defined with differential operator as:

$$e_{BIN} = \frac{\beta B w}{D+\beta}, \; e_{RRW} = \frac{Kw}{D}, \; e_{RR} = \frac{Rw}{D^2 + \sqrt{2}\omega_0 D + \omega_0^2}. \quad (6)$$

TABLE I. SUMMARY OF ERROR SOURCES AND THEIR CHARACTERIZATION

Type of the noise	Abb.	Curve slope	Value of the coefficients
Quantization noise	Q	-1	$Q = \sigma(\sqrt{3})$
Angular/velocity random walk	ARW	-1/2	$N = \sigma(1)$
Flicker noise/bias instability	BIN	0	$B = \sigma_{min}/0.664$
Rate/acceleration random walk	RRW	+1/2	$K = \sigma(3)$
Rate ramp noise	RR	+1	$R = \sigma(\sqrt{2})$

TABLE II. MODEL DEFINITIONS OF FIVE BASIC NOISE ERROR SOURCES

Types of error source	Basis for the model	Mathematical description
Q + ARW	white noise	–
BIN	1st order Gauss-Markov process	$\dot{e}(t) + \beta e(t) = \beta B w(t)$
RRW	random walk	$\dot{e}(t) = K w(t)$
RR	2nd order Gauss-Markov process	$\ddot{e}(t) + \sqrt{2}\omega_0 \dot{e}(t) + \omega_0^2 e(t) = R w(t)$

The substitution of (6) in (5) gives:

$$e_{total} = \frac{\beta B w}{D+\beta} + \frac{Kw}{D} + \frac{Rw}{D^2 + \sqrt{2}\omega_0 D + \omega_0^2}. \quad (7)$$

By rearranging (7) it leads to:

$$\begin{aligned} & D(D+\beta)\left(D^2 + \sqrt{2}\omega_0 D + \omega_0^2\right)e_{total} \\ & = K(D+\beta)\left(D^2 + \sqrt{2}\omega_0 D + \omega_0^2\right)w + \\ & + \beta B D\left(D^2 + \sqrt{2}\omega_0 D + \omega_0^2\right)w + \\ & + RD(D+\beta)w. \end{aligned} \quad (8)$$

Equation (8) can be also expressed in a general form:

$$a_4 e^{(4)} + a_3 e^{(3)} + a_2 e^{(2)} + a_1 e = b_3 w^{(3)} + b_2 w^{(2)} + b_1 w + b_0,$$

which leads to coefficients definition as:

$$\begin{aligned} & a_4 = 1; a_3 = \sqrt{2}\omega_0 + \beta; a_2 = \sqrt{2}\omega_0\beta + \omega_0^2; a_1 = \beta\omega_0^2 \\ & b_3 = K + \beta B; b_2 = \sqrt{2}\omega_0(K + \beta B) + \beta K + R; \\ & b_1 = \sqrt{2}\omega_0 \beta K + \omega_0^2(K + \beta B) + \beta R; b_0 = \omega_0^2 \beta K. \end{aligned}$$

II. EXPERIMENTAL RESULTS AND AVAR

To verify the method of error source coefficients estimation and identification using AVAR there were analyzed two AHRS (Attitude and Heading Reference System) units. Measured data sets taken from accelerometers (ACC) and angular rate sensors (ARS) were 5 hours long and included angular rate and acceleration signals in perpendicular 3D framework. The types of the AHRS units were 3DM-GX2 manufactured by MicroStrain and AHRS M3 from Innalabs (see Fig. 1). All data were sampled with the frequency 100 Hz.

Allan deviation plot of AHRS M3 unit is shown in Fig. 2 and was used for the estimation of corresponding parameters presented in Table 3.

The same evaluation was performed with the 3DM-GX2 unit and results are denoted in Fig. 3 and Table 4.

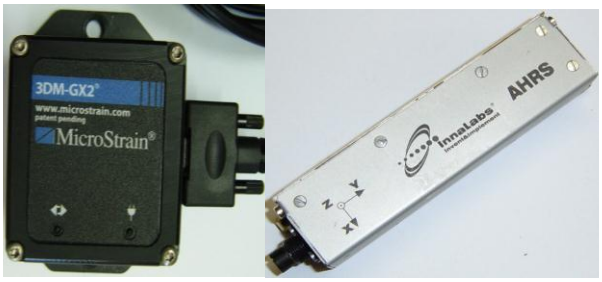

Figure 1. AHRS units estimated – 3DM-GX2 (left), AHRS M3 (right)

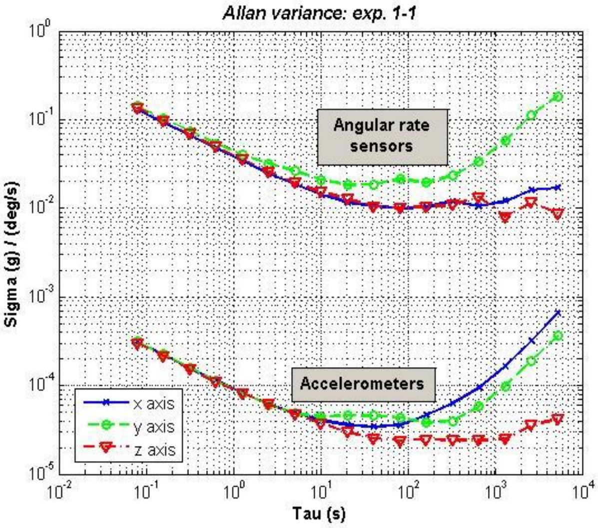

Figure 2. AVAR deviation plot of measured AHRS M3 unit

TABLE III. AHRS M3 – ESTIMATED PARAMETERS OF ARS & ACC SENSORS

AHRS-M3	Datasheet	*Angular rate sensors*		
		x	y	z
ARW (deg/ $\sqrt{hour}$)	6.0	2.3	2.7	2.4
In-run bias stability (deg/s)	0.10	0.06	0.11	0.06
		Accelerometers		
		x	y	z
VRW (m/s/ $\sqrt{hour}$)	0.060	0.052	0.052	0.052
In-run bias stability (mg)	-	0.20	0.23	0.14

TABLE IV. 3DM-GX2 – ESTIMATED PARAMETERS OF ARS & ACC SENSORS

AHRS-M3	Datasheet	*Angular rate sensors*		
		x	y	z
ARW (deg/ $\sqrt{hour}$)	3.5	1.9	1.8	1.8
In-run bias stability (deg/s)	0.10	0.04	0.04	0.04
		Accelerometers		
		x	y	z
VRW (m/s/ $\sqrt{hour}$)	-	0.047	0.053	0.053
In-run bias stability (mg)	1.2	0.20	0.20	0.20

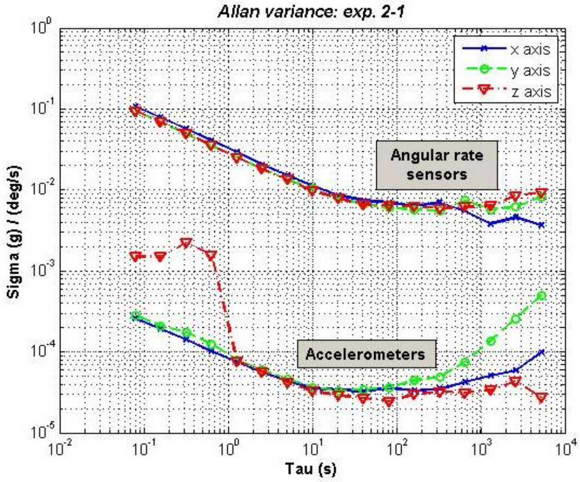

Figure 3. AVAR deviation plot of measured 3DM-GX2 unit

III. VERIFICATION OF ESTIMATED PARAMETERS

To verify the estimated parameters we have designed a model applicable for instance in a system of artificial horizon capable of attitude determination and its consecutive displaying. In a traditional way to get Euler angles (ROLL, PITCH, and YAW angles) from angular rates there is generally used an integration process. This process is applied to both desired angular rates and undesired sensor noises of MEMS inertial sensors. Therefore, the error in estimated Euler angles grows fast and without restrains due to undesired noise integration. This fact is usually overcome by fusing angular rates or angles with aiding systems. In our case the aiding was done with accelerometers orientated perpendicular to each other in 3D framework. The fusion was based on an assumption that only gravity acceleration was applied to the accelerometers [14]. The rest of influencing accelerations were considered as noises with the mean value equal to zero. The advantage of this kind of aiding is the fact that Euler angles estimated based just on measured accelerations do not diverge with time because they do omit the integration and are calculated directly. The model had been proposed for Extended Kalman Filtering (EKF) to provide estimates of gravity accelerations and angular rates corrected by measured accelerations. The principles of Kalman filtering methods and modifications can be found for instance in [15, 16, 17, 18]. Euler angles were then calculated based on estimated angular rates (ARS based estimation), estimated acceleration (ACC based estimation) and their fusion. The YAW angle diverged in case of stable azimuth because there was no aiding available from measured accelerations to compensate the bias and drift of ARS placed in the vertical axis.

The structure of the proposed model for EKF is illustrated in Fig. 4 and has been composed from (9) and (10) [14]:

$$\begin{aligned} \dot{\varphi} &= \omega_x + \omega_y \sin\varphi \tan\theta + \omega_z \cos\varphi \tan\theta, \\ \dot{\theta} &= \omega_y \cos\varphi - \omega_z \sin\varphi, \\ \dot{\psi} &= \omega_y \sin\varphi \sec\theta + \omega_z \cos\varphi \sec\theta, \end{aligned} \tag{9}$$

$$
\begin{aligned}
a_x &= -g\sin\theta,\\
a_y &= g\sin\varphi\cos\theta, \qquad (10)\\
a_z &= g\cos\varphi\cos\theta,
\end{aligned}
$$

where ω_x, ω_y, ω_z denote angular rates, φ, θ, ψ are ROLL, PITCH, and YAW angles, a_x, a_y, a_z represent gravity acceleration components, $g = 9.81\ m/s^2$.

Differentiating the (10) and substituting (9) in the results the system model equations are as follows:

$$
\begin{aligned}
\dot{a}_x &= -\dot{\theta}\cos\theta = \omega_z a_y - \omega_y a_z,\\
\dot{a}_y &= \dot{\varphi}\cos\varphi\cos\theta - \dot{\theta}\sin\varphi\sin\theta = -\omega_z a_x + \omega_x a_z, \qquad (11)\\
\dot{a}_z &= -\dot{\varphi}\sin\varphi\cos\theta - \dot{\theta}\cos\varphi\sin\theta = \omega_y a_x - \omega_x a_y.
\end{aligned}
$$

As measurement inputs there were used raw inertial data from ACC and ARS sensors that might be processed through calibration model to correct deterministic scale factor and axes misalignment errors before they enter the measurement model. The system model was using the absolute values of the angular rates and accelerations. For the accelerations model equation (11) was utilized. Angular rates were modeled by 1st order Gauss-Markov process as:

$$
\dot{\omega} = -\frac{1}{\tau}\omega + \frac{1}{\tau}w(t), \qquad (12)
$$

where τ – correlation time of ARS outputs, $w(t)$ – Gaussian white noise.

The rest of the system model states defined so called shaping filters accordant with error sources of only angular rates. Errors in accelerometer outputs were assumed as white noises, even if the outputs based on AVAR might be treated differently. We have evaluated the entire model for the cases when shaping filters were defined by only BIN and BIN+RRW of errors in angular rates.

We have carried out several evaluations with different shaping filter settings using the same data set. The data set corresponded to stationary experiment so the effect of AVAR based parameters settings could be observed. The results from their comparison evaluated with RMSE for both types of the shaping filters and different settings are indicated in Table 5. The RMSE was calculated with respect to the mean value of corresponding angle. In case of BIN model, mostly exponentially correlated noise model is considered; however, in our case BIN error source had had a large correlation time, which meant that the difference between random walk model and the exponentially correlated model was negligible. Therefore, for BIN shaping filter we used a random walk model. In case of combined BIN+RRW we used both types (random walk & exponentially correlated model).

In case of shaping filter considering only BIN error source the lowest RMSE was reached, see Table 5.

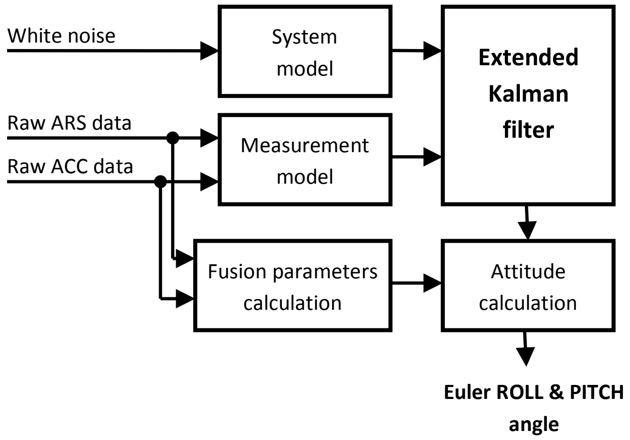

Figure 4. Structure of the extended Kalman filter

Therefore, only BIN model as the shaping filter is utilized in the system model and thus the entire model for continuous time looks based on (11), (12) like:

$$
\dot{x} = \begin{bmatrix}
0 & \omega_z & -\omega_y & & & & & & \\
-\omega_z & 0 & \omega_x & & 0 & & & 0 & \\
\omega_y & \omega_x & 0 & & & & & & \\
& & & -\beta & 0 & 0 & & & \\
& 0 & & 0 & -\beta & 0 & & 0 & \\
& & & 0 & 0 & -\beta & & & \\
& & & & & & 0 & 0 & 0\\
& 0 & & & 0 & & 0 & 0 & 0\\
& & & & & & 0 & 0 & 0
\end{bmatrix} x, \qquad (13)
$$

where $x = \left[a_x, a_y, a_z, \omega_x, \omega_y, \omega_z, BIN_x, BIN_y, BIN_z\right]^T$, β is time constant read from ACF, ω denotes angular rates in 3D, *BIN* is shaping filter defined by only random walk model.

Measurement model used the constraint $a_x^2 + a_y^2 + a_z^2 = 1$, so the form was:

$$
y = h\left(a_x, a_y, a_z, \omega_x, \omega_y, \omega_z\right) = \begin{bmatrix}
-g \times a_x\\
-g \times a_y\\
-g \times a_z\\
a_x^2 + a_y^2 + a_z^2\\
\omega_x + BIN_x\\
\omega_y + BIN_y\\
\omega_z + BIN_z
\end{bmatrix} = \begin{bmatrix}
f_x\\ f_y\\ f_z\\ 1\\ \omega_{mx}\\ \omega_{my}\\ \omega_{mz}
\end{bmatrix}, \qquad (14)
$$

where y denotes measurement vector, $g = 9.81\ m/s^2$, f_x, f_y, f_z are measured acceleration, ω_{mx}, ω_{my}, ω_{mz} represent measured angular rates in 3D frame.

TABLE V. RMSE OF DIFFERENT TYPE OF THE SHAPING FILTER

Type of the shaping filter and parameters used for Q matrix	**RMSE**	
	ROLL	**PITCH**
BIN – random walk – Q ~ B=2.7e-2	0.000023	0.000022
BIN – random walk – Q ~ B=2.0e-3	0.001297	0.001392
BIN+RRW – exp.corr + random walk – Q ~ K=2e-3, B=2.7e-2	0.003116	0.002900

Both system model and measurement model form the core for the EKF. To finish the design of the EKF there is a need to define covariance matrices Q and R. In case of Q matrix values are set accordingly to the structure of used shaping filters and estimated parameters from AVAR analysis (see Table 5). Furthermore, R matrix depends on the variance of measured quantities by ARS and ACC sensors and on a potential weighting function which respects the reliability of measured acceleration. The reliability reflects the suitability of measured acceleration for the angular rate corrections and further angles determination. If the magnitude of acceleration vector is equal to one or close to it, the reliability is high.

The fusion is then executed with respect to the ratio *Q/R*. In Fig. 5 and Fig. 6 there are shown the results of applied filtering and data fusion on data under stationary conditions. In these figures there are shown plots of ROLL and PITCH angle estimated by three processes: based on ARS sensors without and with filtering (used (9)), and based on filtered accelerations (used (10)).

Based on the plots in Fig. 5 and Fig. 6 it is hard to distinguish the difference between estimated angles from filtered ACC and ARS; however, the RMSE is smaller in case of ARS based estimation. Table 6 summarizes the results.

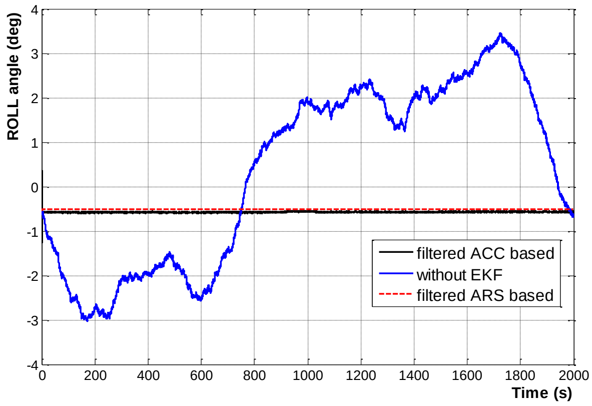

Figure 5. Estimated ROLL angle

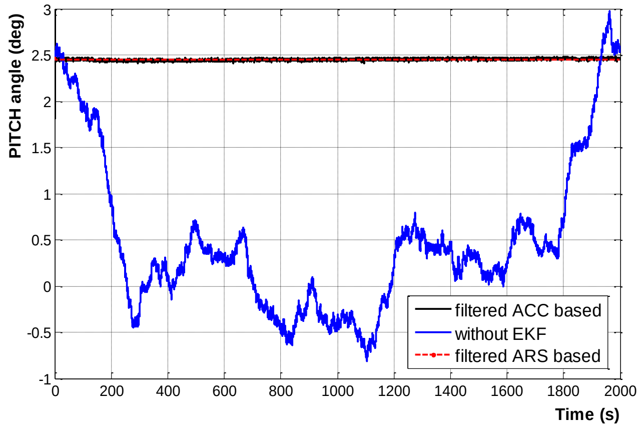

Figure 6. Estimated PITCH angle

TABLE VI. RMSE OF ESTIMATED EULER ANGLES AND ANGULAR RATES

Process of data estimation		**RMSE**
without filtering	ARS based ROLL,PITCH - (deg)	2.14 2.21
	angular rates (x,y,z) – (deg/s)	0.21 0.19 0.19
with EKF	ARS based ROLL,PITCH - (deg)	0.000023 0.000022
	ACC based ROLL,PITCH - (deg)	0.0092 0.0092
	angular rates (x,y,z) – (deg/s)	0.00017 0.00015 0.00015

IV. CONCLUSION

The suitability and applicability of Allan VARiance analysis (AVAR) is presented in this paper. The proof is demonstrated on proposed model fusing angular rates and acceleration. The fusion enables the corrections of angular rate sensors errors sources with respect to measured acceleration. To define the fusion model we designed shaping filters reflecting the results of AVAR analysis and Allan deviation plots which identified the error sources in the measured sensor outputs. Based on the results acquired by applying the extended Kalman filter and based on Table 6 it is clear that ARS based ROLL and PITCH evaluation reached the smallest value of RMSE; however, this evaluation process included the integration of corrected angular rates, therefore the usage of ACC based Euler angles estimation process was preferred. All measurements presented in this paper were done under stationary condition, so the weighting function used in the model to define the sensed acceleration reliability enabled the correction of angular rates in the whole time. The conditions were chosen just to prove the suitability of designed shaping filters with the minimum of results variances to reach. For the other conditions the model can be used but with variable matrices Q and R.

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Analysis the Utilization of Ground Support Equipment in Aircraft Ground Handling

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***Abstract*—The paper is about publication of selected parts of a dissertation thesis on Optimization of the Utilization of Ground Support Equipment in Aircraft Ground Handling. The article presents a newly developed method of tackling the issue, and output diagrams of Ground Support Equipment utilization. These diagrams are converted using the critical path method into the graphs of equipment utilization.**

Keywords-ground support equipment; model diagram of equipment utilization; critical path method; time characteristisc of processes, model graph of equipment utilization

I. WHY OPTIMIZATION THE UTILIZATION OF GROUND SUPPORT EQUIPMENT?

To ensure continuous flow of the air transportation is a complex task for all the elements participating on the operation. It requires adherence to flight plans at airports and elimination of airline flight delays. This purpose is primarily served by efficient ground handling of aircraft at airports. According to the London Gatwick Airport, ground handling of aircraft is the second most frequently cited cause of flight delays. If one is to ensure the highest efficiency of airport operation, it is necessary to perform a detailed analysis of all the individual elements – zooming in on all the partial processes and final integrating the results obtained into the processes planning and decision-making processes at the airport level.

II. MODEL AIRPORT AND INTPUT PARAMETERS

Solution of the dissertation thesis made it necessary to select a model airport. In line with the spirit of cooperation, the Košice international airport has been chosen, with parameters as follows:

- only mobile equipment of aircraft ground handling are available on the airport,
- all aircraft stands are of „taxi-out“ types, for this reason no aircraft towing tractors of equipment are used,
- the airport provides handling services for 7 types of aircraft (ATR42-500, ATR72-202, DH8-402, B737-300, B737-800, MD8, A320).
- ground handling of aircraft has to be performed within established intervals, of the aircraft turn-around, limited by:

a) On-block Time (*T1*),

b) Off-block Time (*T2*).

Let the entire time interval of ground handling servicing be marked as the TAGH. The entire period of servicing is then divided into individual processes. The next diagram is a simplified illustration of all the processes involved.

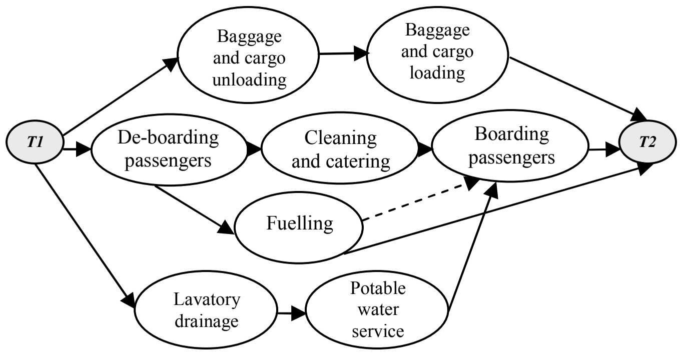

Figure 1. Sequential illustration of the aircraft ground handling process

The diagram is only a starting point of further analysis of the issue as it provides no information on making use of the equipment. In the illustration there is no mentioning of the processes to which the utilization of the Ground Power Unit (GPU) can be matched.

III. METHOD OF TACKLING THE ISSUE

In the processes described, we have to put emphasis on the utilization of servicing equipment. Upon becoming knowledgeable of the aircraft ground handling, when it is important to know the exact flow of the handling process, function and availability of every equipment – rules underlying the processes, to step further. Each flight at the airport can be assigned with the following data. It is known:

- it is an arrival-departure handling ($A\text{-}D_{AGH}$), arrival or departure handling of aircraft only,

- the total time allocated to handling (T_{AGH}),
- the processes to be involved in the ground handling,
- the time periods for each process,
- the equipment needed and utilized in the processes.

The essence of the method of processing utilization consists in matching the handling processes with service equipments. As a matter of course, the separated equipment are assigned to processes in terms of time intervals of their utilization. As part of the process it is of outmost importance to properly determine the sequence of the partial processes or group of processes related to the ones that precede, and properly determining which processes can follow upon their completion. (Based on being knowledgeable of the aircraft ground handling process as a whole.) Each equipment available at the airport is assigned processes, in which they are utilized in a sequence as defined.

Of each equipment it is known which processes they are involved in, what is going on there, when its utilization starts and when it ends as part of the entire process of aircraft handling. One has to become aware of every detail. For example, the boarding steps are utilized during the „dead process“, when passengers are not boarding or de-boarding, but the steps are moved to the aircraft side (during aircraft board cleaning and catering).

The dissertation thesis lead to the development of model diagrams for each of the seven types of aircraft handled at the airport. As an example, the article is demonstrating the ground handling of the AT72-202.

This methodology is reflecting practice, and is maximally adaptable to practice as well. All the input data are variable. The head of the ground handling, based on the given parameters and being knowledgeable of the process, will determine the types and number of equipment to be employed in the process. Thus, it enables development of a model of ground handling equipment utilization for each type of aircraft landing on the airport.

TABLE I. MATCHING PROFCESSES AND EQUIPMENTS

Type of Equipment	**T_{AGH} = 30 minutes (A-D_{AGH}, AT72-202)**		
	Quantity	***Processes***	
Ground Power Unit (A)	1	A1	Roll in to the aircraft and connection to service point
		A2	Electrical power supply
		A3	Starting aircraft engines
		A4	Disconnection from service point and roll out from the aircraft
Baggage tractor with loading area (B)	4	B1	Unloading
		B2	Loading
Passengers stairs (C)	1	C1	Roll in to the aircraft
		C2	De-boarding passengers
		Cx	D/E
		C3	Boarding passengers
		C4	Roll out form the aircraft
Cleaning truck (D)	1	D1	Roll in to the aircraft
		D2	Cleaning
		D3	Roll out from the aircraft
Catering truck (E)	1	E1	Roll in to the aircraft
		E2	Catering service
		E3	Roll out from the aircraft
Fuel truck (F)	1	F1	Roll in to the aircraft and connection to service point
		F2	Fuelling
		F3	Disconnection from service point and roll out from the aircraft
Water service truck (G)	1	G1	Roll in to aircraft and connection to service point
		G2	Potable water service
		G3	Disconnection from service point and roll out from the aircraft
Lavatory service truck (H)	1	H1	Roll in to aircraft and connection to service point
		H2	Lavatory drainage
		H3	Disconnection from service point and roll out from the aircraft

The diagram from table 2 has been developed on the basis of knowing the issue, the general rules underlying aircraft ground handling and supplementary service manuals of the ground servicing staff. As first, the service point of the aircraft is connected to the GPU, then following the process (A1) one can start performing the rest of the aircraft servicing processes. Before starting up the engines (A3), all servicing equipment must be disconnected and rolled out of the aircraft service point area. Fuelling potable water and lavatory drainage must not be performed simultaneously, of hygienic reasons of course (G, H). Although this type of aircraft uses its own steps for boarding and de-boarding passengers, the diagram of equipment utilization has to record a fictions use of boarding steps (C). It has to be done for sequential reasons. Cleaning the aircraft board and catering services of the board kitchen (D, E) operations that can start only on having passengers left, and these activities have to be finished before passengers boarding the plane. Fueling (F) can start only on having passengers left the plane. The end of fuelling in case of AT42-500 handling is limited by the time of boarding passengers (C3). In general, this process can last until time scheduled for A3, depending on the time needed (wide-body aircraft).

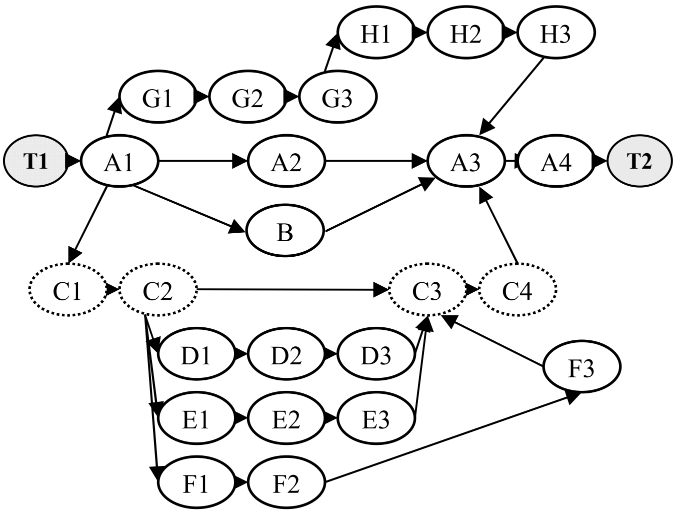

Figure 2. Model diagram of equipment utilization

IV. CRITICAL PATH METHOD

A very suitable method of solution of this type of problem is optimization in graphs making use of the critical path method. The essence of operational research, into which the mentioned quantitative methods belongs to, can be expressed as a research of operations within the framework of a system. The aim is to ensure the best possible functioning of the entire system. By way of the critical path method we are able to perform time-based evaluation of how the ground servicing equipments are utilized and find out time reserves (not in this article) in utilizing the separate types of equipment.

When solving the project, the following steps must be performed:

- subdivide the project into individual activities,
- estimate the time needed to perform the individual activities,
- define the time sequence of performing the individual activities, i.e. determine which activities must be finished before starting the rest of activities,
- based on these steps, develop a network graph.

In the first method described, we have already performed steps one and three. On substituting the times of performance durations, we can go on developing the network graph. The critical path method was selected to perform time analysis of activities performed within the framework of the given project. Its basis is made up of 4 time characteristics for each process of the project (Figure 3). The method helps in performing optimization of the time the entire project realization.

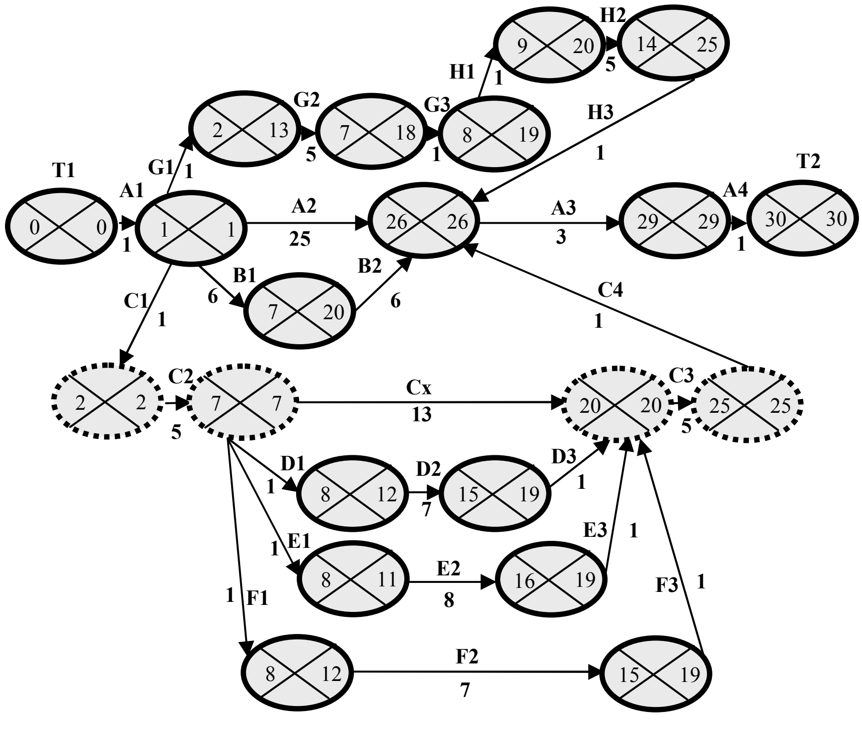

Figure 3. Output graph of equipment utilization (Critical Path Method)

The output graphs of equipment utilization are an intersection of the first and the second method described. The pay due respect to developing both methods and are adaptable to real requirements and conditions. At the same time, these graphs represent inputs for the mathematical model of equipment utilization (not included in this article). In practice, the model helps efficient planning of aircraft ground handling services and facilitates its operative control.

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The EU ETS in the Aviation

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Abstrakt - The EU Emissions Trading System (EU ETS) is a cornerstone of the European Union's policy to combat climate change and its key tool for reducing industrial greenhouse gas emissions cost-effectively. The European Commission has taken an important step in preparing for the full inclusion of aviation in the EU's emissions trading system (EU ETS) from 1 January next year. The European Commission has decided on the historical aviation emissions which will be used to calculate the number of aviation allowances to be available from 2012.

Keywords- Emission, emissions allowances, greenhouse gases, EU-ETS.

I. INTRODUCTION

Initially the EU ETS includes only stationary sources of air pollution as power plants, heating plants, etc.. Since 2012, the system will fully cover also aviation. The legislative framework of emission trading for aviation at EU level has been completed and is formed by:

- Directive of the European Parliament and Council Directive 2008/101/EC of 19 November 2008, amending Directive 2003/87/EC so as to include aviation activities in the scheme for trading emissions greenhouse gases in the Community
- Decision of the Commission of 16 April 2009 amending Decision 2007/589/EC as regards the inclusion of guidelines for monitoring and reporting emissions data and tonne-kilometer of aviation activities.
- Decision of the Commission of 8 June 2009 on the detailed interpretation of the aviation activities listed in Annex I to the European Parliament and Council 2003/87/EC.
- Regulation (EC) No 748/2009 of 5 August 2009 List.

aircraft operators, which at 1 January 2006 or after this date performed aviation activity listed in Annex I to Directive 2003/87/EC specifying the administering Member State for each aircraft operator.

Full effectiveness of the system occurs on 1 January 2012 and will apply to all flights which take-off or landing at/from an EU airport, ie, all the flights operated within the EU, and flights from/to third countries which landing/take-off at/from any airport in the EU and all carriers registered not only in EU but also outside the EU who were not exempted from this obligation.

After the release of the above regulations, the Member States were invited to incorporate them into their legislation.

The Czech Republic acceded to that on May 31, 2010 when became effective amendment to Act No. 695/2004 Coll. conditions for trading in emissions allowances greenhouse gases and amending certain laws, as amended (Act No. 164/2010 Coll.), which carries out the transposition of European Parliament and Council 2008/101/EC of 19 November 2008 amending Directive 2003/87/EC so as to the inclusion of aviation activities in the scheme for trading emissions Community greenhouse gas emissions, which incorporates the activities of aviation into the European Trading Scheme. The new decree as the implementing regulation of Law also performs the transposition of Directive 2008/101/EC and the following procedure for identifying, reporting and verification of GHG emissions and tonne-kilometer data for aviation activities.

In recent years the air transport is rapidly developing of and it is one of the fastest growing sources of greenhouse gases like ground automobile traffic. This is a major problem requiring systemic solutions situation. While the volume of emissions from domestic flights is declining, emissions from interstate flights are increasing.

The official sources say that aviation contribute about 3% to the total anthropogenic emissions, but some sources also say that emissions almost doubled in the EU since 1990 and until now due to international air traffic. Consequently, the EC decided to regulate emissions from aviation that will be included into the European emissions trading system for greenhouse gases.

II. IMPACT ON AIRCRAFT OPERATORS

Each EU Member State under Directive 2008/101/EC will manage flights of the airline companies that are in the territory of a Member State operating with license issued under the EP & R Regulation No 1008/2008 of 24 September 2008 on common rules for the operation of air services in, or have the highest estimated amount of emissions caused by aviation in the State. By 29 January 2010, all affected airliners had to log, so that the European Commission to update the list and assign them to individual member countries.

The Czech Republic, as the Member State, was assigned 25 aircraft operators according to this document , of which 9 Czech, which subject to new duties. This is especially the duty to monitor and report emissions and tonne-kilometer data. Air operators had to handle a „survey's plan“ till 30/04/2011 and submit it for approval to the Ministry of Environment (MoE). Before trading period starting in 2012, the aircraft operators must revise the „survey's plan“. The ministry will assess whether it is possible to change the methodology of the surveys in order to improve the quality of reported data, without leading to unreasonably high costs.

Based on this plan and under the new regulations, aircraft operators will detect and report the amount of CO_2 emissions and tonne-kilometer data. Reporting these data refer on all flights operated during the reporting period listed in Annex 1 to Decree No. 287/2010 Coll. This period was set for one year and is governed by the following principles:

- *Completeness*
- *Consistency*
- *Transparency*
- *Truth*
- *Cost efficiency*
- *Reliability*

The procedure for determination of CO_2 emissions is given in Annex 2 to Decree No. 287/2010 Coll. and is given by:

CO_2 emissions = Fuel Consumption x Emission Factor

The operator in "survey‘s plan" for each aircraft type specifies how the calculation formula be used. As well the data source for determining data of supplemented fuel and possibly what method will be used to determine density. The value of emission factor this Decree is intended for all types of aviation fuel.

The process of determining data tonne-kilometer is then determined in Annex 3 to Decree No. 287/2010 Coll . Aircraft operators detect and report data using tonne-kilometer methodology based on a calculation using the following formula:

Tonnekilometers [t km] = Distance [km] x Payload [t]

An air distance is defined as the shortest distance in kilometers between two points on the surface of the earth and shall be determined by the system referred to in the Convention on International Civil Aviation published under No. 147/1947 Coll. The payload is based on the total weight of cargo and mail, and the weight of passengers and checked baggage in tonnes.

The data required for reporting as the number of flights, number of passengers, flown miles, fuel consumption - are now routinely recorded by airlines (Figure 1), their finding is only an administrative issue. The costs associated with that are primarily dependent on the size of the airline. According to the consultation exercise with Czech Airlines and the Travel Service Airlines the initial one-off costs associated with this agenda will be for larger airlines, which have 20 to 50 aircraft, ranging between 200 to 300 thousand CZK. These costs relate mainly to verify the completeness of database operations and investments in hardware and software. The list of other costs that will have an airline of this size in relation to the amendment of the Act is in Table 1.

TABLE 1. Quantifying the cost of aircraft operators

Activity	***Frequency costs***	***The amount of costs(thousand CZK)***
The initial cost of verification completeness databases, and investment in hardware and software	*One-off costs*	*200 - 300*
Processing the plan to detect emissions and submission for approval to Ministry of Environment.	*One-off costs*	*10 - 100*
Report emissions and tonne-kilometer data	*Once a year*	*20 - 40 / per year*
Verification of reported emissions and tonne-kilometer data	*Once a year*	*10 - 200 / per year*
Application processing for emission allowances	*Every trading period*	*10*
Establishing and maintaining an account in the index trading with emission allowances	*One-off cista; maintaining an account once a year*	*2 / per year*
Buying the needed emission allowances	*Once a year*	*Cannot be quantified in advance*

The including aviation in the EU ETS, as can be seen, means increasing of operating costs of airline operators, which can result in a slight increase in prices and tickets. The impact study by the European Commission (2006) can be expected that the price of return tickets for flights within the EU in 2020 will increase by 1.8 to 9 euros.

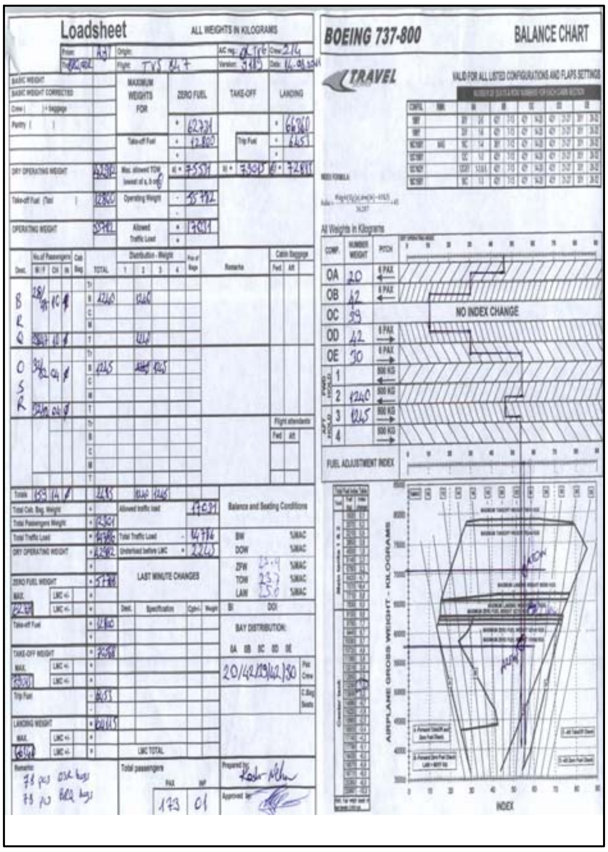

FIGURE 1. Loadsheet (used in Travel Service Airlines)

III. IMPACT ON OTHER STAKEHOLDERS

For small operators will apply the exceptions to simplify procedures for setting the standard amount of emissions. The exception applies to the commercial air transport operators possessing an operating license Air Operator Certification (AOC), which for three consecutive four-month period will take place in each of those periods of less than 243 flights, or who have flights with total annual emissions lower than 10 000 tonnes of CO_2 per year and also for other aircraft operators operating license, although lacking the AOC, but meet the above value of emissions and the number of flights.

IV. SOURCES OF DATA FOR CALCULATING THE NUMBER OF ALLOWANCES

The decision on historical aviation emissions of 219,476,343 tonnes of CO_2 represents the average of the estimated annual emissions for the years 2004, 2005 and 2006 of all flights that would be covered by the EU ETS performed by aircraft operators to and from European airports. Based on this figure for average annual aviation emissions in 2004-2006, the number of aviation allowances to be created in 2012 amounts to 212,892,052 tonnes of CO_2, and the number of aviation allowances to be created each year from 2013 onwards amounts to 208,502,525 tonnes of CO_2.

The calculation of historic aviation emissions was based on data from Eurocontrol – the European Organisation for the Safety of Air Navigation - and actual fuel consumption information provided by aircraft operators. Additional calculations were carried out to account for fuel consumption associated with the use of the auxiliary power units (APUs) on aircraft at airports.

V. CONCLUSION

EU emissions from aviation have increased fast – almost doubling since 1990.

To mitigate the climate impacts of aviation, the EU has decided to impose a cap on CO_2 emissions from flights operating to and from EU airports. From the start of 2012, some 4,000 aircraft operators arriving and departing in the EU will be covered by the EU ETS. Like industrial installations, airlines will receive tradable allowances covering a certain level of CO_2 emissions from their flights per year. Aviation represents around 10% of greenhouse gas emissions covered by the EU ETS.

The inclusion of aviation in the EU ETS is expected to have impact on ticket prices, of course.

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Information Basis of Operational Regulations in Civil Aviation

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***Abstract* - The text contains a brief overview of a project of Ministry of Transport CR for creating Information Basis of Operational Regulations in Civil Aviation. Following paragraphs provide information about whole concept and show key ideas necessary for understanding such software.**

Keywords - civil aviation; division of regulations; electronic regulations; information basis; operational regulations; pdf file

I. INTRODUCTION

Information Basis of Operating Regulations in Civil Aviation (IBORCA) is a grant research project of Ministry of Transport of Czech Republic.

This projects primary goal is to develop specialised software - IBORCA, which is going to contain possibly the most complex database of regulations, directives, conventions etc. Secondary goal is to create methodology for developing and operating such software.

Due to large number of regulations and other normative acts in civil aviation exists a demand for a software tool which allows its users to search and find relevant information above all possible documents. This software shall be quick, easy-to-use and reliable source of information about current (up-to-date) regulatory framework in civil aviation.

It is believed that this software is going to find its users among institutions such as CAA CR, Civil Aviation Department of Ministry of Transport CR etc. Other possible users are universities focused on civil aviation. Further development of this software promisses opening this software to public use.

Project IBORCA has 3 partial goals:

- system analysis and creating system architecture
- creating methodology for developing and operating a software such as IBORCA
- coding and testing IBORCA and deploying final version

Solving team is created by 3 subjects:

- Faculty of Transport Czech Technical University Prague
- Faculty of Mechanical Engineering Brno University of Technology
- Sting Academy – Private university Brno

It is necessary to define term "operating regulations". There is no official definition of this concept. For the purpose of project IBORCA this definition will be used: "Operating regulation is any regulation which has direct application on subjects participating in every-day operation of civil aviation". This broad definition allows authors to integrate specific documents according to presumed needs of users. It also allows to extend the database by new regulations.

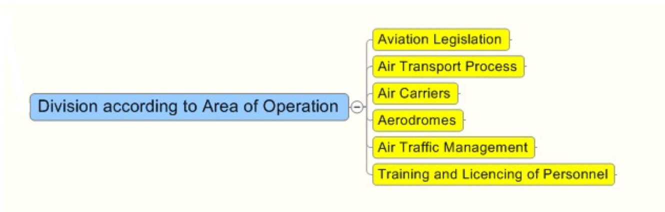
II. DIVISION OF REGULTIONS

In respect of large number of regulatory documents in civil aviation it is considered to be necessary to divide all documents into categories which will be representing interests of potential users. Due to their different needs authors have chosen three ways of division of operating regulations in civil aviation:

- according to Area of Operation
- according to Act on Civil Aviation
- according to Series of Regulations

These three ways create representative division which respects the structure of civil aviation and also allows easy orientation for users.

A. Division according to Area of Operation



Picture 1 – Division according to Area of Operation

B. *Division according to Act on Civil Aviation*

Picture 2 – Division according to Act of Civil Aviation

C. *Division according to Series of Regulations*

Picture 3 – Division according to Series of Regulations

Division according to Series of Regulations is considered to be basic division in IBORCA. However user will have the opportunity to switch among them. Divisions overlap - every document in IBORCA shall belong in every division in at least one category. For example document L 4444:

Division	Category
Area of Operation	Air Traffic Management
Act on Civil Aviation	Utilization of Czech Airspace and Air Services
Series of Regulations	L - Serie

Table 1 – Categorization of L 4444 document

These 3 divisions will be the only divisions in IBORCA, however it is possible to change categories (add, rename, delete) in every division.

Due to IBORCAs primary goal as a research project we are unable to include paid documents and documents with restricted access. This leaves IBORCA as a database of open public documents (free documents). These documents we are able to maintain up-to-date without additional payments.

In respect of development of IBORCA it was decided to include only the most representative documents in each category. The system will be then supplemented with new documents according to feedback from its users.

III. DESCRIPTION OF A SYSTEM

Basic requirements were specified in the assignment of project IBORCA:

- search for a word (combination of words) with the possibility of a search with further criteria
- search above a group of documents
- search with lemmatization
- automatic search of a term in Czech and English language
- library of favourite documents for every user
- implementation of further documents

These basic ideas were (in analytic phase of project) transformed into document of requirements which specifies exactly what a system shall do.

IBORCA is considered to be a free access database. It is being designed as an information system with central data storage with internet access and web graphical user interface.

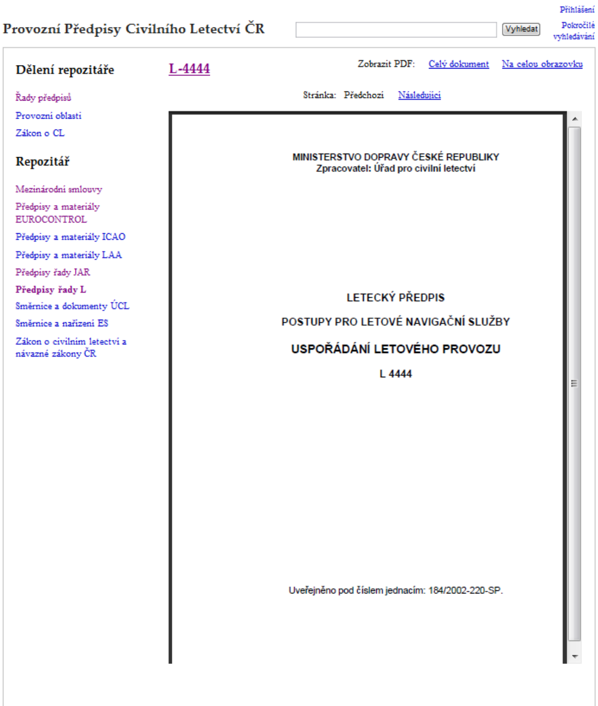
This creates a set of requirements on system itself which is being designed as a Document Management System (DMS).

A. *User Interface*

User interface allows users to find a specific document and list it through. Division of regulations discussed in previous chapter is a key to enable this function to users.

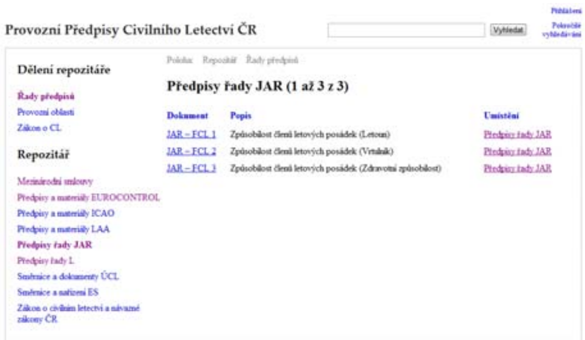
Other function of user interface is to enable search above documents and work with the results. There are few pictures showing user interface of this system:

Picture 4 - Information about specific document



Picture 5 - Listing through specific document

Picture 6 – Advanced search



Picture 7 - Selection of specific document

B. *Data format and search engine*

Authors chose PDF file as a form of document in IBORCA. These files can be easily full-text searched. It is also easily displayed in web-browser. Most of the legal documents are distributed in pdf files, so they can be easily inserted into database without any additional conversion.

Very important role of IBORCA is to find specific word or combination of words in given regulations. For this purpose IBORCA is going to use full text search engine Sphinx. Other key part of this process is lemmatisation. This requires a creation of a lexicon of words from dictionary of common Czech words.

C. *Metadata and key words*

Metadata are used for increasing acurancy of searching process. For every document in IBORCA was created its own set of metadata. These are derived from Dublin Core Standard.

Every document has also its own set of key words and they are derived into 4 groups – Czech key words, English key words, Czech abbreviations and English abbreviations. Key words are also increasing accurancy of search process.

Key words were chosen from every documents set of definitions. Other possibility is to read every document and based on that choose adequate key words. This was not done due to limited timetable of this project.

IV. CONCLUSION

This article was to inform readers about project of Ministry of Transport of Czech Republic for creating Information Basis of Operational Regulations in Civil Aviation. Emphasis was given to key aspects of the project.

IBORCA is now fully operational but is not yet available for public use.

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Human Factor Case – Important Tool of Air Traffic Management for Flight Safety

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Abstract— **This paper presents human factor as a crucial element of flight safety. There is generally known fact that human factors plays an important role within incidents and accidents in aviation, especially regarding pilots, technical personnel and air traffic controllers as well. Air transport amount dramatically grows year by year similarly as the saturation of air traffic service airspace filled with sporting (amateur) aviation, military and other flights (aero-medical, sightseeing flights etc.). The relationship between human performance and safety has been a long-standing issue in Air Traffic Control authorities, since human performance is considered as a critical determinative for Air Traffic Management safety.**

Keywords- Human Factor, Human Performance, Air Traffic Management

I. INTRODUCTION

At sharp end of performance in Air Traffic Management (ATM), professionals manage their own performance at tactical level – controllers, supervisors, engineers etc. Behind the scenes, other groups of professionals and means contribute to the improvement of human performance at a more strategic level. These elements use various principles and methods for measuring and influencing human performance – direct or indirect. Three “enablers” of human performance in ATM are noteworthy (see Figure 1) [1].

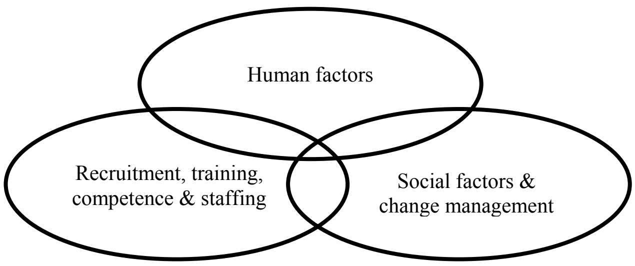

Figure 1. Delivering human performance benefits

- Human Factors (HF) is a design-oriented discipline and profession which develops and applies knowledge about the performance of people at work to the design of work. It focuses on the task requirements, the equipment and technology people use, the rules and procedures they work under, the ways they communicate, and physical and organisational environment in which the operate. HF focuses mostly on “fitting the job to the person”. HF issues are also classified as HF Impacts on Human Performance (see Fig. 2).

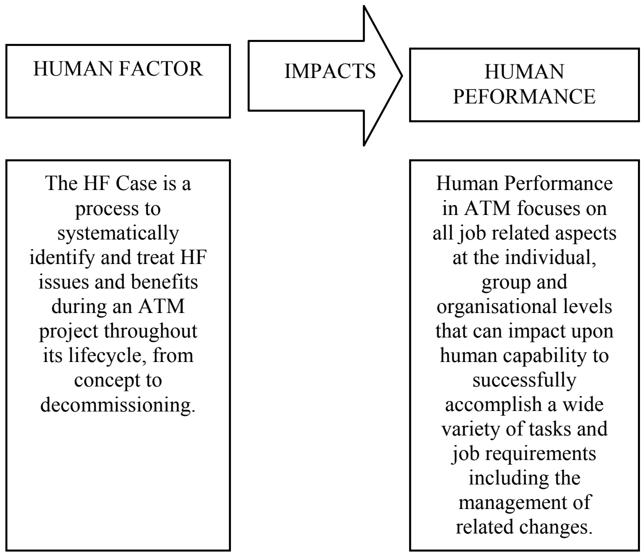

Figure 2. Relation between Human Factors issues and Human Performance

- Recruitment, training, competence and staffing are the primary concerns of human resource management (HRM) and occupational and organisational psychology. The priorities are to attract and retain talented and competent staff, as they will ultimately determine the success and sustainability of the organisation. HRM and psychology focus more on “fitting the person to the job”.
- Social factors and change management refers to a social dialogue and change process, which will pave the way forward for the future concepts if accepted and

recognised by all parties involved and affected by the changes.

All three enablers secure the compatibility or "fitness" between people, their work and the organisation, in whatever way the focus of each issue is different. They overlap in the introduction of large-scale changes, such as Single European Skies ATM Research (SESAR) in Europe, NextGen in the US and Automatic Dependent Surveillance-Broadcast (ADS-B) in Australia and Canada.

II. HUMAN FACTOR CASE

The HF Case is a management tool which systematically identifies and manages HF issues and manages HF issues for an ATM project. It can be divided into five stages:

- Fact Finding – Scope project from an HF perspective
- Issue Analysis – Identify HF issues and potential impacts
- Action Plan – Develop HF Action Plan
- Action Implementation – Implement HF Action Plan
- HF Case Review – Review effectiveness of HF Case Process

It provides and enables:

- A framework to address HF issues
- The application and integration of subject matter expertise and HF knowledge
- A comprehensive qualitative analysis

The HF Case process provides:

- An explicit way to manage HF issues
- A checklist and traceability for HF issues as the project evolves
- Ownership within the project team for HF
- Facilitates decision making to justify resources and budget for HF
- Minimises the risk of HF issues popping up at a critical stage

It means that HF Case is aimed at:

- Programme and Project Managers – Provides assurance that HF is integrated into the project and awareness among the project team.
- Validation – Allows them to track HF issues from simulations and experiments.
- Safety – The HF Case is complementary to a Safety Case and may help them identify safety relevant issues for the Safety Case.
- Training and Staffing – Develops an awareness of staffing and training issues that may need to be tackled later in the project life cycle.

A. *Human Factor Pie*

To facilitate the identification of issues related to human factors within a project, HF issues are classified into following six main categories, called the "HF Pie". The HF Pie underlies the general approach to the identification, assessment and monitoring of HF issues relevant to the project. They are displayed at the diagram bellow (Fig. 3). By investigating each element of given category, the analytic team can identify issues, relevant to a specific project [5].

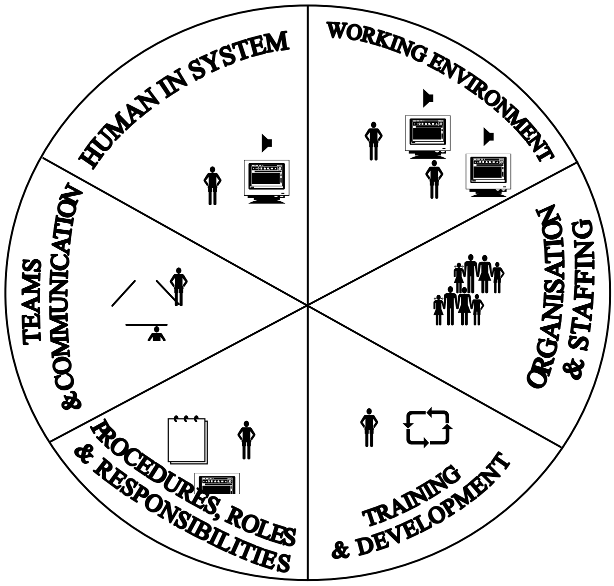

Figure 3. Human Factors Pie

III. HUMAN PERFORMANCE CHALLENGES FOR FUTURE AIR TRAFFIC MANAGEMENT

The future of Air Traffic Management (ATM) will depend on the ability of industry to handles a number of critical challenges concerning human performance. Six key challenges are outlined below.

A. *Designing of proper technology*

Future technology will be a step change from current technology. The focus will shift to collaboration across sectors and centres, and between ground and air to support the shared "situation awareness". Tools will also need to accommodate more advanced planning and look-ahead time, while supporting the flexibility required dealing with unplanned situations. At the same time, it must be ensured that it is possible to handle safely unexpected disturbances and degraded modes. Crucially, the automation must keep the human operator in the loop to be able to maintain control – and therefore safety – in all circumstances [3].

B. Selecting the right people

Major technological and organisational changes may require changes to the type and number of people required to operate the business effectively. This may require changes to manpower planning, recruitment and selection to ensure that we have the right people, in the right numbers at the time.

C. Organising the people into the right roles and responsibilities

A new collaborative approach to ATM will result in new roles and responsibilities for controllers and engineers, as well as other ground staff. In light of increased delegation, such changes will extend will extend to flight crew. Roles are likely to be more fluid than is the case today. The human performance implications of transitioning between roles must be clearly understood and managed.

D. Ensuring that the people have the right procedures and training

New technology, people, roles and responsibilities all impact the training and procedures required, for both new and existing staff. Competencies will need to be maintained also for old skills that may be used more rarely in light of new technology, but are still critical when needed. The new collaborative approach to ATM may require new collaborative approaches to training.

E. Managing human factors processes at a project and ANSP level

Consideration of human performance issues requires human factors to be fully integrated with system development and safety management. The management goals are to meet the demands for efficiency, enabling capacity gains and safety improvement. Performance indicators can be useful here to benchmark and quantify the maturity of human performance assurance at the organisational level.

F. Managing the change and transition process

A successful project depends on a successful change and transition process, where the social, cultural and demographic factors impacting performance are considered alongside the technical and procedural factors.

ATM today is one of very few “high reliability industries”. Throughout the major changes of the future, we need to keep it this way. Strategic, management-level approaches are necessary to maintain performance throughout every stage of the design, development and implementation process, then reaping the performance and safety benefits during the operations phase. The right management systems and organisational culture, including safety culture, will help to ensure that the capacity, efficiency and safety benefits expected are realised.

IV. HUMAN PERFORMANCE AND ORGANISATIONAL BUSINESS PERFORMANCE

Compared to the other high-hazard industries, such as chemical processing, nuclear power, and even aviation more generally, air traffic management still remains “human-centred”. Despite advances in technology, ATM is still critically dependent on the day-to-day performance of highly skilled front-line personnel, such as controllers, engineers, supervisors and other operational staff. Operational personnel safely and efficiently handle millions of flights, and effective human performance at the front line makes this happen. Human performance solutions are required to bring the people, procedures and equipment operate together effectively (see Fig. 4) to make running the business more efficient and safer [2].

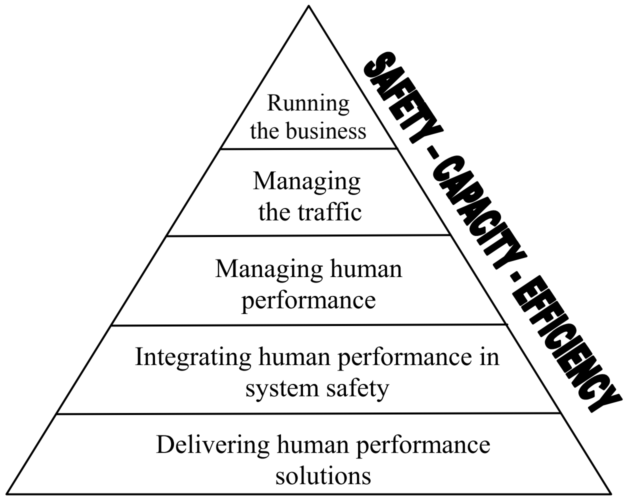

Figure 4. Human performance and organisational business performance

In terms of SAFETY, 2006 and 2009 were the safest years on record worldwide. 2008 was the fifth consecutive year without ATM-related accidents in Europe. Traffic growth is the key challenge to maintaining such a record, because when traffic doubles, risk is squared. The European SESAR programme aims to improve the safety performance by a factor of 10 to 2020. Clearly, the human element will be critical to ensuring that safety is maintained.

The industry needs to gain additional CAPACITY and reduce delays to meet the demands of traffic growth. The SESAR programme aims to enable a 3fold increase in capacity. Again, this can only be achieved with a view on those who are managing the traffic.

A third priority is EFFICIENCY. SESAR aims to reduce the costs of ATM services to airspace users by 50%.

These improvements make significant demands on human performance, but the financial benefits will be significant. According to the European ATM Master Plan, the savings attributable to direct ATM cost reduction, capacity gain and departure delay savings, as well as predictability improvement in case of low visibility conditions, is around €19bn for commercial airlines by 2020, with an additional €12,5bn savings of passenger travel time.

To achieve the right fit, it is necessary to assert proper professional resources in the organisation. Whilst HRM and platforms for social dialogue are more commonplace, HF expertise in ATM is less so. Nevertheless, a number of ANSPs now have specific teams of qualified human factors specialist, integrated into design, selection, training, and safety functions. Some also have human performance teams comprising operational and engineering staff with a special interest in the domain. As human performance issues are a key driver of ATM performance, they need to receive considerable attention in planning, design, operations and maintenance, and should be treated as seriously as other business-critical functions [4].

V. Understanding Human Performance

Human performance at work has been the subject of intense research in several disciplines for decades. Much is now known about how people perform tasks, and why they perform them in the way that they do. But much of this is hidden away in books and journals for academics and specialists.

Human performance, in context of ATM, refers to the adequate performance of jobs, task and activities by operational personnel – individually and together. As a domain, human performance focuses on optimising the people element in complex work systems such as air traffic management. Designing for human performance and managing human performance involves the application of knowledge gained from research and practice in human factors, psychology and management.

Human performance depends on both the person and the context of work. Capability refers to the basic characteristics of the individual, e.g. aptitude, abilities, skills, physical capabilities, knowledge, experience and health. Capabilities are assessed during selection and promotion, shaped and enhanced via training, and considered in the design of jobs, task/activities, systems and tools.

Motivation and attitude influence the use of the person's capabilities. While a person's motivation varies, it is critical in ensuring that capabilities are fully realised in human performance. Motivation, attitude and trust can be improved significantly with the right approach.

The systems, organisation and environment provide the opportunity for good performance, given sufficient capability and motivation, and include systems and technology, the design of the job and tasks, the workplace environment, training and procedures, and management and support. These can be designed and managed directly.

All three components have to be considered carefully. Even very high capability individuals will not perform well if motivation is low or if the systems, organisation or environment (e.g. training and procedures) are poor. Similarly, even the most motivated person, with good training and procedures, may not perform well if capabilities are poorly matched to the job requirements. Human performance can vary, positively or negatively, depending on the capability, motivation, system support, organisation and environment [1].

VI. Conclusion

In ATM, human performance and safety are inextricably linked. While the disciplines involved in improving human performance are themselves continually developing and improving, the techniques to identify and resolve these issues exist. They need to be embraced and integrated into the systems developers' and project managers' "mindsets" and practices.

As ATM continues to evolve in terms on NextGen improvements in the US, and Single Sky, Functional Airspace Blocks and SESAR in Europe, this will create new challenges for human performance and safety, as well as generating system performance advantages.

It is perhaps obvious that safety depends on human performance, and that they need to work together. What is less clear sometimes is how they can work together in practice. This paper has aimed to describe that there are techniques, approaches and data sources which allow a strong synergy to take place between these two disciplines which share a common goal. It is hoped that it may encourage ANSPs, their managers, engineers, safety and human factors professionals, and researchers, to find effective ways to work together so that ATM can continue to enable aviation to remain the safest system of public transport, now and in the future.

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Flight Inspection of Surveillance Radar Systems

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Abstract - **This paper summarizes the flight inspection of aircraft ground equipment focusing on the flight validation of radar surveillance systems in civil aviation in the Czech Republic.**

Keywords – AGE (aircraft ground eguipment); surveillance; navigation; systems; calibration; flight inspection; checking; radar; Civil Aviation Authority

I. Introduction

Precision of aircraft ground equipment (AGE) is affected by many external influences. For this reason these devices need to be regularly checked and calibrated. Calibration can be to certain extent performed on the device itself but to achieve more accurate values it must be carried out by flight inspection.

To promote a better understanding of the topic, the history and the legislative framework of flight inspection in the Czech Republic is briefly described in this paper and purpose of these inspections is explicated. Next chapters are devoted to the complex system of flight and verification procedures in the context of the FAA and ICAO regulations.

II. Introduction to Flight Checking

Aircraft radar equipment or surveillance equipment (surveillance systems) are in accordance with the Act No. 455/1991 Coll., on Civil Aviation, as amended (the "Act on Civil Aviation"), considered as aircraft ground equipment (see Section 2/5 of the said Act: "Aircraft ground equipment means a technical device that is placed on the ground and serves to ensure aircraft safety.").

According to Section 89/1/i of the Act on Civil Aviation the Civil Aviation Authority (CAA) shall approve, recognize and control capability of aircraft ground equipment for use in civil aviation. CAA may authorize other person with assessment and verification of compliance of aircraft ground equipment in connection with development, design, manufacture, installation and operation. However, flight inspections of aviation ground radar (or navigation) devices are carried out regularly by CAA's own capacities [1].

A. Flight checking in the Czech Republic

The first institution in the territory of present Czech Republic which engaged in flight verification was the Department for flight checking within the Czechoslovak Airlines which started its operations in 1946. With the development of civil aviation grew also demands for verification of aircraft ground equipment and related technology. The responsibility for flight inspection was later assumed by the State Aviation Administration (1958), and later on by the Civil Airports Administration and the State Aviation Inspection.

Flight inspections are currently ensured by the Department of flight inspections of CAA which consist of a director, 4 pilot inspectors, 3 flight checking inspectors and 3 aircraft maintenance technicians. The department has established the quality management system meeting the requirements of ISO 9001:2001.

For the purpose of flight inspections CAA currently operates CESSNA 560 XL and ZLIN 43, both equipped with a measuring console UNIFIS 3000. CAA also operates a laboratory that serves as a support for flight inspections [2].

B. Regulation of flight inspections at international level

The main international regulation related to the flight verification activities has been published by ICAO. The Document 8071 consists of:

• Volume I, TESTING OF GROUND-BASED RADIO NAVIGATION SYSTEMS, describes a system of inspections of air navigation aids.

• Volume III, TESTING OF RADAR SYSTEMS, is then devoted to procedures for calibration of primary and secondary radars [3].

Federal Aviation Administration (FAA) describes in detail the flight inspection process in its FAA regulation TI 8200.52 - FLIGHT INSPECTION HANDBOOK (Aviation System Standards) [4].

III. Flight Inspection

Flight inspection is primarily supportive activity while operating the surveillance system. Experience shows that radiolocation (radar) and navigation aids for aircraft are not always sufficiently accurate due to external influences such as electronic jamming or uneven terrain.

A. *The aims of flight inspection*

Flight inspection, if required, is also one of the requirements for obtaining a certificate of operability of aircraft ground equipment. Operability is verified when AGE is completely installed, connected to external data and energy infrastructure. Flight inspection includes control and verification of technical and operational performance of the site by using the flight activity [5].

B. *Types of inspection*

- Ground - parameters that are not affected by the external environment are usually controlled this way. It is the most common type of inspections. The checks mostly consist of the functionality tests, which verify the fulfillment of the requirements for functionality and parameters of the facility environment. The review of required documentation is also a part of the control.
- Inflight – The flight inspection is being used for accurate calibration and control of parameters that can be affected by external influences.

C. *Types of flight inspection*

FAA describes five main types of flight inspection [4]:

- Site evaluation – verification of the location suitability for permanent installation of an AGE.
- Commissioning - complete flight verification of a facility after its installation, but before the introduction into service. It is used to control all the parameters and AGE operating performance. It is the most difficult to prepare due to detailed checking and verification. The values obtained by this measurement are used to compare device performance with other controls.
- Periodic - check whether the system meets all the standards and operational requirements. It is also used for verification of safe altitude above the obstacles and the effects of signal fluctuations.
- Special - verification carried out due to alterations in environmental impacts, reinstallation of the equipment, upon the request of an operator or Aviation Authority. It is being used after the installation of new components or equipment or antennas, after the accident or potential threat to flight which could be associated to the particular AGE.
- Surveillance - unscheduled inspection of previously approved facility. If the check does not record any findings there is no need to draft any message.

D. *Periodicity of flight inspection*

The planning of flight inspection in the Czech Republic is responsibility of the Civil Aviation Authority. Schedule of flights is published each month in advance. The time interval between regular checks standard defines the state in which the facility is located.

Planning is based on operators' requests but it has always to be met by regular intervals between the measurements set out by the directive CAA-D-004-3/10 that determines the validity of the protocol issued by the flight inspection.

The Army of the Czech Republic uses a similar scheme of dates/validity and it orders the service if needed by the CAA under a concluded agreement or it performs the checking by their own.

Intervals for flight inspections of SUR domain:

Precision Approach Radar (PAR) 120 + - 24 days

Other 720 + - 36 days

E. *General procedures of flight inspection [4]*

1) notice of flight inspection
2) flight inspection planning
3) briefing
4) flight inspection
5) analysis and evaluation
6) debriefing and reporting

1) *Notice of flight inspection*

To achieve optimal coordination of follow-up procedures which require the ground assistance, the inspector or operational flight dispatcher must report the date and the exact time of scheduled inspection ion in advance.

2) *Flight inspection planning.*

When planning a flight inspection is primarily necessary to establish the competence and divide preparatory activities. The responsibilities of coordinating these activities have the inspector together with the AGE leading operator.

Responsibility of the inspector (the pilot) is to:

- ensure that flight inspection equipment was calibrated and it is operable
- instruct the radar operators
- instruct the flight crew
- provide the necessary documentation (maps, drawings, installations, data tables etc.)
- provide two-way communication when it is required
- assess the status, characteristics and limits of AGE
- ensure that all publications and records agree with the results of the last flight and verificate that all applicable restrictions have been properly defined
- inform air traffic control.

Responsibility of ground operator of AGE is to:

- ensure that the AGE is ready for two-way communication and has a source of energy
- ensure that all equipment of ground radar device was calibrated in accordance to the technical regulations

- ensure that the operator can carry out correction and adjustment of radar equipment
- provide the necessary transportation facilities and personnel for flight inspection
- provide accurate data on new and relocated AGE
- ensure the skilled operators of location and radar systems in order to minimize operator´s influence on the technical parameters of the equipment
- issue the NOTAM for flight calibration
- if necessary to provide translation and instructions to enable communication with the flight crew [6].

3) Briefing

The technical demands on flight verification and therefore the actual pre-flight preparation of radiolocation systems is significantly lower than of navigation systems due to the fact that most information can be obtained by the ground control.

4) Flight inspection

Procedures for flight inspection of ground facilities are specifically applied for each group of AGE. Regular inspection of air surveillance systems includes:

- pre-inspection planning (develop a technical plan)
- measurement of equipment parameters
- equipment optimization
- site integration
- flight inspection (data collection and analysis)
- documentation of results
- generation of a database (baseline)
- record of all equipment measurements
- preparation of final report [3].

5) Analysis and evaluation

The responsibility of ground personnel of AGE is to implement the following procedures:

- Compare the results of ground and flight control - these results are being used for confirmation of accuracy of the technical parameters of the facility.
- The operator of AGE has to ensure the issue of NOTAM according to national procedures if the results of flight inspection show that it is necessary.

6) Debriefing and reporting

The responsibility of inspector (pilot) is to implement the following procedures:

- provide the ground staff of the AGE by brief information about results of the flight inspection
- define the status of AGE (no limitation, limited or unusable)
- provide an accurate report from the flight inspection and discuss it with the ground personnel of AGE
- provide information about the flight inspection to administrators of AGE to be publish and to control the published information in terms of accuracy
- If possible the Flight inspection Authority should be the only subject which compares the current technical parameters of a radar device with past results and compile the trend analysis [6].

IV. FLIGHT INSPECTION OF SURVEILLANCE RADAR SYSTEMS

A. Surveillance radar

Primary radar equipment used for positioning of distance and azimuth of aircraft on the principle of reflection of radio pulse from the object located in the direction of the source of energy.

TABLE I. CHECKLIST OF THE MAIN PRIMARY SURVEILLANCE RADIOLOCATOR INSPECTIONS [6]

Measured parameter	**Flight inspection**	
	Commissioning	***Periodic***
Accuracy in azimuth	x	
Accuracy in the distance	x	
Vertical coverage/gradient	x	
Horizontal coverage	x	
Accuracy of videomap	x	
Approach with surveillance radar	x	x
Identification of still target	x	
Ccommunication devices	x	x
Backu power source	x	

Tab. 1 consists of the minimum required controls of the primary surveillance radar to be checked on compliance.

B. Secondary surveillance radar (SSR)

Surveillance radar system uses for its activities other equipment on board of the aircraft called a transponder. It consists of three main parts:

- Interrogator (together with secondary radar receiver) – Ground based radio beacon which transmits pulses synchronously with the primary radar via a suitable signal to all transponders in the vicinity.

- Responder - This device automatically receives a signal from all relevant interrogators and sends a coded message to all interrogators against which it is set.
- Radar Screen - Displays the signal returning from the two types of radars. The secondary radar devices are displayed on the screen outputs that show as flight number, altitude, ground speed, the loss of radar contact etc. [4]

An integral part of the equipment ground secondary surveillance systems is a decoder. This device allows the air traffic controller to assign a personal identification code to each aircraft which has the necessary transponder.

Standard SSR reply has the form of three pulses and transmits interrogation pulses on 1030 MHz [3].

TABLE II. CHECKLIST OF THE MAIN SECONDARY SURVEILLANCE RADIOLOCATOR INSPECTIONS [6]

Measured parameter	**Flight inspection**	
	Commissioning	***Periodic***
Accuracy in azimuth	x	
Accuracy in the distance	x	
Vertical coverage/gradient	x	
Horizontal coverage	x	
Side lobe suppression	x	
Unwanted received signal	x	

Tab. 2 consists of the minimum required controls of the secondary surveillance radar to be checked on compliance.

C. Methods of surveillance systems performance monitoring

There are several methods for testing the performance of the systems:

- Testing of internal functions – It means continuous monitoring of systems and subsystems functions such as voltage standing wave ratio (VSWR), receiver noise level, transmitter output power and status of power supplies.
- RTQC - Function that incorporates a set of dynamic tests such as measuring the probability of detection or probability of false alarm.
- Evaluation Programs - These programs are the most important parameters of the statistical analysis of operational performance of the tested system [3].

TABLE III. TOLERANTION/PROCEDURES OFCHECKLIST OF THE MAIN PRIMARY/SECONDARY SURVEILLANCE RADIOLOCATOR INSPECTIONS [6]

Required inspections	**Toleration/Procedures**
Accuracy in azimuth	On the track in the range of ± 0.5 Final approach: 1. Direct in the range of 152 m [500 ft] from the edges of the runway at the MAP (missed approach point). 2. Approach to the runway / on a circular route within the radius of the MAP, which is 5% of the distance from the aircraft to the radar antenna or 305 m [1000 ft], whichever is greater.
Accuracy in the distance	Final approach and route upto 5% of the distance from the station to fix or 152 m [500 ft], whichever is greater.
Signal coverage area	Sufficient to ensure the request. Air traffic controller can use random aircraft. Standard profiles of vertical and horizontal coverage are not required.

CONCLUSIONS

The aim of this work is to briefly summarize flight inspection process, in particular, with respect to ground surveillance systems.

Flight checking status in the Czech Republic is currently primarily influenced by several major aspects:

The main civil aviation operator ŘLP ČR, s.p (Air Navigation Services, Czech Republic) due to its technical equipment made an agreement concerning the partial replacement of financially demanding flight inspection by other technical means (based on evaluation of data from routine operations).

The equipment operated by the Army of the Czech Republic (PAR – Precision approach radar, SRE – Surveillance radar element, SSR – Secondary surveillance radar) shows high technology age and limited resources.

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Hypoxia - Continuing Threat

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***Abstract* - Despite a more than one hundred thirty years old finding that the decrease of barometric pressure reduces the offer of oxygen, aviation still did not countervail effectively against the risk of hypobaric hypoxia. The reasons rest equally in individual, as well as in systemic failures.**

Keywords- physiological limits; technical coverage; professional training; flight planning

I. INTRODUCTION

If we ask, why the effort of total elimination of dangerous consequences caused by hypoxic events in aviation industry has failed, it is necessary to account for the complexity of causes which participate on this situation. The relationship between atmospheric pressure and its reliability in saturation of living tissues with oxygen is known since 1883 from experiments of French physiologist Paul Bert. Since then the technological improvements in reliability and performance of cabin pressurization, oxygen delivery systems and cockpit alarm systems has greatly reduced the incidents and accidents due to hypoxia. Despite these measures risk of in-flight hypoxia has not been eliminated.

There are more causes of this state. In the first place one must consider the man´s physiological limits. Partial pressure of oxygen in the air around the height of 15 000 ft no longer suffices for required covering of red cells with life-giving oxygen. Despite this fact there remains a quite sufficient reserve up to the moment of unavoidable lapse of blood´s oxygenation. This threshold lies around the height of 24 000 ft. The closer to the upper boundary the more serious are the manifestations of oxygen starvation. In the "gray zone" between mentioned levels is the man capable still worse of rational actions and after exceeding the upper limit without oxygen supply the loss of consciousness and death are inevitable.

Neglect of vigilance, mechanical failure of equipment, disregard for indoctrination or improper use of oxygen equipment then inevitably lead to the impairment or incapacitation of the persons on board.

II. CURRENT STATUS

It should be noted that the incidence of hypoxic events has been significantly reduced in recent decades. Occurrence of accidents and incidents caused by hypoxia is different in various sorts of aviation. Most cases are reported by the Air Force. An analysis of USAF hypoxia incidents from January 1976 to March 1990 revealed 656 reported incidents [1]. Certain differences exist within the airline industry. Hypoxic events in line air traffic are mostly associated with depressurization of the cabin accompanied with uncontrolled, rapid or slow decompression. Such cases are relatively rare. Decompression incidents are not uncommon on military and civilian aircraft, with approximately 40–50 rapid decompression events occurring worldwide annually. In the majority of cases the problem is relatively manageable for aircrew. Consequently where passengers and the aircraft do not suffer any ill-effects, the incidents tend not to be considered notable. The statistics show, that over the past 57 years there were only 36 such events. The death toll has exceeded 4000 people, however [2]. The failure of cabin pressure maintaining is not unusual even in pick-up traffic, operated by Learjet or Beechcraft planes [3, 4].

In a comprehensive review of 2696 fatal general aviation accidents from 1990-1998 in-flight hypoxia was involved by 4.16 % [5]. As shown below, neither recreational flying may not be protected against the risk of hypoxia.

III. CAUSES OF HYPOXIC EVENTS

Surprisingly hitherto only a few authors applied a systematic approach to the problem of in-flight hypoxia. A key aspect of such approach lies in finding of an answer to the question whether the event was unavoidable or not. There is not enough just to find out the immediate source of oxygen starvation (in other words the *active failure*). Concurrently one must search for *latent condition*, present in the system well before a damaging outcome is experienced. Such an approach is based on Reason´s accident causation concept, which cannot be ignored [6]. Not only it allows distinguishing between errors and violations, but it forces all aviation professionals to evaluate the effectivity of resources provided by the system to protect against the safety risks.

Preconditions of hypoxic events can be divided arbitrarily into three main categories: environmental, individual and systemic respectively.

Environmental preconditions include all cases of rapid and slow decompression. Their mutual ratio is about 1:1[2]. While in cases of the total destruction of a plane hypoxia is only a subordinate lethal factor, slow or gradual decompression allows the crew to control the situation with rapid descent. Decompression events are more frequent in the civilian than in military aviation [1].

In this context an unexpected problem emerged in recent years. It consists in ignoring of cockpit alarm indicating the critical loss of pressure, and thus a lack of oxygen in the cockpit [7]. The most deadly result to date was the August 2005 crash of Helios Airways Flight 522, in which 121 passengers and crew were killed when a Boeing 737-31S crashed into a mountain north Athens. Recently has Boeing announced a plan for retrofitting older 737s with an improved alarm system. At the same time it shows, that the technological improvements may not guarantee the system´s reliability. According Fabey Boeing 737 pilots ignored the horn for years, even after it became known the main cause of the Helios 522 crash. There are several reasons why it is happening.

Perhaps the more important is that in the 737 the horn is an ambiguous alarm. It serves a dual purpose. Before take-off it warns pilots if the aircraft is not configured for the flight. The warning that sounds after the take-off, pilots frequently misinterpret as a false alarm. Adding to the confusion is the fact, that pilots often contend with false alarms and related pressurization equipment miscues in flight. FAA and manufacturer have recently found the solution both in the improvement of the system, and in issuance of a new airworthiness directive.

The environmental conditions also include cases of unexpected ascend of a glider (lacking effective anti-hypoxic protection) to dangerous level during the long wave flight [8]. Currently a few tragic cases of lethal exposure of hang glider pilots, lifted involuntary with thermal lifts to altitudes above 40 000 ft are known as well.

Individual preconditions consist primarily in individual hypoxic tolerance, in the thoroughness of indoctrination, allowing in-time recognition of hypoxic threat and in the adherence of conscious discipline to the use of protective measures.

General limits for hypoxic tolerance mentioned above can be sometimes weakened due to other situational effects. In these cases detectable symptoms of hypoxia begin to appear at relatively low altitudes. Nishi [9] has recently reported on significant decrease of oxygen saturation in aircrews, operating UH-60J helicopters below 5000 ft. The most common manifestation of failure is cognitive impairment [1, 5].

Hypoxia may be gradual and individually different and that is all complicated by all other contributing factors, such as fatigue, darkness, boredom, nutritional state, hydration level and so on, which all may be minor factors, but are contributing when added to each other [10]

Already before the World War I the applicants for service in the aviation were routinely exposed to the Lottig´s test, consisting in the demonstration of oxygen depletion at 24 500 ft. Currently this procedure is mandatory only for flying staff of Air Force. Although the high rates of recognition of own symptoms reinforce the value of hypoxia training, even this preventive tool did not remove completely the risk of failure [11, 12].

After Helios crash some have suggested to restore mandatory hypoxia training for all aircrews in civil aviation. The idea did not meet with understanding, inter alia due to considerable costs of such action. Generally acceptable and affordable solution could be the use of a reduced oxygen breathing device (ROBD) or a s.c. "hypoxicator" [13, 14], not requiring the altitude chamber.

Common violations in the pre-flight check and in faulty oxygen drill are difficult to understand [15]. According Rayman and McNaugton [16] 50 % of cases occurred in training aircraft highlight the fact, that breach of O_2 discipline is most likely in young pilots.

The latter causes of hypoxic events cannot be explained solely on individual basis. As a rule, they interfere with *systemic preconditions* whether in the technical support, or at safety management level. Inadequate ground servicing, improperly assembled oxygen set, damaged hoses or regulators, failure of demand regulator to give correct concentration of oxygen or inadvertent break of connection between oxygen mask and regulator are relatively frequent latent sources of in-flight hypoxia (up to 45 %). Constantly repeating the same faults show the need of tighter control over maintenance personnel. This opinion confirms our own experience. Among 44 physiological incidents 11 (i.e. 25 %) were associated with poor maintenance of oxygen sets [17]. At present some reliability problems persist with on-board oxygen generating systems malfunctions [9, 11, 18].

IV. SCOPE FOR PREVENTION

1. In-flight hypoxia still remains a serious and worrying threat to aviators in particular and aviation community in general. This calls for constant vigilance and awareness throughout the aviation community to fight the menace [12].

2. Prevention must focus both on individual and systemic components of air operations.

3. The basic measure from the individual point of view lies in thorough hypoxia indoctrination training, reinforced periodically.

4. The fundamental measure, resting both on individuals and on the compliance with organization rules, is the strict adherence to O_2 system discipline by the aviators.

5. Reliable logistic support and reliable maintenance monitoring of oxygen and cabins pressure systems are absolutely essential parts of safety management in preventing of hypoxic events.

6. Unambiguous warning systems can provide early warning of aircrew.

7. It would be worth to pay more attention to ATCs´ capability to recognize signs of impaired speech whether by listening or through the voice analysis and, if necessary, immediately provide assistance to the pilot.

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Global Geography of Airport Ground Handlers

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Abstract: **The paper explains how methodology known as network spread index can be used in the case of airport ground handlers. Innovation within this approach is discussed to develop new typology of airport ground handlers in global handling business. New methodology is applied for seven independent ground handling companies which operate at the biggest European airports. Issues of quantitative aspects as well as qualitative ones are discussed when describing global ground handling business.**

Keywords: airport, ground handlers, globalisation, deregulation, geographical spread index, internationalisation index

I. Introduction

Air transport sector may not be considered as a homogeneous sector as it involves heterogeneous actors, handling companies included. Ground handling services previously integrated within airlines, are nowadays often outsourced to third parties creating specific network market operated on airport platforms. [1] In the European Union the ground handling market has been facing a trend towards liberalization initiated by the EU directive 96/67/EC resulting in the state in which ground handling services can be provided in-house by airlines themselves, by airlines as third party handlers, by independent ground handling companies and by airports. [2] Although the level of ground handling market liberalization differs among the EU countries, airports and market segments [3], presence of independent ground handling companies is without question in the EU air business and attracts research attention.

Tendency towards far-reaching integration is expected in future as independent ground handlers will be confronted with increasingly powerful customers (airlines) and evolution similar to that observed in other industries may result in a limited number of ground handling groups companies operated internationally or even globally. [4] This paper tries to provide a new look at independent ground handling companies at the EU important hub airports revealing and quantifying their global geography through index of geographical spread.

II. Measuring Firms Globalisation: the Case of Ground Handlers

When capturing the question of firms degree of globalization, many approaches and methodologies are at disposal to measure the phenomenon. [5] Some indices are based on unidimensional measures, whereas other are composed of several ones. All they help to describe different aspects (financial or non-financial or both) of firms global expansion, so as serving as a quantitative value towards which firms global results can be compared and ranked (for example global financial performance). Transnationality Index (TNI) published by UNCTAD [6], the Transnationality Spread Index (TSI) introduced by Ietto-Gillies and the Degree of Internationalization Scale (DOI) of Sullivan taking many modifications can be mentioned as very common in comprehensive management literature. [7]

Any globalisation index (not taking into account how it is labelled by the name)[1] has its own strenghts, weaknesses and limitations. Infrastructure sectors with its specific features and "globalisation working" require specific approach in measuring degree of globalisation of key infrastructure players. The form of presence of key players in foreign markets can include variety of options, including "soft forms" [8] as the internationalization of infrastructure has taken varying trajectories in different parts of the world". [9] Therefore, when describing global geography of independent ground handling companies which provide ground side infrastructure services in air transport value chain, tight methodology ought to be applied respecting the most significant peculiarities of ground handing markets as well as data sufficiency.

Our approach used in this paper is a modification of Geographical Spread Index (GSI) used by UNCTAD. This index demonstrates a degree of geographical spread of activities of transnational companies. The GSI is calculated as the square root of the Internationalization Index (II) multiplied by the number of host countries in which transnational corporation operates and the Internationalization Index that is a number of foreign affiliates divided by the number of all affiliates. When analyzing global geography of key players in ground handling markets we have decided to replace a number of foreign affiliates by the number of airports abroad at which handling company operates in the II. Total number of airports at which handler operates will serve as a denominator in the II. This enables us to cope with foreign presence of independent handler abroad in a broader scope not taking into account whether the presence abroad has a form of affiliate or whether there is one or more affiliates of the handler at one concrete airport. Another modification of the GSI is aimed to take into

[1] Transnationalisation, global spread, internationalisation etc. are the most requent alternatives.

consideration not only presence of ground handlers in foreign countries but also presence in foreign world continents. Whereupon, our approach to the GSI is that it is designed as a three component measure, the third root of the II multiplied by the number of foreign countries and the number of foreign continents in which handler operates. [2]

$$GSI_3 = \sqrt[3]{II.n_c.n_{wc}} \, ,$$

Where:

GSI_3 … Global Spread Index composed of three elements,

II … Internationalization Index as a ratio (number of airports abroad at which handler operates and total number of airports at which handler operates)

n_c … number of foreign countries in which handler operates, (out of country in which handler has principal residence)

n_{wc} … number of continents in which handler operates.

According to our opinion, this approach enables to distinguish more precisely among key ground handling players which expand really globally and those which operate internationally, however with stronger geographical concentration in one world continent, not achieving global spread of its activities in several (or all) world regions. Following this methodology, we analyze seven chosen independent ground handlers using step-by step demonstration (the II, the GSI as the square root and the GSI as the third root).

III. Global Geography of (Chosen) Ground HandlerS

Due to continuing liberalization, a different structure of ground handling markets has been developed at European airports. [10] The list of actors operating as ground handlers at European airports is rather comprehensive and airports, airlines or airlines subsidiaries as well as independent ground handling companies are belonging to it.

Our effort to quantify a degree of geographical spread in activities in ground handling business will be narrowed only to actors who operate their activities with status of so-called specialized independent ground handler, airlines or airlines subsidiaries not including. Similarly, we limit our analysis only to those independent ground handlers who are the most frequent a scope of the biggest European airports according to ACI. [11] Although rather arbitrary, a choice of handlers for our purpose represents handlers in diapason according principal residence: handlers with principal residence in different European countries (Menzies Aviation, Servisair, Air Dispatch - Great Britain, Aviapartner – Belgium, Swissport – Switzerland, Randstad - Germany), and also out of Europe (Worldwide Flight Services –USA). To compute the indices mentioned, the IGHC IATA data has been used, time status August 2011. [13]

The results obtained are contained in Table 1.

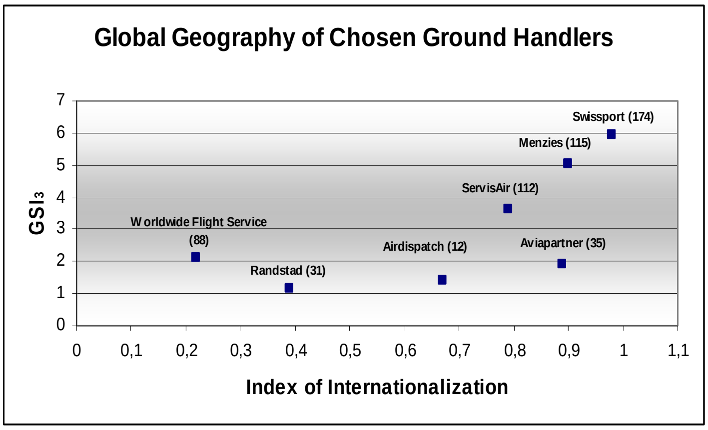
TABLE 1.

Global Geography Indices of Chosen Ground Handlers

Handler	II	GSI_2	GSI_3
Airdispatch	0,67	1,64	1,39
Aviapartner	0,89	1,89	1,92
Menzies Aviation	0,90	4,65	5,06
Randstad	0,39	1,25	1,16
ServiceAir	0,79	3,44	3,62
Swissport	0,98	5,94	5,96
Worldwide Flight Service	0,23	1,79	2,13

Source: Own computation.

The application of the II and the GSIs on a data set on chosen independent ground handlers operating markedly at European airports indicates that there is no “single globalization measure” able to capture exhaustively to what extent global handlers are really globalized. The Index of Internationalization of lower levels can be accompanied with rather high GSI_3 (as in the case of World Flight Service), on the other hand the relatively significant value of the II need not mean inevitably broader geographical scope of handler business worldwide (as in the cases of Airdispatch and Aviapartner). We see as rightful to use both the GSI_2 and GSI_3 options to distinguish between handlers with similar level of the GSI_2 (Airdispatch, Aviapartner and Wordlwide Flight Service), as they develop differently their business inter-continentally.



[2] Europe, Asia, North America, Latin America, Africa, Australia and Middle East.

Figure 1.[3]

There are four boxes of possible options in stipulating handler typology according to the path in global handling business:

- Handlers with low Index of Internationalization and significant values of Global Spread Index,
- Handlers with low Index of Internationalization and low values of Global Spread Index,
- Handlers with high values of Global Spread Index and high Index of Internationalization,
- Handlers with high values of Global Spread Index and not so significant values of Index of Internationalization.

Towards New Typology of Handlers in Global Handling Business

Handlers Typology in Global Business		GSI_3	
		high	low
II	high		
	low		

Figure 2.

Within the typology developed it will be necessary to state a distinct value line between high and low levels of the typological attributes considered. To achieve this aim, a more comprehensive application of the GSI_3 and the II on broader sample of independent handling companies will be needed in future research. Similar approach as it was done in this paper for European airports can be useful concentrating attention on the most significant handlers at the biggest airports in world regions. Then some arbitrary, however qualified decision of experts about the list of independent handlers analyzed ought to be taken. As far as the II this issue of strict splitting line seems to be easier task, as 0,5 value of the II means that the number of airports at which handler operates its activities in residential country is equal to the number of airport abroad. The value higher than 0,5 indicates a higher proportion of airports abroad in total number of airports considered. As far GSI_3 splitting lines, alternative of only two GSI_3 components (number of countries multiplied by number of continents) can be discussed in the typology designed.

IV. Conclusions

Issues of global architecture in any business are in the focus of researchers as well as practitioners as they enable to comprehend more a complex nature of strategy and success of key global players. Independent handlers are not out of the globalization wave, therefore any methodology and analysis aimed at description how globalization works within this specific business can be helpful. Our approach towards typology of handlers in global business is stemming from quantitative indices which demonstrate “only degree of globalization” attribute represented by the II and “also geographical scope of globalization” attribute represented by the GSI (including number of foreign countries and world continents). We must, however, admit that this approach is mirroring only geographical path of globalization in ground handling business, not reflecting financial path of globalization (assets abroad, revenues abroad etc.) or other aspects of firm globalization strategy.

Another research problem that ought to be answered in future is a qualitative question about services portfolio that are provided by handlers at their airport network. Following this issue, strategy of specialization or diversification in global handling business could complete typology of handlers in global handling business, combining quantitative as well as quantitative aspects of globalization in this specific globalizing market.

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Rail Repair Of The CFM56 LPT Case

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***Abstract*— Low pressure turbine cases are exposed to mechanical loads transferred through aerodynamic forces from the vanes into the case rails. These "vane carriers" commonly show heavy wear on the contact area between vane cluster and rail inner side.**

This paper deals with the current repair process of the case rails and highlights an underestimated problem. While particular focus has been taken on the welding process and heat treatment in the development phase, the distortion and final machining have not been identified. The presentation closes with the ongoing development in terms of heat reduced welding and fixture based rail restoration.

I. INTRODUCTION

Several operators of CFM-56 jet engines reported about in-flight shout downs of their engines. Reason for the shut down was excessive engine vibration due to the low pressure turbine (LPT) failure. Subsequent inspections revealed severe damage of loosen LPT vanes hitting into the rotating system. In-shop inspection detected missing rail segments vane clusters are attached to, figure 1.

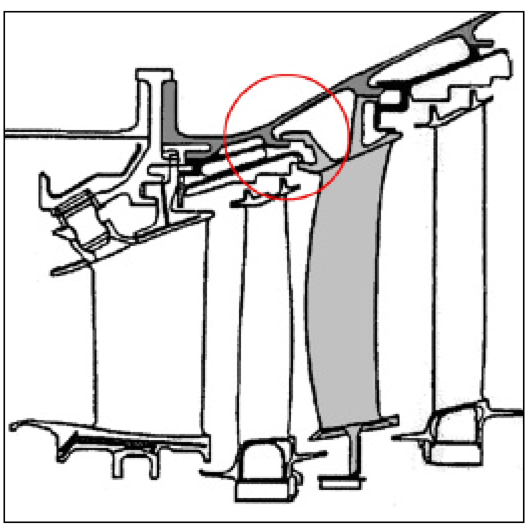

Figure 1. Vane cluster attached to the LPT case rail

II. FAILURE ANALYSIS

Failure analysis took place in order to determine the root cause. Fractography of broken rail segments confirmed axial and circumferential cracks with independent crack growth. Break out occurred when a crack propagating circumferentially met an axial one as shown in figure 2. Crack morphology is given in figure 3.

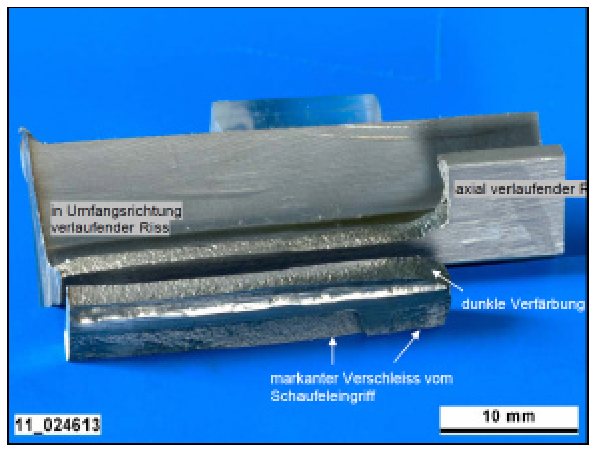

Figure 2. Broken rail segment

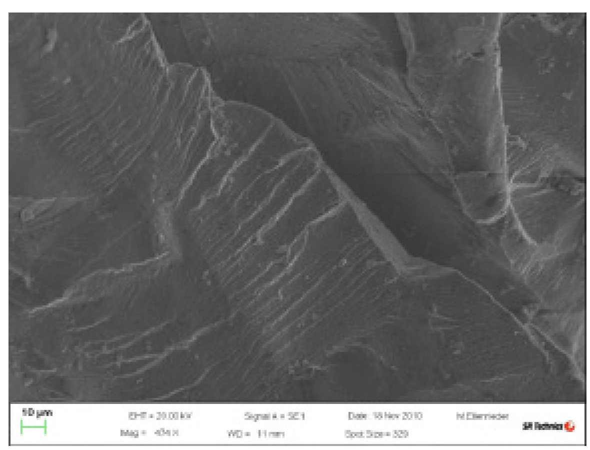

Figure 3. Striations in SEM view

Further investigation of the broken rail showed that rail was previously restored by the TIG weld build up. The crack propagated along the weld joint as shown in figure 4. On the other hand, the weld was of a good quality, no voids or other irregularities could be detected. Hardness measurement showed a smooth gradient through the heat affected zone.

Some concerns regarding the heat treatment and heat input brought up the clarification of residual stresses in the weld area. Cut compliance method was used to validate residual stresses the principle directions. Even these results could not confirm the thesis as residuals stresses occurred at a very low level.

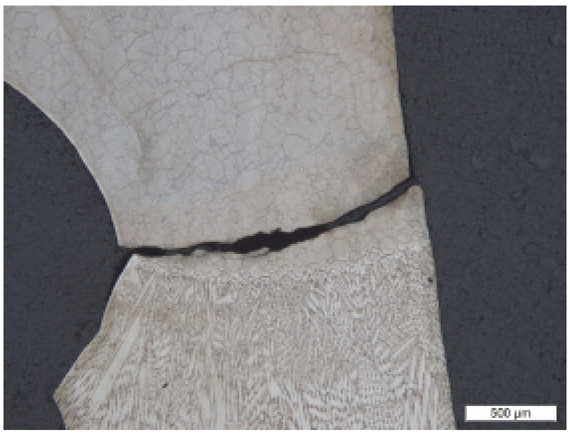

Figure 4. Crack propagation along the weld joint

The shape of various repair rails provided the assumption that mechanical loads of the rail might cause the failure. Hence, qualitative analysis compared origin rail shape versus “as shown” shape in figure 5. FEA showed unacceptable stress peaks due to the notch effect.

Figure 5. Various rail shapes of investigated LPT-cases

Following list summarizes the testing plan and the goals:

- Fractography: to detect failure mode based on crack morphology.
- Metallography: to investigate weld quality.
- Hardness: to investigate mechanical integrity of weld seam-heat affected zone-parent material.
- Residual Stress: to analyze impact of the heat treatment and heat input from weld process.
- FEA: to investigate various rail shapes in order to determine stress concentration.

Coming to the conclusions:

- Axial cracks (hoop stress) and circumferential cracks (bending stress) have different load modes. Axial cracks are result of thermal-mechanical fatigue while circumferential cracks occur due to mechanical bend load introduced by the vane cluster. Multiple cracks initiate from the inner rail side, merge and propagate circumferentially in transgranular mode.
- Heavy wear (fretting) on the inner side of the rail indicates massive pressure load from the vane segment and poor alignment of vane and rail.
- Residual stress measurements confirm hypothesis about bending stress as compressive stress has been measured at the outer side of the rail.
- Tests attest welding process of a good quality.
- FEA shows unacceptable stress peaks due to notch effect in the repaired rail. Notch effect is the reason for failure.

As notch effect was found to be the reason for failure, dimensional inspection revealed rail’s outer surface out of roundness and machined inner surface within inspection limits. Considering the entire repair process, the case is exposed to various heat impacts during the repair. Heat input from the welding process and heat treatment before and after welding led to an unacceptable distortion of the case which was not consequently respected during final machining. Hence, notches and different rail thicknesses were subject to fatigue.

III. PREVENTIVE ACTIONS

Reduction of heat input and adequate tooling are the main tasks to meet the mechanical integrity of the rail. Heat input will be reduced by the use of advanced repair techniques like micro-plasma, laser or EB welding. Instead of weld building up layer by layer, virgin material ring might be joined to the rail root with one single weld pass, figure 6. These actions are subject of the ongoing cooperation project with the OEM.

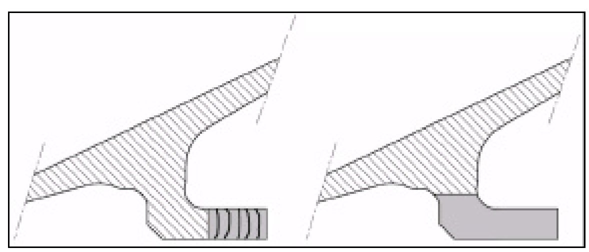

Figure 6. TIG welded rail versus EB welded ring

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The Airport CDM System and its Implementation at the Prague Ruzyně airport

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***Abstract*—A tendency of last years is increasing of civil aviation. One of variety of quality indicators is delay. This article deals with a problem of delays caused by insufficient information exchange among all units involved into aerodrome traffic (air traffic control, airline operators, handling services providers, airport etc.).**

For this purpose FAA developed a system called Collaborative Decision Making (CDM). Later, the idea inspired Eurocontrol to develop the CDM for European airports. It is built up on monitoring of all processes which affect rate of delay and airport planning.

Paper also refers about implementing of CDM at the Prague Ruzyně airport.

Keywords- collaborative decision making, target off block time, target start approval time, target take off time, calculated take off time

I. Introduction

Prague airport is one of the most growing airports in the central European region. In the last twenty years number of passengers increased nearly seven times. The number of aircraft movements per year is almost 120 000 higher than twenty years ago. This growth was slowed down by economical crises in 2008 and by problems of Czech Airlines. Nevertheless, in the future is growing trend expected.

Demand for flying from and to Prague reasoned out realizing of many projects like building Terminal 2 and departure part of Terminal 1, fast exits on 24/06 runway, apron stands capacity enhancing etc. The future milestone for the Prague airport should be building up of parallel runway 24L/06R. At the moment, the runway capacity is the most restricting factor for whole airport capacity, especially at the peak hours.

Physical extension of an airport is not the only way how to increase or optimize its capacity. One of the “non-physical” possibilities is the Airport CDM system. In general, it is based on operational information exchange among all partners involved in airport processes.

The lack of runway capacity at peak hours at the Prague Airport and with the uncertain new parallel runway construction launch led to the decision that Prague Airport will become a CDM airport. The system is supposed to improve punctuality and predictability, safety, better use of ATFM (air traffic flow management), reduce apron and taxiway congestion, etc.

II. The concept of Airport CDM

A. History

The origin of the idea of the CDM is in the 80’s and early 90’s of the last century in the United States. While in Europe the biggest concerns were about a lack of capacity on flight routes, U.S. airlines faced increasingly problems on the ground.

There were various problems at the big hub airports. For example, long taxi times due to late information about runway in use change and some similar but just simple examples of problems affecting all airports in the U.S.A. Airlines and Federal Aviation Administration (FAA) have formed a group to create a solution.

The FAA recommended using common sense, telling the truth about canceled flights, work together, and share any information which could help. Those examples came from two airports in Philadelphia and Atlanta. There they experienced an almost miraculous improvement in accuracy and predictability [2].

At the same time the European air traffic rather than delays on the ground faced the en-routes capacity problems. But under threat of similar future problems CDM was accepted and further modified by Eurocontrol for the European purposes.

B. The CDM philosophy

As the name implies, the basic idea is based on collaboration among partners involved in the all airport processes. Collaboration means the real-time information sharing on predefined platform which is used by other partners. The platform is usually some kind of operational database provided by airport operator. The information from the database is accessible to all partners. For each partner it is both, an information resource and a place where own information could be shared.

The result of whole process is more accurate and better predicted off-block time and start up time. These two key milestones are in CDM language called Target Off-Block Time (TOBT) and Target Start Approval Time (TSAT).

C. The CDM partners and their role in the process

There are five partners in the CDM process:

- Air traffic control
- Aircraft operator
- Ground Handling Services Provider
- Airport Operator
- Central Flow Management Unit (CFMU)

Air Traffic Control (ATC) provides TSAT, calculates departure sequence and approves start up request at TSAT interval. All calculation is made by automated system called Start Up Manager (SUM).

Aircraft operator is mainly supposed to keep the flight plan updated and inform about all consequences which could affect TOBT.

Ground Handling Services Provider with a Handling agent or Station dispatch responses for accurate TOBT, which is the key issue for TSAT calculation.

Airport Operator use CDM data for departure gates and apron stands allocation and supervises Airport Operational Database as well as whole CDM.

Involving CFMU into the CDM is the final step at implementation. With a providing of automated messages is the airport connected to the Air Traffic Management (ATM) network.

D. Implementation

There are six Concept Elements in a CDM implementation recommended by the Eurocontrol CDM Implementation Manual [3]:

1) Airport CDM information sharing: This element creates a foundation for other implementation steps and functions. Therefore it is essential to implement it before all other elements. Information sharing is supposed to:

- Connect Airport CDM partners to the data processing systems
- Provide common set of data, describing the flight intentions
- To serve a platform for information sharing between partners

The figure 1 shows information shared by CDM partners.

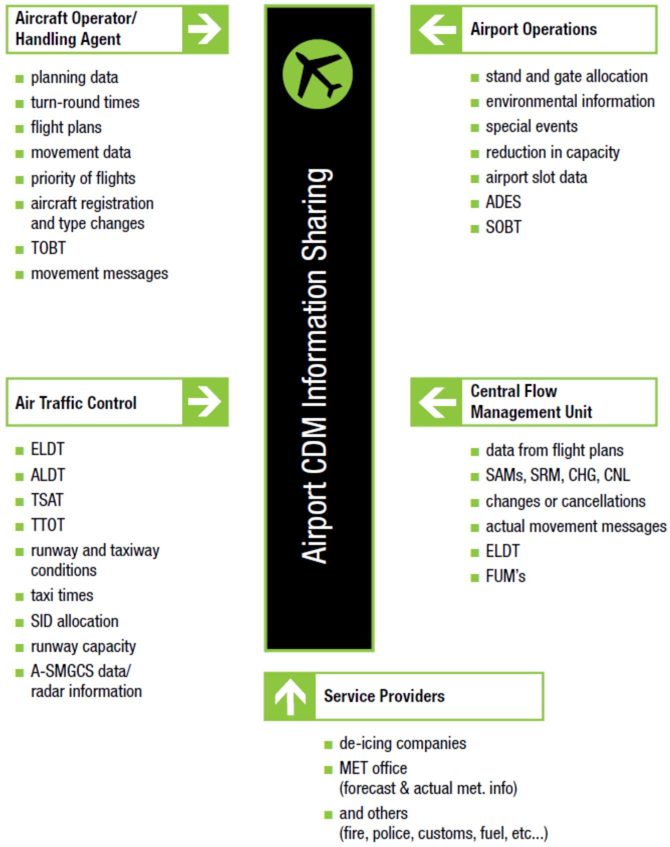

Figure 1. Information sharing layout [3]

2) The milestone approach: The next step of CDM implementation is flight lifecycle milestones establishing. Compared with current procedures, this is the main innovation. Eurocontrol suggests flight lifecycle with 16 milestones. A whole process begins with flight plan activation three hours before estimated off-block time and ends with the take off of the aircraft.

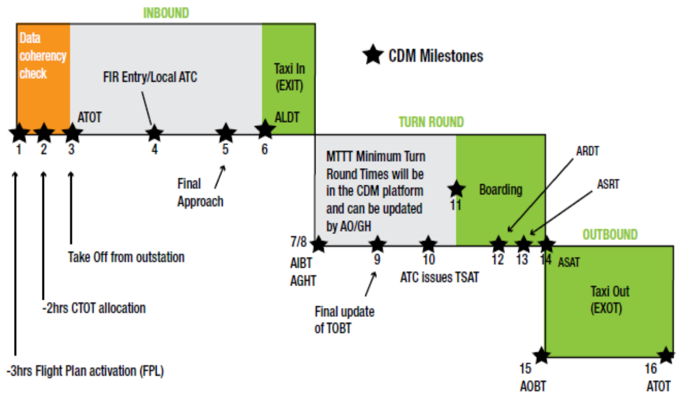

Figure 2. The flight lifecycle milestones [3]

3) Variable taxi time: With the lifecycle milestones established, there is much easier to anticipate TOBT. The next step to take is Variable Taxi Time (VTT) establishing which is required for Target Take Off Time (TTOT) calculation. Simplified, VTT depends on runway in use, aircraft stand etc.

4) Collaborative pre-departure sequence: With previous three elements implemented, the next step is pre-departure sequencing installation in order to regulate taxi way traffic, shorten taxi time and reduce environmental impacts. With this sequence Target start Approval Time (TSAT) is Calculated as well as TTOT using a VTT.

5) CDM in adverse conditions: This is the last local CDM element for implementation. Sequencing in adverse conditions (e.g. de-ice conditions, runway or taxiway closure etc.) enables ATC to keep capacity maximally utilized even in case of significant capacity drop.

6) Collaborative management of flight updates: With all local Airport CDM Concept Elements successfully implemented, the airport is ready to connect with the CFMU for Departure Planning Information (DPI) exchange. The predicted TTOT's coming out of the TOBT prediction and sequencing processes are sent to CFMU, feeding them to adjust the CFMU derived Calculated Take Off Time (CTOT) accordingly. With this element in place, CFMU starts to react on predictions coming from the Aircraft Operator, rather then to impose restrictive and inflexible constraints to an airline as is done today. [3]

III. Airport CDM implementation at the Prague Ruzyně Airport

The first discussions about possible CDM implementation at the Prague Airport begun at the end of Eurocontrol Prague Capacity & Enhancement study in 2006. The Cost and benefit analysis in 2008 proved that CDM would bring efficiency increase for the Prague Airport. The project has been launched in the mid of 2008 and involved following partners:

- Prague Airport
- Air navigation services of the Czech Republic
- Czech Airlines
- Menzies Aviation

The project has got three phases which implement all above mentioned CDM elements.

A. Phase 1

Phase 1 was launched in October 2009. The main objective was to implement CDM information sharing. For this purpose were developed a CDM functions for the Central Airport Operational Database (CAODB) and CAODB Web Interface (CWI).

A necessity of some kind of mobile device resulted in a development of MobileGHA application for Motorola PDA used to insert and update TOBTs by ground handling agents by both Czech airlines and Prague airport. Menzies Aviation doesn't use any mobile device but CWI on the station dispatch.

In Phase 1 were set VTTs as well as new procedures were tested.

B. Phase 2

Phase 2 was launched by the end of August 2011 and is currently running. Collaborative pre-departure sequence procedures were set. The crew is supposed to request push-back at TSAT +/- 3 minutes otherwise the flight will be penalized in terms of start up sequence.

The next step to take in Phase 2 is setting the system for adverse conditions.

C. Phase 3

With launch of Phase 3 will CDM locally fully implemented. Last task is to connect the Prague Airport to the ATM network using a Collaborative management of flight updates.

IV. Conclusion

Although the process of implementation at the Prague Airport hasn't been finished yet, the process can be considered successful in a general view.

There were some problems of technical nature like bad wi-fi signal coverage for mobile devices, too long data flow between mobile devices and ATC gateway, software errors etc.

All above mentioned problems can be solved soon or later but very difficult is being found to "get the procedures on board". As soon as all members of the process will fully follow the CDM rules, it will work as expected.

Prague Airport is at the moment in Phase 2 of implementation. Although the project has a little delay, it seems the CDM has brought its first benefits in the form of reducing taxi times and smooth departure ground processes at the peak hours.

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Ecological Aspects of the Usage of Alternative Fuels in Transport

Production of Greenhouse Gases, Energy Demand and Price of Alternative Fuels

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Abstract—**It is not possible to evaluate only the final stage of consumption in vehicles when assessing ecological advantages of using alternative fuels, but we must consider the entire "life cycle" including the previous stages of production resources, fuel production and distribution to the consumer. Only a comprehensive analysis is objective and allows to count with the fact that in some cases the production phase is so environmentally and energy-intensive, that the positive effect the final consumption of fuel in the vehicle.**

Keywords- Life Cycle Assesment, Well-to-Wheels, Well to Tank, Tank to Wheels, Alternative fuels

Environmental reasons are one of the main arguments for using alternative motor fuels. Alternative gaseous and liquid fuels compared to conventional fuels petroleum-based - automotive gasoline and diesel fuel generally, represent a smaller burden on the air both in terms of greenhouse gas (GHG) emissions, as well as other inorganic and organic pollutants contained in exhaust gases of internal combustion engines - carbon monoxide (CO), nitrogen oxides (NO_X), total hydrocarbons (HC), particulate matter (PM) and minor organic compounds with a high risk potential (eg. polyaromatic hydrocarbons, aldehydes, alkenes). The biggest advantage of gaseous fuels is the fact that in case of their release, they don't have constant pressure on water resources and land, another advanatge of some liquid alternative fuels from plant sources - biodiesel, bioethanol - is their biological degradability compared with conventional motor fuels petroleum-based.

It is not possible to evaluate only the final stage of consumption in vehicles when assessing ecological advantages of using alternative fuels, but we must consider the entire "life cycle" including the previous stages of production resources, fuel production and distribution to the consumer. Only a comprehensive analysis is objective and allows to count with the fact that in some cases the production phase is so environmentally and energy-intensive, that the positive effect the final consumption of fuel in the vehicle (eg hydrogen) is completely negated in the overall balance. A comprehensive assessment of the environment impact of fuel (LCA - Life Cycle Assessment) is currently the subject of worldwide activities of numerous research centers, it is a very complex issue that requires analysis of a large number of different data inputs from a number of economy sectors (agriculture, mining and raw materials, energy, automotive industry, chemical industry, economy).

As one of the best comprehensive analysis of this type of study can be considered "Well-to-Wheels Analysis of Future Automotive Fuels and powertrains in the European Context", prepared by EUCAR associations (the European Council for Automotive R & D), CONCAWE (the Oil Companies 'European Association for Environment, Health and Safety in Refining and Distribution) and JRC (the Joint Research Centre of the EU Commission) in 2003 and its refinement in 2005. The study provides analysis of the balance of GHG emissions for conventional diesel fuel (petrol, diesel), alternative gas (CNG, LNG, biogas, LPG, H2-C, L-H2, DME) and liquid (ethanol, methanol, ETBE, FAME, FAEE, synthetic NM - GTL, BTL) fuels in terms of different modes of production and distribution. The analysis also counts with the use of alternative fuels in vehicles with different levels of technical solutions to internal combustion engines corresponding to 2002 and projected for 2010, vehicles with hybrid drives and fuel cells. The study quantifies the cost of production respectively. GHG emissions savings.

Analysis of the environmental review of each fuel is divided into two parts. The first part, so called the Well Tank (WTT) "from the source to the tank," assesses the energy demands and greenhouse gas emissions in the steps preceding the final consumption of fuel in the vehicle. The second part, called the Tank Wheels (TTW) "from the tank to wheel", balances the stock of energy consumption and GHG emissions in the production stage of final consumption of fuel in the vehicle. Both parts together comprise the entire "life cycle" of a particular fuel, the Well's Wheels (WTW) "from the source to the wheels." The most important findings of this study can be summarized as follows:

• a key role in the production of GHG emissions and energy consumption is not only the character of motor fuel and method of its production, but also the efficiency of the engine in the vehicle;

• alternative motor fuels based on renewable resources can deliver significant GHG reductions in emissions, but generally at the cost of higher energy intensity;

• results of the analysis of environmental impact must always be furthermore assessed in terms of real resources, practical feasibility, costs and favorable public acceptance;

• the shift from fossil to alternative fuels from renewable sources is currently financially very difficult. Reduction of GHG emissions has always resulted in increased costs. However, higher costs do not automatically mean a greater reduction in GHG emissions;

• there is no simple way that would allow to ensure sufficient number of "low carbon" fuel in the near future. The market will feature a wide range of alternative fuels in the combined range of manufacturing technologies. Due to reasonable cost for a transitional period, when possible, appears unlikely to use a mixture of conventional and alternative motor fuels;

• production of synthetic fuels or hydrogen from fossil fuels - coal or natural gas is effective in reducing GHG emissions in the process of end-use only, when appropriate technology can capture and store carbon dioxide, produced in the process of production of these fuels. Synthetic fuels and hydrogen in the future have a greater potential to replace fossil fuel than today's conventional biofuels (ethanol, biodiesel). The main obstacle of development of mass production of this type of fuel is the high cost and complexity of production;

• optimal use of renewable sources like biomass and wind energy, is to be assessed in terms of total energy requirements, ie not only transport but also energy.

In general, we can say that virtually with all alternative motor fuels, except for natural gas and LPG, the phase prior to final energy consumption is very difficult. Energy consumption in the WTT phase in the better case corespondens to their own usable energy of alternative fuels (synthetic liquid fuels, DME, hydrogen produced from natural gas or biomass), but in most reported variations usable energy content of fuel is from 1.5 to 5 times exceeded (bioethanol, biodiesel, electrolytic hydrogen). This confirms that the energy contained in biomass or natural resources is very small and concentrated and the greater part of the exploitable potential of renewable energy should be reserved for the production of alternative fuels and will not be effectively used at the final stage of consumption.

Consumed energy from renewable resources is more or less almost in the process of production of each type of alternative fuel. Mostly we speak about electricity and motor fuels in agriculture and transport. Minimal consumption of nonrenewable resources is primarily associated with the use of waste biomass in cogeneration units in a joint production of electric energy and heat.

Electrolytic hydrogen is the most expensive production ever. It should be mentioned that the increase in oil prices partly reflects the growth in prices of alternative fuels. Further increases in oil prices is likely to erase differences in the prices of diesel and gasoline on one hand and bioethanol and biodiesel on the other hand, and these fuels become competitive. With lower oil prices, it is necessary to arrange tax advantage for raw materials and alternative fuel costs. In terms of financial costs, production of synthetic diesel fuel (except Russia), do not appear in Europe too real as well as especially processed of GTL (Gas to liquid) or CTL (Coal to liquid), due to lack of material resources. Also, mass production of this type of fuel from biomass process of BTL (Biomass to liquid) is very unlikely due to economic reasons in the medium term.

A very important criterium for production use, regarding environmental impact, is the total GHG emissions (in the form of converted carbon dioxide) per unit of consumed energy. The majority of alternative gaseous and liquid fuels produced from renewable energy-provides significant reductions in greenhouse gas emissions. In case of biogas produced by fermentation of livestock manure and ethanol, when the energy is provided during the manufacture by cogeneration unit burning waste straw, specific emissions ar even negative, and that is due to the efficient and targeted use of material that would otherwise rot in the process of uncontrolled fermentation and issued to atmosphere considerable amounts of greenhouse gases.

In terms of GHG gases emissions, not only the production of alternative fuels (DME, CTL, GTL) based on fossil raw materials (coal, natural gas) is problematic, but also the production of alternative fuels from renewable resources (agricultural production), during which the energy consumes from fossil fuels such as ethanol production by coal burning. A comparison of the production of alternative fuels derived from specifically grown crops or waste from processing of biomass and wood mass balance based on GHG emissions is expected to be significantly more favorable from both of these options.

The dominant position belongs and will belong to internal combustion engines. The following general conclusions can state as the conclusion of this subchapter. Total WTW emissions of greenhouse gases in the use of CNG as motor fuel relative to the usable energy content are smaller than the corresponding emissions of automobile gasoline and diesel.

Long-distance transport appears to be critical for the overall energy balance and GHG emissions for natural gas extraction. Extension of pipeline transport to more distant deposits of natural gas is associated with an increase in the number of compressor stations and thus higher energy consumption and higher production of GHG emissions. Currently, the average transport distance gas pipelines in Europe is about 4000 km (Middle East) and the future is expected to extend up to 7000 km (western Siberia).

LPG in comparison with petrol and diesel leads to minimal reduction of GHG emissions, which is much more significant contribution to reducing emissions of hazardous pollutants, especially for the older fleet. Sources of LPG are closely tied to sources of oil and natural gas, in the medium-term it is motor fuel especially.

Limited potential of reduction of CO2 emissions associated with higher costs of distribution infrastructure and higher cost of vehicles is also a reason for the relatively high specific cost of 1 t of CO2 savings in the use of LPG and CNG as motor fuel. Unlike other alternative fuels, nevertheless their advantage is seamless access to the market.

With hydrogen as an alternative fuel is environmentally advantage / disadvantage fundamentally affected by the source and manner of its production. If the hydrogen would have been produced by steam reforming from natural gas, we could achieve an overall reduction in GHG emissions, but only if produced using hydrogen in fuel cells. The combustion of hydrogen in vehicles equipped with conventional combustion engines is the total energy consumed and total GHG emissions of gases is higher than for conventional motor fuels or CNG. However, in terms of cost, the combustion engine is much cheaper than fuel cells. Natural gas is in the short and medium term, the only acceptable source of hydrogen production in terms of adequate capacity, production costs and relatively low production of WTW GHG emissions. Electrolytic hydrogen, for which production is used electric energy distribution system EU, means in terms of total GHG emissions greater environmental burden than hydrogen produced from natural gas. Hydrogen produced from non fossil sources (biomass, wind energy, nuclear energy) brings significant savings in GHG emissions, but only at the cost of considerably high production costs. More efficient use of renewable resources is directly for the production of electrical energy instead of the production of motor fuels.

Indirect use of hydrogen in fuel cells through an integrated (on board) autoterm reformer in comparison with progressive conventional propulsion units or hybrid systems, brings only a small benefit of GHG emissions savings. The advantage of on-board reformer, is the fact, that it allows you to use fuel cell technology and distribution infrastructure of conventional motor fuels.

Dimethyl ether (DME) can be produced from natural gas or biomass with better overall balance of energy and GHG emissions than other GTL or BTL synthetic fuel. Potential production of DME is relatively large, its implementation as a motor fuel requires similar technical solutions for modification of vehicles and infrastructure as LPG.

There are many ways of production of alternative liquid fuels that can be used in a mixture with conventional petroleum fuels or in pure form for the current drive motor vehicles without major changes in the current distribution infrastructure. Balance of energy and GHG emissions in the "life cycle" of bioethanol and biodiesel is significantly influenced by the raw materials, processing methods and also by the way of using by-products. The positive balance of GHG emissions is not entirely clear, because of difficult quantifiable emissions of nitrous oxide (N2O) from agricultural production (use of nitrogen fertilizers). The possibility of using agricultural production for the manufacture of liquid alternative fuels is due to the increasing consumption of motor fuels on a European scale very limited. Potential sources of raw materials for production of alternative liquid fuels will therefore be extended to include waste biomass or biomass specifically uncultivated plots (straw, wood material, waste from paper production), the use of less valuable materials will as well improve the economic balance of liquid biofuels.

High-quality synthetic diesel fuel produced from FT synthesis gas (GTL - Gas to liquid) are in terms of overall GHG emissions increased burden on the environment than conventional diesel fuel, but still significantly smaller than the synthetic fuels produced from coal (CTL - Coal to liquid). Synthetic GTL (or CTL) fuel is a real benefit in the medium term. A variant of the production of synthetic fuels from biomass (BTL - Biomass to liquid) is very advantageous in terms of GHG emissions savings, but still very energy consuming and in terms of production cost ineffective.

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Use of CAD/CAM Technology in Prototype Manufacturing Composite Light Sport Aircraft (LSA).

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Abstract—**Production of small composite ULL and LSA aircraft is currently implemented by smaller-size final producers, who managed and developed technology to manufacture composite aircraft by the hand lay-up method in female-style molds. Production of new molds for the fabrication process associated with development of every new type of aircraft or its modification is for this companies financially and time wise a heavy burden. As suitable qualitatively higher level replacement for the current technology a new method of fabricating models and molds for composite aircraft parts with consistent application of CAD/CAM technology was developed and in praxis tested. The main means of production of the new method is a powerful 5 – axis machining center with adequate working space, which is specialized for machining of non-metal materials. Major steps of the method is preparation of a semi finished product and subsequent surface treatment or fabricating molds. The introduction of the new method helped to significantly improve accuracy of production, reduce production time needed for mold manufacturing, reduce material consumption and, ultimately, reduce impacts of production on the environment. Bonus, which a manufacturer receives implementing the new method is also unlimited repeatability of the manufacturing process that was with the previous practices practically impossible.**

Keywords-LSA; CAD/CAM; CNC machining; composite; mold

I. INTRODUCTION

Light Sport Aircraft (LSA), is simply a classification of one or two seats single engine aircraft with a maximum gross takeoff weight of not more than 1,320 pounds (600 kg) specific to the United States. From April 2005 (LSA rules effective) to 1st April 2010 there were registered 1769 factory build aircraft by 60 companies (32 of them are Europeancompanies). The sales statistics show that in 2008 there was 31% decrease and in 2009 41% decrease against the previous year in numbers of new registered aircraft (from LAMA EU Microlight an LSA statistic data [1]). After initial sales the market got satured and a tough competition began. Opposite to legislatively higher categories of airplane, which are controled by only a few large manufacturers (e.g. Cessna or Piper), in the LSA category, there is larger number of smaller manufacturers who do not possess such capacities to develop a new aircraft or modify older types, which are necessary for preserving the position on the market. Another factor is the penetration of major manufactures from higher airplane categories (which inevitably can not be ignore by a large group of customers interested in this category) to the LSA category. Therefore smaller LSA manufacturers must seek after new technology that speeds up and also refines the process of development and preparation of serial production of a new aircraft or new aircraft components compared to manual methods that were used previously.

In small composite LSA exterior surface of airplane is also the primary structure manufactured by the hand lay-up and pressure-molding on female molds. Carbon or glass fibre reinforcing fabric is placed in female – style mold and then manualy saturated with a wet epoxy resin and worked into the fabric. Then the fabric layup in the mold is covered with bleeder/breather material and a vacuum bag and a vacuum is pulled on part. The mold is then left at temperature room in order to ensure a proper curing process. The main production facility for the manufacturer of composite LSA airplane are the molds for all aircraft parts. Molds manufactoring during preparation of serial production is a major financial investment and a considerable extension of the production preparation for the manufacturer.

II. OLD METHOD DESCRIPTION

So far, composite LSA airplane manufacturers have been mostly producing molds by manual methods. In the manual molds manufacturing method first a male – style model must be created mostly from polystyrene blocks material . This material is used primarily for its easy machinability. After that the surface of the model must be reinforcemented, which means the surface is covered with glass fabrics with epoxy. Cured model surface is then manually grinded. If the model surface is adequately grinded, the model is sprayed with the first layer of filler and again repolished. These activities are repeated several times until the surface is sprayed with paint and polished. The finished model will serve to female – style mold manufactoring. The mold is usually manufactured from layers of fiberglass fabrics manually saturated with resin epoxy. Layers of materials are placed on the prepared surface of the model and then cured. Subsequently, the composite shell of the new mold is reinforced (usually with a welded stell tube truss structure) and completed by adding technological features.

The result of the manually factured female – style mold shape geometry is highly dependent on the skills of workers, but in any case the result comes close to accuracy greater than 1 mm (particularly for large parts such as wing or fuselage). The geometric accuracy of aircraft shape has a significant influence on the aerodynamic characteristics of the product and its failure can negatively affect the flying qualities of the aircraft. Another problem of manual molds production is the impossibility of compliance with the symmetry of the mold (for exmple, mirror symmetry of left and right halves of the fuselage).

III. NEW METHOD DESCRIPTION

The requirement to make molds for composite parts of the new LSA aircraft in a short time with accuracy smaller than 1 mm led to development of a fully used CAD/CAM method that is already currently proved in practice. The principle of acceleration is based on direct female - style molds working from appropriate materials, which eliminates labor-intesive model fabrication. From these makeshift made molds are manufacturers able to produce only a few parts. But immediate serial production is not the main purpose of these molds. The parts from the CNC machined molds are used to construct several prototypes that are intended for various tests (flight, strength, ergonometric etc.). These tests in most cases result in needs to modify aircraft parts (eg, need to change tail size or geometry). Change manually manufactured molds is difficult and in most cases lead to new forms manufacturing (which is expensive and takes a long time). The new method allows application of required changes directly to thedesign of the CAD model, which is again used inCNC machining center. These models will serve to female – style molds manufactoring that are designed for serial production.

IV. INITIAL DESIGN WORK

At the beginning it is necessary to make the design of the future molds, to add all the technological and design elements such as dividing planes of the mold or molds reinforcement. The shape of the future female – style mold is based on the desired part shape. Individual steps of the new method will be further illustrated by the new composite propeller blade part.

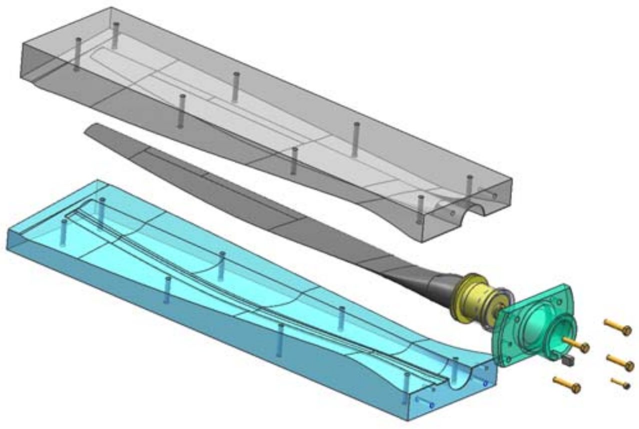

Figure 1. CAD propeller blade molds (with jigs)

V. CAD/CAM

Computer Aided Design (CAD), also known as computer-aided design and drafting (CADD), is the use of computer technology for the process of design and design documentation [2]. CAD equipment enables the designer to quickly produce very accurate and realistic virtual molds to be manufactured. CAD output is in the form of electronic files (.stl, .igs, .x_t) for machining operations. For this specific project theauthor used SolidWorks CAD software, but it is possible to use any other CAD software that allows making parts in the form of 3D solid. Computer Aided Manufacturing (CAM) is a system of automatically producing finished molds by using computer controlled production machines. The CAM software needs to know the physical shape of the part before it can compose a proper set of fabrication. For the project the author used SolidCAM software with modul that provides various 5-axis machining strategies. The CAM software must provide a simulation of the complete machine tooling, enabling collision checks between the tool and the machine components. CAD and CAM work together so the digital model generated in CAD is inserted in the CAM software package. CAM software system will automatically generate G-code via postprocessors. G-code is generally a code telling the machine tool what type of action to perform.

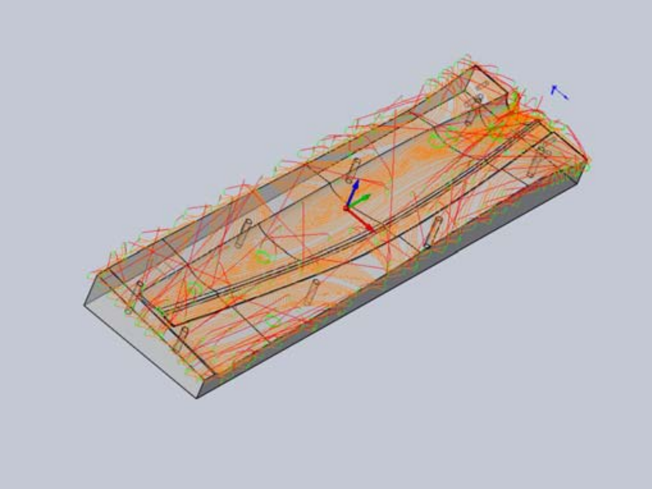

Figure 2. CAM – semi-finishing simulation

VI. STOCK PREPARATION

For machining female – style molds for prototypes boards and blocks from MDFs (medium density fibreboard) or resin materials are used Common features of all of these are good mechanical properties, easy machinability and fine microstructure. MDF material is cheaper, but the mold surface must be modified before parts lamination process. Resin blocks with a higher price allows direct lamination process on the machined mold‘s surface. In practice, small precision molds such as propeller blade are made of resin material, large molds such as wings are made of MDF boards. Described materials are supplied in blocks, which must be glued to the gross shape of the future mold. For good bonding it is essential to use suitable clamps. Imperfect gluing of blocks can cause mold depreciation (thin gaps between the blocks are difficult to repair on the finished mold surface).

VII. MACHINING PROCESS

For the machining process author used powerful 5 – axis machining center POWER FC 9000. This machining center is specialized in machining of large nonmetalic parts and provides a working space of 9 x 3 x 2 m. The size of the working space of this machine is ideal for all LSA composite aircraft female – style molds including large parts such as halfs of fuselage or wings. Most machining progresses trough main stages, of which each is implemented by a variety of basic and sophisticated strategies. The first main stage is roughing, which begins with a raw stock, known as billet, cutting it very roughly to the shape of the final mold. The result often gives appearance of terraces. The second stage is so called semi-finishing. It begins with a roughed parts and finishes on the fixed offset distance from the final surface. The third main stage of machining progress is finishing, which involves a slow pass of the tool across the material in very fine steps (from 0,25 to 0,75 mm depending on the desired surface quality and tools geometry) to produce the finished molds surface. The last main stage is so called contouring. On the mold surface it is important to mark the outline of the part or places for holes cutting. These boundaries are marked by a shallow contour (0,5 mm depth) by the tool with diameter 1 – 2 mm.

Figure 3. Roughing

Figure 4. Finishing

VIII. FINAL MOLD SURFACE MANUFACTURING

If the female – style mold is machined from the resin blocks other forms of surface treatment are not necessary. If the mold has been made of MDF, it is necessary to feed the mold surface with epoxy resin to obtain desiredsurface hardness. Then manual surface grinding and polishing follows, because the feeded surface is rough. By this operation the production with help of the new CAD/CAM method of the female – style mold for the prototype ends. Now the molds are ready for lamination of parts of the LSA airplane.

Figure 5. Finished propeller blade molds

IX. CONCLUSION

Using the new CAD/CAM method of the LSA aircraft prototype molds can accelerate the process of prototype or innovative variant production of small aircraft producers The acceleration of new product development is necessary due to a saturated LSA aircraft market. Bonus of introducing the new method is increase of the accuracy and reduction of the impact of production on the environment. Finally, it should be mentioned that from a financial point of view, purchase of large machining centers is not profitable for small producers. But recently it is not a big problem to find a reliable supplier (working mostly for the automotive industry) specialized on CNC based manufacturing.

Figure 6. Finished composite propeller blade

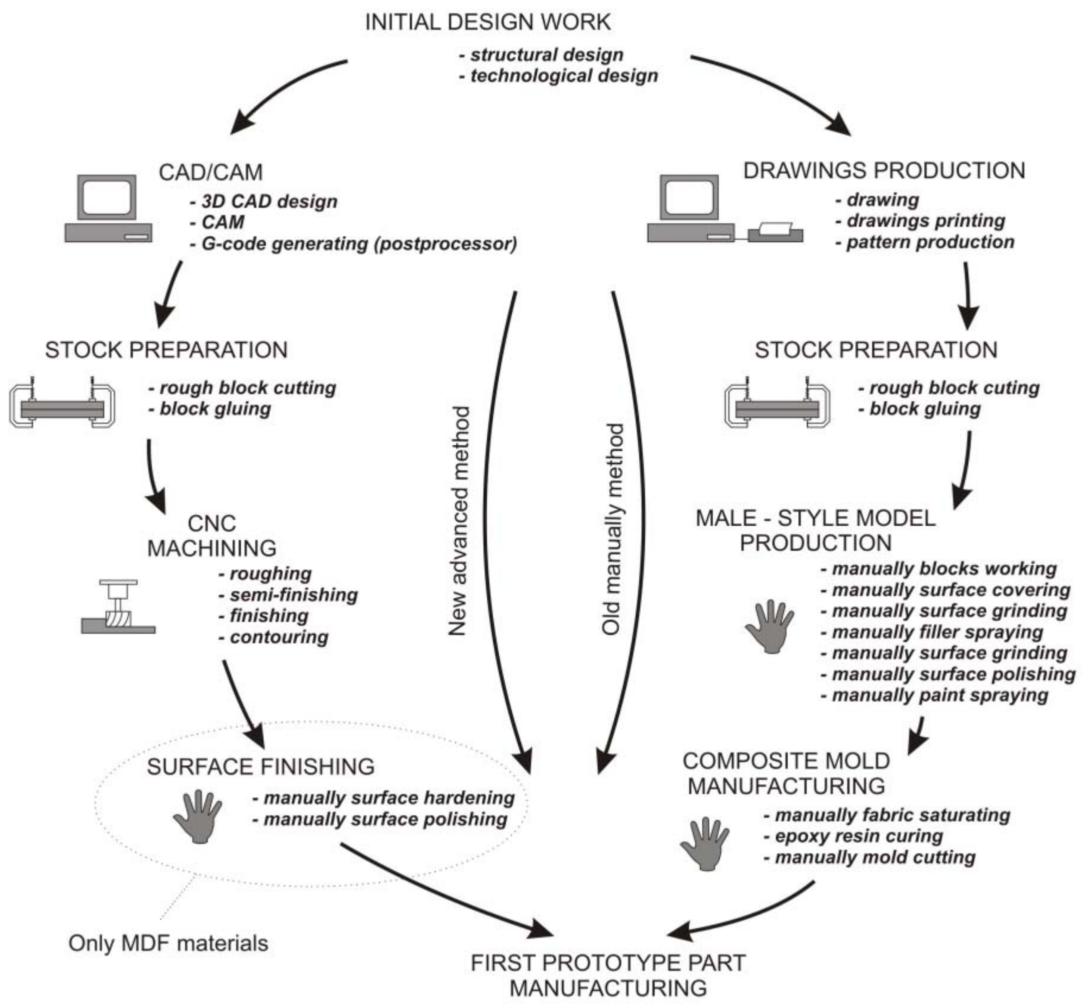

Figure 7. New and old method scheme

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Research of new combustion chamber concept for small gas turbine engines

Project FT-TA5/073 supported by Ministry of Industry and Trade of the Czech Republic

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***Abstract*—Theoretical and experimental research of a new possible combustion chamber concept for use in small gas turbine engines (under 200kW) is described in this paper. Special focus was on NOx emission reduction, combustion stability, efficiency and technological complexity. Main concept was evaluated, the Combustor with (Premixing) Delivery Tubes based on Jet Stirred Reactor. C(P)DT concept showed significant tendency to pressure pulsations and narrow operational envelope what is very prohibitive for aviation operations. The NOx emission attained were on levels of 20ppm, the concept has potential for stationary turbines where wide range of operation is not required.**

Keywords-combustion, gas turbine engines, microturbines, emissions.

I. Introduction

Small gas turbine engines (under 200kW) have specific requirements on combustion system consisting of combustion chamber itself and system for distribution and dispersion of the fuel. Complexity and weight issues are of most importance to reduce price and weight. Most of the small gas turbines use reverse flow annular combustion chambers to reduce length and weight of the engine and simple pressure swirl atomizing nozzles. Due to the lower pressure ratio and combustor inlet temperature the combustion chamber accommodates bigger part of the engine volume compared to the big size engines with high pressure ratios. Lot of work have been recently done in research and development of new more efficient and environmentally friendly combustors for big size engines as the emission requirements are becoming more and more stringent (ref. CAEP). State of art combustion systems used for big size engines attain high efficiencies and low NOx emission but due to their design and technological complexity they are unacceptable for small gas turbines. Focus of the presented research was on new possible combustion concepts for small gas turbines, with respect of improving efficiency, lowering NOx emissions while maintaining simple design (manufacturing complexity) and low weight. As a baseline the Czech company's PBS Velka Bites,a.s. turbojet engine TJ100 was used. The TJ100 utilizes annular reverse flow combustor, the fuel is delivered through 12 spill return pressure swirl nozzles.

II. Combustor Description

C(P)DT concept

Evaluated concept which was initially scope of the FT-TA5/073 project was "Combustor with (Premixing/ Prevaporizing) Delivery Tubes" (C(P)DT). This concept is based upon well known principle of the Jet Stirred Reactor (JSR) [1][2]. Basic schema of the C(P)DT is shown in the fig. 1, significant portion of the primary air enters through the delivery tube into the reaction zone in opposite direction to the main reference flow of the combustor. This creates strong recirculation zones on sides of the incoming jet where flame stabilization takes place. Also this jet creates strong turbulence and mixing of the fresh mixture and hot exhausts what is beneficial for high combustion efficiency and reduction of hot spots (important for low NOx emissions). Fuel injection opposing to the main flow also provides enough time for liquid fuel evaporation. Additional primary air is added to the reaction zone via holes in the combustor liner to provide optimal AFR ratio. Dilution air is added to the combustion gasses to cool them for required turbine entry temperature and required temperature pattern.

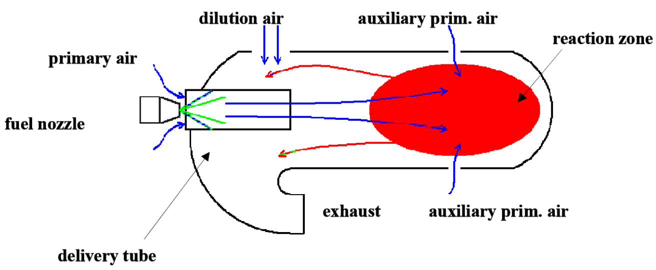


fig. 1 – C(P)DT concept

III. Numerical Modeling Description

Numerical research

At the first stage the initial C(P)DT combustor design was prepared based on thermodynamic parameters of the TJ100 engine manufactured by Czech company PBS Velka Bites a.s. The TJ100 engine uses reversed flow annular combustor with 12 pressure swirl fuel nozzles. The initial design was examined

Identify applicable sponsor/s here. *(sponsors)*

using CFD modeling to determine optimal shape of the combustor, sizing and position of the delivery tubes, primary and dilution holes. In the first project phase the combustion was modeled with gaseous methane fuel. This was chosen for it's simplest chemistry and relative well known properties. For simulation the CFD solver OpenFOAM was used with extension for solving chemistry in steady state based on alternate Steady Chemistry Reacting Foam solver [6][6]. In this solver the combustion was solved as chemical reaction in volume using partially stirred reactor presumption. Chemical kinetics was modeled using single step chemistry by classical Arrhenius equation (1) and equations were solved by ODE solver implemented in reactingFoam module.

$$k=A.T^{b}.e^{-\frac{E_A}{R.T}} \tag{1}$$

The single step chemistry was chosen due to the numerical capacity limitations. For simplicity and calculation robustness also the wall heat transfer was neglected and walls were simulated as zero gradient boundary condition.

In second project phase, the combustors were modeled with 2 phase reactive flow, to determine behavior with liquid fuel burning. For this reasons the CFD solver was extended to liquid phase modeling and combustion with multi step chemical reactions, detailed description is in [5].

IV. EXPERIMENTAL SETUP DESCRIPTION

Planar combustor sector experimental system

For experimental examination of the C(P)DT combustor parameters and to validate and tune numerical models the experimental test rig for planar combustor sector with three fuel nozzles and optical access was designed and manufactured. The experimental system scheme is shown in the fig. 2 and fig. 4.

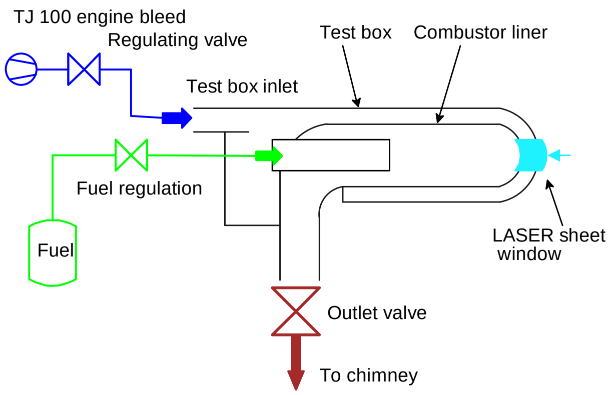


fig. 2 – planar combustor sector test rig scheme

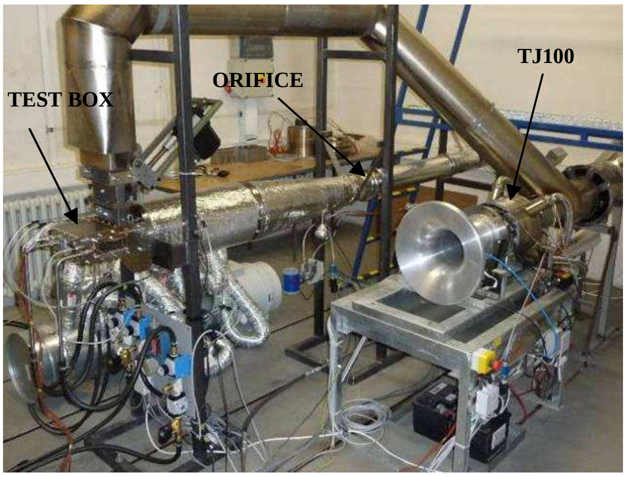


fig. 3 – planar combustor sector test system (VZLU)

The combustor sector is integrated into the test box which is of modular design enabling easy combustor components access and change. The test box is supplied with compressed and heated air delivered by modified TJ100 turbojet engine. The bleed air flow is controlled by precise regulating valve, mass flow is measured using standard orifice and finally the flow is straightened in settling chamber before entering the test box. Counter pressure is adjusted using specially designed choke valve which is capable to withstand temperatures up to 1100°C. Gaseous methane fuel is supplied from pressure bottles and mass flow regulated by PID controlled regulation valve Omega FMA 2613A. For experiments with liquid fuel, the test box is supplied with JetA1 fuel from main storage tank via computer controlled fuel pump with spill return valve. All experimental system control and data acquisition is done via PC software environment.

The combustor sector contains 3 fuel nozzles (reps. delivery tubes), the middle tube is examined and the two side tubes are to simulate circular boundary conditions of the annular combustor. The size of the combustor sector is same as the full annular combustor of the TJ100 engine. The combustor is optically accessed for examination of combustion processes using High Speed Camera, PIV and PLIF. On both sides of the combustor sector there are quartz observing windows, which enable comfort optical access into the primary zone. The LASER sheet enters the measurement zone through synthetic quartz window which is located opposite to the middle fuel nozzle.

Operating parameters during testing were set to correlate with operating parameters of the TJ100 engine. Because of the air supply limitation, the test was not able to be operated under full pressure of real engine, practically the maximum tested pressure was 2.5 bar, the mass flow was corrected using the well known theta parameter (2) [7] to correlate TJ100 conditions. The inlet temperature was able to be set arbitrary.

$$\theta = \frac{p_{1c}^{1.75}\exp\left(\frac{T_{1c}}{300}\right)}{m_{air}} \times 10^{-4}\,[-] \tag{2}$$

Identify applicable sponsor/s here. *(sponsors)*

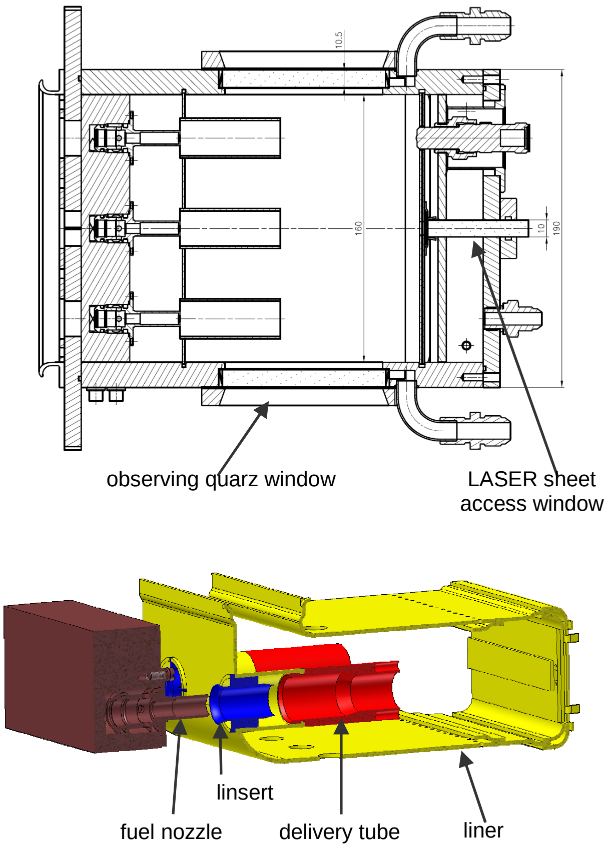


fig. 4 – Planar combustor sector

V. RESULTS

First part of the project was focused on the C(P)DT planar sector combustor research, the experimental tests showed significant tendency to pressure oscillations induced by combustion unstability. According to the high speed camera captures, the source of the unstability was found to be in undetermined position of the recirculation zone, caused by impingement of the primary jet on the opposing wall to the delivery tube exit. This creates initial aerodynamic fluctuations which are then amplified by combustion and create burning “pockets” fluctuating around the primary jet as seen in the set of images captured with high speed camera (HSC) fig. 5. The HSC was equipped with narrow depth of field objective which was focused on the middle delivery tube reaction zone, eliminating side tubes. In the pictures can be seen fluctuation of the reacting zone between upper and lower part of the dome, also the longitudinal position changes significantly.

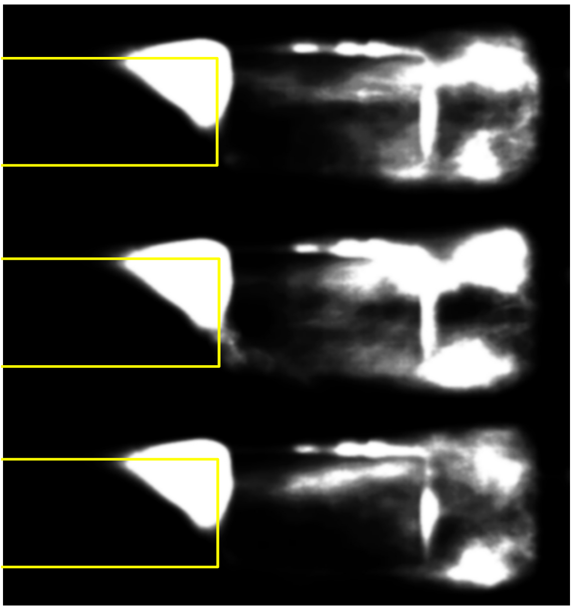


fig. 5 – C(P)DT, V08v, HSC 1.5ms step

Assumed this behavior, different delivery tubes lengths L and diameters D (fig. 6, tab. 1) were tested to minimize effect of jet tip fluctuation.

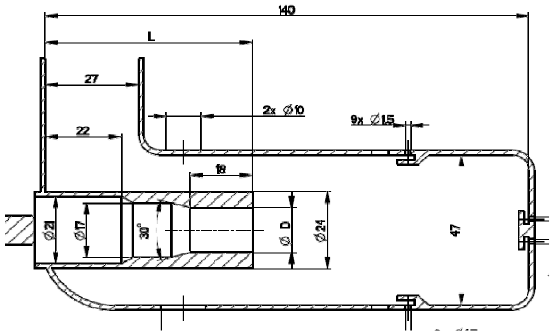


fig. 6 – C(P)DT sector arrangement

tab. 1 – delivery tubes dimensions

variant	*D*	*L*
V07	21	57
V08	14	60
V08v	14	60
V09	15	60
V11	14	47
V12	14	70
V13	14	60

It was expected that longer delivery tube would more determine the flow pattern within the primary zone and stabilize combustion. These expectations were partially confirmed but the pressure oscillations were not removed completely from whole operation envelope. Experiments with liquid fuel showed expected improvement in combustion stability, but still the pressure oscillations were on unacceptable levels for gas turbines.

OH PLIF measurement [8] is in relatively good agreement with CFD simulations fig. 7 and fig. 8, the reaction zone is "anchored" on the upper end of the delivery tube. Moreover these results are very similar to the images from high speed camera, which was focused in narrow area similar to the PLIF LASER sheet using narrow field objective. This technique showed to be very effective for fast and relatively cheap examination of the combustion processes before more precise PLIF measurement.

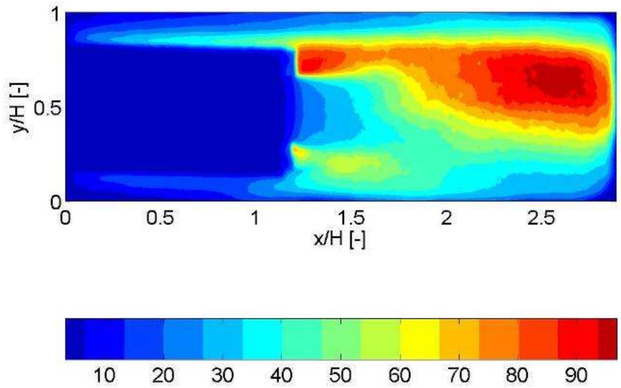


fig. 7 – C(P)DT V08v OH PLIF signal across the middle delivery tube [8]

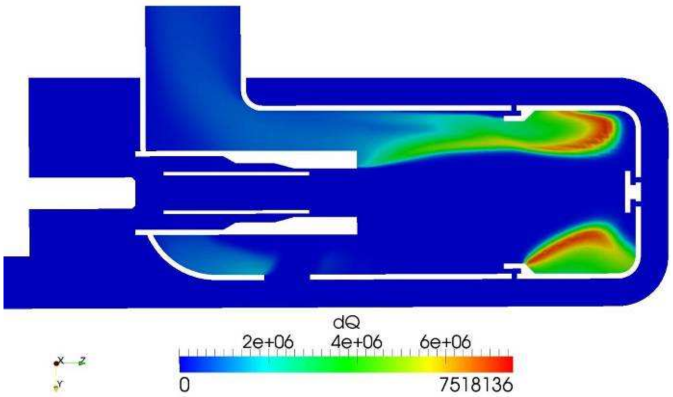


fig. 8 – C(P)DT V08v CFD reaction rate, delivery tube middle section

Emission levels for each delivery tube modification measured with methane fuel are shown in fig. 9 and fig. 10. The measured values are corrected to 15% of oxygen. The first set of NOx and CO emission measurements is for atmospheric testing conditions with combustor inlet temperature 360K, the temperature was maintained within +-5K range. Mass flow rate was determined from constant flow number of the baseline TJ100 combustor and corresponds to the idle regime.

The second set is also for atmospheric conditions but inlet temperature of 440K, the mass flow rate was set also according to constant flow number and corresponds to the 100% regime.

The results show the tendency to lower the CO emission and higher NOx when going to higher "variant number", this difference is mainly caused by reduced AFR within the primary zone, corresponding to the reduced delivery tube orifice diameter D and delivery tube length L.

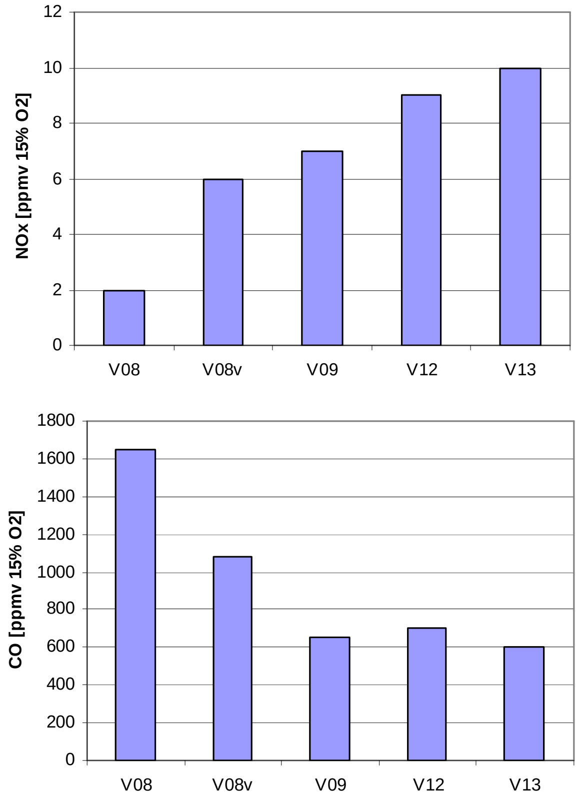
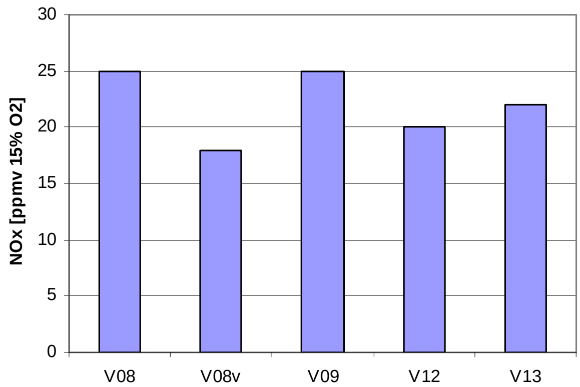


fig. 9 – C(P)DT emissions with methane fuel, atmospheric conditions (100kPa), inlet temperature 360K



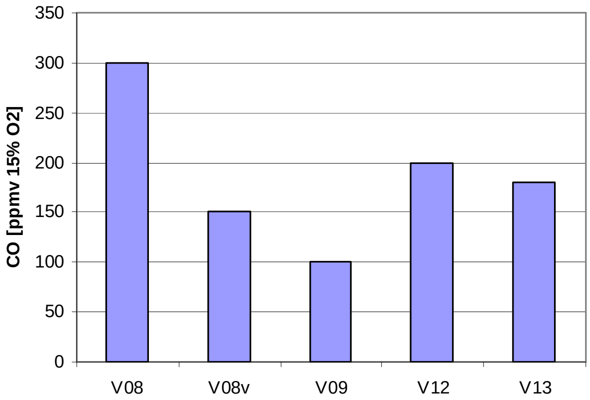


fig. 10 - C(P)DT emissions with methane fuel, atmospheric conditions (100kPa), inlet temperature 440K

VI. CONCLUSIONS

Combustor concept was numerically and experimentally examined for possible applicability in small gas turbine engines. Results showed that the researched concept based on the principle of Jet Stirred Reactor is not suitable for aviation gas turbine as it is very prone to pressure pulsations induced by aerodynamical/combustion instabilities. This concept could be suitable for stationary applications where optimal regime could be maintained during all operations. The emission levels are very promising and possibly could be even more lowered by future research.

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