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Preface

The proceedings contain contributions from participants of the 10th International Scientific Conference of Doctoral Students, which took place on 20th to 21th of May 2021 on the WEBEX platform through the online meeting due to the Covid-19 pandemic.

This scientific conference has a long tradition at the faculty and is an opportunity for doctoral students to present their own scientific and professional papers from various fields, not only from aviation and their philosophical aspects.

We would like to thank all authors, organizers, sponsors and especially those who presented their contributions at the conference. Thank you for the successful course of the conference and we look forward to further cooperation.

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Until you spread your wings,

you have no idea how far you will fly.

Conference goal and topics

The main goal of the conference is to provide an international forum for a PhD. students to share research findings and practical experience. The conference aim is to provide a meeting place where people can identify new research ideas and techniques for introducing them into widespread use.

The conference topics involve, but are not limited to:
- air transport operations,
- economic aspects of air transportation,
- air traffic management,
- aviation safety and security,
- aerospace engineering,
- unmanned aerial systems,
- human factors and ergonomics in aviation.

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A Framework for Real-Time Operating Systems Used in Development of Control Algorithms

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***Abstract*— The paper focuses on creation of a framework for development and implementation of algorithms built in program Matlab – Simulink. These algorithms, with use of a real-time operating system, could replace built-in control systems in an autopilot Pixhawk PX-4. An improvement in fast and reliable converting of algorithms can quicken the process of building the control systems for a specific UAV. After adjustment of a UAV's parameters it is possible to enhance its controllability and stability. It is also possible to create aircraft's model in order to replace whole built-in control systems with progressive control algorithms.**

I. INTRODUCTION

Improvement of the civilian and military application of drones has drawn bigger interest to a UAV field, due to its usability, flexibility and portability. The main control element of the UAV is an autopilot. The autopilot unit is responsible for collecting values from the sensors and RC receiver, and using these values to control an aircraft. The autopilot Pixhawk PX – 4 is an independent open-hardware project which is broadly used in many UAV configurations. The autopilot Pixhawk PX-4 was used in small unmanned aerial vehicle Skydog. For the improvement and building own control algorithms, it is helpful to have a framework for the implementation of such algorithms. This paper aims to describe the framework of the process for further work and increasing effectiveness of testing and tuning these systems. It includes theoretical description about the implementation of tested basic algorithms. After the creation of prototype aircraft model in MATLAB/Simulink, it will be possible to import the model into UAV's autopilot [1].

A. Sky-dog overview and Pixhawk description

The Skydog model of the UAV is small fixed-wing aircraft that is mostly used in recreational flying, pilot training or glider towing. It is possible to control aircraft attitude by RC controller. The operator can maneuver with aircraft through the change of the position of elevator, rudder and ailerons, lift can be adjusted by flaps variations, which can be also used as airbrakes. The fuselage of the aircraft is big enough for all electronics. That involves servos, cables, batteries, receiver and mainly the autopilot Pixhawk. For the control of the surfaces are used 7 servos – one for each surface, including ailerons and flaps. Control surfaces are connected via servos to autopilot's output pins. Signals are sent, through these outputs, into servos which change the position of the specific control surface. Thanks to this change it is possible to variate attitude of the aircraft. Every electronic device that is on-board, is connected to the Pixhawk autopilot [2]. All inner and external sensors and operator commands are defined as inputs to the autopilot. Output signals are pulse-width-modulated (PWM) signals for actuators and servos and for the change of motor's RPM regulator [2].

Figure 1. Unmanned aerial vehicle Skydog

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The autopilot Pixhawk, shown on the Figure 2, has its own built-in IMU unit with 3-axis gyroscope, 3-axis accelerometer and 3-axis magnetometer. Measured data from these sensors can be saved to an inner SD card or/and simultaneously sent by a telemetry radio signals to ground station. Communication between autopilot and ground unit is ensured by telemetry radio stations, where one is situated on-board of the aircraft and the second is connected to the ground station. Ground station is consisting of software in PC to which is radio transmitter/receiver connected [2,4].

Figure 2. Autopilot unit Pixhawk PX4

All avionics devices and connections between add-on modules are graphically shown on a Figure 3 below.

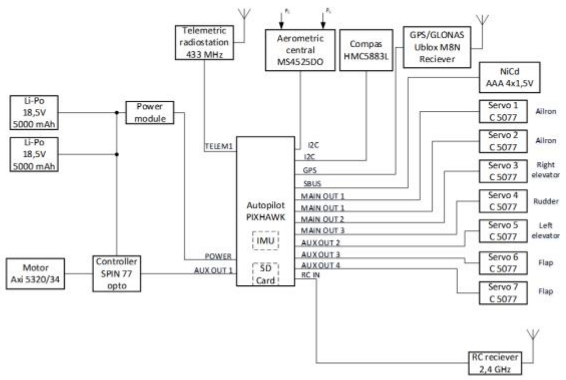

Figure 3. Electronics connections to autopilot Pixhawk PX4 [2]

II. DESCRIPTION OF THE AUTOPILOT ALGORITHMS

A. High-level architecture

For the control of the autopilot and implementation of an own control algorithm it is necessary to understand the high-level software architecture. It consists of two parts. The first part is responsible for the communication between applications and processes within unit. The second part is responsible for collecting, calculating, and monitoring data from sensors and sending them to appropriate control surface.

Every algorithm in the Pixhawk is based on publish/subscribe principle which is broadly used in real-time operating systems. This process is based on subscribing data (messages) from the libraries (themes) in the Pixhawk software and then publishing these messages into another theme. The process is very reliable and fast. It can ensure continuous work of the autopilot on software level. To control specific surfaces, it is necessary to know which library corresponds to which control/monitoring system. After this acknowledgement we can then subscribe/publish data that are needed [3].

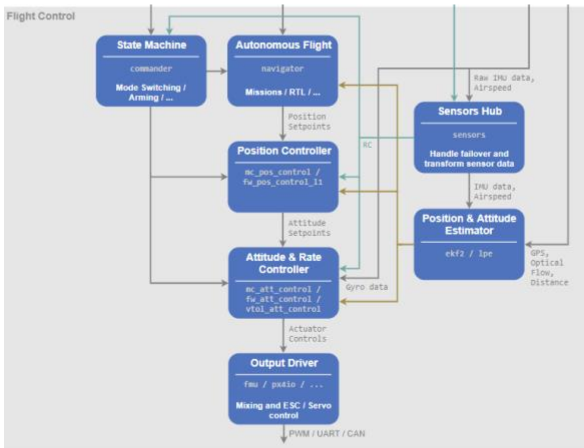

Figure 4. Part of the Pixhawk's high-level architecture [3]

The block scheme shown in the Figure 4 provides a part of the Pixhawk's high-level software architecture. Arrows in the scheme show the information flow for the most important connections between modules. Connections in the Figure 4 shows which data are necessary for individual processes within unit. This principle is possible to use in creating of an advanced control system in MATLAB simulation environment and then implementing the control system in the autopilot [3].

III. BUILDING AND IMPLEMENTING AN AIRCRAFT'S MODEL

For building the required aircraft's model in Matlab/Simulink it is needed to install Matlab's add-on "PX4 Autopilots Support from Embedded Coder ". This add-on provides the whole library with all necessary blocks, which will be used for the model. Also, it allows to generate C++ from Simulink models specifically tailored for the Pixhawk FMU (flight management units) [4]. It is possible to customize algorithms or to build and replace built-in control systems. Whole installation process is self-explanatory and very easy to setup. In the installation window it is first necessary to decide approach for compiling and implementing the code. It is possible to choose two options. The first is "Cygwin Toolchain" which was also used in this paper. The second option is to use "Bash on Windows Toolchain" which uses Linux subsystem in windows OS [4].

Windows Cygwin Toolchain is easy to install and use. The installation of the toolchain includes all necessary

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third-party utilities and build environment in the PC. The setup process needs to be done only once. After the installation of the toolchain, it is possible to proceed to the next step in which it is needed to verify installation of the toolchain and download a PX4 source code. The source code for the Pixhawk is downloaded from "GitHub" website. In the next step of the add-on installation, the source code is validated. The source code consists of the Firmware which will be used in firmware uploading process.

In the next step it is possible to choose which board is used and which build is going to be implemented. Before it is done, it is also possible to choose additional applications we want to include in the Firmware. This can be done in "CMake" file inside the Firmware folder. If there are any applications which are not included in basic build, they can be added by removing hashtag in front of application itself, in Cmake file. This will allow us to implement them in a Firmware uploading process. Adding an application can be done only if the board has enough of free memory. In other way we must dismiss adding of chosen applications.

The last step of the add-on implementation consists of building the Firmware itself. To build the PX4 firmware based on chosen CMake file it is necessary to connect the autopilot to PC via USB cable and then click "Build Firmware". In this installation process it is possible to choose a build for the specific board [4,5].

The following step is very important in firmware uploading process. To allow communication between MATLAB and Pixhawk board, a specific text file must be added to a micro-SD card, which will be used in the autopilot. This text document ("rc.txt") is stored in the folder which can be found via Matlab command. Instructions where and how to add the file are written at the page included in installation process. After adding the file, the micro-SD card must be inserted back to PX4 autopilot board. The text file on the micro-SD card will suppress the execution of some of the default startup processes and run the application generated by Simulink. Only then it is possible to communicate with the autopilot through the Simulink and test created algorithms [5].

A. PX4 Autopilots Support from Embedded Coder library

After the process of the add-on installation, it is possible to use Simulink's library. This library will help with communication with the autopilot unit. The main advantage is that it provides specific blocks, which are built for PX4 boards. These blocks represent Pixhawk's interface. It is possible to build whole control systems using this library. The PX4 autopilots support from embedded software library consists of blocks, through which it is possible to publish/subscribe data from specific autopilot's part. For example, it has sensor blocks shown in the Figure 5, which can be used to monitor data from sensors. These data can be then processed and send to appropriate control surface [5,6].

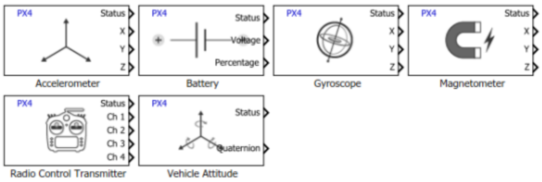

Figure 5. Sensor blocks from PX4 Simulink add-on

Another type of blocks are "communication" blocks which are represented as "uORB Read", "uORB Write" and "uORB Message" shown in the Figure 6 [6].

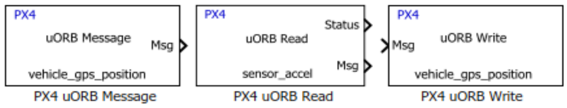

Figure 6. PX4 communication blocks

Blocks shown in the Figure 7 can be used in control system development for PX4 PWM Output control, Serial Receive/Transmit etc. With these blocks it is possible to create systems which can control aircraft's surfaces [6,7].

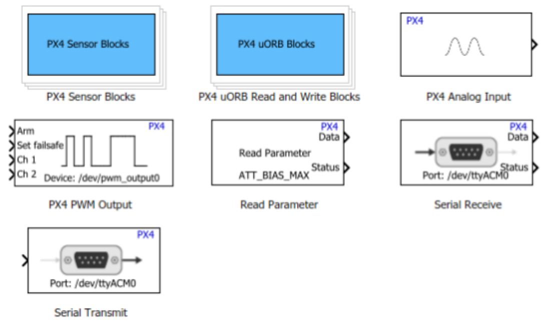

Figure 7. PX4 Autopilots library blocks [6]

B. Simple examples of algorithms implemented through Matlab/Simulink.

For connecting the autopilot to PC, was used a microUSB interface. Inserted microSD card allowed us to connect Simulink environment with the autopilot's software. Then it was possible to transfer created algorithm and implement it in the autopilot unit. In this part of the paper a short example of data acquiring algorithm from built-in sensors, will be described.

If we want to use built-in sensors it is necessary to use specific block that correspond to these software/hardware parts. In the first case of data acquisition those are "accelerometer", "gyroscope" and "magnetometer blocks". It is also important to use correct data format to allow data flow from the Pixhawk to the simulated application. Another approach is to specifically access the data through uOrb communication and use the "PX4 uOrb read" block and address the library in which these data are generated. The second way is much simpler because we can monitor specific data we want. If the first approach was used it would require filtering the data and correcting them from errors such as bias. This could be used in creating of an advanced control system where it would be possible to use advanced filters, use artificial intelligence or apply self-created algorithms to enhance the controllability of the autopilot.

In the Figure 8 is shown Simulink model of the gyroscope data acquisition application. This application allows to monitor data collected from Pixhawk's sensors [7,8].

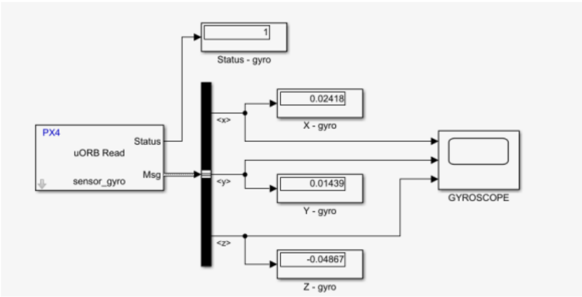

Figure 8. Gyroscope data monitoring application

In this application it is possible to monitor angular velocity from built-in gyroscopes. The application displays angular velocity of the autopilot in X, Y and Z axis. As it is shown in the Figure 8, when the autopilot is in standby position the output from the sensor is 0. Small values of velocities are sensed because of a very sensitive sensors within unit. In the Figure 9 are shown values of the angular velocities while the autopilot was moving [7,9].

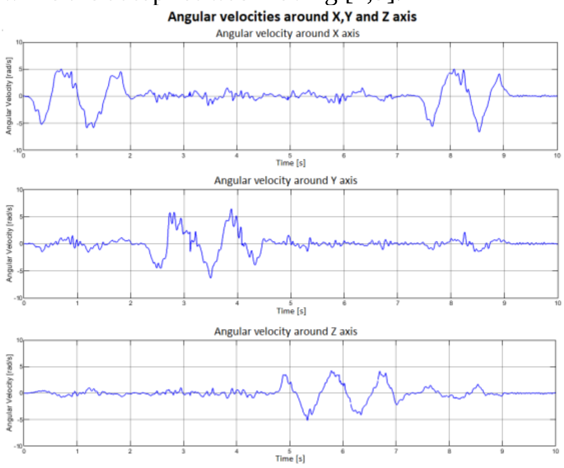

Figure 9. Output from built-in sensors

Variations in values shown in the Figure 9 describe the movement of the autopilot around specific axis. In the first part, the movement was done around X axis, followed with the movement around Y axis and then around Z axis. With the further advancement and adjusting it is possible to include similar data collection in control system, where it will collect data from gyroscopes and use them for aircraft's stabilization [10,11].

CONCLUSION

Study described in this paper is focused on implementing and testing own application, which was built in Simulink. The application can be used in UAV Skydog, which corresponds with the autopilot Pixhawk PX4. In the beginning, the paper focuses on Skydog's description, which includes used avionic connections. It is also necessary to understand Pixhawk and its high-level software architecture in order to work with the unit. The architecture can be used in an application build process. For the implementation of such application, it is inevitable to have appropriate software which is described in the paper. After the installation it is possible to begin building and creating own application. The paper also describes library, which is specifically created for such process. This library involves special blocks, which represent specific parts of the unit. Thanks to these blocks it is possible to use systems within unit such as sensors, filters, estimators etc. In the last part the paper shows simple application which can monitor data from internal gyroscopes. The application collects angular velocities around each of autopilot's axis. After that, the angular velocities are shown at the display. The paper shows possibilities in a creation of control systems, with use of the Simulink. Program gives lot of options in order to create and advanced control system, which could in the future improve aircraft's stability, monitor its values for envelope protection etc.

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Economic Aspects of Standard Arrival and Departure Routes at Selected Airport

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Abstract— **This article deals with the economic evaluation of standard arrival and departure routes, which have a direct impact on the fuel consumption of selected types of aircraft. The aim of the article is to quantify and compare the amount and price of aviation fuel in flight on standard arrival and departure routes of the selected airport. The article contains theoretical calculations according to the flight manuals of the given types of aircraft and experimental verification of the current fuel consumption on board these aircraft. The result is the price of fuel, which is theoretically and also really needed for the flying of standard arrival and departure routes of the selected airport with the given types of aircraft.**

I. INTRODUCTION

By increasing the number of aircraft and flights performed, it is necessary to reduce the cost of aviation fuel.[2][13] The main task of this work is to calculate the amount and price of fuel needed for the flight on the standard arrival and departure routes of Malacky Airport using two types of aircraft.[6][10] Calculations for fuel consumption are calculated using theoretical knowledge and information from the flight manuals of the types of aircraft, as well as real measurements from the aircraft deck.[4]

Individual chapters:

• **Characteristics and tactical-technical data of the used aircraft technology**. There are two types of aircraft technology at Malacky Airport, which are used to calculate fuel consumption. Types of aircraft are C-27J SPARTAN and L 410 UVP-E20 Turbolet.[1]

• **Standard arrival and departure routes**. The most frequently used standard arrival and departure routes of Malacky Airport.[12]

• **Calculation of fuel consumption based on theoretical knowledge and information**. All calculations are calculated using flight manuals of the type of aircraft and information provided by flight personnel.

• **Fuel consumption based on real measurements.** Obtaining the necessary information by real measurements on board the type of aircraft.

• **Comparison of fuel consumption and price based on theoretical knowledge and real measurements**. Evaluation and Comparison of the information obtained by both methods of determining fuel consumption. The final calculation is based on available current information on the price of aviation fuel used.

II. CHARACTERISTICS AND TACTICAL-TECHNICAL DATA OF USED AIRCRAFT

Malacky Airport is the home airport of two types of aircraft C-27J SPARTAN and L 410 UVP-E20 Turbolet. [14][8] Due to the fact that the Kitchen transport wing has been deployed at Malacky Airport, the flight staff and equipment are primarily focused on the transport of people and material. This airport is also included in the emergency system of the Air Force of the Armed Forces of the Slovak Republic as a diversion airport for sharp cash operating at Sliač Airport.[11]

C-27J SPARTAN

It is an Italian transport aircraft from Alenia, a high-flying aircraft with conventional tail surfaces. [3]The aircraft was developed for strategic operations on short and medium routes, for transport, supply, airborne and evacuation flights. [10] The first aircraft arrived at Malacky Airport on October 31, 2017 and has been an indispensable part of the Slovak Armed Forces Air Force ever since.[9]

Tactical and technical data of the aircraft:

- crew: 2 + 1 (pilots + flight technician)
- capacity: 60 soldiers or 46 paratroopers
- Medevac capacity: 36 stretchers and 6 paramedics
- length: 22,70 m
- span: 28,70 m
- height: 9,64 m
- area: 82 m2
- weight of empty aircraft: 18 200 kg
- maximum take-off weight: 32 500 kg
- maximum load weight: 11 600 kg
- maximum amount of fuel: 12 320 liters

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- power unit: 2 x Rolls-Royce AE2100-D2A turboprop engine with an output of 3,460 kW
- propellers: 6-blade Dowty 391 / 6-132-F / 10 with a diameter of 4,15 m
- maximum speed: 602 km/h
- cruising speed: 583 km/h
- runway required for take-off at maximum take-off mass: 680 m
- runway required for landing at maximum take-off mass: 380 m
- access: 9 144 m
- access at 95% of maximum take-off weight: 8 229 m
- range with maximum load: 4 260 km
- range with maximum fuel: 5 926 km
- range with a load of 4536 kg: 5 112 km [5]

Figure 1. C-27J SPARTAN

L 410 UVP-E20 TURBOLET

It is a Czech transport aircraft of the company LET Kunovice, a high-altitude self-supporting monoplane. The construction of the fuselage consists of all-metal half-shell, the wing is double-girder, equipped with two-slit flaps and spoilers.[7] The aircraft has a constant speed propeller with the possibility of battalion and reverse. It is capable of landing on small and unpaved surfaces and is capable of operation in extreme conditions from +50°C do -50°C.[15]

Tactical and technical data of the aircraft:

- crew: 2 + 1 (pilots + flight technician)
- capacity: 19 passengers or 1 710 kg of cargo
- length: 14,42 m
- span: 19,48 m, with additional tanks 19,980 m
- height: 5,83 m
- bearing area: 35,18 m2
- weight of empty aircraft:3 960 kg, with additional tanks 4 020 kg
- maximum take-off weight: 6 600 kg
- power unit: 2 x Walter M-601E turboprop engine with an output of 560 kW and Avia V510 propellers with a diameter of 2,3 m
- maximum amount of fuel: 1 301 kg
- maximum speed vMO: 181 kt IAS (335 km/h)
- cruising speed: 181 kt TAS (315 km/h)
- range: 1 040 km
- access: 7 000 m
- climb: 468 m/min, 90 m/min per one engine [8]

Figure 2. L410 UVP-E20

III. STANDARD ARRIVAL AND DEPARTURE ROUTES

Standard arrival route – instrument. The most frequently used standard arrival route of Malacky Airport for RWY 19 is BERVA2A see Figure 3.

Description of route:

- Highllights: BERVA, RIBKI (IAF)
- MAG route: 310°
- Minimum IFR Altitude: 6000 ft MSL to dist. 32,4NM from VOR/DME NIT; 5000 ft MSL from dist. 32,4NM VOR/DME NIT to RIBKI

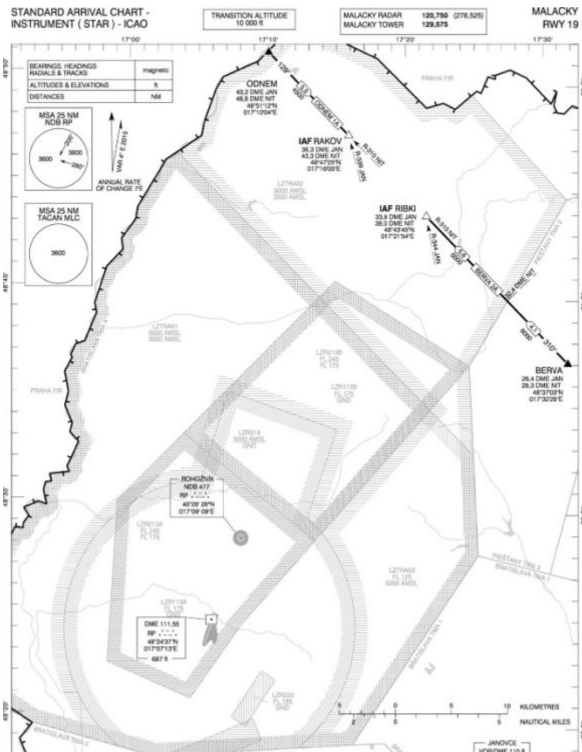

Figure 3. Standard arrival routes STAR

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Standard departure route – instrument. The most frequently used standard departure route of Malacky Airport for RWY 19 is BERVA3A see Figure 4.
Description of route:

- Designation: BERVA3A
- Route: Climb the runway course, at altitude 1200 ft AMSL turn right for flying the route 038° (QDM 038° NDB RP) to RP, fly the route 057° (QDM 057° NDB RP) to BERVA
- Frequency: MALACKY RADAR, 120,750 MHz (259,625 MHz)
- Notes: Max. IAS 210kt to flying the route 038° to NDB RP. Climbing gradient 5% to 2700ft AMSL for remaining in controlled area. Minimum tilt angle 25° during the first turn. To BERVA reach 6000ft MSL.

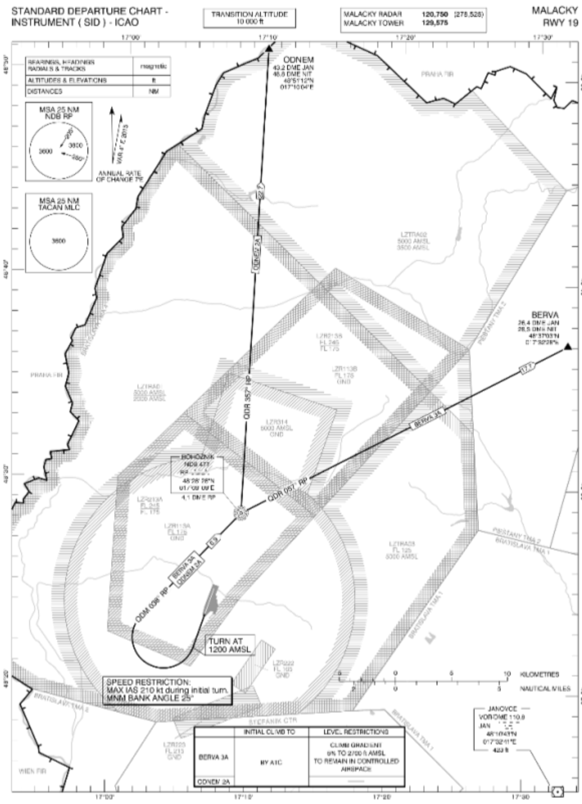

Figure 4. Standard departure routes SID RWY 19

IV. CALCULATION OF FUEL CONSUMPTION BASED ON THEORETICAL KNOWLEDGE AND INFORMATION

The fuel consumption calculations were performed by a combination of flight manuals of the given types of aircraft and on the basis of consultations with pilots who fly on the given types. After this combination, the average fuel consumption was determined during the climb, horizontal flight and descent. To calculate the consumption in theoretical calculations, it is necessary to enter the same altitude conditions as in real flight, for the final comparison of theoretical and real calculations.

A. Average fuel consumption C-27J SPARTAN:
Fuel tank meters in pounds are installed in the aircraft.

TABLE 1. Avarage fuel consumption C-27J SPARTAN

	IAS Speed	Fuel consumption per hour	Rate of climb or descent
Climb	170 kt/h	3000 pounds	4000 ft/min
Horizontal flight	190 kt/h	1500 pounds	-
Descent	180 kt/h	1200 pounds	1000 ft/min

Description of the standard arrival route BERVA 2A:
After BERVA point the aircraft flies to RIBKI point 9,7 NM, descents from 7 000 ft MSL to 5 000 ft MSL two and half minutes it continues in horizontal flight. At RIBKI point it turns left to runway heading 194°, it descents one minute to 4 000 ft MSL and to IF point two and half minutes it continues in horizontal flight 9 NM. From IF point it flies to FAF point 5 NM and it descents one and half minute, so that the aircraft has 2 500 ft MSL to FAF point for establish to the ILS. After FAF point it continues in descent for the landing four and half minutes 5,9 NM.
Fuel consumption calculation:

- One minute of descent = 20 pounds of fuel, one minute of horizontal flight = 25 pounds of fuel
- Fuel consumption to RIBKI point during descent is 40 pounds and 12,5 pounds during horizontal flight.
- Fuel consumption to FAF point during descent is 50 pounds and 62,5 pounds during horizontal flight.
- Fuel consumption after landing during descent is 90 pounds.

The total calculated fuel consumption for flying the standard arrival route BERVA 2A is 255 pounds.

Description of the standard departure route (SID) BERVA 3A:
After take-off, the aircraft climbs fluently to flight level 170 seven minutes, it climbs of runway heading to altitude 1 200 ft AMSL, then it turns right to heading 038° to NDB RP point. After NDB RP point it turns to heading 057° to BERVA point. After reaching flight level 170 it continues to horizontal flight. The total flight time of the standard departure route BERVA 3A is eight and half minutes with a total distance 31,1 NM.
Fuel consumption calculation:

- One minute of climb = 50 pounds of fuel, one minute of horizontal flight = 25 pounds of fuel
- The fuel consumption of the first seven minutes of flight during the climb is 350 pounds. Fuel consumption for next one and half minute of flight to BERVA point during horizontal flight is 37,5 pounds.

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The total calculated fuel consumption for flying the standard departure route BERVA 3A is 385,5 pounds.

B. Average fuel consumption L 410 UVP-E20

Fuel tank meters in kilograms are installed in the aircraft.

TABLE 2. Average fuel consumption L 410 UVP-E20

	IAS Speed	Fuel consumption per hour	Rate of climb or descent
Climb	120 kt/h	340 kg	1000 ft/min
Horizontal flight	150 kt/h	280 kg	-
Descent	150 kt/h	200 kg	1000 ft/min

TABLE 3. Fuel consumption per hour of flight with two engines kg/h

Pressure height (m)	Economy mode	0,8 MCR	0,9 MCR	MCR
1800	280	327	364	388
2400	267	317	349	370
3000	259	305	336	360
3600	250	294	318	345
4200	242	284	304	330

MCR - maximum continuous mode, given by generator speed (%). The economy mode is determined by the pressure height and the corresponding speed.

TABLE 4. Kilometer fuel consumption with two engines kg/km

Pressure height (m)	Economy mode	0,8 MCR	0,9 MCR	MCR
1800	0,900	0,952	1,000	1,029
2400	0,871	0,914	0,943	0,981
3000	0,830	0,874	0,910	0,943
3600	0,790	0,836	0,862	0,890
4200	0,762	0,800	0,820	0,857

Description of the standard arrival route BERVA 2A:

After BERVA point the aircraft flies to RIBKI point 9,7 NM, descents from 6 000 ft MSL to 5 000 ft MSL one minute and three minutes it continues in horizontal flight. At RIBKI point it turns left to runway heading 194°, it descents one minute to 4 000 ft MSL and to IF point four minutes it continues in horizontal flight 9 NM. From IF point it flies to FAF point 5 NM it descents one and half minute and one minute it continues in horizontal flight, so that the aircraft has 2 500 ft MSL to FAF point for establish to the ILS. After FAF point it continues in descent for the landing five minutes 5,9 NM.

Fuel consumption calculation:

- One minute of descent = 3,333 kg of fuel, one minute of horizontal flight = 4,666 kg of fuel
- Fuel consumption to RIBKI point during descent is 3,333 kg and 14 kg during horizontal flight.
- Fuel consumption to FAF point during descent is 8,333 kg and 23,333 kg during horizontal flight.
- Fuel consumption after landing during descent is 16,666 kg.

The total calculated fuel consumption for flying the standard arrival route BERVA 2A is 65,666 kg.

Description of the standard departure route BERVA 3A:

After take-off, the aircraft climbs fluently to altitude 6 000 ft MSL six minutes, it climbs of runway heading to altitude 1 200 ft AMSL, then it turns right to heading 038° to NDB RP point. After NDB RP point it turns to heading 057° to BERVA point. After reaching altitude 6 000 ft MSL it continues to horizontal flight. The total flight time of the standard departure route BERVA 3A is thirteen minutes with a total distance 31,1 NM.

Fuel consumption calculation:

- One minute of climb = 5,666 kg of fuel, one minute of horizontal flight = 4,666 kg of fuel
- The fuel consumption of the first six minutes of flight during the climb is 34 kg. Fuel consumption for next seven minutes of flight to BERVA point during horizontal flight is 32,666 kg.

The total calculated fuel consumption for flying the standard departure route BERVA 3A is 66,666 kg.

V. FUEL CONSUMPTION BASED ON REAL MEASUREMENTS

Real measurements and readings on board aircraft probably have a high measurement error rate, due to the error in reading the values and the error of the fuel meters installed in the aircraft, mainly during climb, descent, but also horizontal flight. The description of standard arrival and departure routes for both types of aircraft is identical to the description in the theoretical calculations.

A. *Real fuel consumption C-27J SPARTAN*

In the aircraft is an assumption a lower error in measuring fuel consumption due to the new digital fuel consumption meter.

Standard arrival route (STAR) BERVA 2A: Fuel consumption to RIBKI point was 50 pounds. Fuel consumption to FAF point was 50 pounds. Fuel consumption after landing was 250 pounds. The total real fuel consumption after flying standard arrival route BERVA 2A was 350 pounds.

Standard departure route (SID) BERVA 3A: The total real fuel consumption after eight and half minutes of

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flight on standard departure route BERVA 3A was 450 pounds.

B. Real fuel consumption L 410 UVP-E20

In the aircraft, there is a presumption of a higher error of fuel consumption measurement due to older analog fuel consumption meters.

Standard arrival route (STAR) BERVA 2A: Fuel consumption to RIBKI point was 25 kg. Fuel consumption to FAF point was 25 kg. Fuel consumption after landing was 25 kg. The total real fuel consumption after flying standard arrival route BERVA 2A was 75 kg.

Standard departure route (SID) BERVA 3A: The total real fuel consumption after thirteen minutes of flight on standard departure route BERVA 3A was 75 kg.

VI. COMPARISON OF FUEL CONSUMPTION AND PRICE BASED ON THEORETICAL KNOWLEDGE AND REAL MEASUREMENTS

The price of fuel is different for armed forces and private companies, where the armed forces refuel tax-free aircraft and private companies with tax.

Price of JET A1 aviation fuel:

- 1 liter of fuel for the armed forces without tax = 0,545 €
- 1 liter of fuel for private companies with tax = 1,185 €

The data provided are given according to the purchase invoices. The weight of one liter of JET A1 aviation fuel is approximately 0,81 kg.

Convert kilograms and pounds:

- 1 kg = 2,20462 pounds
- 1 pound = 0,453 kg

A. C-27J SPARTAN

The theoretical calculation of fuel consumption when the aircraft flies of the standard arrival route BERVA 2A is 255 pounds. The real fuel consumption when the aircraft flies of the standard arrival route BERVA 2A is 350 pounds. The difference between the theoretical calculation and the real fuel consumption is 95 pounds. 95 pounds of fuel = 43,035 kg = 53,13 liters, which, when converted, represents a value of 28,96 € excluding tax and 62,96 € including tax. The theoretical calculation of fuel consumption when the aircraft flies of the standard arrival route BERVA 3A is 385,5 pounds. The real fuel consumption when the aircraft flies of the standard arrival route BERVA 3A is 450 pounds. The difference between the theoretical calculation and the real fuel consumption is 64,5 pounds. 64,5 pounds of fuel = 29,2185 kg = 36,07 liters, which, when converted, represents a value of 19,66 € excluding tax and 42,74 € including tax.

B. L 410 UVP-E20

The theoretical calculation of fuel consumption when the aircraft flies of the standard arrival route BERVA 2A is 65,666 kg. The real fuel consumption when the aircraft flies of the standard arrival route BERVA 2A is 75 kg.The difference between the theoretical calculation and the real fuel consumption is 9,334 kg. 9,334 kg of fuel = 11,52 liters, which, when converted, represents a value of 6,28 € excluding tax and 13,65 € including tax. The theoretical calculation of fuel consumption when the aircraft flies of the standard arrival route BERVA 3A is 66,666 kg. The real fuel consumption when the aircraft flies of the standard arrival route BERVA 3A is 75 kg. The difference between the theoretical calculation and the real fuel consumption is 8,334 kg. 8,334 kg of fuel = 10,29 liters, which, when converted, represents a value of 5,61 € excluding tax and 12,19 € including tax.

CONCLUSION

The final difference in price and fuel consumption between the theoretical calculation and the real measurement was influenced by several factors. The main factors were the different flight modes between theoretical calculation and real measurement, errors in reading fuel values on board aircraft, errors on meters installed on board aircraft, air temperature in individual flights and other meteorological conditions that affected engine performance and aircraft aerodynamics such as wind speed and shear, pressure and humidity. During the real measurement of the C-27J SPARTAN flight, the flight controller significantly reduced the flight due to fuel consumption, because the temporarily limited space LZR 131B was active up to 8,500 ft MSL. The C-27J SPARTAN received an altitude restriction from the air traffic controller before take-off to a minimum of 9,000 ft MSL to the NDB RP, which had a negative effect on fuel consumption, as the aircraft had to climb sharply outside the tables and had a flight level 120. It should be added that the results of the theoretical calculation are idealized without any external influences and limitations. Given these factors and limitations, the difference between the theoretical calculation and the real measurement was expected, but relatively acceptable. Measurement errors could be minimized by several repeated flights under better meteorological conditions and without limitation of temporarily limited areas LZR 131A, B. This work should point to a number of external influences on the price and fuel consumption

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Statistical evaluation of Kosice-London flights with Wizz Air just before lockdown the commercial flights due to Covid-19 pandemics

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***Abstract* — The main aim of this article is statistical comparison of Kosice-London flights by Wizz Air just before lockdown due to Covid-19 pandemic restrictions. Statistical data processing focuses on comparing the number of transported passengers in January, February and March in 2020. The selection of months was focused on operations just before lockdown the air traffic due to Covid-19 pandemic and the closure of Kosice Airport. This pandemic affected the whole world and the aviation industry with a very large impact on their existence. Major factors such as border closures, the banning of commercial flights and the closure of airports for several months had a devastating impact on the smooth functioning of the aviation industry.**

I. INTRODUCTION

Actual pandemic situation is not good for aviation in global point of view. This research analyzes few months before lockdown at Kosice Airport and statistically describe the number of transported passengers in months January, February and the most affected month March in year 2020. These statistics belongs to Wizz Air flights enroute KSC-LTN. Several authors dealt with similar problematics for example Local Modular Departure Control System for Airports by Adamcik F. et al. where the authors talk about actual results of a design and implementation of a modular and local departure control system of the IMARA system with a primary focus on low-cost airlines [1]. Galanda J. et al. in The Imara Project – The Local Departure Control System for Airports in project which was designed and then implemented a solution that would meet the highest criteria of reliability, safety, and usability of the proposed solution in the field of its deployment. The primary target groups are local carriers, airlines, and airports operating in Slovakia with a special focus on regional low-cost companies and charter companies [2]. Information System to Support The Management Of Winter Airport Maintenance by Svab P. et al. talks about winter airport maintenance. It discusses the use of an information system to support winter maintenance of airports in the process of planning and coordination. Specifically, it aims to define the key components which are necessary for proper operation and quality outputs of this system [3]. Iacus SM. in Estimating and projecting air passenger traffic during the COVID-19 coronavirus outbreak and its socio-economic impact talks about coronavirus global crisis, most countries have put in place restrictive measures in order to confine the pandemic and contain the number of casualties. Among the restrictive measures, air traffic suspension is certainly quite effective in reducing the mobility on the global scale in the short term, but it also has high socioeconomic impact on the long and short term [4]. Vajdova I. et al. in Environmental Impact of Burning Composite Materials Used in Aircraft Construction on the Air dealt with negative impact of air incidents and emergency situations results from the leakage of liquids into the soil and water and the leakage of flue gases and combustion products of aircraft structural materials into the air during fires [5]. Another article with topic Severe airport sanitarian control could slow down the spreading of COVID-19 pandemics in Brazil by Ribeiro SP. et al. talks about scenario of COVID-19 spreading in Brazil through the complex airport network of the country, for the 90 days after the first national occurrence of the disease. After the confirmation of the first imported cases, the lack of a proper airport entrance control resulted in the infection spreading in a manner directly proportional to the amount of flights reaching each city, following the first occurrence of the virus coming from abroad [6]. Carulla SR. et al. talks about COVID-19 and Air Transport (February 9 – April 30, 2020). This study brings together and analyses the norms enacted as well as the practices followed by the Spanish Government and the institutions of the European Union in relation to air transport, from February 14, the date of declaration of the state of alarm, until April 30, when plans for lifting the containment measures in force

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were put on the table. The restrictions of flights imposed by the authorities has caused a severe crisis in air transport, whose actors are demanding public aid from States [7]. Szabo P. et al. in Sage math for education and research talks about complex system that can be applied to perform complicated calculations but can be also used in education. This contribution describes how and in what areas the system can be used in general [8]. Article with topic 3D Modeling and Simulation of the Check-in Process Using Information Technology by Galanda J. et al. deals with information technology at the airport facilitates the management of all processes and ensures the highest degree of security. In addition to these information systems, airports may also use information systems that allow pre-test the impact of the expected changes in the activities before their implementation in full operation thereby saving considerable costs if the expected change is inappropriate. This is done by modeling and simulation programs that allow you to create and view any reality and see how the system behaves when the input data is entered [9]. Covid-19 pandemics also influence the cash flow of airports and airlines largely. In article the COVID-19 pandemic and airline cash flow model by Vinod B. deals with seismic impact on the travel industry. With a steep drop in demand and flight cancelations on international routes, airlines have reduced capacity on a scale that we have never seen before. In the current environment, airlines are strapped for cash, and cashflow is a prerequisite for survival. As airlines navigate through the resumption of flights in a Covid-19 and post-Covid-19 era, this paper recommends an approach for airlines to generate cashflow from corporations for their mutual benefit [10].

A. Methodology and Data Collection

The statistics was collected from the Ticketing Sales Office at Kosice Airport where Wizz Air flights statistics are recorded daily. After data collecting we prepared the simple graphs showing the individual days of the month and the exact number of passengers who departed from airport. The graphs were created for the months of January, February and March in 2020. The statistical data evaluation took place in comparison with month of January and month of March and then the month of February with month of March. The reason for these comparisons is the fact of the lockdown due to Covid-19 pandemic. Last plane flew to London on March 11, 2020 and then the airport closed the gates for several months.

II. STATISTICAL EVALUATION OF KOSICE-LONDON FLIGHTS WITH WIZZ AIR JUST BEFORE LOCKDOWN THE COMMERCIAL FLIGHTS DUE TO COVID-19 PANDEMICS

The Covid-19 changed the whole world situation, affected the entire aviation and this fact is the main reason why we prepared this article. Airports and airlines had to adapt the world situation and respect the State Government Regulations belongs to all countries worldwide. Kosice Airport and Low-cost airline Wizz Air also joined the pandemic honestly and closed their operations on 11 March 2020. In January the operation was normal, and the number of transported passengers was also like in standard operation. These indicators are shown in Figure number one

Figure 1. Number of transported passengers in January 2020

The average number of transported passengers in January was around 222 passengers. The largest number of transported passengers was on 17, 22, 24 and 29 of January where the aircraft departed with load factor equals to 100%. Figure 2 shows the number of passengers carried in February.

Figure 2. Number of transported passengers in February 2020

The month of February brought an average of 209 passengers for Wizz Air flights to London. Most passengers departed on February 23 with 225 PAX on board with 97.83% load factor. The lowest number of passengers with a load factor of 83.48% departed on 28 February 2020. Figure 3 shows the month of March where the last Wizz Air flight from Kosice Airport to London Luton Airport departed on 11 March 2020.

Figure 3. Number of transported passengers in March 2020

As can be seen the number of passengers on the last day of departure was only 137 passengers with a load factor only 59.57%. The largest number was collected on March 1 with a value of 207 passengers. From the lockdown date the number of transported passengers until the end of the discussed month takes the zero value.

A.Statistical Data Evaluation

For the fact about decrease the number of transported passengers we choose the statistical data evaluation. The comparison focuses on classic months with the affected month in pandemic year 2020. The first comparison is focused on the comparison of the month of January with the month of March. Where January appears as a month of normal operation and March as affected month by pandemic situation. Table 1 shows the values entering the statistics.

TABLE 1. Statistic compare months January vs March

Months	Mean value for January	Mean value for March	Standard Deviation for January	Standard Deviation for March	p Variances
January vs March	222,3043	61,75000	7,329586	89,99626	0,000000

The mean value for January in the number of transported passengers is 222.3043. In the month of March, it´s only 61.75000. The standard deviation in January reached the value of 7.329586 and in March 89.99626.

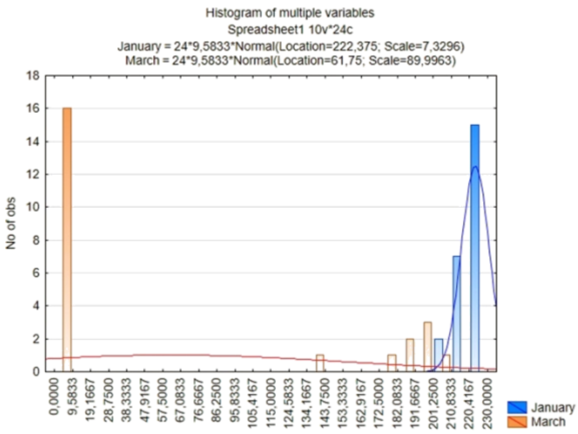

Figure 4. Histogram for January and March compare

For data normality verification we used the histogram method which could confirm the non-normal data distribution. We have reached the confirmation of traffic decrease in month March compared to month January at the level of significance p 0.000000. The decrease in operations is confirmed at 99.99%. Before the complete probability of identification, we need to do also the comparison with the month of February and followed the relevant instructions as in previous cases.

TABLE 2. Statistic compare months February vs March

Months	Mean value for February	Mean value for March	Standard Deviation for February	Standard Deviation for March	p Variances
February vs March	209,3043	61,75000	11,32750	89,99626	0,000000

The mean value of transported passengers in February was 209.3043 and the standard deviation was 11.32750. The values for March remained unchanged. Also in this case we used the histogram method to determine the normality of data distribution where we obtained the same results as in first case.

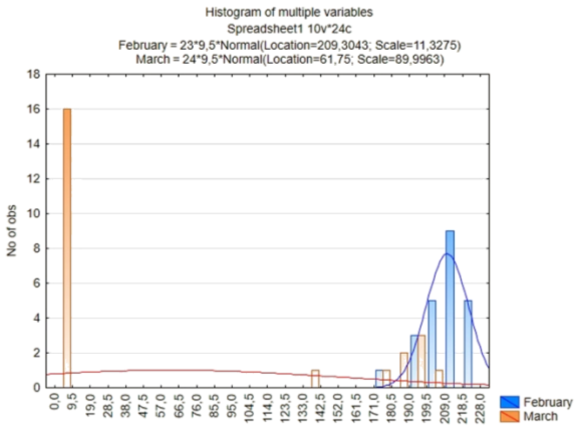

Figure 5. Histogram for February and March compare

We concluded and confirmed the assumption of traffic decrease in comparison with the month of February at the level of significance p 0.000000. The decrease in traffic is thus statistically confirmed at 99.99%.

CONCLUSION

The main article goal was to collect the necessary data before the outbreak of the Covid-19 pandemics. Subsequently, process these data into graphs where we chose two months before airport closure and the cancellation of all Wizz Air flights from Kosice to London. From these graphs we see the rapid decrease in transported passengers in March 2020. That´s the main reason why we decided to confirm this clear fact by statistical evaluation from the collected data.

In our case we used the Mann-Whitney U test to evaluate the test and came to the following conclusion:

- There is a 99.99% ($p<0.001$) difference between January and March in the number of transported passengers,

- There is a 99.99% ($p<0.001$) difference between February and March in the number of transported passengers.

We statistically confirmed with 99.99% the meaning of decrease in transported passengers in March compared to the previously selected months of year 2020.

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Detection of minimal set of trips causing the necessity to use extra vehicle for vehicle scheduling problem – a case study

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***Abstract* — vehicle scheduling problem addresses the task of assigning vehicles to cover all trips in a timetable. Minimum number of vehicles is determined by the number of trips in the peak hours of demand. We propose an approach to detect the minimal set of trips (critical trips), such that omitting them allows to lower the amount of necessary vehicles. In this case study we show the usage of critical trips identification algorithm on timetabled data of selected public transport company, where modification of 2 trips lead to reduction of both necessary vehicles and crew by 2.**

***Index Terms*—vehicle scheduling, graph theory, shortest disjoint paths, case study**

I. INTRODUCTION

Vehicle scheduling is a widely studied problem having many subsequent questions and solutions found. As a vehicle is usually the most expensive asset, transportation companies tend to minimize the number of vehicles. The problem of mini- mizing the number of vehicles needed to satisfy the timetable schedule can be solved for example by vertex covering or graph coloring [1], maximum flow [2] and many more. We can optimize the costs even further within the vehicle scheduling problem, minimizing not only the costs of used vehicles, but also the costs of death trips, which can be solved by means of linear programming [3], [4]. Outputs of both of these problems are blocks of trips to be covered by the minimal number of vehicles m. If some of these blocks are very small, containing for instance only 1 trip, it is questionable whether it is cost effective to cover them by a vehicle. Especially if the transport company is running short on vehicles, cancellation or outsourcing of the minimal block can be considered, as it will most likely be a cost effective solution. Within paper [5], we proposed an algorithm for critical trips identification, i. e. identification of the minimal set of trips, such that omitting them from the vehicle scheduling problem lowers the amount of vehicles necessary to cover the timetable. The algorithm is suitable for single-depot single-vehicle scheduling problem.

Within this case study, we aim to apply method of critical trips identification, evaluation and handling on timetabled data of public transport company of Liberec and Jablonec nad Nisou. The timetabled data is taken for Saturday schedule during winter of 2017, for buses only. There is only one bus depot. The bus fleet is heterogenous, however, Saturday chedule requires less than half of the available vehicles and can be fully covered by low-floor buses. Therefore, without limiting the generality, we treat the schedule as single-vehicle.

There are overall 997 timetabled trips within 28 routes, the summary is provided within table I. The value of uniformity coefficient will be explained within next section.

Figure 1 shows for each time moment within Saturday the amount of timetabled trips and the necessary amount of vehicles to cover them. The necessary amount of vehicles is computed by vehicle and crew scheduling system Kastor, see [6]. We can observe in figure 1 that the number of necessary vehicles is almost flat between 8:30 and 18:30, with a minor peak around 13:00.

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TABLE 1. Routes and trips summary for saturday timetable[1]

Route name	Number of trips	Number of durations	Duration range	Number of start stops	Uniformity coefficient
12	140	11	12 - 31	4	0.96
13	36	2	18 - 33	3	0.69
14	38	1	24	2	0.00
15	40	3	10 - 14	3	0.83
16	38	6	13 - 34	4	0.24
17	14	1	14	1	0.92
18	39	6	9 - 31	4	0.11
19	33	4	11 - 18	3	0.79
20	40	3	14 - 22	3	0.28
21	40	3	6 - 16	2	0.92
22	117	19	8 - 42	7	0.48
24	78	4	13 - 35	4	0.22
25	107	4	8 - 22	4	0.90
26	39	4	15 - 34	3	0.39
27	4	1	11	2	undefined
30	29	2	11 - 13	2	0.58
31	6	2	15 - 16	2	undefined
32	2	2	7 - 10	2	undefined
34	1	1	11	1	undefined
38	8	1	5	2	1.00
90	3	1	22	1	1.00
91	3	1	18	1	1.00
92	3	1	20	1	1.00
97	1	1	25	1	undefined
98	1	1	18	1	undefined
99	1	1	37	1	undefined
500	59	2	7 - 10	2	0.85
600	77	2	9 - 10	2	1.00

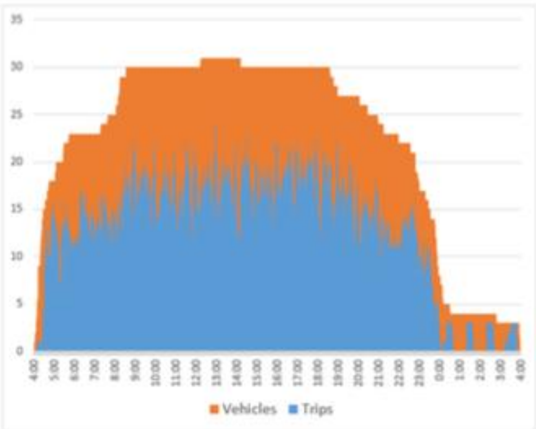

Figure 1. Number of trips and necessary vehicles for Saturday timetable

II. METHODS

We use the methods proposed and described within [5]. First, we detect critical trips and select the desired number of vehicles. We obtain meaningful number of critical trips alternatives. Then, in tight collaboration with subject matter experts from public transport company of Liberec and Jablonec nad Nisou and building on their input, for selected handling methods we evaluate the critical trips alternatives. Based on the evaluation, the choice of given amount of critical trips alternatives for handling is made. Considered handling methods are

- Rescheduling of the trip to a different time frame
- Outsourcing
- Trip cancellation
- Covering of the trip by a backup vehicle and a temp crew

When considering trip shifting to a different time frame, it is preferable to select trips from the lines with non-uniform differences between consecutive trips. For example trips within lines which operate in the manner of interval transport are highly unsuitable for rescheduling. Therefore, we define the uniformity coefficient, which evaluates uniformity of the sequence of time spans between consecutive trips of a selected line.

Let us define Kronecker delta as

$$\delta_{ij} = \begin{cases} 1, & \text{if } i = j, \\ 0, & \text{if } i \neq j. \end{cases}$$

Let $t_1, t_2, ..., t_n$ be the ordered sequence of start times of trips within selected line l on given weekday. Then the sequence $d1 = t2 - t1, d2 = t3 - t2, ..., dn-1 = tn - tn-1$ is the sequence of time differences between consecutive trips. Then the uniformity coefficient of line l (as well as each of its trip) on given weekday is defined as

$$U_l = \frac{\sum_{k=1}^{n-2} \delta_{d_k d_{k+1}}}{n-2},$$

i. e. it counts the number of value changes in the sequence $d1, d2, \ldots, dn-1$, and normalizes the result by dividing it by the amount of possible changes. The value of U_l ranges from 0 to1, where $U_l = 1$ for a line where $d1 = d2 = \cdots = dn-1$ and $U_l = 0$ for a line where $d1 \neq d2, d2 \neq d3, ..., dn-2 \neq dn-1$.

We evaluate the uniformity coefficient of each critical trip, and select those with low enough value of uniformity coefficient as candidates for rescheduling. Then, the maximal time shift window needs to be set for each candidate.

We can observe from table I that most of the routes contain trips with multiple different durations and multiple different start stops. In order to compute uniformity coefficient for each route within table I, we focused on timetables of one central station within Liberec, which is Fügnerova station. All the trips except for exactly three trips from routes 34, 97 and 98 run through Fügnerova station. Each of the routes 34, 97 and 98 contain only one trip, therefore, the uniformity coefficient is undefined by default. For routes which have both directions defined, the uniformity coefficient is computed for one direction only.

The necessary amount of vehicles and crew is computed by vehicle and crew scheduling system

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Kastor, see [6]. Kastor is vehicle and crew scheduling system, therefore solution yielded by Kastor can generally use more vehicles than the mini- mal possible amount. However, here, the amount of vehicles yielded by Kastor is minimal possible.

III. DISCUSSION

Relevant measures for the original result of vehicle and crew scheduling run upon the timetabled data are provided in table II. Upon the timetabled data, we run algorithm for critical trips identification to obtain the critical trips.

Figure 2 shows last 9 vehicle schedules after the last run of the algorithm, i. e. the last 9 shortest disjoint paths. Apparently, the last two critical paths contain only one trip each. These 2 trips were identified as critical, therefore they are colored in orange. To summarize, we aim to remove 2 critical trips to lower the amount of necessary vehicles by 2 to 29. Algorithm for identification of critical trips alternatives yielded 3 further alternatives of critical trips, colored in grey.

Let us denote the critical trips alternatives from figure 2 as a_1, a_2, a_3, a_4, a_5 (colored in grey and orange) from top to bottom. Having the full list of critical trips alternatives, trip a_5 was proposed by the subject matter experts to be cancelled right away.

TABLE 2. Original results of vehicle and crew scheduling

Measure	Count
Number of trips	997
Number of vehicles	31
Number of crew shifts	59

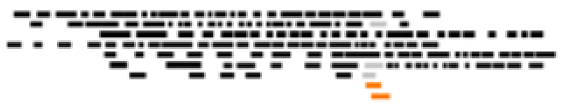

Figure 2. Segment of vehicle schedule for Saturday timetable with critical trips identified in orange and critical trips alternatives in grey

Therefore, there were 4 alternatives a_1 , a_2 , a_3 , a_4 left for handling of 1 critical trip. The chosen handling method was trip rescheduling. Table III summarizes the values of unifor- mity coefficients for each critical trip alternative.

Based on the value of uniformity coefficient, alternatives a_3 and a_4 were selected as candidates for rescheduling, with time window of 15 minutes. The trip shifting algorithm as per [7] found a feasible schedule for alternative a_4 with time shift of −8 minutes, which was considered reasonable for given trip and route. Therefore, trip a_4 was rescheduled by shifting it to an 8 minutes earlier timeframe.

CONCLUSION

Within this case study, we applied methods for critical trips identification, evaluation and handling on Saturday timetable of public transport company of Liberec and Jablonec nad Nisou.

Based on the amount of critical trips, we set the desired reduction of number of necessary vehicles to 2. We performed the search for critical trips alternatives, which yielded in total 5 alternatives for consideration, and together with subject matter experts from public transport company of Liberec and Jablonec nad Nisou we performed critical trips evaluation and handling. One critical trip got cancelled, and one rescheduled. Comparison of vehicle and crew scheduling results before and after critical trips handling is provided in table IV. By handling 0.2% of trips, we lowered the amount of necessary vehicles by 6.5% and the amount of crew shifts by 3.4%. Solutions provided by Kastor have as uniform shifts as possible. Within the original solution, Kastor distributed 997 trips between 31 vehicles and 59 crew shifts, where the lengths of all crew shifts should be as uniform as possible. By handling 2 trips, it was possible to cover 996 trips by only 29 vehicles and 57 crew shifts, which stepped up vehicle utilization as well as the amount of productive time of the crew.

ACKNOWLEDGEMENT

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TABLE 3. Uniformity coefficients of critical trips alternatives

Critical trip alternative	Uniformity coefficient
a_1	0.96
a_2	0.96
a_3	0.24
a_4	0.11

TABLE 4. Results of vehicle and crew scheduling before and after critical trips handling

Measure	Original count	Count after handling
Number of trips	997	996
Number of vehicles	31	29
Number of crew shifts	59	57

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The effectiveness of the measures taken by the two different countries

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***Abstract*—During COVID-19 pandemic there were different approaches to countermeasures amid countries in the world with various efficiency. This article compares approach of China and USA as markets with strong domestic and international air travel in the matter of COVID-19 population spread, its negative impact on air travel and recovery to see, which scenario had better results and could be taken as an exemplary case in its effectivity**

I. INTRODUCTION

The aim of this work is to review and evaluate effective practices and measures taken in the hope that they will be useful in the future in the fight against a similar global pandemic, thus mitigating the impact on global air transport as we see today.

A. Modern virus with pandemic status

Modern infectious disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) poses a serious threat in China and around the world. In China, where the disease first appeared and where it started, and which is facing this serious situation, it has taken many measures to prevent its transmission.Most countries see more cancellations for international flights than for domestic ones. Weekly scheduled flights compared to last year.

B. Current state of the pandemic

At present, the number of newly diagnosed cases per day on the Chinese mainland has dropped to only a few or even zero. In other countries, however, the situation remains serious.

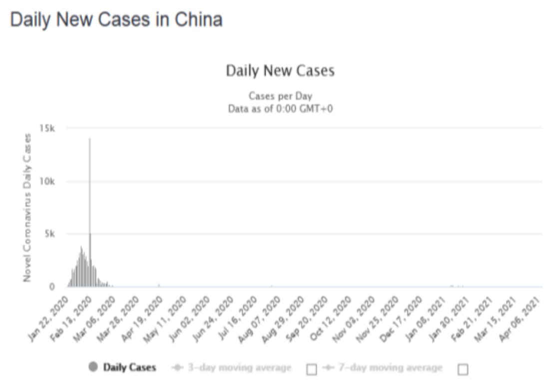

Figure 1. Daily new cases in China

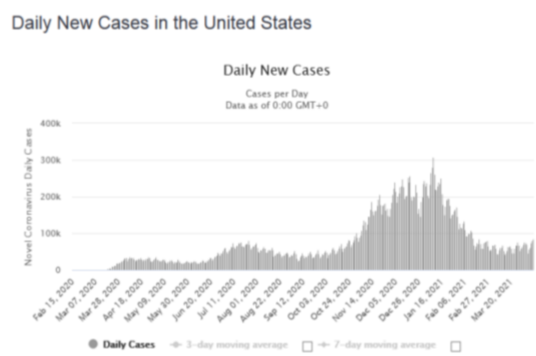

Figure 2. Yearly evolution of COVID-19 cases in USA from Feb 11th

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Figure 3. COVID-19 cases and deaths on April 10th 2021 in comparison

As of October 4, 2020, China had confirmed 90,604 COVID-19 and 4,739 deaths, while the United States registered 7,382,194 cases and 209,382 deaths. On April 18, China had 83,800 infected and 4,836 deaths, while COVID-19 occurred in the United States on March 17 with 1,822 new cases.

II. STATE OF AIR TRAFFIC

Traffic Results

System-wide global commercial airlines	Passenger traffic (RPK), % Year-on-Year							Passenger capacity (ASK) % Year-on-Year						
	2015	2016	2017	2018	2019	2020E	2021F	2015	2016	2017	2018	2019	2020E	2021F
Global	7.4	7.4	8.1	7.4	4.2	-66.3	50.4	6.7	7.5	6.7	6.9	3.4	-57.6	35.5
Regions														
North America	4.5	4.3	4.0	5.3	4.0	-66.0	60.5	4.1	4.7	3.9	4.9	2.9	-51.6	36.4
Europe	5.8	5.3	9.1	7.5	4.2	-70.0	47.5	4.5	5.3	6.9	6.5	3.5	-62.4	35.5
Asia-Pacific	9.6	11.1	10.8	9.3	4.7	-62.0	50.0	7.5	10.1	9.0	8.7	4.4	-55.1	38.4
Middle East	9.9	11.4	6.8	5.0	2.3	-73.0	43.0	12.6	13.2	6.2	5.8	0.1	-64.5	23.6
Latin America	6.7	4.5	7.3	7.4	4.2	-64.0	39.0	6.5	3.3	5.4	7.8	3.0	-60.0	34.3
Africa	3.4	7.3	5.5	6.1	4.7	-72.0	35.0	2.4	6.9	2.2	4.3	4.5	-62.8	21.5

Source and Note: IATA. Includes domestic and international traffic, and all commercial airlines. Historical data are subject to revision.
Updated: 11/2020 Next Update: 06/2021

Figure 4. Global air traffic stats showing COVID-19 impact

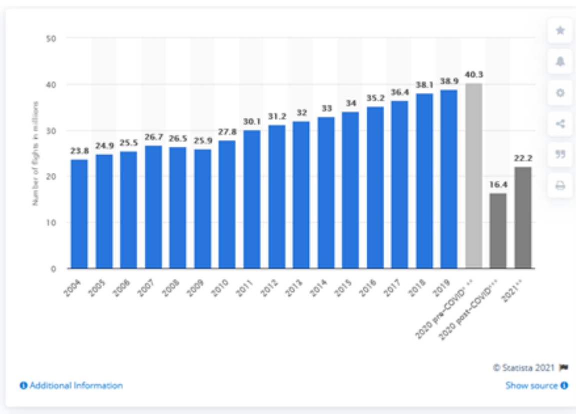

Figure 5. Global air traffic stats showing yearly growth and COVID-19 impact

The coronavirus had a detrimental effect on both the world economy and aviation. One year after the outbreak of the Covid-19 pandemic (October 2020), we can see that China has brought the virus under control and managed to overcome the pandemic quickly and effectively, unlike the rest of the world, where covid-19 is still being fought.

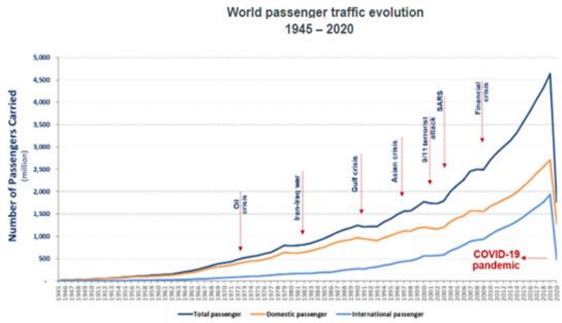

Figure 6. Significance of COVID-19 pandemic in comparison to another global negative events
* March 2020 data is preliminary

Figure 7. Map of air travel intensity during COVID-19 pandemic showing decrease of Chinas air travel in comparison of USA no change. March 1st.

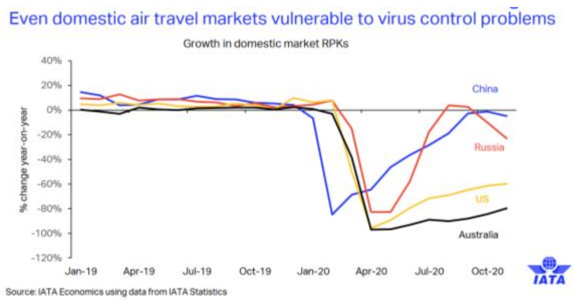

Figure 8. Regional air travel convalesce

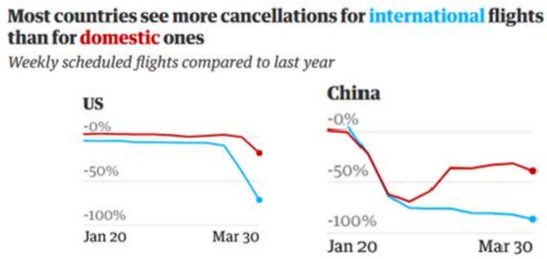

Figure 9. Difference in air travel cancellations during pandemic China vs. USA. Note Dates and evolution

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III. THE BEGINNING OF THE COVID-19 PANDEMIC

The government in Wuhan, China, confirmed for the first time on December 31 that dozens of cases had been treated by health authorities. A few days later, scientists in China identified a new virus that infected dozens of people in Asia. At the time, there was no evidence that the virus spread easily through humans. Health officials in China have said they are monitoring it to prevent an outbreak. Following past experience with the SARS virus and vigilance against the new virus, Chinese President Jinping has called on nations for a joint international response to overcome the current pandemic. Within three months, 80,000 cases had been identified, killing 3,000 people.

A. Comparison of China toward USA

In early April, the Chinese government restricted the spread of the virus so much that it felt comfortable reopening Wu-chan. Seven months later, China confirmed another 9,100 cases and recorded another 1,407 coronavirus deaths. People in China travel, eat in restaurants, go to theaters and children go to school without much concern for their health. Compare that to what people in the United States experience. To date, more than 11 million cases have been confirmed, with a weekly increase of around 1 million.

SARS has revealed serious weaknesses in China's public health system and called on the government to re-establish its public health system. COVID-19 has revealed similar deficiencies in the US public health system. To date, however, the current administration has taken a completely opposite approach, which has destroyed the US public health system.

The US administration has made major cuts in the budgets of the National Institutes of Health and the Centers for Disease Control and Prevention.

B. China strategy

From the first case, the Chinese government's strategy in the fight against unknown and unexplained pneumonia can be divided into 3 stages:

In the first stage, it was necessary to identify the possibilities of human-to-human transmission, the susceptible part of the population, as well as the clinical and epidemiological signs and manifestations of the new virus.

From 20 January 2020, the second stage in the fight against the virus took place, which was the most critical and difficult period, namely the prevention of the spread of the virus between areas. As cases began to spread outside the city of Wuchan to other provinces during this period, on January 23, the city was closed and isolated from the rest of China and the world, for the first time in Chinese history. Immediately afterwards, another 17 places in the province of Chupej were closed due to proven cases.

During the epidemic, medical resources were constantly supplemented and improved. The third stage was to support economic development and disease prevention and control.

C. Efficiency

Chinese practices (including active case monitoring, rapid case diagnosis and quarantine, rigorous monitoring and quarantine of close contacts and issuing instructions to assist the public in understanding and complying with control measures), plus a rapid and effective high-level policy decision, full activation of the public health system and the full involvement of society is effective in the prevention and control of COVID-19.

Figure 10. Graph of Chinas air travel departures evolution from start of COVID pandemic. Note quick increase after deep fall.

The impact of COVID-19 on air transport manifested itself in the third week of January, when transport in China fell by almost 75%. After falling by more than 80% by mid-February, in the last week of February to the first week of March, traffic in China has recovered to 40% of normal.

D. China approach to the pandemic

China was well placed to cope with the disease, such as a centralized epidemic response system, and most chinese adults remember sars-cov and the high mortality associated with it, so the speed of china's response was a decisive factor.

In china, the covid-19 epidemic began just before the spring festivities, the event with the largest population movement in the world. The first reported cases of the disease occurred in Wuhan, hubei province at the end of december 2019, a city with 11 million inhabitants. The government's prompt response from the outset was a key factor in managing the disease. In the early days, the authorities introduced some important public health measures, in particular:

1) reporting to the public on an unexplained outbreak of viral pneumonia;

2) intensive surveillance and epidemiological investigation;

3) case detection, quarantine and reporting;

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4) sanitation and disinfection of the environment and the closure of the seafood market in huanan on 1 january;
5) medical observation of close contacts in order to obtain evidence of human-to-human transmission;
6) communication on public risk, efforts to raise public awareness and take measures for self-protection;
7) communication with who and other countries;
8) virus isolation and rna sequencing,
9) creating and sharing pcr detection kits. subsequently, the government has designated many fever treatment institutions to admit fever patients in each city.

On the night of January 22, 2020, it was decided to close the outbound traffic from Wuhan City on January 23, imitating other cities in Hubei Province. As of January 27, another 17 cities in Hubei Province had been closed, and only one city, Shennongjia, had been unlocked. Although other cities in China have not taken the same steps, people in these places have been trapped in their homes. Initially, they were suggested to stay at home, and were later assigned a 24-hour closed community report. Specifically, one household could send one person to go shopping for daily necessities every two or three days, and others could not go outside. Who allocated daily necessities.

China released the genomic sequence of the virus, a technology that allows large sections of DNA to be sequenced on January 10th 2020 and began to take strict countermeasures. Later that month. Wuhan was subjected to a strict closure that lasted 76 days. Urban public transport and all other forms of transport and any logistics services have been completely suspended. Shortly afterwards, similar measures were introduced in all cities in Hubei Province. Across the country, 14,000 health checkpoints have been set up in public transport hubs. The reopening of schools after the winter holidays has been delayed and population movements have been significantly reduced. Dozens of cities have imposed family external restrictions, which usually meant that only one member of each household was allowed to leave home every few days to gather the necessary supplies. All forms of gatherings and meetings, including work, visiting and school activities, were prohibited. For this reason, the spring holiday (Chinese New Year) was extended from January 30 to February 2, but continued much more significantly. The deadlines for resuming work and reopening schools have also been postponed, changing from place to place with the local epidemic situation (Table 2) and carefully planned in different regions and units to avoid maximum passenger flow. Cultural and tourist exchange activities were not recommended and were subject to approval by the local COVID-19 Prevention and Control Leadership Group, and from 24 January 2020, all group tours in China were suspended. Schools have abolished all forms of examinations. Online training, instruction, communication and discussion were recommended to avoid gathering as much as possible. All costs of treating diagnosed and suspected cases with COVID-19 were covered by national medical insurance and designated hospitals were prepaid by national medical insurance to dispel patients 'and hospitals' financial problems and guarantee their diagnosis and treatment. If a person were quarantined for treatment or medical observations for COVID-19, they would not suffer a salary reduction or dismissal. Almost all official ministries have made every effort to guarantee manpower and material resources. As the world's largest manufacturer of personal protective equipment, it has been relatively easy for China to increase the production of clinical gowns and surgical masks. In addition, the Chinese easily accepted wearing a mask. Consistency and cooperation of the population was very high, and for comparison with the USA, where even in June and July, when the virus increased, people still refused to use masks. One of the tools for China's virus prevention was the introduction of drones with loudspeakers, which inspected residents outdoors and alerted to the wearing of masks, sent home, or resembled hand disinfection. Unlike the United Kingdom, where 150,000 people were allowed to attend racing races in mid-March, 10 days before the country was locked, and 460,000 Americans gathered in Sturgis, South Dakota in August to take part in a motorcycle rally. A total of 16 new hospitals have also been set up in China since February 5, 2020, starting in Wuhan in public stadium and exhibition center locations to isolate patients with mild to moderate COVID-19 symptoms. Patients who began to show signs of serious illness were quickly transferred to regular hospitals. These new temporary hospital networks were adequately equipped with a bed capacity of 13,000 beds in the post office, which meant that patients with COVID-19 did not have to isolate themselves at home, reducing the risk of infection of family members. By 10 March 2020, the newly established hospital networks were no longer needed.

Those who came from abroad and entered the country were tested and quarantined. A model study by Chen suggested that China's public health measures between January 29 and February 29 could have prevented 1.4 million infections and 56,000 deaths. Another benefit of China's early settlement of the pandemic was that the economic situation did not have the same impact on the population as in other parts of the world, where many, especially businesses, went bankrupt due to escalating measures and closure. Although Wuhan has been an empty city for several months and also without any tourists, this situation has bypassed China and businessmen continue without major losses compared to other countries.

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IV. AIR TRAVEL IN THE USA AFTER PANDEMIC OUTBREAK

According to the Bureau of Transportation Statistics (BTS), according to data provided by US airlines, which skillfully provide 99% of transportation in the United States, there was a decrease of 51% in scheduled commercial air transport passengers in March 2020 compared to March 2019. This means a decrease to the lowest level. air transport in two decades in the United States. In March 2020, airlines carried a total of more domestic and international passengers than in September 2001, the month of the 9/11 terrorist attacks. Number of passengers in March 2020 (report by 24 carriers):

- Total: 38.7 million passengers, a decrease of 51% since March 2019 (79.9 million)
- Domestic: 34.1 million passengers, a decrease of 51% since March 2019 (69.6 million)
- International: 4.6 million passengers, down 53% from March 2019 (9.9 million)

On January 31, 2020, government restrictions on travel from China to the United States were issued in the United States, and on March 11, an order was issued to restrict travel to the United States from most European countries.

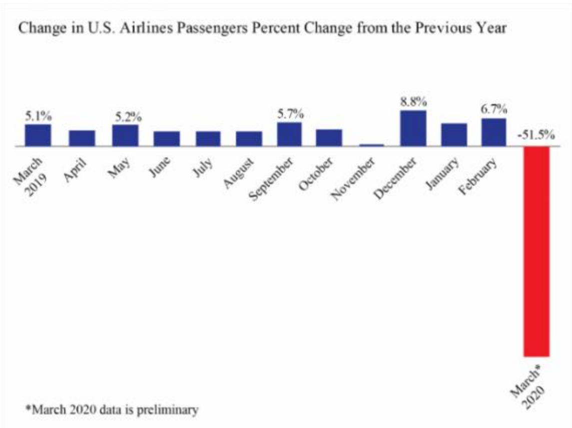

Figure 11. Graph depicting negative impact of COVID-19 on US air travel in passenger percentage**.**

A. USA approach to the pandemic

On August 9, 2020, the United States crossed over the five-million mark in the covid-19 case, just over a quarter of all global cases. On that day, more than half of the states in the United States qualified as hot spots for coronaviruses.

On the same day in South Dakota, the town of Sturgis, with less than 7,000 inhabitants, prepared to welcome 250,000 cyclists to its annual motorcycle rally. Because the mostly conservative rural state does not require any social distances or face masks, it would be the largest known public gathering in the world amid a covid-19 pandemic.

At the same time, 40 million Californians lived with a mandatory order to wear mask and the state imposed on the governor when the state's decision to open its economy led to a resurgence of covid-19 infections.

Tensions between Democratic mayors and Republican governors also developed in Texas and Florida, two major states where the virus was on the rise.

In New York, where the state underwent the worst epidemic in the United States after strict public health measures, the infection rate was low enough for the governor, whose daily press conferences became national television events, to announce his readiness to open schools. So did the American response to covid-19: a mixture of state and local government responses, sharply divided along democratic and liberal lines.

The American medical system has performed well and even bravely in many ways, increasing capacity and saving lives where possible. Uninsured people and working people face much higher direct costs and surprising costs than in other countries. The disappointment of the US response to covid-19 was the failure of politics and leadership, not health care, mainly due to two fateful political decisions:

The federal government as a backup - after first in office, President Trump made a major political shift in April, shaping the US response to the pandemic ever since. He said states would have the primary responsibility for arresting the virus, with the federal government having a "back-up" role. The role of the state in public health is traditional in the United States, and any national plan would allow for adaptation to reflect regional and national circumstances. Delegating primary responsibility to states in crisis is unprecedented. As far as is known, this was the first time that a sitting US president sought to decentralize power and responsibility during a national crisis.

The motivation for policy change has never been clearly articulated. While this is in line with conservative principles that allow states and local governments to adapt solutions to local conditions, it could also be an effort, albeit in vain, to get rid of political responsibility for the growing pandemic of the upcoming presidential election. As a former state commissioner for human services, Drew Altman CEO and president of the KFF (Keizer Family Foundation), who had experience with the whims of the state administration, he felt at that time that the consequences were predictable. April 5th he tweeted: "This is the result of leaving it up to the states to decide what to do on their own, with the federal government as an advance." "Pacesetters, a confused center and lagging people, often in the south. The consequences can be tragic this time." In practice, the consequences were even more complex when all states, regions and cities ha to fill the vacuum created by the lack of an overall national response.

The USA has 3141 counties. Some are rural and do not have health departments; others are as large as states and have health directors with strong independent authority to implement public health measures, such as

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residence orders. Three hundred cities in the United States have a population of 100,000 or more. In some jurisdictions, county and municipal authorities overlap. The city can provide health services and the county can manage public health. The school system can work independently of both. There is virtually every combination across the country. There was a lack of a centralized federal response, and this fragmentation resulted in extreme variations in the national response to covid-19 by and within states. For example, at the time of writing, 33 states introduced mandatory mask orders, while other states placed small orders or none at all.This change has had significant implications for public health. Some states opened their economies earlier than others - and in general, states that opened their economies earlier eventually suffered as larger outbreaks. This led directly to a second fateful political decision shaping the US response: Trump administration's decision to push for the opening of the economy before the virus was arrested - and the country to break up along party lines. The White House initially sought to introduce so-called "entry criteria", which states should meet before opening them. These guidelines could have brought more discipline to the inconsistent response of the state and local government, but the criteria were dropped. The answer was the defining and most annoying characteristic of the American response to the pandemic: states and the American people strike along partisan lines in their response to the covid-19, as if the country had a red (Republicans) and blue (Democrats) pandemics. When that happened, the public's willingness to prevent the spread of the virus collapsed across Red America. The partisan gap could be seen in almost every dimension of the epidemic. Democrats estimated it was about twice as likely as Republicans that the worst period of a pandemic in the United States was yet to come (Figure 12), and a great gap had opened up between Democrats and Republicans in the debate over school opening.

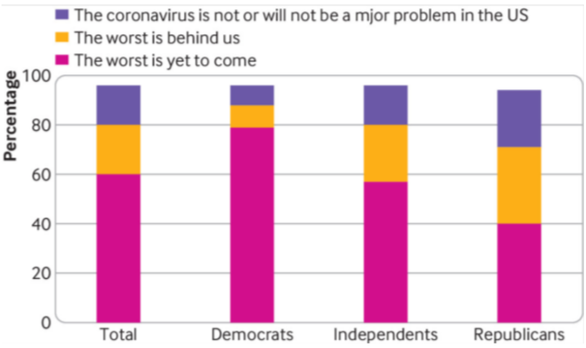

Figure 12. Democrats twice as likely as Republicans to say worst of coronavirus is yet to come. Source: KFF health tracking poll (conducted July 14-19 2020)

CBS and YouGov surprisingly found in a survey in late August 2020 that 90% of Democrats said the number of coronavirus deaths in the United States was unacceptable. However, a majority (57%) of Republicans said it was acceptable, in part because they believed the death toll was exaggerated.

Other reasons correspond to poor performance in the US. Historical neglect and insufficient funding from states and the local public health system have also contributed to the weak US response. The country's public health system also operates independently of the health care system. Overall, however, the US response to the pandemic is much more related to the basic political decisions that are being made - and not being taken - in the White House, than to the nature of the much-discussed health care system. The decentralized US response structure could work more effectively if the federal government's role as a "back-up" was supported by a national plan overlapping state responses and more comprehensive federal support for testing, contact tracing, personal protective equipment, school reopening, and other response elements requiring national policies and resources. focused on national and local conditions. Failure to defend against coronavirus in the US was not necessary and may not be permanent, and it is unusual for a country to be divided rather than unified in times of crisis.

CONCLUSION

Comparison of two world economic powerhouses in response to COVID-19 pandemic. As a result we could see two countries with different government, of similar landscape area, but with China having four times bigger population than USA, having diametrical difference in results of COVID-19 cases which is directly connected with impact on air travel and its convalescence. Study has shown effective way of fighting the virus in China due to experience with previous SARS pandemic which helped in China´s preparedness, population awareness and implementation successful actions into crisis management laws and procedures. The world´s largest population with central government managed to contain the virus in about three to four months, with 90 400 cases and about 4 700 deaths, this lead to fast convalescence of not its air travel after virus countermeasures proved to be successful but also in many other economic areas. On the other hand, the USA has the most COVID-19 cases of 31 800 000 and 575 000 deaths with number still rising even after one year after their first case. USA as a country divided into many states, counties and politically into two fractions fought the virus separately based on this dividing, which lead to many differences of countermeasures and it was shown to be ineffective.

It is clearly seen that Chinas mutual, centralized fighting effort was successful. Quick response effectiveness of strict countermeasures, population awareness, discipline and government social help in economic areas were the core of short effective fight against pandemic and low impact on economy of the

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country. Pandemic in USA has shown the gaps, weaknesses in their scattered fight which had lead to still ongoing pandemic, high number of deaths and heavy economic impact.

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Aircraft selection of an aircraft fleet for a national air carrier

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***Abstract*— Fleet planning is a process of strategic importance for an airline. Airline fleet composition, which means determining the airplane types and the numbers of each type needed by an airline, is important in affecting its operational performance. Airlines have a tendency to match their capacities and passenger demand for corresponding market conditions, which has a direct impact on airline profitability and costs. It is necessary to consider many different factors in order to make a good fleet plan. The goal of this paper, is to select a suitable type of aircraft, for the needs of the proposed national air carrier in Slovakia, using the Analytic Hierarchy Process (AHP). At the end of this paper will be recommendations given, for selecting the suitable aircraft.**

I. INTRODUCTION

Each airline company must respond to current passenger demand during its operation. Strategic planning of the composition of the aircraft fleet is one of the main threats, as airlines are constantly facing declining air revenues. One reason is the high level of competition caused by market liberalization and deregulation. Therefore, airlines companies are forced to constantly reduce their operating costs. Airline's operators must take appropriate measures to bring the demand for air transport as close as possible to its transport capacity. The process of selecting and planning an aircraft fleet is generally a very demanding process. It is necessary to take into account several factors such as aircraft economy, aircraft performance, level of comfort and services provided, and last, but not least, safety and reliability. Airline's operators use their aircraft over a relatively long period of time and have a significant impact on the company's economic performance. Therefore, the investment in the aircraft fleet is long-term and highly capital intensive. [1,2]

The aim of this article is to select suitable types of aircraft for the aircraft fleet of the Slovak national air carrier, based on predetermined evaluation criteria. We used the analytical hierarchy process (AHP) to select the suitable aircraft type. The AHP method is a decision-making process technique, that is used to analyze complex decisions and is also suitable for selecting a specific aircraft type. The result of this analysis will be the list of aircraft types, which will determine the appropriate aircraft types, which we will decide on in the final phase. The AHP method is suitable for this type of decision-making because the logic of this method is clear and rational. The calculation itself is relatively simple, based on a pairwise comparison of individual criteria. [3]

II. AIRCRAFT FLEET COMPOSTION

The composition of the aircraft fleet means, determining the type of aircraft and their number for the airline according to the analysis and forecast of expected demand for the planned period. Its main objective is to select the appropriate type of aircraft from a technical and economic point of view to meet the demand for air services. In order for the demand for air services to be aligned with the airline's capacity, the airline must adopt an appropriate methodological approach to the aircraft fleet planning process that is in line with its business model. Weekly timetables must also be taken into account when planning the aircraft fleet. Each type of aircraft is characterized by its operating and fixed costs, transport capacity for each class of travel, maximum range. The main measure of fleet performance is the profit, which is generated by a set plan and schedule, from which the fixed costs of aircraft are deducted.

The process of selecting a specific aircraft type is part of a very complex fleet planning process. Many factors need to be taken into account, such as the economical operation of the aircraft, the performance of the aircraft, the relatedness of the aircraft types, safety of operation, reliability, the actual assessment of the aircraft on the market and the purchase price. The market environment in which each airline operates is only predictable for a relatively short time and the uncertainty grows over time. Therefore, each airline must take all factors into account when choosing the structure and size of the fleet. [3,6]

According to the planned concept of the business model, the Slovak national air carrier is defined as a hybrid air carrier, that will operate airlines primarily

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within continental Europe using a “point-to-point” route system, using the aircraft fleet also for charter flight. It will primarily focus on narrow-body aircraft, which are designed for regional and medium-sized flights. The aircraft market is currently dominated by two manufacturers, namely European Airbus and American Boeing, whose aircraft together account for almost 91% of the total number of used transport aircraft in the world. Other manufacturers that offer smaller aircraft of this type are the Brazilian Embraer, the Canadian Bombardier and the French-Italian manufacturer ATR. Other manufacturers are practically negligible, because their aircraft have not undergone the EASA approval process or are focusing exclusively on regional markets in their home country. Due to the nature of the planned air lines, we will choose from the following aircraft:

- Airbus A 220-100
- Airbus A 319neo
- Boeing 737 – 700
- Embraer E2 175
- Bombardier CRJ 1000
- ATR 72 – 600
- Dash 8 Q400

III. AIRCRAFT SELECTION THROUGH THE AHP

The evaluation and selection of a suitable aircraft type for a national air carrier is based on the planned flight plan and business model. To make a decision on the most suitable choice of transport aircraft, we will use one of the multicriteria methods, which are a very popular tool for decision-making or evaluation. In our evaluation, we will use the method of analytical hierarchical process (AHP). The AHP method is a multi-criteria decision-making approach designed to solve a complex problem. This method is the most popular decision-making method in the world, because it works with fixed data, in our case the price of the aircraft, the maximum take-off weight, fuel consumption, aircraft capacity and the like. It allows mathematically to derive the weight of individual criteria, instead of subjectively choosing the weight of criteria, as used by other decision-making methods. The essence of the AHP method is to divide the main problem into a hierarchy of problems. In this case, the main problem is the selection of a suitable type, or types, of aircraft that would ensure operation on the planned routes. When planning the routes, care was taken to ensure that they could be provided with the same type of aircraft. Similar flight routes have the same character of passengers, require similar aircraft capacity and flight distances are comparable (related to the maximum range of the aircraft). These factors can affect the specific choice of aircraft. This method uses a basic scale to evaluate the criterion, which expresses the importance of the individual evaluation criteria. The scale consists of a verbal assessment of preferences:

- same - numerical evaluation 1
- moderate - numerical rating 3
- strong - numerical evaluation 5
- very strong - numerical evaluation 7
- extremely important - numerical evaluation 9

The evaluation also uses the evaluation of mean values between individual judgments. [4,5,6]

The main goal, which is at the top of the hierarchical pyramid, is to choose the appropriate type of aircraft or aircraft. At the second level, 7 measurable criteria are proposed to help solve the main problem. Based on expert consultations, we have determined the following evaluation criteria that will be used in the application of the AHP method:

- **Aircraft purchase price** - the initial investment for which an airline buys an aircraft. The purchase price will be for a new aircraft. In this analysis, we will not consider the purchase of "used" aircraft due to increased maintenance and service costs during the operation itself, the value of which cannot be planned. Another reason is the absence of information on the prices of such aircraft. As the price for the purchase of a used aircraft is always agreed between both parties.
- **Aircraft capacity** - the maximum possible number of transported passengers in a given aircraft. Flexible response to demand for air services depends on aircraft capacity.
- **Maximum take-off weight (MTOW)** - represents the weight at which the aircraft is able to fly. It consists of the sum of an empty aircraft with operating fluids, crew, passengers and cargo. MTOW is an important criterion, as its value calculates airport charges, which make up a significant part of the cost.
- **Aircraft speed** - flight speed is the biggest competitive advantage of air transport over other types of transport.
- **Fuel consumption** - fuel consumption is one of the main factors influencing the airline's profitability. Fuel costs represent around 40% of an airline's total costs, and in the event of volatile aviation fuel prices, this factor will always play an important role.
- **Maximum range** - is the distance that the aircraft is able to cover without the need to refuel.
- **Maximum cargo volume** - is related to the transport of cargo and determines the volume of cargo space. If necessary and maximum usability of aircraft, they can also be used in freight transport.

These evaluation criteria represent the second level in pairwise comparisons and we will then compare them with each other between aircraft types. The following table shows the values of the individual criteria for the individual aircraft types to be used in the pairwise comparison using the AHP method.

TABLE 1. Overview of individual evaluation criteria

Source: Author / [7,8,9,10,11,12,13]

Criteria Aircraft type	**Price (mil., USD)**	**Capa city (pass.)**	**MTOW (kg)**	**Speed (km/h)**	**Consum ption (kg/km)**	**Range (km)**	**Max. cargo (m^3)**
Airbus A 220-100	81	110	58 967	828	2,57	5 463	24
Airbus A 319neo	92	134	75 500	829	2,98	6 940	27,7
Boeing 737 - 700	89,1	149	65 500	838	3,21	5 575	25
Embraer E2 175	45,7	80	44 800	876	2,44	3 735	21
Bombardier CRJ 1000	25	104	41 640	829	2,66	3 056	16,8
ATR 72 - 600	26	70	23 000	510	1,42	1 528	11
Dash 8 Q400	27	82	30 481	556	2,16	2 040	11,5

Correct and objective determination of weights for individual evaluation criteria is one of the basic tasks in solving multicriteria tasks. In determining the weights of the evaluation criteria, we cooperated with experts in the field of air transport. We used an expert method that helped us refine the weights of the criteria. These expert methods differ according to whether the awards are awarded on the basis of the opinions of one expert or a group of experts. In practice, we used group determination of weights, using the Delphi method by sending a standardized questionnaire to individual experts who have personal experience in the field of air traffic control. After processing the questionnaires, we created a matrix of pairwise comparisons between the evaluation criteria and determined the priority vector for each evaluation criterion and its overall impact on the subsequent decision. The following table is a matrix of pairwise comparisons of the evaluation criteria themselves.

TABLE 2. Pairwise comparison matrix for the first level

Source: Author

	Price	Capa city	MTOW	Speed	Consum ption	Range	Max. cargo
Price	1.00	4.00	2.00	3.00	1.00	2.00	3.00
Capacity	0.25	1.00	2.00	3.00	0.50	1.00	3.00
MTOW	0.50	0.50	1.00	4.00	0.50	1.00	3.00
Speed	0.33	0.33	0.25	1.00	0.33	0.33	2.00
Consuption	1.00	2.00	2.00	3.00	1.00	3.00	4.00
Range	0.50	1.00	1.00	3.00	0.33	1.00	4.00
Max. cargo	0.33	0.33	0.33	0.50	0.25	0.25	1.00
Priority vector	0.25	0.13	0.12	0.06	0.24	0.13	0.046

CR: 5,1%

TABLE 3. Result from the comparison of evaluation criteria

Source: Author

	Priority	**Ranking**	**(+)**	**(-)**
Price	25.5%	1	12.7%	12.7%
Capacity	13.9%	3	5.6%	5.6%
MTOW	12.9%	5	4.7%	4.7%
Speed	5.9%	6	2.2%	2.2%
Consuption	24.1%	2	6.7%	6.7%
Range	13.1%	4	3.3%	3.3%
Max. cargo	4.6%	7	1.8%	1.8%

From a pairwise comparison of individual evaluation criteria, it is clear that the highest priority in the evaluation is the purchase price of the aircraft, with an impact of 25.5%. The consumption of aircraft is slightly lower at 24.1%. It can be stated that both criteria will have a significant impact on the actual selection of the aircraft. The consistency factor (CR) in this pairwise comparison is at 5.1%, indicating an acceptable level of inconsistency. If the CR value is less than 10%, such a solution is valid.

The following tables calculate the pairwise comparison matrices, according to the individual evaluation criteria for the selected aircraft types.

TABLE 4. The domination measure of one aircraft over another with respect to price

Source: Author

Price	Airbus A 220-100	Airbus A 319neo	Boeing 737 - 700	Embraer E2 175	Bombardier CRJ 1000	ATR 72 - 600	Dash 8 Q400
Airbus A 220-100	1.00	3.00	3.00	0.20	0.20	0.20	0.20
Airbus A 319neo	0.33	1.00	1.00	0.33	0.33	0.33	0.33
Boeing 737 - 700	0.33	1.00	1.00	0.33	0.33	0.33	0.33
Embraer E2 175	5.00	3.00	3.00	1.00	0.33	0.33	0.33
Bombardier CRJ 1000	5.00	3.00	3.00	3.00	1.00	1.00	1.00
ATR 72 - 600	5.00	3.00	3.00	3.00	1.00	1.00	1.00
Dash 8 Q400	5.00	3.00	3.00	3.00	1.00	1.00	1.00
Priority vector	0.07	0.05	0.05	0.13	0.23	0.23	0.23

CR: 8,6%

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TABLE 5. The domination measure of one aircraft over another with respect to seat capacity

Source: Author

Seat capacity	Airbus A 220-100	Airbus A 319neo	Boeing 737 - 700	Embraer E2 175	Bombardier CRJ 1000	ATR 72 - 600	Dash 8 Q400
Airbus A 220-100	1.00	0.50	0.25	4.00	3.00	5.00	4.00
Airbus A 319neo	2.00	1.00	0.50	5.00	4.00	5.00	5.00
Boeing 737 - 700	4.00	2.00	1.00	5.00	4.00	5.00	5.00
Embraer E2 175	0.25	0.20	0.20	1.00	0.50	1.00	1.00
Bombardier CRJ 1000	0.33	0.25	0.25	2.00	1.00	3.00	2.00
ATR 72 - 600	0.20	0.20	0.20	1.00	0.33	1.00	0.50
Dash 8 Q400	0.25	0.20	0.20	1.00	0.50	2.00	1.00
Priority vector	0.17	0.25	0.35	0.05	0.08	0.04	0.05

CR: 3,6%

TABLE 6. The domination measure of one aircraft over another with respect to MTOW

Source: Author

MTOW	Airbus A 220-100	Airbus A 319neo	Boeing 737 - 700	Embraer E2 175	Bombardier CRJ 1000	ATR 72 - 600	Dash 8 Q400
Airbus A 220-100	1.00	5.00	4.00	0.50	0.50	0.25	0.33
Airbus A 319neo	0.20	1.00	0.50	0.33	0.33	0.20	0.25
Boeing 737 - 700	0.25	2.00	1.00	0.33	0.33	0.20	0.25
Embraer E2 175	2.00	3.00	3.00	1.00	0.50	0.25	0.33
Bombardier CRJ 1000	2.00	3.00	3.00	2.00	1.00	0.33	2.00
ATR 72 - 600	4.00	5.00	5.00	4.00	3.00	1.00	2.00
Dash 8 Q400	3.00	4.00	4.00	3.00	0.50	0.50	1.00
Priority vector	0.10	0.04	0.05	0.12	0.18	0.33	0.19

CR: 6,8%

TABLE 7. The domination measure of one aircraft over another with respect to speed

Source: Author

Speed	AirbusA 220-100	Airbus A 319neo	Boeing 737 - 700	Embraer E2 175	Bombardier CRJ 1000	ATR 72 - 600	Dash 8 Q400
Airbus A 220-100	1.00	1.00	1.00	0.50	1.00	5.00	5.00
Airbus A 319neo	1.00	1.00	1.00	0.50	1.00	5.00	5.00
Boeing 737 - 700	1.00	1.00	1.00	0.50	1.00	5.00	5.00
Embraer E2 175	2.00	2.00	2.00	1.00	2.00	5.00	5.00
Bombardier CRJ 1000	1.00	1.00	1.00	0.50	1.00	5.00	5.00
ATR 72 - 600	0.20	0.20	0.20	0.20	0.20	1.00	1.00
Dash 8 Q400	0.20	0.20	0.20	0.20	0.20	1.00	1.00
Priority vector	0.16	0.16	0.16	0.27	0.16	0.04	0.04

CR: 1,0%

TABLE 8. The domination measure of one aircraft over another with respect to fuel consumption

Source: Author

Fuel consumption	Airbus A 220-100	Airbus A 319neo	Boeing 737 - 700	Embraer E2 175	Bombardier CRJ 1000	ATR 72 - 600	Dash 8 Q400
Airbus A 220-100	1.00	4.00	6.00	0.50	3.00	0.25	0.33
Airbus A 319neo	0.25	1.00	3.00	0.33	0.50	0.20	0.33
Boeing 737 - 700	0.17	0.33	1.00	0.20	0.25	0.14	0.17
Embraer E2 175	2.00	3.00	5.00	1.00	3.00	0.25	0.33
Bombardier CRJ 1000	0.33	2.00	4.00	0.33	1.00	0.25	0.33
ATR 72 - 600	4.00	5.00	7.00	4.00	4.00	1.00	3.00
Dash 8 Q400	3.00	3.00	6.00	3.00	3.00	0.33	1.00
Priority vector	0.12	0.05	0.03	0.14	0.07	0.37	0.22

CR: 6,9%

TABLE 9. The domination measure of one aircraft over another with respect to range

Source: Author

Range	Airbus A 220-100	Airbus A 319neo	Boeing 737 - 700	Embraer E2 175	Bombardier CRJ 1000	ATR 72 - 600	Dash 8 Q400
Airbus A 220-100	1.00	0.33	1.00	5.00	6.00	8.00	7.00
Airbus A 319neo	3.00	1.00	3.00	5.00	6.00	8.00	7.00
Boeing 737 - 700	1.00	0.33	1.00	4.00	5.00	7.00	6.00
Embraer E2 175	0.20	0.20	0.25	1.00	3.00	5.00	4.00
Bombardier CRJ 1000	0.17	0.17	0.20	0.33	1.00	3.00	2.00
ATR 72 – 600	0.13	0.13	0.14	0.20	0.33	1.00	0.50
Dash 8 Q400	0.14	0.14	0.17	0.25	0.50	2.00	1.00
Priority vector	0.23	0.38	0.20	0.09	0.05	0.02	0.03

CR: 5,8%

TABLE 10. The domination measure of one aircraft over another with respect to maximum cargo volume

Source: Author

Max. cargo	Airbus A 220-100	Airbus A 319neo	Boeing 737 - 700	Embraer E2 175	Bombardier CRJ 1000	ATR 72 - 600	Dash 8 Q400
Airbus A 220-100	1.00	0.33	0.50	5.00	6.00	8.00	8.00
Airbus A 319neo	3.00	1.00	3.00	5.00	7.00	8.00	8.00
Boeing 737 - 700	2.00	0.33	1.00	4.00	5.00	7.00	6.00
Embraer E2 175	0.20	0.20	0.25	1.00	3.00	6.00	5.00
Bombardier CRJ 1000	0.17	0.14	0.20	0.33	1.00	3.00	3.00
ATR 72 - 600	0.13	0.13	0.14	0.17	0.33	1.00	1.00
Dash 8 Q400	0.13	0.13	0.17	0.20	0.33	1.00	1.00
Priority vector	0.21	0.38	0.22	0.09	0.05	0.02	0.03

CR: 7,2%

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The consistency ratio (CR) of the pairwise comparisons was below 10%, confirming the validity of the calculated results. We used the results from individual pairwise comparisons in the following table to compile the final matrix with the finite vector of priorities.

TABLE 11. Local and global priority weights

Source: Author

	Airbus A 220-100	Airbus A 319neo	Boeing 737 - 700	Embraer E2 175	Bombardier CRJ 1000	ATR 72 - 600	Dash 8 Q400
Price (0,253)	0,07	0,05	0,05	0,13	0,23	0,23	0,23
Capacity (0,139)	0,17	0,29	0,35	0,05	0,08	0,04	0,05
MTOW (0,129)	0,10	0,09	0,05	0,11	0,18	0,33	0,19
Speed (0,059)	0,16	0,16	0,16	0,27	0,16	0,04	0,03
Consump. (0,241)	0,12	0,05	0,03	0,14	0,07	0,37	0,22
Range (0,131)	0,23	0,34	0,20	0,09	0,05	0,02	0,03
Max.cargo (0,046)	0,21	0,38	0,22	0,09	0,05	0,02	0,03
Final priority vector	0,13	0,14	0,12	0,12	0,13	0,20	0,15

CR 4,5%

TABLE 12. Final ranking

Source: Author

	Priority	**Final ranking**
Airbus A 220-100	13,41	4
Airbus A 319neo	14,17	3
Boeing 737 - 700	12,14	6
Embraer E2 175	11,99	7
Bombardier CRJ 1000	12,8	5
ATR 72 - 600	20,27	1
Dash 8 Q400	15,02	2

According to the AHP method, the ATR 72-600 turboprop aircraft is considered to be the most suitable aircraft for the Slovak national carrier. The advantage of this type of aircraft is the low purchase price, fuel consumption and MTOW, which directly affects the amount of airport charges. All these criteria were significant from the point of view of evaluation, therefore ATR 72-600 finished first in the final ranking. Other places included Dash 8 Q400, Airbus A319neo and Airbus A220-100. The differences between 2 and 4 places are minimal, so deciding between these types of aircraft will depend on other factors. As completely unsuitable aircraft, according to this analysis AHP, we can consider Bombardier CRJ 1000, Boeing 737 -700 and Embraer E2 175.

The final choice of the appropriate aircraft type will depend on the planned airlines. From the proposed business model of the national air carrier and the scheduled air connections, we would decide that the main airplane should be the Airbus A220-100. The main reason is, that scheduled air connections are with a distance greater than the maximum range of the ATR 72-600. Another reason is the intention, to use the aircraft fleet for charter transport, which the ATR 72-600 cannot provide, due to capacity, range and the absence of sufficient cargo space. ATR 72-600 could serve as an aircraft designed for planned regional or short flights (up to 1500km). Dash 8 Q400 is unsuitable, for the same reasons as ATR72-600. This follows from the nature of the design of turboprop aircraft. Although they have a lower purchase price and operating costs, jets have higher capacity, speed, cargo space and range.

The decision between the Airbus A220-100 and the Airbus A319neo was influenced by the purchase price, MTOW and fuel consumption, which are better in favor of the Airbus A220-100. If we did not take into account the size of the cargo space in the overall evaluation, the Airbus A319neo would end up in a worse place even in the AHP. In all other parameters, the "bigger brother" from the Airbus family is better, but they are not important for the needs of the national air carrier and the capabilities of the smaller Airbus A220-100 will be satisfying.

CONCLUSION

The strategic decision in the airline companies definitely includes fleet planning and the selection of a suitable aircraft type. The aircraft fleet significantly affects operating costs and thus affects the overall economic indicators. The choice of aircraft must be related to the expected passenger demand for the airline's services. The goal of every airline operator is to make the most of the aircraft fleet as usable and the lowest operating costs, while offering a certain level of comfort and level of service that passengers expect.

The selection of the aircraft itself, is only a partial step in the complex planning of the aircraft fleet. In the article, we used the AHP method, which is often used in various decision-making areas, when selecting a suitable aircraft type. And it can be used as a supportive method for making important decisions. In the comparison itself, we took into account selected criteria that are important from the point of view of the national air carrier. We then compared these criteria in pairs using selected AHP method for selected aircraft types, and the result is the final ranking of aircraft types. After a thorough analysis, we selected two types of aircraft (Airbus A220-100 and ATR 72-600), which are suitable for the planned business model of the national air carrier.

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Economic Evaluation of Basic Training of Military Air Traffic Controllers

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Abstract— This article focuses on the financial analysis of the basic training course and compares the ATC training organisations in Slovakia. Air traffic controllers belong to highly professional, mentally demanding and responsible professions. For this reason, training is an integral part of their profession. The aim of the article is to find out the cost effectiveness of the course between two subjects and to point out the eligible costs associated with the course. The article contains the calculations of four members of the Helicopter Wing Prešov, on the basis of which it was possible to point out the favourable management of the financial resources of the Ministry of Defence of the Slovak Republic.

I. INTRODUCTION

After the outflow of military air traffic controllers to retirement,the future and staffing of vacancies would be considered. [8]The Ministry of Defense of the Slovak Republic is particularly aware of the need to train additional air traffic controllers in order to be able to continuously control the ever-increasing frequency of air traffic in Slovakia.[3] This process is time consuming.In the field of military aviation of the Slovak Republic, the rules for issuing licenses to dispatchers of military operations who provide their services in the airspace apply.In order to maintain safety in the airspace, it is necessary to provide each military professional with such training that the possibility of reducing the level of safety in the airspace as far as possible is excluded in the performance of his function as military air traffic controller. [5]The key to increasing safety in this particular area is to set up the entire training process so that current trends are effectively implemented and maximize the possibility of using available technologies in practice, but also in the training of these aviation specialists.[1].

II. AIR TRAFFIC CONTROLLER (ATCO)

Air traffic control (ATC) is a ground service provided by air traffic control personnel who operate and coordinate aircraft on the ground and in the air.[2] An air traffic controller is a trained expert who ensures safety and fluency in the airspace of the Slovak Republic and near airports.[4] At the Regional Control Center, it controls air traffic by maintaining the prescribed minimum distance (spacing) between individual aircraft and navigates them along the flight paths at the appropriate flight levels. The approach center and the airport control tower are responsible for the safety of airport arrivals, departures and movements at airports. The air traffic controller provides each aircraft entering the area of responsibility with a control service, an information service and an emergency service called air traffic services. ATCO gives pilots instructions as well as recommendations and information to make the flight safe and smooth. In his work he uses information provided by radar and modern computer systems.[6]
Depending on the type of flight and airspace classification, ATCO may issue instructions to be followed by pilots or only flight information to assist pilots in operating in airspace. In all cases, the pilot has the ultimate responsibility for flight safety at his discretion and may deviate from the ATC instructions in the event of an emergency.[11] To ensure mutual communication, all pilots and air traffic controllers must speak and understand English. The national language of the region can also be used.[13]
The performance of ATCO work is associated with high demands on personality traits, skills. His above-average personal assumptions are analytical thinking, attention, practical thinking, ability to apply knowledge and experience in practice, accuracy and systematics, accuracy, spatial imagination, self-confidence, independence, self-control, stress tolerance, ability to handle high workload, internal stability, fluency. speech, a sense of duty and self-discipline. ATCO must be able to handle unexpected

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events, weather changes, unplanned flights, emergencies and incidents.[7]
A prerequisite for the performance of the air traffic controller function is, in addition to medical and linguistic competence, also the completion and successful completion of approved training courses, which lead to the acquisition of the relevant qualifications and endorsements.[9]

III. TRAINING ORGANIZATIONS OF THE SLOVAK REPUBLIC FOR AIR TRAFFIC CONTROLLERS

A. Air Navigation Services

Training center of Air Navigation Serviceswas established in 2008. It is approved by the Transport Authority and accepted by all EU Member States.[10] They train ATM personnel in accordance with applicable European Union legislation.
In the training center of Air Navigation Services tries to do everything to meet the customer's requirements. A qualified team, above-standard equipment and courses organized in small groups with an individual approach guarantee a high level of quality of services provided.Training center provides the following courses:

- Initial training
- Basic training
- Qualification training
- Training of practical instructors
- Training of evaluators
- Tailor-made course

Figure 1. Training Center of Air Navigation Services

B. Faculty of Aeronautics of Technical University of Kosice

The training organization for basic ATC training is integrated into the structures of the Faculty of Aeronautics. Her work is at the Department of Flight Training. Admission to a basic training course is conditional on the attainment of a full secondary or a full secondary vocational education.[11]
The course is focused on the training of air traffic controllers in civil aviation. As part of the course, participants in the course complete professional aviation subjectsrequired by the relevant regulations and ordinances. The scope of the course covers the requirements of the relevant regulation. Basic training takes place in training organizationof Faculty of Aeronautics under the guidance of approved lecturers.[1]

Figure 2. Training Center of Faculty of Aeronautics

C. Armed Forces Academy of General Milan Rastislav Štefánik

The Academy of the Armed Forces launched an air traffic control simulator in 2010, the construction of which is divided into several steps, so that in the final phase it meets the requirements for a realHight simulator - fidelity Simulator.[12]
The training implemented through a real certified simulator provides comprehensive functionality for the training of members of the Air Force of the Slovak Armed Forces. The staff consists not only of air traffic control radar, but also of tower and control radar, air force operators and the pilots themselves.[4]
The aim is to build a comprehensive training center for training flight controllers of the Armed Forces of the Slovak Republic, which will guarantee a comprehensive and quality workplace where it will be possible to conduct a variety of training, compliance with international standards and regulations, as well as training focused on local conditions, including short-term courses with emphasis on practical training, which will become the basis for the preparation of the ATC.[6]The simulator is designed for training at the following types of ATCO workplaces and air force guidance of the Slovak Republic:

- The air traffic controller of the Operational air traffic (OAT) sector at the ACC regional air traffic control center
- Workplace air traffic controller tower (TWR)
- Radar control flying and control landing at the workplace radar center (RC)
- Flight guidance of the guidance station at the workplace of the central guidance location.

The training of air traffic controllers of the Ministry of Defense is in the training organization ATC of the Academy of the Armed Forces gen. M.R. Štefánik

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implemented through the following trainings and courses:

- Initial -qualification training
- Transition training phase
- continuing - maintenance training
- continuing - retraining training.

Furthermore, training by practical instructors is carried out, which leads to the issuance, extension or renewal of the OJTI / STDI clause, and training of the assessor, which leads to the issuance, extension or renewal of the assessor's clause.The main advantage is that all types of training in this training organization are low cost. The training is carried out by experienced and skilled professional soldiers with qualification clauses who are fully acquainted with the specific military environment and management in such an environment.

Figure 3. Training Center of Armed Forces Academy

IV. FINANCIAL ANALYSIS OF THE COSTS OF THE BASIC TRANING COURSE

The task of financial analysis is to assess the financial situation using specific methods and tools and identify the causes that affected it. [3]Another task is to determine which factors and with what intensity contributed to the formation of the financial situation. The result of the financial analysis is the identification of weaknesses that could lead to problems and strengths that the company can rely on in the future.[2] When providing a basic training course, the financial analysis forms the budget of all eligible costs. Costs are the financial expression of the consumption of housing or materialized labor in order to generate output over a period of time. In this case, we will divide the costs into entry and eligible costs related to the training.

A. Definition of input variables:

Input quantities of direct costs represent the prices of individual courses depending on the number of hours, set by specific regulations - Commission Regulation (EU) No. 2015/340

- Inputs of eligible costs related to training are reimbursements of individual types of training.
- The result of the analysis will be a detailed financial evaluation of the training costs and a comparison of the training provided by both entities.

Comparison of direct costs of a basic training course between two subjects.Price specification of hours for contracts in training organization od Faculty of Aeronautics and training organization of Air Navigation Services.

TABLE 1. Advantage of courses

Basic ATC training	**Training organization FoA**	**Training organization ANS**	**difference**
Price of theoretical training for 1 person in euros	2400	2407,91	7,91
Price of 1 radar exercise in euros	96	349,93	253,93

The calculation shows the advantage of courses in training organization LF TUKE, how more the price calculation is and at the same time provide additional services in the form of an English language course, procedural training of 13 hours, radar training of 15 hours, training to obtain a radio operator's license.

B. Eligible costs

Eligible costs related to training are business travel costs provided in accordance with the Travel Compensation Act No. 283/2002 Coll., As amended. SpecificallyEmployees posted on a business trip belong:

- reimbursement of proven travel expenses,
- reimbursement of proven accommodation expenses,
- meals,
- reimbursement of proven necessary ancillary expenses,
- reimbursement of proven travel expenses for trips to visit his family to the place of permanent residence or between the employer and the employee of a pre-arranged family stay, if the business trip lasts more than seven consecutive calendar days, each week unless otherwise agreed in the collective agreement; in the employment contract or in another written agreement with the employee, this compensation is agreed for a longer period, but no longer than for one month.

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V. DISCUSSION

The following table shows the complex costs calculated for one member of the Armed Forces of the Slovak Republic, specifically from the Prešov helicopter wing. The amount of eligible costs - the fare is only indicative, because it is the average calculated km of commuting to training organizations.

TABLE 2. Costs of the basic training course

Cost per person in the basic training course in euros	**Training organization FoA**	**Training organization ANS**
Direct costs - course price	6034,29	7267,26
Eligible costs - Travel	1376,40	2026,80
Eligible costs - Accommodation	0	2100
Eligible costs - Meals	456	456
Together	7866,69	11850,06

The table shows the advantage of the course in training organizationof Faculty of Aeronautics. The Prešov helicopter wing approved the daily commute to the Faculty of Aeronautics training organization for its members. The following table shows the difference between the final amount of the basic training course, if the Prešov Helicopter Wing replaced its member with a daily commute to training organizationof Faculty of Aeronautics, with accommodation in the amount of 35 € / night.

TABLE 3. Proposed basic training course costs

Cost per person in the basic training course in euros	**Training organization FoA**	**Training organization ANS**
Direct costs - course price	6034,29	7267,26
Eligible costs - Travel	275,28	2026,80
Eligible costs - Accommodation	2100	2100
Eligible costs - Meals	456	456
Together	8865,57	11850,06

The table shows the advantage of the course in the training organization of Faculty of Aeronautics even if the member would replace the daily commute with accommodation.If the Helicopter Wing provided accommodation for its members, theprice of the basic training course would increase by approximately € 998.88 per participant in the course in Košice.

CONCLUSION

This article focused on the issue of air traffic controller training. The increased volume of air traffic also increases the demands and burden of performing the ATC service. Ensuringa high level of training leads to a safe and smooth flow of air traffic.The article contains a brief description of air traffic controllers, its range of services, character traits that are important in the performance of their demanding and responsible work.ATC training organizations in Slovakia were described in detail. Each of them is focused on a certain type of training. The training is carried out in accordance with the established regulations and requirements of Commission Regulation (EU) No. 340/2015.

The aim of the article is a financial analysis of the basic course. On a sample of four members of the PrešovHelicopter Wing, the advantage ofchoosing a suitable course between two training organizations was emphasized and the costs associated with this course were compared.

The financial analysis revealed that the basic training course at training organizationof Faculty of Aeronautics is financially more advantageous than the course offered at training organization of Air Navigation Services, because training organizationof Faculty of Aeronautics provides services for several English courses, which include procedural training for 13 hours, radar training for 15 hours and more.

The financial analysis also pointed to the advantageous treatment of the resources of the Ministry of Defense of the Slovak Republic. Because it was found that the eligible costs for a daily trip to the Faculty of Aeronautics training organization were demonstrably lower than the costs associated with accommodating members of the Prešov Helicopter Wing.

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Airport security legislation

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***Abstract*— The purpose of this article is to clarify the existence of legal standards in the field of security of public international airports and to emphasize their importance at the global and European level, and point out their implementation into national legislative and corporate standards. Also, briefly describe the individual regulations, the area to which they apply and how they affect the transport object's protection, assess their pros, point out the shortcomings, and propose solutions to eliminate them.**

I. INTRODUCTION

Air transport has experienced a big boom in this century. Based on statistics, it is the safest and fastest transportation mode, providing a certain comfort level, saving time and low-cost routes, and saving money. It also carries certain risks that may arise from breaches of security regulations, which lead to the possible occurrence of an act of illegal interference [1]. It is known for the activities of various terrorist or extremist groups and perpetrators of individuals - persons with a criminal past, mentally disturbed or other antisocial groups. These groups also commit crimes against the state's strategic or otherwise essential objects, not excluding transport objects such as airports and aircraft. As an airport is a specific object for the arrival and departure of aircraft, the equipment of arriving and departing passengers and related services have great value, potential, and many people and material, which evokes the perpetrators of the act of illegal intervention [2]. Also, an aircraft occupied by terrorists with passengers on board is, from the potential perpetrator's point of view, one of the best objects for committing a crime. It is essential to protect these critical transport facilities from potential perpetrators, who usually act in a planned manner, with preparation, material and knowledge equipment for a specific purpose. Sufficient precautionary measures must be taken and implemented from airport operators' position to prevent acts of unlawful interference [3].

These measures are carried out by security staff and all airport staff or contractors who are specially inspected and trained. They operate following.

III. GENERAL LEGISLATION

A. International legislation

International legislation - issued by the International Civil Aviation Organization (ICAO), namely:

- **DOC 8973** Security manual for security measures in civil aviation.

It is the basic standard for security; it sets out all the detailed procedures and tasks with essential security measures. An important and unique regulation also contains all the samples of the necessary documents, tables, and other graphic sketches necessary to secure and carry out security procedures. It is a classified document and is of a recommendatory nature [4].

- **Annex 17**

International Convention on Civil Aviation, to which the Slovak Republic acceded in 1993. It is an essential document in civil aviation security; it contains extracts from all annexes necessary for the performance of security protection [5].

- **International conventions in Civil aviation (CA):**

- Chicago Convention - on International Civil Aviation (Contains “Appendices, so-called Annexy.. Security is covered by the aforementioned Annex 17).
- Tokyo Convention - on Offenses and Other Acts Committed on Board Aircraft
- Hague Convention - on the Suppression of Unlawful Seizure of Aircraft
- Montreal Convention - on the Suppression of Illegal Acts Threatening the civil aviation security
- Amendment to the Montreal Convention - on Combating Illegal Acts of Violence at CL Airports.
- MEX Convention - concerning plastic explosives.

International legislation is usually recommendatory, but if there is no regulation or law at the European or national level, this recommendation is considered binding.

B. European legislation

ECAC European Civil Aviation Conference, develops ICAO standards through documents:

- **DOC 30,** part II - harmonization of BOCL standards - recommendations, proposed procedures and requirements in the field of BOCL.

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- EP and CEU Regulation **No 300/2008** lay down standard rules in civil aviation security and the basis for a common interpretation of "Annex 17" to the Chicago Convention within the EU.

Applies to:
- all airports located in the territory of an EU Member State used on CA
- all operators, including air carriers, that provides CA services
- all entities are operating from inside and outside CA airports

- Commission Implementing Regulation (EU) 2015/1998 and its amendment under No **2017/815** laying down detailed measures for the implementation of common standards in the field of BOCL.
- Commission Implementing Decision 2015/8005 and its amendment under No **2017/3030** laying down detailed measures for the implementation of the common basic standards on aviation security containing the information referred to in Article 18 (a) (a) of Regulation (EC) No 300/2008 / EU classified information /.
- Commission Implementing Regulation (EU) 2019/103 of 23 January 2019 amending Implementing Regulation (EU) **2015/1998** as regards the clarification, harmonization, simplification and reinforcement of certain specific aviation security measures.
- Commission Implementing Decision C (2019) 132 final of 23.1.2019 amending Commission Decision C **(2015) 8005** as regards clarification, harmonization and simplification, and the strengthening of certain specific aviation security measures.

C. National legislation

- **Act 143/1998 Coll.** on Civil Aviation (Aviation Act). Security protection is covered by the following paragraphs:

- § 34 Protection against acts of unlawful interference
- § 35 Public order and security at airports
- § 36 Obligations of persons participating in air transport [6]

- Regulation **L-17** “Protection of CL against acts of unlawful interference".

This regulation specifies the basic concepts in civil aviation security organization, airport operations, aircraft operators' obligations, quality control and others.

- **Supplement to L-17**
- **The National Program for the Protection of CA against Acts of Unlawful Intervention**, which aims to achieve and maintain the highest level of safety, security, regularity and effectiveness of CA in the Slovak Republic through international and national regulations for the protection of CA against acts of unlawful interference to ensure public order, and safety of life; health of persons and property.
- **The national quality control program** is a means for airports and air operators to comply with security measures and monitor their compliance.
- Resolution of the Government of the Slovak Republic No **748/2004** on the division of competencies in the protection of CA.

IV. AIRPORT LEGISLATION

- **Security protection program**

It is an essential document for airports and aircraft operators in the Civil aviation security (CAS) area. It is based on individual international, European and national regulations, which must be incorporated into it. This document is constantly being supplemented and changed in response to the new rules. The transport office gives the structure of this document. It contains parts:

A - basic operator information related to Security protection (SP). It shows the SP's basic scheme, the duties and responsibilities of individual persons for the SP, characterizes the security committee, etc.

B - the most significant part. It characterizes the airport's zones, such as reserved area, reserved security area, borders, possibilities of entering separate zones, methods of control of persons and vehicles, supervision, patrols, and others. It also describes the SP of aircraft, passengers, their hand and checked baggage, methods and procedures of screening, list of prohibited items. Also control of cargo, mail, in-flight supplies and airport supplies.

It specifies the training of the persons involved, their duties and responsibilities. A separate part describes the various types of detection techniques and their possibilities. It also deals with cybersecurity.

C - local procedures, recognition and resolution of crises, crisis planning system, civil protection is described.

D - This section describes quality control, efficiency monitoring, monitoring supervision, system and content of individual rules, periodicity, subject, evaluation, etc.

- **An airport contingency plan** that talks about what to do in an incident at the airport.

V. SECURITY LEGISLATION

- **Act 171/1993 Coll**. (Law on the Police Force)

The police force is one of the security forces operating at every international civilian airport. Border Control Departments of the Police Force (BCDPF) participate in the performance of local security and public order according to § 2 para. 1 letter a) to n) of the Police force (PF) Act, thus fulfilling its cooperation with the airport operator. Pursuant to § 2 par. 1 letter o) of the PF Act performs the performance of cooperation in ensuring civil aviation protection. As the international airport is

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also a state border, BCDPF members check the identity documents of departing and arriving passengers at the airport, are responsible for guarding the Schengen border, and adequately executing measures in connection with the established rules of Schengen passenger flow. They perform supervision over screening and ensure prevention and detection of crime in airport facilities. They also perform pyrotechnic and canine services [7].

- **Act 190/2003 Coll.** (Weapons and Ammunition Act)

There are several components at airports that provide security protection:

- the Border Control Department of the Police Force of the Slovak Republic,
- the airport security itself and the customs office.

These are armed forces, where the carrying and use of a weapon, the rights and obligations of the holder of the gun and ammunition are subject to Act 190/2003 Coll[8].

- **Act 473/2005 Coll**. (Private Security Act)

Pursuant to this Act, it carries out its activity "Self-protection of the airport". These are employees in airport security who continuously carry out their activities at the border of public and reserved security areas. External protection is focused on:

- regime measures,
- checks on entrances and entrances,
- including screening persons other than passengers and
- items they carry,
- perimeter control,
- surveillance and
- patrols [9].

VI. SUMMARY

The specificity of air transport is mainly its international character. It is an international transport of passengers and cargo, and almost all legal norms in their name have the word "common", so they should be uniform - the same in all states. Nevertheless, there are specific gaps in this area about international and European legislation. It is, e.g. o transporting liquids in hand luggage. Commission Regulation (EU) **No 245/2013** of 19 March 2013[10] amending Regulation (EC) **No 272/2009** as regards screening of liquids, aerosols and gels at EU airports limits the carriage of liquids in hand luggage to a maximum of 10 pieces in 100 ml packages, BUT this is ONLY a European regulation NOT an international one, which may lead to European countries allow the transport of liquids in hand luggage over the permitted quantity of 1 liter. Although controllers at airports outside the EU should make sure that European regulations are complied with when handling flights to an EU country, this is often not the case as screening workplaces do not. Another difference is, e.g. leaving responsibility for the contents of the transported hand luggage and checked baggage on the screen, so that, e.g. for hand luggage and carrying, e.g. sharp objects that meet the statutory blade length of up to 6 cm. The screener has the right and opportunity to evaluate the passenger overall and in case of his subjective negative evaluation to take away the object [11].

Airports also can tighten the criteria in their internal standards, i.e. in security programs. This is a precedent, as passengers passing through several airports should have clear transport instructions and not different ones from each airport. The above points to the fact that the legal standards in the field of BOCL have quite several gaps, and it is essential to point out, alert the competent authorities and demand their complete unification and make travel more accessible and more pleasant for passengers, thus avoiding various inconveniences when handling aircraft and interfering with human rights [12].

CONCLUSION

Airport security legislation has several functions. One of the most current and essential is the function of prevention by preventing acts of illegal intervention. The objects themselves, the entrances to them, the perimeter, but especially the people, employees and clients using their services must be adequately protected.

Last but not least, property and the environment that concern us all and the state's interests. For this purpose, we have a protective shield of a broad legal spectrum at our disposal in the form of various legal norms at the international, European, state or company level. Airports are a specific object where ICAO international standards must be complied with, as it involves transporting passengers, animals and cargo between countries or continents. These standards are primarily recommendatory, so European regulations are also available, covering ECAC and the EU. All these regulations are implemented in national legal norms. These are mainly the Aviation Act or rules and decrees of the given industry. There are many legal standards in place to protect airports. This article describes the most important and most used ones. It is essential to ensure sufficient legal awareness of employees and professionals, and stakeholders in the field but especially of the general public, i.e. each of us. It is essential to know what is allowed and what is forbidden, and what sanction is threatened, and we will not miss us if we do not comply with these measures. The existence of legal norms serves to prevent TC and to remedy in the sense of the well-known.

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Selection of a suitable control methodology for a small unmanned airplane – Skydog

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***Abstract* - The article presents a description of the used aircraft control methods, an exploration of current trends and the selection of a suitable control methodology for a small unmanned aerial vehicle Skydog, which is used as a platform for research and development of advanced control systems. An overview of the current control methods is focused on comparison of control systems used in commercial aircraft with small unmanned aerial vehicles. The performed review and evaluation access of control approaches describes the advantages and disadvantages of the current methodologies used in flight control. The main purpose of the article is the analysis of these methods and the subsequent selection of the most suitable approach for flight control of a small unmanned aerial vehicle Skydog, with fixed wings.**

I. INTRODUCTION

Control is the purposeful action of one to another system to achieve a set achievement. As in other areas, control systems are incorporated into the design of aircraft control systems. [1] Their significant advantage is that they are more flexible in the event of changes. The result is a modern system working together as a one. The aircraft control system differs depending on the type of aircraft.

The main focus of this research is the selection of a suitable control method for a small unmanned Skydog aircraft with fixed wings. The selection of the most appropriate method consists of a description of the currently used control methods. Nowadays used control methods focus on control in commercial aircraft compared to small unmanned aircraft. It also justifies the difference in management between them. A high-quality and detailed overview of current management trends and approaches identified a narrow number of methods that would be suitable as the selection of a suitable control methodology for UAV Skydog. Their detailed analysis focused on the principles of operation of individual control methods and current approaches explain the possible advantages and disadvantages of these methods. The evaluation of current control trends selects one of the controlmethods that is suitable for UAV-Skydog with fixed wings.

To select the most suitable control method for the small unmanned Skydog aircraft, it is first necessary to make an overview of the nowadays control trends, which are currently used in transport aircraft. The evaluation of current control approaches in transport aircraft is compared with the control methods currently used in UAV aircraft. The transport aircraft have much greater longitudinal stability compared to UAVs, where control systems are very easy to implement and use. These systems make it easier for pilots to keep the aircraft in a stable state to avoid unwanted deflections. UAV aircraft have in compared to transport aircraft much less stability than airliners, but this increases their maneuverability. This means that UAV aircraft can pass beyond borders of the flight envelope, which is not possible in transport aircraft, as they are limited by systems.

The description of the used control methods and the review of current trends points to the differences in control in transport aircraft with UAV aircraft. Their comparison explains what control methods are currently used. The small unmanned Skydog aircraft with fixed wings is different compared to other types of UAVs, and therefore it is not possible to apply all the control methods currently used on UAVs / drones to it. For this reason, an analysis was needed to assess which of the control methods are suitable for a small unmanned Skydog aircraft. The analysis also determined which of the control methods is most suitable for UAV Skydog. The aim of this article is to analyze the systems used in transport aircraft and select the most suitable system, or a combination of systems that could facilitate the control of UAV Skydog.

Further research is possible to create a proposal for the implementation of a suitable method of control in a small unmanned aircraft Skydog.

II. OVERVIEW OF AIRCRAFT CONTROL SYSTEMS

This part of the article describes an overview of currently used control methods. It focuses on the difference between control methods in transport

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aircraft compared to small unmanned aircraft. The overview of methods performed below presents several approaches from which the most suitable method for UAV Skydog could be selected. The selected control method must first be analyzed from large transport aircraft and compared with the UAV control. Subsequently, the article discusses a suitable control method that could provide effective UAV control with possible maximum dynamic elements for high-intensity maneuvering.

A. Control methods used in transport aircraft

This chapter of the article describe control of the transport aircraft themselves. The control systems in transport aircraft make it easier for pilots to control the aircraft itself. Without these systems, control would be more difficult and not only a two-member crew would be used. These systems provide pilots with stable flying, where the systems adjust engine power, balance, help maintain the direction and altitude of the flight, etc.

Automatic control in large transport aircraft is systems Fly-by-wire, Flight control systems, Autopilot/Automatic flight control system, Flight control computer, Engine indication and crew alerting system and others.

Fly-by-wire implies a purely electrically signaled control system. It´s a system, which replaces the manual flight controls of an aircraft with an electronic interface. It means that all the movements of flight controls which commanded by pilots are converted to electronic signals. Then these signals are transmitted by wires to the flight control computer, which determine how to move actuators at each control surface. [2]. The Fly-by-wire system has a lot of advantages such as lighter weight, improve economy in flight, maintenance reduction, easier interfacing to auto-pilot and other automatic flight control systems, etc. System also includes flight envelope protection system into its flight control software. [2][3] This system is used in all modern commercial aircraft.

Autopilot/Automatic flight control system. The main principle of the autopilot is to allow economical and precision control while maintaining a given heading angle in which aircraft fly. [4] It is an automatic flight control system which control trajectory, weather, and on-board systems of an aircraft without necessity continual manual control by a human operator. Autopilot doesn´t replace the human operators, but system only assists them. This type of system can operate with full authority from takeoff to full land.

Flight control systems consists of components which include sensors, hydraulic actuator, electric actuator, flight control surfaces, the respective cockpit controls, connecting linkages, the necessary operating mechanisms and digital flight control computers. This system is an electrical system with digital technologies like Fly-by-wire. [5] The flight control system provides aircraft control and envelope protection in all axes: roll, pitch, yaw.

Flight control computer. All system processing on flight control system is performed by flight control computers. [5] The computers have very important role because they are the only components of this system, which have a function implemented in software.

Engine indication and crew alerting system is defined as an integrated system used in modern aircraft. The aircraft used this system for displaying engine parameters and alerting crew to system configuration or faults. EICAS screen contains a crew alerting system (CAS) field, which displays alerting messages. [6] EICAS show the pilots information about different engine parameters, including speed of rotation, temperature values, fuel flow and quantity, oil pressure etc.

B. Control methods used in UAV aircraft

Nowadays, UAV control systems are still in the research process. Its therefore, necessary to use control systems to manage UAVs to avoid adverse effects. Before the chosen control system itself, it must be considered that the UAV aircraft has a different flight envelope than the transport aircraft. This means that, unlike transport aircraft, the UAV can go beyond the edge of stability, thus increasing its maneuverability. When choosing the right system, the UAV operator must consider what activity the UAV will be used for. This part of the article shows some control systems that are currently used in UAVs. The most suitable option would be the implementation of auxiliary combined control systems, which would limit us beyond the flight envelope, but would not limit fast, efficient, and acrobatic flying. This system would be similar to the system used by the military in its military fighters.

At present, UAVs use three basic modules of systems for control, regardless of the category in which UAV belongs. It is an aeronautical module, ground (control) module and processing module. [7]

The aeronautical module consists of engines, receiver, batteries, control unit, navigation, and GPS (Global Positioning System).

The engines in UAV aircraft are electric motors (direct current / alternating current) and internal combustion engines (glow/petrol). Direct current motors also function as generators and can therefore be used as an electrodynamic brake. The advantage is their versatility and simplicity and, in comparison with an alternating current motor, also the possibility to achieve any speed. On the other hand, in the case of AC (alternating current) motors, they are limited by the frequency of the power distribution network. The advantage of internal combustion engines is their higher performance, but they are more difficult to maintain. Their disadvantage is also that the fuel used

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in them behaves aggressively (corrosively) and not only towards the materials from which their individual structural elements are made. [8]

The receiver in the UAV is used for its remote control. They are located inside the UAV aircraft. The receivers receive the signal from the transmitter and transmit it to the individual devices in the UAV, which are in the charge of the movement of the aircraft.

Batteries (accumulators) are a source of energy for UAV aircraft. There are currently many different types of batteries: Nickel-cadmium batteries (NiCd), Nickel-metal hydride battery (NiMH), Lithium-polymer battery (Li-Pol), Lithium-ion battery (Li-lon). Each battery has its own safety precautions and certain advantages and disadvantages. [9] Their choice depends on which of the batteries best suits the needs of the UAV user (power / weight / capacity / effect / aging, etc.) and his type of UAV aircraft.

Using the information obtained from the transmitter and receiver, the control unit distributes the power to the necessary parts of the control surfaces (servomechanisms), the engine and other accessories with which the UAV can be equipped. The control unit thus controls the movement of the aircraft in space.

The navigation of UAV aircraft is provided by the navigation unit. It contains accelerometers and gyroscopes. The data from it can also serve as an inertial measurement unit IMU (Inertial Measurement Unit). [7]

The GPS device determines the position of the aircraft. When receiving a DGPS signal, the position determination is with a standard accuracy of 2 m. [7] The GPS device is connected to the inertial unit IMU.

The ground (control) module consists of a transmitter, control software, telemetry, on-board video output and a recording device.

The transmitter transmits a control signal and the receiver located in the UAV receives this signal by the receiver. The transmitter is a controller (joystick/steering wheel) held by a human operator in the hand. Lever controls having two main levers are preferred for controlling UAV aircraft. They control the functions of UAVs by moving in different directions.

The control software is a system that allows the human operator to easily control the UAV. Using the software will allow him to better evaluate situations and intervene correctly/incorrectly. It will also allow us to monitor current data with other systems and later evaluate the status of the UAV and its parts. The choice of software depends on the type of UAV that the human operator uses, and for what purpose.

Video output from the UAV aircraft deck can be obtained on a mobile device, built-in display in UAV, special glasses. All these devices show us basic information about the flight, the aircraft and with the help of an FPV camera it is possible to get a direct view from the transferred cockpit.

A recording device is part of every UAV. The device is used to record flight information, which later helps to determine and predict the condition of the aircraft, the accuracy of the device and all-important information such as flight time, distance, battery life, flight altitude, etc. The data is used for flight control, aircraft maintenance and possible research.

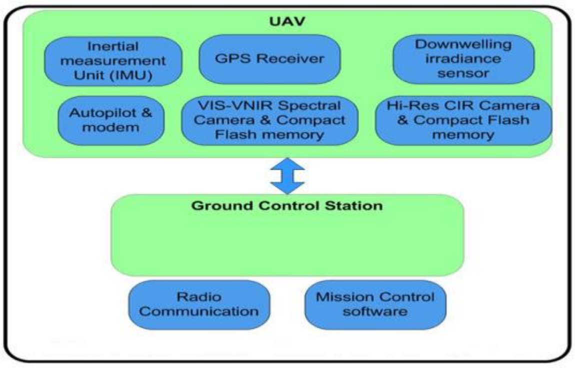

Figure 1. UAV control and control systems [10]

UAVs are controlled in several ways. The human operator controlling the movement of UAVs from the ground, represents the communication between them using the function of a transmitter or computer, it is a manual method of control. The automatic control mode is a UAV with a programmed flight distance. The programmed information contains all the elements that the UAV should perform during the flight (navigation points, landing place, taking pictures, making videos, presetting the UAV's inclination to the horizontal plane, etc.). [7] Semi-automatic control is a combination of manual and automatic control. UAVs may contain some programmed information and the human operator may only focus on piloting or data collection.

The processing module is a specialized software and hardware for processing a specific type of acquired data. [7] In certain industries, UAVs are used to collect image data. They help to create 3D models of surfaces and orthographic images.

III. FACTORS AFFECTING THE CONTROL OF MANNED AIRCRAFT AND UNMANNED AIRCRAFT

The control of transport aircraft and the UAV aircraft are influenced by a several factors. One of the most important factors which to affect control are human factors, design and manufacturing factors and environmental factors.

Elements of human factors to affect control in transport aircraft are flight crew, air traffic controller, maintenance, and dispatch. It was the failure (fatigue, family problems, inattention, etc.) of the human factor that led to many air accidents. The failure of the human factor in the UAV represents reduced attention, which results in exceeding the permitted heights in space, poor navigation, and control, which can cause the UAV to fall into populated areas.

Design and manufacturing factors for transport aircraft: aircraft and ground. Elements of aircraft are corrosion, stability, maneuver limits, aircraft systems (flight control, hydraulics, pneumatics, navigation, communication, etc.) and propulsion systems (engine, reversers, etc.) Elements of ground are air traffic controller systems (radars, radios, control computers and display, etc.) and maintenance facilities. This element has effect on the UAV. [11] From a design point of view, the material (what material the UAV is made of), aerodynamic profile, load-bearing capacity and center of gravity are taken into account.

Environmental factors are weather condition (wind, turbulence, rain, clouds, etc.), visibility, icing and high-intensity radio frequency. For environmental influence are a very different between transport aircraft and UAV aircraft. The transport aircraft can fly during turbulence, heavy rain, thunderstorm and even icing, but with UAV the human operators fly only during good weather conditions. The UAV aircraft are more susceptible to wind disturbance than transport (manned) aircraft. It´s influenced by factors such as the lower flight speed lighter takeoff weight, smaller size, and lower flight altitude. [12] Strong gusts of wind can lead to instability or even to fall. More specifically, it depends on the type of construction of the UAV, weight, power, and the ability of the human operator. The effect of wind on a UAV can be considered as a process of energy transfer. UAV aircraft works in different terrain, altitudes temperatures and time periods. The results of this factors the UAV is susceptible to atmospheric disturbances. The disturbance of the atmospheric environment increases the control difficulty and affects flight safety. [12] A relatively limiting element is also rain. The humidity and impaired visibility influence control of the UAV.

IV. ANALYSIS OF CONTROL METHODS

This chapter of the article describe the analysis of control methods. Is focused on advantages and disadvantages of control systems, which are used in transport aircraft and UAV aircraft. The analysis discusses about control methods which could be a suitable method for UAV Skydog.

A. FLY-BY-WIRE SYSTEM

Analysis of fly-by wire system found that this system can be program to do almost anything and its one of the big advantages. Other advantages include wires, which weigh is much less than mechanical controls, system can prevent the pilot from bad action to control, system can make the aircraft more controllable and able to overcome instability. The system does not have many moving components, which means less wear and less intervention of maintenance. Fly-by wire system has a better precision in control of control surface movement like another systems. Communication with aircraft systems, engine systems, autopilot, director systems and other has a better interface. Good used has fly-by wire system also in emergency situation, because help pilot to control the aircraft and if it needs to do something unusual still keep the aircraft of the control. One of the disadvantages is that the system shut down or failure. Consequence of failure is disastrous because the system has no back up. It means that must be designed to be fault tolerant.

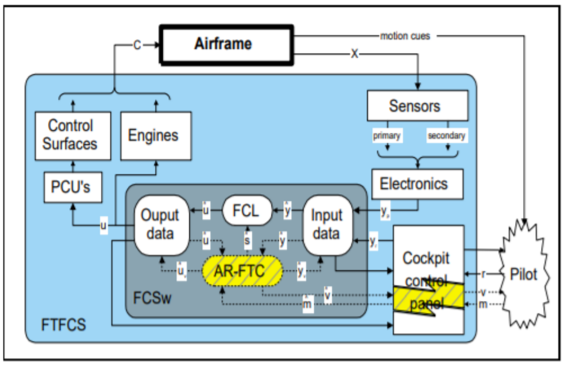

Figure 2. Fly by Wire flight control system [13]

B. AUTOPILOT

Analysis of Autopilot/Automatic flight control system show that system can free pilots' attention from tiring control tasks. Autopilot does not replace the duty of pilot but can reduce the work. System is used in all transport aircraft. Specially, nearly the entire flight. In the bad weather conditions autopilot can be used even during take-off and landing. System provides pilot more time, which they can be devoted to planning, monitoring the aircraft systems observe weather hazard and others. Autopilot has a several advantages. The system help keep the crew out of fatigue, improve fuel efficiency, passenger comfort, because act made by an autopilot are more subtle than act made by hand (pilot). One of the autopilot disadvantages is that system discourage pilot from manual flying. Pilots lose the manual ability to control the aircraft. Autopilot can also failure. If some problem happened during the flight envelope, flight could be dangerous. In this situation pilot cannot engage the autopilot and if they cannot turn it off the aircraft might crash.

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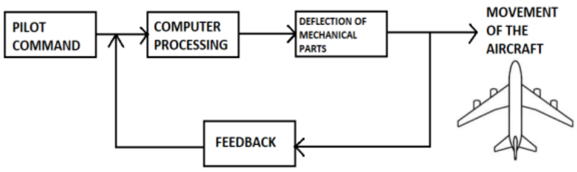

Figure 3. Basic autopilot model

V. OBJECT OF RESEARCH – THE UAV SKYDOG

An object of research is a small unmanned aerial vehicle Skydog. UAV Skydog is a small fixed-wings aircraft used as a platform for research and development of advanced control systems. The aircraft uses Pixhawk PX4 autopilot as a control unit, electric motor to create thrust and batteries to power all electronics. The radio telemetry Skydog has for communication with the ground station and attitude of the aircraft is controlled by operator from a ground station via RC controller. [14] For to change position of control surfaces the aircraft uses 7 servos, where each is connected to one control surface (rudder, ailerons, elevator, flaps).

All electronic devices are connected to the Pixhawk autopilot. The autopilot is equipped with its own IMU (Inertial Measurement Unit) with accelerometer, gyroscope, barometer, magnetometer, global positioning system module, power system and interfaces. [15]

Figure 4. The UAV Skydog [16]

The UAV Skydog serve also as a platform for future research. An analysis of the relevant systems is performed for this object. The selection of a suitable control method will be designed for this object, so it is important to take into account all control systems that are already applied to the object, may be extended or delivered in the future.

VI. CHOOSING THE SUITABLE CONTROL METHOD FOR UAV SKYDOD

The methods shown below represent several approaches that can be used to improve the control of a small unmanned aerial vehicle Skydog, with fixed wings. The flight control system of the fixed wings small unmanned aerial vehicle like Skydog is consists of flight control surfaces, the competent cockpit control, connecting linkages and aircraft engine controls. The UAV also uses operating mechanisms, which are needed to control an aircraft's direction in flight. According to the analysis of control systems, it was evaluated that the most suitable control method for improving UAV Skydog is a possible combination of several systems. These systems are divided according to the needs of the UAV operator's activities. If the UAV will be used for photography or other work, the best combination of systems is fly-by wire with full use of the system, autopilot and EICAS. These systems will allow for high stability and fewer risk situations in which systems could fail. This stability is highly desirable when performing aerial work using UAVs for accuracy, quality and to meet the requirements of the human operator. For UAV aircraft for sport and acrobatic flying, the combination of fly-by-wire systems with the possibility of immediate deactivation of the system limitation and autopilot with the possibility of returning home is the most suitable. One of the most suitable methods was found from the analysis of fly-by wire. The system looks like one of the control methods which could be choose as control methods for UAV Skydog. The advantage of this system is it´s the weight, so it would not be difficult for UAV Skydog. Systems could be design for UAV Skydog, but system will be all electronic or electro sensory. It means no wires, no control cable or hydraulic. Using electronics or electro sensors, the system will be able to provide the aircraft with the necessary power, stability, maneuverability, and safety. Inserting systems from transport aircraft into the UAV Skydog is not easy, due to the different dynamic, mass, aerodynamic and other properties of the aircraft. Systems would need to be modified, some features removed, and some added or replaced. Functions such as aircraft balancing due to weight change (fuel loss, weight change due to cargo / human movement, etc.). However, this balance must be adjusted for the rapid change in aircraft dynamics that may occur during rapid maneuvers. Other features also need to be adapted to this type of UAV.

For all systems to function properly and in accordance with each other, it is necessary to use a control unit that will obtain information from the engine and all flight properties and adapt the mechanisms to the given situation.

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CONCLUSION

This article aims to describe the principle of control of transport aircraft and UAV aircraft. It points to the difference between control in transport aircraft, UAV aircraft of any category and UAV Skydog with fixed wings. The overview presented presents some control methods that are currently used. One of the main parts of this article is the analysis of these control systems. The analysis explains which of the control methods is the most suitable control method for a small unmanned aerial vehicle Skydog. Analysis of the systems will help in further research and improvement of the UAV itself. In further research it would be possible to implement the most suitable methods for flight control of a UAV Skydog, with fixed wings. Based on the verification that was done, the research shows, that the most suitable control method for UAV Skydog is a combination of systems used in transport aircraft with UAV control systems. A fly-by-wire system would be the most suitable method, which would also be appropriate for further improvement of UAV equipment. The benefit of the research is the selection of a suitable control method for UAVs with fixed wings, which can then be designed and created by combining systems and applied to UAVs.

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Comparison of selected economic indicators and trends of the air carrier the Czech Airlines

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***Abstract* — The paper presents the first part of the study and focuses on the evaluation (identification, analysis and evaluation) of selected economic indicators of the Czech Airlines in the five years before the global pandemic with a negative effect of COVID-19 on the company's performance and personnel policy, with a view to 2020. Selected indicators are specific data relating to the company's personnel costs, revenues from the sale of the company's products and services, the number of passengers and revenues transported, the company's main activities and trade payables. Using the descriptive method and the method of analysis and synthesis, the investigated data are evaluated, which are then compared by a comparative research method. With the evaluated data from the main part of the study and then from the second part of the study especially focused on 2020, we try to gain valuable knowledge of the air carrier, which on May 5, 1924 as Czechoslovak State Airlines launched the first commercial flight on the route between Bratislava and Košice, which followed the connection between Prague and Bratislava, how it manages the impact of the pandemic situation on the company.**

I. INTRODUCTION

The Czech Airlines (CSA) is the flag carrier of the Czech Republic and has been a part of the SmartWings Group since October 2018. It is one of the five oldest aviation communities in the world. CSA's main area of business is the commercial transport of passengers on regular routes. The Czech Airlines, a.s. (ČSA) is an airline with its main base at Václav Havel Airport in Prague. The reason why this issue was chosen is due to curiosity of how our neighbour is handling the pandemic situation. Therefore, this article will focus on the issue of coronavirus and will focus on the overall impact of coronavirus situations on the operation of the company, what indicators and parts of company have been most affected and which steps company has taken to reduce the overall impact on company resources.[1]
We have compared a selected transport indicators from:

1. Selected transport indicators:
   - Passengers transported on CSA routes;
   - Passengers carried for other carriers;
   - Total passengers transported by CSA;
   - Number of flights.
2. Selected personnel costs:
   - Labor costs;
   - Social security and health insurance costs;
   - Personal expenses.
3. Revenues from sales of products and services
4. Liabilities:
   - Current liabilities;
   - Long-term liabilities.
5. Revenues from main activities

In this article we will compare the most critical indicators which are the most important (total passengers carried, total flights and revenues from main activities). These indiactors are affecting the other indicators at most, because they are the crucial indicators of airlines.

II. METHODOLOGY

In this article was used a combination of research methods. Using the descriptive method and the method of analysis and synthesis, we evaluated the obtained data. Data were obtained from the company's annual reports for the most accurate analysis. The analyzed data were then compared by a comparative research method. Based on the examined data, it was possible to compare the indicators and monitor the development of the company's trend until the pandemic year 2020, which will be the subject of a separate article.

III. RESULTS

In 2019, Czech Airlines carried a total of 3,653,038 passengers as shown in figure 1, on board the company's aircraft, which means that the number of passengers was 19% more year-on-year compared to 2018. We can observe an increase in the following years until 2015. The SmartWings Group, which includes SmartWings and CSA, carried approximately 1.3 million passengers last year (2020). [2,3]

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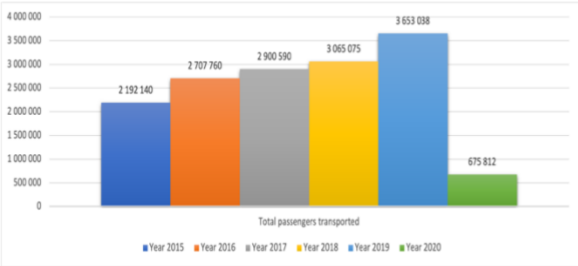

Figure 1. Total passengers transported by the Czech Airlines

Compared to year 2019, this represents a decrease of 81.5%, which was due to restrictions on air transport following the onset of a new coronavirus pandemic. [2,3]

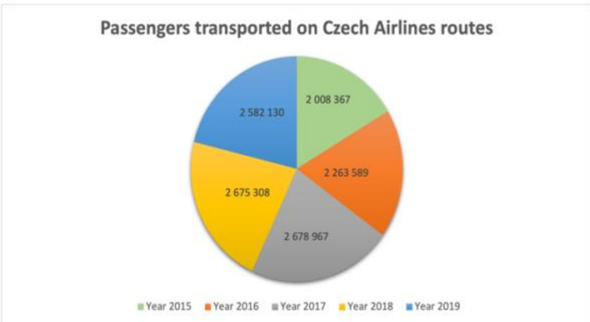

Figure 2. Passengers transported on Czech Airlines routes 1

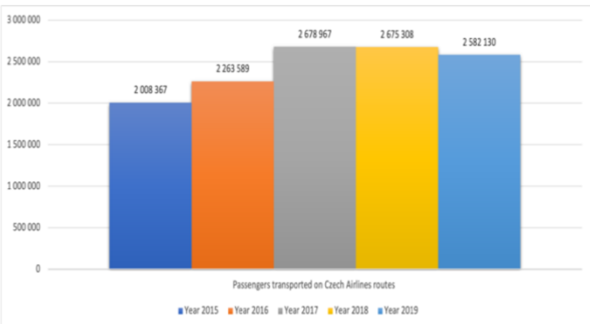

Figure 3. Passengers transported on Czech Airlines routes 2

With the number of flights performed by CSA year-on year, we can observe an exponential increase from 2015 to 2018. On average, the number of flights increased by 6% every year as shown in figure 2. In 2019, there was a significant decrease of up to 18.52%. The main reasons were factors influencing the economic side of scheduled transport, including growing competition, expansion of low-cost carriers, continued strong pressure on ticket prices and, on the other hand, rising cost - increase in supplier prices in aviation services including fees, fuel prices and aircraft rental prices.Passengers transported for other carriers have been extraordinarily improved since 2015, it can be said that every year we can monitor several times more transported passengers. [3,5]

We can observe the largest increase in 2019, where the company has an increase of up to 175% in transported passengers compared to 2018. The reason why the year-on-year increase is the highest this year is due to the fact that the company began to lease its aircraft equipment to other companies. These were mainly Lufthansa Group transport companies from the Stuttgart, Brussels and Munich bases. [3,5]

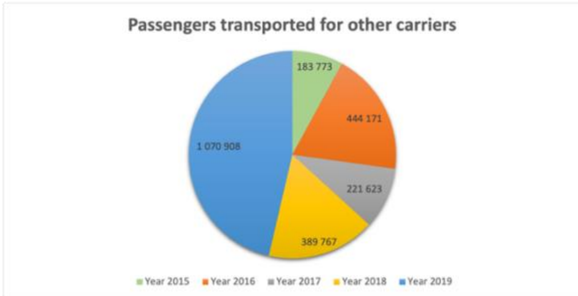

Figure 4. Passengers carried for other carriers 1

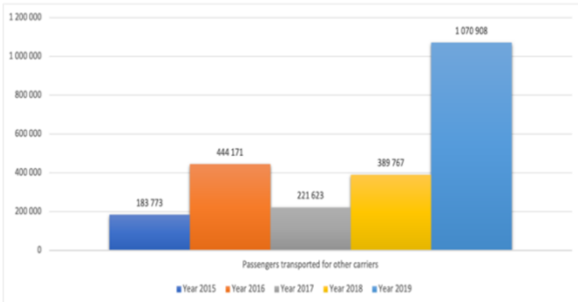

Figure 5. Passengers carried for other carriers 2

But the biggest factor was the arrival of the coronavirus as such. Smartwings in 2020, it completed a total of 13,500 flights, a decrease of 78.4% compared to 2019.[6] Due to the current crisis, the group previously announced the dismissal of approximately 600 employees between July 2020 and February 2021. [3,5]

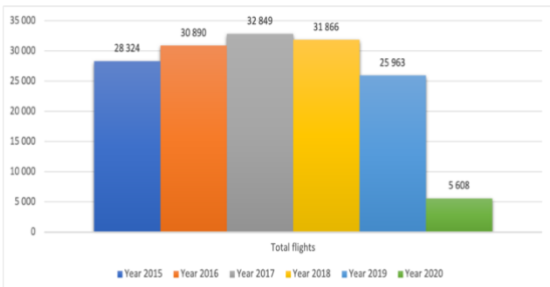

Figure 6. Total flights

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Figure 7. Total flights

As of 31 December 2019, Czech Airlines had a total of 587 employees, of which 150 were pilots, 207 flight attendants and stewards and 230 were administrative staff. During 2019, the company reduced the total number of employees by 163, of which by 29 pilots, 97 flight attendants and stewards, and by 37 administrative staff.

The average recalculation of the number of employees in 2015 was a total of 628 employees. In the graphs at the top (Fig. 9.10) the costs of social security, health insurance and other social costs have not changed significantly over the years, but we can say that in 2019 the company optimized with great intensity and reached the level of costs the lowest in the last 5 years and it is 193,320 CZK. Compared to 2018, this is a decrease of 30,448 CZK. [3,6]

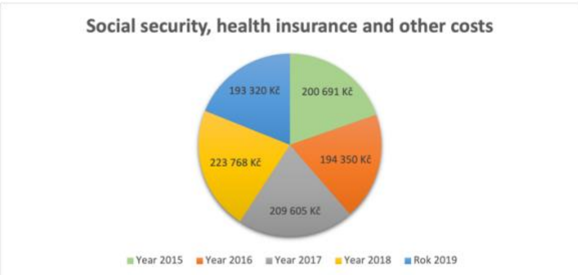

Figure 8. Social security, health and other costs 1

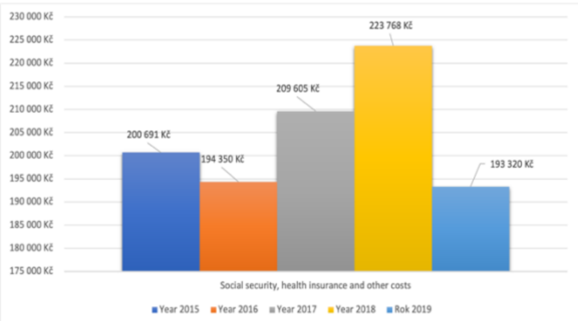

Figure 9. Social security, health and other costs 2

CSA's wage costs are part of the total personnel costs, among other costs, such as social security costs and medical costs. Wage costs in 2015 were at the level of CZK 502,534, of which CZK 32,437 was management costs and CZK 475,845 were costs for the remaining employees. In 2016, these costs increased by CZK 43,294. Wage costs for 2016 totaled CZK 554,230, of which management costs amounted to CZK 34,029 and CZK 517,547 were costs for the remaining employees. In 2017, the amount of personnel costs increased by another CZK 39,373 and in 2018 again by another CZK 35,370. As mentioned above, in 2019 we can observe intensive work of CSA on optimizing these personnel costs as well as employees, as the company managed to reduce personnel costs to the amount of CZK 533,973, which means a reduction in costs by 96,000 CZK. [2,3]

Figure 10. Labor costs 1

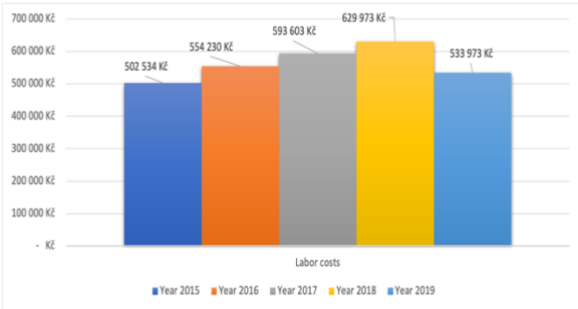

Figure 11. Labor costs 2

CSA's personnel costs in 2015 amounted to 703,207 CZK. Compared to 2016, personnel costs increased by 45,373 CZK. In 2017, personnel costs increased again by 54,628 CZK and in 2018 by another 50,533 CZK. There was a strong intervention by management in optimizing employees and costs. Personnel costs include labor costs, social security and health insurance costs and other costs.

The management of the SmartWings Group has implemented a number of measures, especially in the area of minimizing costs and expenses, e.g. Negotiations with aircraft lessors in order to reduce rents and deferrals, reduction of wages and other personnel costs using partial unemployment in accordance with the provisions of § 209 of the Labor Code, as amended, reduction of working hours, especially for pilots, negotiations with lending banks in connection with possible conclusion stabilization agreements so-called standstill, etc. From this title, we can see in the graph that the company in 2019 managed to reduce personnel costs to almost the original value as it was in 2015. [6]

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Figure 12. Personal expenses 1

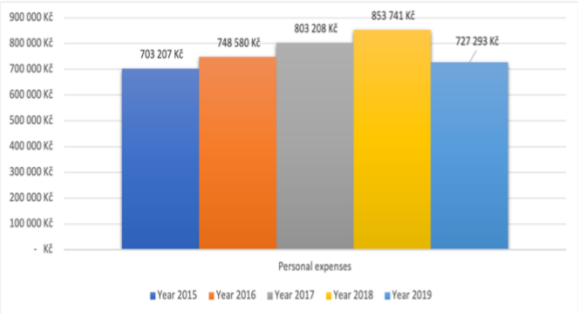

Figure 13. Personal expenses 2

Revenues from the main activities as shown in figure 3 represent revenues from scheduled and non-scheduled transport, passenger transport for other transport companies, revenues from the sale of services, revenues from fees associated with the operation of air transport and taxes, revenues from the refund of maintenance reserves and settlement of unused transport documents. Revenues from main activities in 2015 amounted to 8,067,118 CZK, which in 2017 decreased to 7,975,248 CZK. Year 2016 was particularly significant for the company, as there was a very significant increase in revenues by 1,090,332 CZK, bringing the company's revenues to 9,065,580 CZK. [2,3]

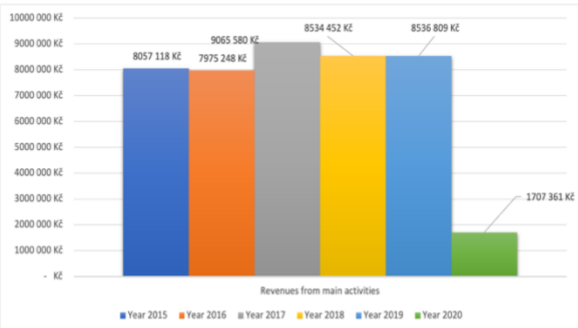

Figure 14. Revenues from main activities

Revenues decreased to 8,534,452 CZK in year 2018 and the company maintained in 2019 with an increase in revenues to a value similar to year 2018. Overall, however, this means that the company increased its revenues over the years by 479,691 CZK. Due to coronavirus and pandemic restrictions revenues from the main activities were strongly affected and there was a huge drop of revenues. Revenues decreased by the year in 2020 to 20% of total revenues of year 2019. [6]

IV. DISCUSSION

The suggestion part of this article is based on the trend in which the company's economy is evolving and based on the data obtained. It can be assumed that SmartWings company has two options.

1.First option is that company will wait until the pandemic situation calm down and everything returns to the state before the pandemic. This option is really a risky thing because oposse these tough times could be dificult even for a company of this size. Nobody knows exactly when this pandemic situation will end and how long it will to take to handle it. [6]

2.The second option is much more rational, which means to be redeemed by the Czech Republic as itself, which will put company under the administration of the Ministry of Transport of the Czech Republic. On the one hand, it will provide the subsidies needed to maintain the company and the company name which was built for decades and it will also not be necessary to lay off hundreds of employees. [6,7]

CONCLUSION

The outlook and trend of SmartWings and CSA were successfully created using annual reports from year 2015 to the present. Exploring further information, we concluded that in 2020, the company had to take several steps to reduce the impact of anti-pandemic measures associated with the new coronavirus. One of these measures was the dismissal of employees and also the declaration of an extraordinary moratorium under the so-called lex covid law, which protects the company from the actions of creditors. By taking such a step, the company deprived its creditors of the right to file an insolvency petition or start execution. So far, SmartWings and CSA are resisting with all possible tools that are available for them. But even though each state tries to lend a helping hand to its entrepreneurs in the form of various social packages, it is difficult for companies of this size to maintain their economy, people, but also the name of the company. [8]

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Application of progressive methods in the use of meteorological information sources by the airports

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***Abstract*— The article deals with the application of selected progressive methods in the use of meteorological information sources in ensuring the operation of the airport. In the introduction of the article, the authors present the organization of meteorological offices, their impact, and their role at the airport. Subsequently, it is defined which information the airport can use from the meteorological information network based on the available airport equipment. The third chapter deals with the possibilities offered by the implementation of selected progressive methods into this information structure. In conclusion, in addition to the summary, the authors point out other research questions that need to be addressed in the future.**

I. INTRODUCTION

Regarding airport equipment, ICAO Annex 14 - aerodromes, is important. In this regulation, airports are divided into certain categories based on specific specifications. Based on this categorization, the necessary airport equipment is then determined. Most or almost every airport is therefore equipped with a monitoring system. Such monitoring systems are used to monitor either the runway surface and other aerodrome areas or to monitor general external conditions. However, in addition to monitoring the conditions on the surface of runways and areas, they monitor a wide range of other key variables that are necessary for the operability of the airport [1]. This spectrum of quantities that are monitored depends on the specific technical type of equipment, as the individual variants differ from each other, although slightly. There are systems whose measurements are focused exclusively on quantities that help predict changes in weather conditions and transitions from one state to another [2]. However, there are also systems in which the monitoring of meteorological variables is a secondary task, as the primary determination focuses on measurement and control in another area. In this article, we will take a closer look at the mentioned systems that are used at the global level.

It is important to focus on the territory of the Slovak Republic. A so-called partial monitoring system has been built and is in operation in this area. This system was established under the auspices of the Ministry of the Environment of the Slovak Republic. More specifically, it is operated within the Slovak Hydrometeorological Institute, abbreviated SHMI. However, it was not a matter of designing and setting up a completely new monitoring network, as meteorological measurement networks are among the oldest networks in terms of systematic observations in Slovakia. The project is complemented by a comprehensive monitoring system, as well as its other nationwide systems. The aim of this monitoring system is mainly to provide meteorological information, data for early detection and monitoring of climate fluctuations and its changes, as well as to predict and reduce the impacts of these changes. It also provides the data needed for climate modeling. As already mentioned, this system is divided into different subsystems. These are various networks of ground synoptic stations, meteorological radars, subsystems of meteorological measurements using satellites, but it is also necessary to mention precipitation and phenological stations and radio sounding measurements [3].

An inseparable element of the monitoring system is telecommunication, information but especially database systems. Data from individual subsystems of the partial monitoring system are stored in the climatological and meteorological information system, abbreviated KMIS. Data enters this database system in different ways, but they are entered either automatically or manually, depending on the specific network. In the case of subsystems operating with a dense frequency of data collection, this operational

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data is fed into the database system through the National Telecommunications Center. In the case of stations where paper reports are prepared, these reports are entered into KMIS manually. All input data, whether manually or automatically, is subject to a completeness check as well as a formal and logical check. In case of detected deficiencies, they are edited immediately. The administration of the database is provided externally, it is not accessible to external users and its individual users, access rights of various levels are assigned within the SHMI. The database is filled not only with current but also historical data, as the received data is archived. KMIS contains data about archives as well as metadata. Metadata can be characterized as data about data.
A brief introduction to this sub-monitoring system is followed by a network of the above-mentioned terrestrial synoptic stations. The aim of this network of stations of the Slovak Hydrometeorological Institute is to measure and monitor the condition and development of the weather, to the greatest possible extent, frequency, but especially with sufficient accuracy and representativeness. The obtained data are used mainly for the purposes of synoptic and aeronautical meteorology, which greatly influences and helps the process of planning and organizing winter maintenance of airports. Furthermore, however, these data are also used to ensure the operation of nuclear power plants within the activity of meteorological security. As for the network itself, it is a system of 34 automated stations, which are equipped with VAISALA MILOS 500 or MPS04 devices. This data set must have a high data transfer rate and frequency. At the next levels, there are already specific database systems, where the data are checked and prepared for their further use, for example in practice in the field of climatology [4].

II. COMPONENTS OF AERODROME METEOROLOGICAL NETWORKS

Synoptic messages are sent automatically, at prescribed time intervals using telecommunication modules. Sent messages are archived on the telecommunication computer. These messages are then forwarded to specific computers and information systems for further processing. There they are re-archived, inspected and subsequently used by the processing departments. The spectrum of quantities that are observed and measured represents a really large set of data. On most devices that provide measurement of these quantities, it is possible to set both the measurement of elements whose measurements are exact, but also qualitative phenomena, which are determined subjectively. A map of these ground synoptic stations can be seen in the figure below, with the points marked in red representing the synoptic stations and the points marked in blue, the auxiliary synoptic stations.

Figure 1. Map of synoptical stations in SR

Synoptic stations are also located in the airport area, essentially directly at the airports, and are distributed as follows. The MIDAS 600 system operates at the General Milan Rastislav Štefánik Airport in Bratislava, specifically at the aeronautical meteorological station located at this airport. It is a dual airport monitoring system, which ensures monitoring in the area of the runways. They also provide gradient measurements, from the ground up to a height of 586 meters. At the international airports in Poprad and Košice, there is also a monitoring system, but it is a simpler airport system IMS4. It is therefore a synoptic observation system, which is used in many other areas in addition to aviation. The user can choose from several model variants, while the variants differ in the number of available functions. The system set-up, specifically IMS4 automatic observer workstation, can be seen in the example in Figure 2. At the top are various meteorological observation and weather measurement sensors, which the user can select depending on the variant. The pressure sensor is located separately. The system is powered by an electrical source or can be powered by a solar panel. It also includes a backup power supply, in most cases a battery cell. In the event of a power failure from the primary source, there is an immediate switch to the secondary source, as it is a system with continuous operation.

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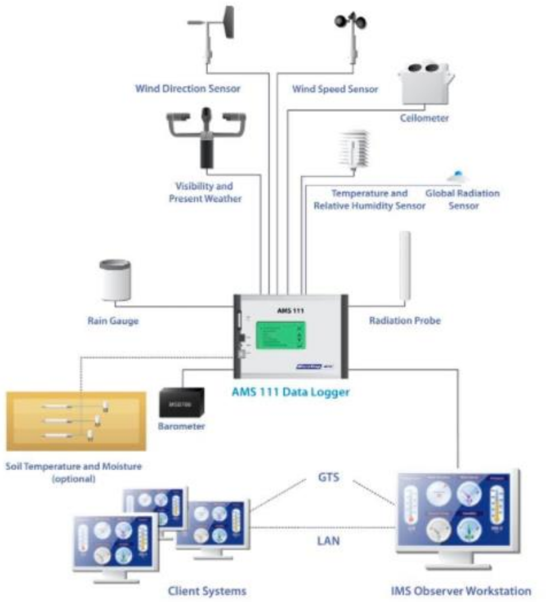

Figure 2. IMS4 automatic observer workstation

For all data measured by this system, this data is stored in a data logger. It consists of a graphical touch screen, an LED operating status indicator and a memory card to which the measured data is backed up. The recorder is connected to the motherboard, by means of which it is also connected to an interface that allows access to the distribution network. With it, the recorder automatically sends the collected data at predetermined time intervals. Once received, they are stored in a remote data collection system so that they can be used subsequently. In most cases, these are computer computing units.

A. MET offices

For the correct and smooth performance of individual activities, flawless coordination of individual airport departments and units is essential. The airport dispatching and LPS cooperate, in this case the airport tower. However, it is necessary to draw attention to the fact that the so-called MET offices are also included here within the cooperation, in translation we can call them meteorological offices. These offices are basically under the administration, respectively they are established by SHMI. They are strategically located throughout Slovakia, and we can basically say that the offices that are most technically equipped are located at the airports. Meteorological offices at the airports in Bratislava, Košice and Poprad-Tatry Airport are among the most strategically important. This is because they provide meteorological services not only on domestic flights, but also for flights within the European Union and flights from the European Union to other ICAO areas. These offices serve as a kind of central node at the mentioned airports, where data measured by the respective airport facilities are stored and collected. Data is stored on server units. Not all data that is collected is evaluated and analyzed in a given office. Each office has its own computing capabilities. These are given both by the technical equipment of the stations and by the qualifications of the workers.

A meteorological garden is a part of an airport, in most cases enclosed by a fence or other physical barrier. In this garden, there are devices and sensors needed and intended for observation and measuring many meteorological characteristics. The devices can be, and in most cases are, connected to a comprehensive, automatic weather observation system, abbreviated AWOS. Meteorological characteristics include, for example, the lower cloud base, wind direction and speed, humidity, and in many cases solar radiation. Thus, the data obtained from these devices is stored on servers and subject to further processing. Data is updated and received at predetermined intervals. Within the MET office, one of the operational outputs is the creation of the METAR report. This is a report format that contains weather information. This scheduled air service is mainly used by aircraft pilots, but it is also widely used by the airport and its departments, such as airport dispatching.

The establishment of MET offices is not typical only for Slovakia. MET officially occurs worldwide, while in each country they are subject to the administration of their superior element, or body, as is this element in Slovakia SHMI. Each MET office has technical support. It may be in the form of a technical officer assigned to the office or belonging to another section or department of the airport. In addition to data servers, he is also in charge of maintenance and inspection of the meteorological garden. In the event that a more serious fault is detected, in such a case a service technician of the given manufacturer, who is responsible for the production of gears, is called. As for the equipment of MET offices, we can say that it is very similar to synoptic stations. The layout is equally similar. It therefore consists of equipment in the outer part, and subsequently of equipment in the inner part.

The first part consists of internal equipment. The data stream comes to the internal part, either via optical cables or in the form of transmission over the distribution network using 4 receivers and an omnidirectional antenna. The receiving station is the MET office, specifically its data server. From this server, the data is forwarded via a local computer network, in the case of AFTN airports. They are received by three workstations. Each workstation consists of a computer unit and software that is specially adapted for use by that station. Each is operated by a separate employee, qualified for this function. The first is the AVIMET technical support workstation, where the correctness of the received data is checked. Faults are also checked, as this system automatically sends an alert to AVIMET if a fault is detected. The data is also archived in the central data

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processing unit. After the initial check, the data travels to the second workstation, which is the meteorological station. The third station is the observation station. The external, i.e., external, equipment of such a station essentially consists of devices and sensors intended for measuring predetermined quantities [5].

III. THE POSSIBILITY OF USING PROGRESSIVE METHODS

The basic precondition for the smooth operation of the airport is quality security and management of individual activities that have a significant impact on the overall course of the airline, from landing through ensuring the handling of the aircraft to the subsequent departure of the line. At each airport, its employees are divided into individual departments, while each department or section is in charge of a different part, we can literally say that it plays a different role in this process. It is therefore essential to ensure continuous communication and coordination between these components for smooth operation. Time is vital in managing any airport activity that affects its operation. Whether in terms of time management of activities such as technical handling, but in this context, it is perceived by the authors as the time needed to move information from one department or section to another. It is also a transfer of information from one employee to another. Any failure in the information exchange process can have a severe impact on the smooth running of the timetable and the performance of the activities of the individual sections. It is therefore common practice to use standard radio equipment, such as walkie-talkies, for the rapid transmission of information at the airport.

In a slightly more modern design, these are hands-free sets, where the worker just inserts the receiver implemented in the earphone into his ear. Such equipment involves the efficient and relatively fast transmission of information, and these devices are affordable. As there are many sensors, sensors, transmitters and many other electrical equipment at the airport, there can often be interference in the transmission of information. If we look at it in general, such interference should not have a serious consequence. However, if interference occurs when this is a key piece of information, this can be a problem. Of course, the worker can use the walkie-talkie to request the information to be provided again, but valuable time is lost.

What poses a greater problem is the analysis, evaluation and subsequent transmission of meteorological information obtained from the collected data. As mentioned, each airport has a MET office at its disposal, which at the airport acts as an advanced base for the main provider of meteorological information or the main meteorological office of the relevant State. However, due to the dimensions, technical equipment and categorization of the aerodrome according to ICAO Annex 14 - aerodromes, each aerodrome does not have the appropriate equipment for the correct analysis, evaluation and interpretation of data. After the collection of MET data by the office, in case the necessary technical equipment is missing at the airport, unused data is sent, which the airport does not have the capacity to evaluate either to the nearest airport that can do it or to the central office where such equipment is already located. Again, this is an information data flow and its exchange when it is necessary to manage this process without any errors. However, the human factor responsible for providing and forwarding correctly interpreted facts back to the receiving airport may also be wrong in this process. This process is largely automated to prevent human error, but the human factor already plays a major role in providing the information obtained between the airport's MET office and individual departments.

Augmented reality is an effective tool to eliminate this potential for error. Augmented reality is the transmission or transcription of reality through the digitization of data, where digital information is layered by the user directly on the seen reality. Glasses or another type of display are necessary for this process, through which the user can see both the seen reality and its digital overlay. If augmented reality or glasses with integrated AR were used directly in this process, this would significantly reduce the time required to transmit information, while the transmitted information and data would be error-free. This applies to airport processes in general, not just the transmission of meteorological data. However, in the field of meteorological data transmission, a worker using AR spectacles, such as the HoloLens spectacles, which are the most popular and used in the field, could switch between data channels as needed, gaining access to specific information on each data channel. From the point of view of aeronautical meteorology and data transmission and analysis, given that airports have to forward data that non-lines process to other offices or central nodes, as already mentioned, AR goggles provide a comprehensive answer. In this process, using this progressive method, the possibility arose to create a single server, where this data would be uploaded and accessible to all airports in real time. In practice, this would be a simplification of the information exchange process, where the central office would not have to report and evaluate the analyzed and evaluated data and information back to the airport from where it received it, but would simply upload it to the server. This would eliminate the need for a human factor for the necessary reception of information and its transfer between the MET office of the airport and the individual airport departments. A worker with AR glasses would simply switch to a pre-specified data channel, where he would have access to all the data transmitted from the server, in real time.

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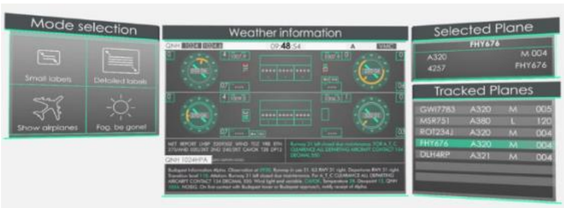

Figure 3. HoloLens aerodrome interface

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CONCLUSION

Aeronautical meteorology is an essential part of ensuring safe and smooth air traffic. With the help of analysis and correct interpretation of the obtained data, it is possible for the airport to properly prepare for individual weather events and at the same time it is possible to provide flight crews with meteorological information well in advance. Despite the abundance of sensors, sensors and other technical security at every airport, not every airport has the ability to analyze and evaluate all the data obtained. It must therefore send this data to another airport with available equipment or to central meteorological offices. Although this process is generally very well managed, it is a potential section where mistakes can occur. To ensure the constant increase and provision of the required level in air transport, where safety always comes first, it is necessary that with the development of aviation technology also develops technology that contributes to ensuring smooth air traffic, but especially with the development and implementation of progressive methods. Only through continuous improvement, research and implementation of progressive methods in aviation can the safety and efficiency of this mode of transport be constantly increased. There is huge potential in this sector for virtual and augmented reality systems, but for proper implementation in aerospace processes, they need to be properly addressed and constantly researched, with an emphasis on development and research.

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Cybersecurity of airports and suggestions to increase cybersecurity in the workplace

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***Abstract*— The paper aims to define the concept of cyber security at airport workplaces and to propose a solution, based on the identified best measures that have proven themselves in practice at airports. Point out security gaps in cyber security options and, on that basis, propose solutions that would increase the level of cyber security. The content of the object of research is information security in airport infrastructures, which are important for their proper functioning.**

I. INTRODUCTION

Thanks to globalization, the development of information technology, computers, and the Internet have become an integral part of our daily lives. In aviation, we use them to store, collect information for communication, airspace management, navigation, etc. Therefore, we have created a new domain related to cyberspace. We are increasingly encountering the dependence of technology or people on cyberspace, and thus its vulnerability is growing.

The constant development of information and communication technologies in aviation is noticeable for every user. They are used in day-to-day work, such as pilot communication with ATC services, data exchange between airports, airspace management, air incident investigations, etc. Everyone is aware of the importance, sensitivity, and value of processed data, but their safety is still underestimated, and securing the equipment by which they are processed. Therefore, there is no need to underestimate the current threats these days, and these are cyber-attacks. Their huge advantage is anonymity.

Over the last quarter of a century, cyber-attacks have been shown to be carried out on organizations and countries as part of politics or military conflict. Aviation is no exception. These factors tell us that we are facing a new kind of threat in aviation, in its security environment, and therefore it is necessary to actively address security issues in cyberspace.

II. METHODOLOGY

The problem-solving methodology was based on the collection and analysis of professional literature from available sources, summarization, and synthesis of knowledge based on our own experience and consultation with experts in the field.

Methods of summarizing the facts and summarizing the available data, consulting activities for the interpretation of one's own opinion, and the correct formulation of the findings were used to obtain the data. The statistical method was used to summarize information related to the type of cyber-attacks on airports and aviation facilities in the world. The next step based on the analysis was translated into the form of a proposal for a cybersecurity solution at the airport.

III. RESULTS

Technical advances in the design and navigation of air navigation systems have significantly helped reduce the likelihood of death in air accidents, but computer dependence presents new types of risks. Cybersecurity is a branch of computer technology also known as information security, applied to both computers and networks. [6.]

Figure 1. Objects of cyber-attacks [6]

Technology and digitalization bring many benefits to aviation, but they also create challenges in managing cyber vulnerabilities in this complex environment. The aerospace industry is very broad and an attractive target for the cyber threats of all its users, from stealing data or money to disrupting and damaging various systems. The picture mainly shows the objects of cyberattacks. [7.]

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A. Types of cyber attacks

There are many cyber-attacks and new and more sophisticated types are constantly appearing, we will mention only those types that are most common in aviation.

Defacement - an attack on a website that aims to change the typical appearance of a website, such a propagated attack often displays its own website on the attacked website.

SQLi - Structured Query Language Injection aims to compromise the database that organizes data collection and other data structures. Data can include usernames, passwords, text, etc.

Account Hijacking - is a process in which a user's account, email account, computer account, or any account that is associated with computer technology or computer services is stolen.

Targeted Attack - in computer and network security terminology, it refers to a targeted attack. It is one that has been targeted at a specific user, company, or organization.

DDoS - this attack is not used to obtain, break, or copy sensitive data. The DDoS attack has a simple task, and it is simply to flood the server. The site or service under this attack will crash and report unavailability.

Malware - is a type of program that was developed to damage computer software.

Phishing - is a computer attack in which fraudsters use bait in electronic communications to deceive and misuse users' personal information, such as passwords, usernames, and credit card information, to misuse them for inappropriate purposes, such as extortion and identity theft. [7.]

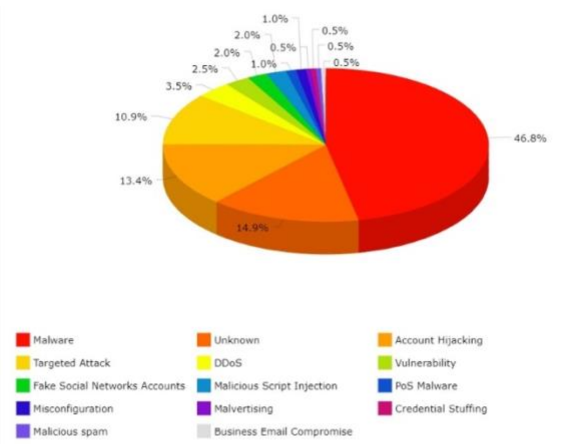

Figure 2. Cyber-attack statistics for September 2020 (Source: https://www.hackmageddon.com/2020/11/11/september-2020-cyber-attacks-statistics/)

A graphic representation of the most popular cyber-attacks in the world in September 2020 is shown in the figure. As we can see malware is the biggest threat to computer software.

B. Airport security

Airports are also highly dependent on networked computer systems for day-to-day operations and are therefore vulnerable to computer threats, especially with the growing use of mobile applications and mobile hardware.

In addition to traditional IT infrastructures, such as e-mail and the Internet, there are several potential targets for cyberattacks in the field of internal airport operations, such as radar systems, airport databases, camera systems, telephone networks.

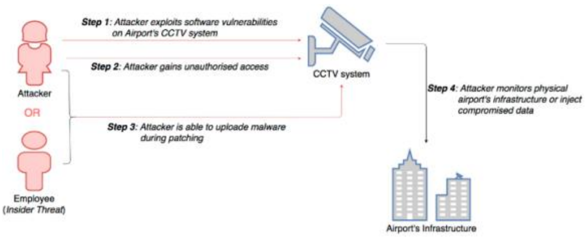

Figure 3. An example of an attack on airport camera system [7]

Although many airports have robust systems in place (the ability of a computer system to deal with errors during operation and to deal with incorrect entry) to address common hacker threats, they have not always taken a holistic approach to the IT computing environment or not considered a broader threat to aviation infrastructure.

In this regard, the IATA Member States, and IT stakeholders have promoted coordination on aviation strategy, politics, and information sharing in order to identify critical vulnerabilities that are needed for each other and to develop systematic sharing of information on cyber threats, incidents, and the consequences of cyberattacks. [2.]

Any design of a data and information protection system must be based on a thorough analysis of all risk factors and the use of available data protection knowledge. The consequences of accidental mistakes tend to be less harmful than the consequences of carelessness and disorder. The analysis of security incidents shows that the easiest and most frequently used way of entering the information system is the use of internal intrusion by members and employees of the organization. [5.]

On this basis, a range of standards has been developed, such as: 1) European Norms (EN) 16495 for ATM air traffic management, issued for civil aviation, with supporting information security guidelines for organizations operating in civil aviation; 2) International Society for Automation (ISA) / International Electrotechnical Commission (IEC) - 62443, which is a set of standards, technical reports and related information that define procedures for the implementation of electronic industrial automation and control systems; (3) NIST 800-82 Industrial Control Systems (ICS) Safety Inspection Manual.

The Civil Air Navigation Services Organization (CANSO) has developed a handbook to increase the

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level of safety of air traffic management (ATM), presenting cyber threats and risks. CANSO proposed a model for addressing cybersecurity in combination with international standards, the NIST Cybersecurity Framework, as well as a risk assessment methodology. [3.]

C. Analysis of cyber threats at airports

Although many security threats can occur unintentionally, in this work we have focused on cyber threats, the intention of which is intentional and targeted at strategic objects of airports.

Hackers can use various methods to compromise airport IT assets. Each of these attacks can lead to security incidents with violations of privacy, integrity, availability and should be considered when assessing airport risks in order to maintain safe traffic. [1.]

We will explain more about the main categories of threats at airports that can be analyzed:

- Network and communication attacks: Networks are exposed to attacks from malicious sources, which are divided into two categories: passive attacks, when an intruder intercepts data, and active attacks when a hacker disrupts normal network traffic and gains access to devices available through that network. Despite legislation that prevents eavesdropping on airports, airports remain an attractive target for tampering or network attacks. As a result, networks may be down, passengers may be delayed and flights may be delayed, the reputation of the airport may be damaged and potential financial damage may occur. [8.]
- Malware: is capable of infecting common information systems, can also compromise intelligent devices, including portable devices for passengers and employees, servers, and other intelligent components, including control and data collection systems at the airport. It leads to serious problems with intelligent airport systems, such as the check-in system, errors in the remote control of hangar gates, entrances, and exits.
- Tempering (Manipulation with airport devices): Unauthorized modification involves the manipulation of data in central reservation systems, administrative information systems of airports. The threat of unauthorized manipulation also includes unauthorized modification of hardware or software with removal or corruption of data, which can affect the behavior of airport self-service systems, building management, etc. [8.]
- Social attacks: Airport staff who do not have sufficient security knowledge and do not follow these procedures can pose a significant risk to the airport's cybersecurity. Social attacks can manipulate or mislead people to act on behalf of the attacker. E-mail remains the primary method for threatening hackers and allows an attacker to gain full access to the target, identity, and authorization of victims. Even though organizations install filtering features, phishing emails can still crawl and force the victim to take malicious action without their knowledge. [7.]

IV. DISCUSSION

The suggestion part of this paper is based on a summary of proposals and measures which was identify that have proven themselves in practice at airports. Which, when implemented, could increase the cybersecurity of networks and equipment in airport infrastructure.

1. Stocktaking of airport workplaces assets: Identification of all information assets and mapping of workplaces infrastructure. This can be achieved by using network scanning tools. The output is a list of devices that are connected to individual networks. Proper inventory identification and management help ensure effective asset protection. The asset list must include the device name, IP address, MAC address, the operating system under which it runs, and location. It is advisable to assign the devices to the user who is responsible for him.
2. Network segregation: All devices are connected to the workplace infrastructure, which means the information network. To increase cybersecurity, it is proposed to separate the individual networks in order to prevent the spread of possible malicious codes or viruses. [6.]
3. Introduction of regular training on cybersecurity: Raising the awareness of airport staff about cybersecurity is a key task for the provision of information technology and for its proper use in practice. Creating the right model that will be constantly updated and accessible to employees in the field of cybersecurity and handling of work electronic devices will significantly increase the overall security of the company.
4. Creating a separate network for administration is important mainly because the administrative workforce uses the Internet, USB devices, email communication at work. All these platforms pose a high risk of infection and the spread of malicious code. Creating an isolated network for process equipment is the most important step in preventing downtime caused by possible infection. If it is necessary to have a connection between the process and administrative network, they must take place through the firewall and DMZ (is a physical or logical subnetwork that contains and exposes an organization's external-facing services to an untrusted, usually larger, network such as the Internet). [4.]

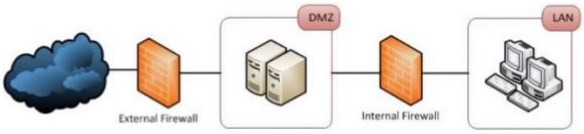

Figure 4. Computer network protection scheme [4]

5. Introduction of encryption keys: Email encryption is the encryption of email messages to protect the content from being read by entities other than the intended recipients. Email encryption can also include authentication. Email is prone to disclosure. Most emails are encrypted during transmission but are stored as plain text, making them readable by third parties such as email providers or advertisers.

Figure 5. Key encrypton
(Source: https://sectigostore.com/page/encrypt-an-email-on-gmail-or-outook/)

CONCLUSION

This research focuses on cybersecurity and cyberattacks, which can occur during unauthorized network intrusions and other dangerous acts, as the integration of intelligent systems at airports brings new vulnerabilities in their infrastructure. The idea was to raise cybersecurity awareness for all parts of the airport. We have tried to identify the key issues of cybersecurity at airport workplaces in a simple and comprehensible way and to propose measures to protect the airport infrastructure.

During the research, it was found that the information security of airports depends primarily on their security politics. We can assume that the given area constantly needs experts to solve various tasks, which confirms the topicality of this issue.

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TECHNICAL UNIVERSITY OF KOSICE, FACULTY OF AERONAUTICS
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Drone regulatory environment in the European Union

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***Abstract*— The increased use of drones in government, military and commercial applications has presented countries across the globe with regulatory challenges. Some of the biggest challenges include the need to ensure that safe drone's operations in urban environment, efficient and safe integration of drones in the national airspace within existing infrastructure, impact on public and national security and ways that would protect areas of national, historical, or natural importance. Aforementioned aspects of drone sector are all depended on regulatory framework, which will dictates standards, operational procedures, certification of technologies, personnel and institutions such as unmanned traffic management services and supplementary services providers. While some individual countries have adopted legislation or implemented temporary provisions on the operation of drones, various regulatory and legislative proposals are currently being considered. Efforts to harmonize rules of drone operations are currently being undertaken by the European Commission, which has introduced a proposal to integrate all drones, regardless of their size, into the European Union (EU) aviation safety framework. This paper presents overview of European union's position and forming regulation in existing regulatory environment**

I. INTRODUCTION

The turning point was in 1991 when, during the war in the Persian Gulf, the US military services and their allies realised that the potential of drones for military applications was wide ranging. Following these experiences, the manufacturing industry not only increased the production of military drones, but soon started to promote their civil use. The first civil aviation authority promulgating rules for the civil use of drones was the Danish Civil Aviation Authority (CAA) in 1986 [1].

Since the number of uses and availability of drones have been on the rise in the non-military sectors, aviation and aeronautical authorities have been concerned with discussing and establishing appropriate safety standards, and legal and ethical rules. One such international forum is the International Civil Aviation Organization (ICAO), which establish in 2007 a Study Group [2]. This specialised United Nations (UN) agency is responsible for managing the Convention on International Civil Aviation (often referred to as the Chicago Convention) and works together with its 193 member states to agree on common standards and practices – including on drones. In 2011 the ICAO issued a circular titled Unmanned Aircraft Systems (UAS). Serving as a first look at the subject, the circular calls on states to provide comments, particularly with respect to its application and usefulness, in an effort to proceed with the development of the fundamental international regulatory framework through Standards and Recommended Practices (SARPs), with supporting Procedures for Air Navigation Services (PANS) and guidance material, to underpin routine operation of UAS throughout the world in a safe, harmonized and seamless manner comparable to that of manned operations [3]. Manual on Remotely Piloted Aircraft Systems has been published later in 2015 further updating SARPs and PANS based on three year long discussion with engaged actors. In 2016, the ICAO developed a UAS toolkit addressing the need to respond to the regulatory challenges raised by the rapid proliferation of UASs [4]. The toolkit provides guidance for drone operations and for regulators.

Another platform engaged in concepts of rulemaking agenda is Joint Authorities for Rulemaking on Unmanned Systems (JARUS) gathering regulatory expertise from 59 countries and working together with European Union Aviation Safety Agency (EASA) and Eurocontrol. The aim is to recommend a single set of technical, safety and operational requirements for all aspects linked to the safe operation of drones. However, since its last Plenary Meeting in Chengdu, China in October 2019, no official recommendations has been published and. It should be noted that Joint Authorities Rulemaking on Unmanned Systems (JARUS) is the only forum (other than ICAO) where

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the world's NAAs and aviation industry communities can meet and collaborate to prepare guidance for a safe future for drone operations. JARUS is also the only existing international forum where NAAs from all countries can interact, share best practices, and learn from each other's national drone regulation implementation experiences.

A. Armed drones

In the case of military grade drones, which include also systems carrying ammunition or are ammunition themselves, the regulatory framework encompasses three areas of international law, namely, international humanitarian law, international human rights law, and the law on the use of force. Additionally, the United Nations Convention on Certain Conventional Weapons [5] from 1980 needs to be listed as another regulatory source. The convention set up a group of governmental experts on emerging technologies to tackle the ethical and moral aspects of deploying them in armed conflict. The perspective of deployment of armed drones or unmanned technology raises numerous questions from responsibility to accountability and as the numbers of states owning armed unmanned technologies increases notions examining outcomes of their actionability will be more present. Nowadays, activities discussing these challenges and questions have been criticised for being too cumbersome to address such fast evolving and technologically challenging matters properly.

B. Question of exports

Another challenge posed by the swift development of drone technology concerns export control in order to oversee the exports of certain strategic goods such as advanced avionics systems to prevent misuse and safeguard international security. This is particularly complicated when it comes to the dual-use nature of drone technology – meaning that with minor modifications a legitimate civil drone can be easily turned into an armed one [6] [7]. The EU's dual-use export control regulation establishes a regime for the control of such goods and is currently under review [8]. As it stands, the regime covers military drones and some civil drones, namely those that can fly beyond the line of sight (BVLOS) and with an endurance of between 30 minutes and one hour. Specifically, BVLOS operations are of significant importance to many commercial application and regulation on BVLOS systems is therefore two-fold, safeguarding peace but also foster swifter civil applications. By and large, EU position on arms exports commits EU members to cooperate towards convergence of national arms export policies and to prevent exports of military technology (including drones) that could be misused by importers. On the other hand, enforcement and cooperation of EU member states collides with national sovereignty, which invokes difficult situations. The Wassenaar arrangement on export controls for conventional and dual-use goods and technologies is a voluntary regime aiming to promote responsibility and transparency in arms and dual-use goods exports [9]. Upon review of the agreement, it's deemed increasingly obsolete, given its inability to capture dual-use drones. The last international regulation necessary to be mentioned is the Arms Trade Treaty, a multilateral treaty adopted by the UN General Assembly that regulates trade in conventional arms also includes provisions for the responsible use of drones [10].

II. LOOKING INTO THE VOCABULARY OF DRONES

Unmanned aircraft or unmanned aerial vehicles (UAV), remotely piloted aircraft systems (RPAS) and unmanned aircraft systems (UAS) are all different ways of referring to what are most commonly known as drones. While referring to the same concept, different terms actually represent different parts of the overall system. ICAO Annex 2, Rules of the Air defines Remotely Piloted Aircraft (RPA) as "*An unmanned aircraft which is piloted from a remote station*" [11]. Additionally, ICAO Cir 328 defines RPAS or Remotely Piloted Aircraft System as "*a set of configurable elements consisting of a remotely-piloted aircraft, its associated remote pilot station(s), the required command and control links and any other system elements as may be required, at any point during its flight operation*". Correspondingly, ICAO Cir 328 defines Unmanned System as: "*an aircraft and its associated elements, which are operated with no pilot on board*" [3]. By and large, aforementioned definitions describe the systems, which fall into the category of Unmanned Aircraft explained by ICAO by the definition: "*any aircraft intended to be flown without a pilot on board is an unmanned aircraft. They can be remotely and fully controlled from another place (ground, another aircraft, space) or pre-programmed to conduct its flight without intervention*" [4]. For simplification purposes, the term drone will hereafter be used for all types of unmanned aircraft, aerial vehicle and aircraft system.

EUROPEAN REGULATORY ENVIRONMENT FOR DRONES

Regulatory issue has been firstly raised by the European Commission in study analyzing the current activities in the field of UAV in 2007. Content of the study presented the economic potential and industrial benefits of drones for the European market in civil applications as well as usability for safety and rescue systems. In the analysis of individual countries, Slovakia was identified as candidate potentially prioritizing the procurement of drones in national security branches and a weak environment to support development of civilian applications [12]. Multiple reports and technical opinions were presented within

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the EU or internationally with a significant political discussion followed by joint statement at European level issued at the conference of the remotely piloted aircraft in Riga [13]. Following the Riga conference, EASA was tasked with developing a regulatory framework for drone operations and proposals to regulate low-risk drone operations. In September 2015, following Notices of Proposed Amendment A-NPA 2015-10 Introduction of a regulatory framework for the operation of drones [14] EASA issued Proposal to create common rules for operating drones in Europe [15]. Furthermore A-NPA 2015-10 submitted 33 proposals in line with the Riga Declaration, including a proposal to introduce three categories: "Open" (low risk),"specific" (medium risk) and "certified" (high risk), each with different safety requirements.

In the process followed regulatory amendments were made in the Regulation 216/2008 on common rules in the field of civil aviation, which established the European Aviation Safety Agency in 2008. NPA 2017-05 on Introduction of a regulatory framework for the operation of drones — Unmanned aircraft system operations in the open and specific category from 2017 summarized works and created foundation for 2018/1139 on common rules in the field of civil aviation, which position drone as a promising and progressive element of the future air traffic and airspace [16] and repealed 216/2018. The new regulation encompasses not only RPAS but all unmanned aircraft as per article 3, paragraph 30:"*any aircraft operating or designed to operate autonomously or to be piloted remotely without a pilot on board*".

III. EUROPEAN REGULATION ON DRONE OPERATIONS

The European Commission has recently published two delegated regulations on the systems of unmanned aircraft, drones or UAS and on their rules and procedures for use. This is Delegated Regulation (EU) 2019/945 [20] of the Commission of March 12, 2019 and Implementing Regulation (EU) 2019/947 [21] of the Commission of May 24, 2019. Regulation 2019/945 deals with the requirements of unmanned aircraft systems and the requirements to be met by designers, manufacturers, importers and distributors in order to obtain conformity markings and monitor the market for safety and interest in the competitiveness of it. Regulation 2019/947 deals with the rules and procedures for the use of unmanned aircraft by pilots and operators, defining categories of use and a series of requirements for their use.

Proposal to European Commission of the Opinion 01/2020 was presented in March 2020 to create and harmonise regulation framework for manned and unmanned aircraft to operate safely in the airspace, specifically, in the airspace where new set of services designated as U-Space are provided as form of digitalized air traffic control, to prevent collisions between aircraft and to mitigate the air and ground risks [22]. Therefore, the 01/2020 regulatory framework, supported by clear and simple rules, should permit safe aircraft operations in all areas and for all types of unmanned operations. This is the first regulatory step to allow immediate implementation of the U-space after the entry into force of the Regulation and to let the unmanned aircraft systems and U-space technologies evolve.

Commission implementing regulation (EU) 2020/746 was accepted to amend implementing regulation (EU) 2019/947 as regards postponing dates of application of certain measures in the context of the COVID-19 pandemic. The regulation postponed the applicability of regulation 2019/947 until 31.12.2020 and transitional period for UAS in the "open" category, which do not comply with the requirements of 945/2019 is extended to 30 months. More importantly, making information on UAS geographical zones publicly available in a common unique is extended to 01.01.2022.

CONCLUSION

The new common rules will make operating drones commercially and recreationally across European borders easier and safer. As the EU Aviation Safety Authority points out, the requirement that drones be registered and individually identifiable will both reduce the likelihood of major incident threatening air traffic infrastructure or other crucial and vulnerable elements of today's society. However, while the common rules replace existing national regulations in individual EU countries, member states will also be able to define so-called 'no-fly zones' (these may include airports and airfields, or city centres) where, through satellite geo-location, drones will not be permitted to enter, as well as areas where UAVs are allowed more freedom, such as beyond line of sight (BVLOS) flights. However, while the common rules 2019/945 and 947 replace existing national regulations in individual EU countries, member states will also be able to define so-called 'no-fly zones' where, through satellite geo- location, drones will not be permitted to enter, as well as areas where drones are allowed more freedom, such as beyond line of sight (BVLOS) flights, certify provider or providers of U-Space services and other supplementary services such as weather data or mobile network coverage. EASA aims to facilitate and help to comply with the regulation by issuing standard scenarios for drone operators to have access to. By and large, Europe might become the first region in the world to have a comprehensive set of rules ensuring safe, secure and sustainable operations of drones – both for commercial and leisure activities. With support of U-Space service allowing for higher degree of automation and certified drone operations bringing transportation of people, ongoing regulatory development fosters flexible and dynamic implementation of necessary technologies and processes.

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New knowledge of the use of technological sensors applied in aircraft tires

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***Abstract*- The article is focused on smart technology which uses in the aerospace industry for lasted identification and determines life cycle tires. Also discusses describing on simplification of maintenance for an aerospace company. Among the most important maintenance tasks belongs to tire pressure tracing. Tires with an implement radiofrequency chip are better maintained and shorten the time when measuring pressure in a tire.**

I. INTRODUCTION

The article includes new knowledge in the field of implementation of chips in aircraft tires. The article presents the possibilities of implementing RFID chips (tags). Using tags, it is possible to determine the degree of wear of the tire's service life. The typical life of an aircraft tire is given in the number of landings.

II. RFID TAGS IN AVIATION

While the advantages of RFID have been well-established on the ground — from supply chains to manufacturing plants to airports — extending those advantages to the airborne world has proven difficult.

Technology experts say it is past time for RFID to take to the skies.

RFID is a little amusing.Some applications, such as those used in the railroad industry in the United States, are well-established and have proven to be effective. But in the airlines where it's it in beginnig, it's creeping along. There has been a huge issue with (meeting) global standards.

Compatibility with other (radio) communications is problematic.There's a lot of promise here.

The FAA issued an RFID policy in May 2005, stating that passive RFID tags, which do not have a dedicated power supply and depend on a reader for operation, pose no security risk and are suitable for use in civil aircraft under certain conditions.[1]

III. "AERIAL" RFID

Following years of adopting RFID requirements for use in the aerospace supply chain, airline members are seeing substantial cost savings "in-flight," allowing them to track and control avionics and other products after they have been mounted.

As part of its traceability requirements, the Air Transport Association released Spec 2000 in 2004, which requires airlines and suppliers to use RFID to permanently classify parts and their life cycles, allowing for quicker and more precise identification of these parts during maintenance and supply chain processes when monitoring freight.

However, retailers, distributors, airlines, and government bodies all have different degrees of visibility standards when it comes to monitoring a specific piece of equipment or pallet of cargo by radio frequency after it leaves the ground. Getting them to work together has proven to be a challenging task.[1]

In October 2005, Boeing announced that RFID tags will be used on the 787 Dreamliner for "maintenance-significant components" to improve configuration control and better manage parts maintenance and repair inventories.

Intelleflex Corp., Santa Clara, Calif., was chosen by the airframer in April 2006 to provide 64 kilobit, UHF silicon chips for the tags. The high-memory chip will be included in Confidex's Ironside RFID tag, according to the company.

Boeing said it had successfully completed two in-service tests of passive RFID "smart labels" on a FedEx MD-10 freighter at the time of the Dreamliner announcement.

"The tests showed that passive RFID devices have no adverse effect on the simultaneous operation of any aircraft systems or interfere with continued flight safety," Boeing said. In 2006, Boeing and FedEx teamed up again to test the use of active RFID tags on an in-flight MD-10 freighter.

The active tags, which were supplied by Identec Solutions of Addison, Texas, were battery-powered and could read up to 300 feet, compared to the passive tags' 10-foot read range. [2]

The tags were placed in various areas of the plane, including the flight deck, avionics compartment, cargo compartment, and wheel wells, with the aim of detecting any possible electromagnetic interference.

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Boeing concluded that "active RFID devices do not adversely affect the operation of any aircraft systems or interfere with the continued safety of flight" following the assessment.[2]

IV. POSSIBILITIES OF RFID APPLICATION

The use of RFID tags embedded in rubber goods has made its way into tires.

The growth of radio frequency identification technology in the tire manufacturing industry has been exceptional.

The use of vulcanizate RFID tags on each tire regulates the tire's entire life cycle, from the manufacturing machine to vulcanization, relation to the end-user, and finally scrapping. RFID tags that can be customized have been created to help with fleet management, anti-theft solutions, and new commercial store models. Also small tire businesses, such as retreads and repair shops, may deliver new business models to local fleets by creating slots in a new or existing tire.

First arrivals, first exits, identification of unique/individual tires in the warehouse, inventory control, automatic clutch for orders, identification of gray imports, matching the tire with the end-user, and simple support for the removal process are all logistical problems that RFID tags can help with.[3]

Aircraft tire wear is a complicated process that is influenced by a number of interconnected variables.There is currently no certification test or reliable method for estimating tire life due to the numerous variables.

Although enhancing tire life has been shown to save up to $14 million over the life of such aircraft, the current United States Air Force (USAF) method for realizing such savings is a costly and time-consuming Life Cycle Cost (LCC) evaluation program. The US Air Force commissioned a 168-inch internal drum dynamometer (168i) designed specifically for aircraft tire wear testing in order to do more predictive laboratory wear testing. The Landing Gear Test Facility (LGTF) 168i of the 96th Test Group, Aerospace Survivability and Safety Operating Location (96 TG/OL-AC), has demonstrated the ability to compare wear test tires; however, its predictive wear capabilities require further growth. The results of these comparative wear tests have shown that simple tire wear predictive testing schemes can be produced based on tire, brake, and aircraft system level parameters. An initial predictive tire wear testing software is introduced and discussed based on these findings. A Finite Element Method (FEM) computational model has also been developed to aid predictive laboratory research in an effort to simulate an aircraft's Missionized Profile (taxi, takeoff, and landing).

These findings show that predictive tire wear research on the 168i, combined with FEM computational modeling, can be used to predict tire life before the tire is placed into service.[3]

V. POSSIBILITIES OF RFID APPLICATION IN AVIATION

Boeing and Airbus are reducing their parts inventory and speeding up aircraft repairs by using RFID tags (Radio Frequency Identification).

Each of these aerospace gigant has been using RFID for years, steadily extending its usage through their logistics, servicing, and manufacturing operations to collect more reliable and timely data.

Airbus was a forerunner in the use of RFID in the aerospace supply chain, considering projects as early as 2000. It now uses passive and active RFID to monitor work-in-progress, components, kits, equipment, and other elements in real time.[3]

It tracked nearly 3 million products used in aircraft production as of 2018. Managers and operators can see what's going on in real time with RFID, allowing for smooth interactions. In the beginning, Boeing used RFID tags to collect data for component histories by reading and writing data as each part was assembled, tested, or repaired throughout its aerospace supply chain.

This extensive history allowed for more precise lifecycle management for each part, lowering the costs of monitoring individual components.[3]

Boeing has extended active, passive, and UHF RFID monitoring to its internal manufacturing facilities since those early days. It now follows 7,000 pieces as they pass around a facility before being assembled into planes.

Passive RFID tags are now being used by aerospace manufacturers on individual parts before they are delivered to customers. According to industry sources, this aids manufacturers in reducing inventory and improving production performance. RFID tags help verify that third-party parts are authentic as RFID spreads across their aerospace supply chains. RFID tags embedded in components are being discussed in the industry to prevent 3-D printed parts from being substituted for original parts, reducing the use of unapproved parts and improving protection.[3]

Airlines Rely on RFID Tags From Supply Chains to Baggage

Passive RFID tags are now considered important in the operations of Boeing and Airbus.

Airlines and other aerospace companies are following their lead and integrating RFID monitoring into their operations. Since around 2015, Delta has used RFID in its maintenance operations. For example, by labeling each cabin's emergency equipment, it ensures that each life jacket, oxygen generator, oxygen tank, medical kit, defibrillator, and other item has the longest possible shelf life. Passive RFID tags are also used to classify and monitor tire inventory and other products. Since 2013, Lufthansa has been using RFID tags to replace manual object monitoring in its logistics, warehousing, and material supply systems. Initially, the tags were

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used to track items with expiration dates, such as sealers, adhesives, and paints.[3]

Passive RFID tags are also being used by airlines for passenger baggage as well. Resolution 753 of the International Air Transport Association (IATA) requires passenger baggage to be tracked at four points during a journey (effective in 2018). According to the International Air Transport Association, several airlines, such as Air France and British Airways, are moving from barcodes to passive RFID tags, claiming that they are more reliable.

When opposed to the normal practice of barcoding, an IATA study found that using passive RFID tags decreased lost and mishandled baggage by 25%. RFID tags allowed for quicker loading and unloading because they allowed for more automation. As a result, RFID baggage tagging is being implemented in Tier 1 and 2 airports worldwide.

NASA also uses passive RFID tags on the International Space Station to monitor tools and equipment as they travel across the space station.[3]

RFID Can Even Monitor Handling in the Aerospace Supply Chain

Although these companies use RFID tags to track parts as they pass through their aerospace supply chains and internal facilities, the tags can also be used to track how each component is treated and handled.

The ShockWatch RFID® tag from SpotSee effectively combines tracking and condition monitoring into a single application that can be handled easily via a warehouse management or enterprise resource planning framework.[3]

As a result of using ShockWatch RFID to prevent, detect, and diagnose harm, damaged parts – including those with concealed damage – are practically impossible to enter into inventory.

This is why:

- These passive RFID tags may be used in the field and record impacts that exceed certain thresholds.
- Any impacts that reach thresholds are read and entered automatically into the warehouse management or enterprise resource planning system each time a part's UHF RFID tag is scanned.
- When thresholds are exceeded, the passive RFID tags turn red, providing a visual backup to spot potential damage.[3]

Condition management is a constructive risk control strategy.Effect management systems, for example, have reduced supply chain harm by 40 to 60%.Such a program promotes transparency, and handlers are more cautious when they feel any harm can be traced back to them. Actionable Data Throughout the Aerospace Supply Chain with ShockWatch RFID

The procedure is straightforward – for example:

The RFID tag registered no impacts at point X but did when it was read at point Y, indicating that the impact happened between those two points. There is no doubt on who is to blame. When negotiating with insurers, selecting carriers, and designing packaging, this expertise is invaluable.[3]

Of course, risk management entails more than just assigning blame. Managers may plan ways to mitigate potential harm by understanding the impacts parts and components encounter before they are mounted. When assessing harm patterns, knowing the answers to the questions "what, where, where, and who" provides aerospace supply chain managers with the predictive data they need to improve the supply chain — retrain handlers, redesign packaging, upgrade processes, or switch logistics providers. It's simple to put the ShockWatch® RFID software in place to deter, track, and diagnose. Any current UHF RFID tag reader can read the tags. They also don't need line-of-sight, allowing them to be connected to components deep inside pallets or cartons and read remotely at each handoff.The tags are also tamper-proof.[3]

VI. RFID-BASED TIRE PRESSURE SENSOR

The method of measuring tire pressure is one of the more common and time-consuming activities associated with aircraft maintenance, whether commercial or private.

Aircraft owners and operators must ensure that all tires are fully inflated on a regular basis, normally every day or two, whether using a manual pressure gauge or an onboard cable sensor. It takes about an hour to manually calculate tyre pressure on a single aircraft.[4]

Some airlines and private jet operators have tracked this information using a radio frequency identification solution offered by Crane Aerospace and Electronics for the past seven years. Crane is currently applying for a Federal Aviation Administration (FAA) license for the use of an RFID-enabled SmartStem Wireless Tire Pressure Monitoring System at the request of a major airline that has applied for the appointment (TPMS).

Figure 1. The filling valve of the tire company Crane [4]

When testing tire pressure, aircraft operators must refer to the maintenance manual that came with the plane.

On-board systems calculate pressure and monitor cabin data, but not all aircraft are equipped with this feature, and some pilots still check the pressure manually because on-board systems aren't always reliable. Any air is released from the tire during each test if the

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normal form of manual pressure testing is used.As a result, the tire must be inflated on a regular basis to replace missing air. Not only can this be time-consuming, but it can also shorten the tire's lifespan.[4]
The sensor Crane proposes to replace the traditional wheel fill valve is the company's solution.
The sensor is provided by the company (or its dealers) to aircraft manufacturers, who then mount the gauge on customer tires, as well as the aircraft operator. A hand-held RFID counter is used to detect the meter, which records temperature and pressure data as well as a specific sensor identification number. Crane's technology includes Phase IV Engineering's readers and labels, which were provided by Colorado Wireless Engineering Company. Only the Crane reader is capable of detecting the meter's RFID tag.

Figure 2. SmartStem handheld reader [6]

A passive Phase IV SensIC chip with a frequency of 134.2 kHz is included with the TPMS sensor, and it contains an encoded unique identification number as well as information about the aircraft itself, which is stored in software on a handheld device.
Despite the fact that SmartStem uses LF RFID technology, Crane does not refer to its technology as RFID (due to concerns that customers might incorrectly assume that RFID always uses the high-frequency bandwidth).
This is a significant difference, according to the company, because customers may assume that high-frequency RF transmissions could interrupt cockpit operating systems.[4]
The meter also has a pressure and temperature sensor, and the reader reads data from all of these sensors at the same time. The collected data is then shown on the device's front screen, and data records from the handheld can be transferred to the maintenance monitoring machine via USB or Bluetooth. Given the world in which the sensors will have to work, identifying the best technology for the solution has proven difficult. [5]
Temperature spikes, shocks, and vibrations that the tires are subjected to have made it difficult to mount devices that need batteries, such as active RFID, according to reports.
Instead, with a passive approach, the reader's inductive signal switches on the RFID chip, which obtains temperature and pressure data and then forwards this information to the reader. The 1024-bit chip memory can also store other data, such as tire location on a particular wheel in the aircraft, as well as how it behaves, depending on the measured temperature and pressure. [5]

Users may also use their software program or a basic Microsoft Excel spreadsheet to perform additional historical data analysis. They can then assess how well the tires are doing, which ones need to be refilled more often, and when they should be replaced. [5]

Figure 3. Reading data from a manometer [4]

VII. CURRENT STATUS

Michelin, in collaboration with the aircraft equipment manufacturer Safran, has developed a tire with automatic wireless tire pressure measurement. This innovation will facilitate and speed up ground flight maintenance and has passed a successful air test. Originally a French company, the Michelin company is a traditional supplier in the field of aviation, footwear for small and large transport aircraft as well as military machines. He recently joined forces with another French player - Safran Landing Systems - a successful developer and the largest supplier of landing systems, which he manufactures for Airbus, for example. The result of their joint project is the first wirelessly monitored tire with the PresSense system.[8]
PresSense is a wireless embedded system to facilitate ground maintenance. An electronic sensor collects tire pressure data and transmits it remotely. Measurements are saved and the results can be checked via the web interface. This innovation will make it easier for airlines to maintain their fleet. The connected sensor is connected to the reader and it is connected to the database, which in practice means that maintenance workers will no longer have to perform valve checks manually using a manometer. The ground tests were carried out by the PresSense system at the beginning of 2019, and now tire monitoring must be tested in real flight conditions. The first sharp and successful tests in the air took place in June at the Istres air base in southern France on a Falcon 2000EX aircraft from Dassault Aviation. Further flight tests on other types of aircraft will take place in late 2019 and early 2020. Frank Moreau, senior vice president of Aircraft Business Line Michelin, said: "Tires play a crucial role in aircraft safety during takeoff and landing. With PresSense, we can guarantee the right pressure, plus shorter measurement times in all circumstances and at any civilian airport. "Continuous improvement of safety

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is a crucial part of Michelin's approach to sustainable mobility. The first successful flight of the monitored tire is a milestone in our history and we are proud to have been able to share this moment with our partner Safran." Ongoing flight tests are in the last phase of PresSense system development, these innovative tires are scheduled to enter the market in 2020. [8]

CONCLUSION

The presented article addresses an issue that is very topical given the situation in air transport. At present, the complex logistics process in air transport, which also includes activities related to safety in interaction with maintenance, is becoming increasingly important. The malfunction of air transport due to insufficient maintenance of aircraft, in particular maintenance and replacement of tires, is the cause of the failure of the transport process and the emergence of serious safety risks.

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Possibilities of Using Magnetically Detectable Filament for the Magnetorquers Cores Production

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Abstract- The magnetorquers are one of the most used subsystems designed for an attitude control, detumbling and stabilization of the nanosatellites, based on the interaction between Earth's magnetic field and generated magnetic field. Their power performance is largely dependent on the properties of the ferromagnetic core that is used to amplifies the magnetic field generated by a torquer winding. The crucial parameter of the ferromagnetic core is its shape on which the magnitude of the demagnetizing field depends. Since the demagnetization field acts against magnetization of the specimen, there is an increase in power consumption of magnetorquer to obtain required magnetic field. There are studies referring the impact of the shape of specimen on demagnetization field. According to these studies the most precise value of demagnetization field can be obtained in case of specimen with ellipsoidal shape. However, only prismatic shaped, or cylindrically shaped ferromagnetic cores are used for the magnetorquer. The reason is the technical complexity of the feasibility of an ellipsoidal shaped ferromagnetic core. The way how to treat with this problem can be use of 3D printing. Nowadays there are several thermoplastic filaments which contains defined amount of the ferromagnetic particles, but their magnetic properties are not well known. Therefore, also magnetic characteristic of different specimen shapes made by these filaments are unknown. This article deals with possibility of ferromagnetic filaments usage for the ferromagnetic core production. For this purpose, the various shapes of cores have been printed and measured. Each specimen was magnetized by varied applied magnetic field to obtain magnetic hysteresis. The measurements of the specimen magnetization as the function of magnetic strength are presented and analyzed in the article.

I. INTRODUCTION

The development of the nanosatellite is currently a significant trend in the area of engineering research and space science technologies. The nanosatellites are low-cost space craft systems well known for its small dimensions (typically $10x10x10\ cm$), fast delivery advantages, low mass and power consumption. The most of them are designed and constructed under the auspices of universities as research project based on the commercially available technologies.

Due to their small dimensions, it is not possible to use certain technological systems that are commonly used in the larger types of satellites. Typical example of this kind of restriction is the usage of attitude control system (ACS). Full-scale attitude control system commonly used on the large satellites is generally too large to be installed on nanosatellites. Therefore, another technological solution had to be used. Since the typical operational altitude of the nanosatellite is in a low earth orbit range (LEO), an magnetorquers actuators were developed.

The magnetorquer actuator generates a magnetic dipole moment that interacts with the geomagnetic field to create a control torque to obtain desired orientation of the nanosatellite. The magnetic dipole moment is generated by magnetorquers coil, better known as solenoid, where certain amount of current produces a corresponding magnetic moment. For the purpose of amplification, a ferromagnetic core is implemented into the solenoid. If the appropriate material of core is chosen, the amplification of generated dipole is significant. In general, the main goal is to choose the magnetic material, which during its magnetization process can generate required magnetic field with the lowest possible excitation current. As a result, lower power consumption is ensured. Typically, a soft ferromagnetic material such as nickel-iron or cobalt-iron alloys are used.

However, during the process of core magnetization, a demagnetization field is also created. It arises due to bounded magnetic moments located on the edges of sample and try to act against its magnetization. The

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demagnetization field is functionally dependent just on the shape of the sample, so must be considered during design process of core. Inappropriate core shape can have a significantly bad effect on the efficiency of the magnetorquer.

In order to determine demagnetization field of magnetized sample, the demagnetization effect of some geometrical bodies was quantified. This quantification is set in form of dimensionless coefficient called a demagnetization factor. The precise value of the demagnetization factor can be determined only in case of ellipsoidal shaped bodies. Nevertheless, the most common cores for magnetorquers application are in the shape of right cylinder or rectangular prism. The reason is that the production of the elongated ellipsoid core by the commonly used alloys is technologically demanding.

II. MAGNETIC DIPOLE MOMENT- NOTION OF ELETROMAGNETISM

The magnetic dipole moment is one of the most important parameters to ensure the required stability and attitude control of the nanosatellite. It determines the efficiency of the control torque so the specific magnetic dipole moment must be obtained to overcome on-orbit disturbances such as external torque due to aerodynamic drag, solar radiation and Earth magnetic field. The relationship between control torque and generated magnetic dipole moment is described by the following expression:

$$\vec{\tau} = \vec{m} \times \vec{B} \qquad (1)$$

where $\vec{\tau}$ is the control torque given as cross product of magnetic moment $\vec{m}$ and geomagnetic field $\vec{B}$. From (1) it is clear that $\vec{m}$ must be increased in order to receive higher value of torque $\vec{\tau}$. Since $\vec{B}$ is inversely proportional to operational altitude of satellite, the higher value of magnetic moment must be generated to obtain same control torque at higher altitude (in case of same position of both magnetic vectors).

The vector of magnetic moment is the function of magnetic field strength H and comes from two separate sources, the solenoid and magnetized core. These are the key components of magnetorquer that must be considered during design phase to ensure the required magnetic moment to control angular momentum of nanosatellite.

A.Magnetic dipole moment od solenoid

The magnetic field strength H at the centre of the finite solenoid can be calculated according to following equation [1]:

$$H_{(x=0)} = \frac{NI}{l} \cdot \frac{l}{\sqrt{d^2 + l^2}}, \qquad (2)$$

where N, l and d denote the number of turns, the length and diameter of the solenoid, respectively and I represent the current in the windings. If the winding of the solenoid consists of more than one layer, the diameter d may be replaced by the average value of the inner diameter d_1 and outer diameter d_2:

$$d_{av} = \frac{1}{2} \cdot (d_1 + d_2). \qquad (3)$$

If consider a long solenoid, where $l >> d$, the term d^2 can be neglected with respect to l^2 so (1) is simplified and quantification of magnetic strength in the centre of solenoid is then given by the well-known relation [1]:

$$H_{(x=0)} = \frac{NI}{l}. \qquad (4)$$

From (2) and (4) it is obvious that more numbers of turns generate greater magnetic dipole moment at the constant current value. However, in order to obtain more turns, the longer conductor is needed, which leads to an increase in the resistance of the conductor and, ultimately, in the weight of magnetorquer. In case of length and diameter of solenoid the dependence is inversely proportional, so higher value of l or d must reduce magnitude of generated dipole moment. These features of the solenoid must be considered during design process of the magnetorquer to obtain required magnetic dipole moment for specific operation phase of the nanosatellite.

B. Magnetic dipole moment of core

The core is an important part of magnetorquer since it increases the generated magnetic field and thus magnetic dipole moment. Increase occurs when the material of the core has a positive magnetic susceptibility χ_m, which is in the case for paramagnetic and ferromagnetic materials. The magnetic susceptibility is a measure of how much a material will become magnetized in an applied magnetic field. It is the ratio of magnetization M to the applied magnetic field H:

$$\chi_m = \frac{M}{H}. \qquad (5)$$

Correlation between magnetic susceptibility and relative permeability μ_r of material is given by

$$\mu_r = (1 + \chi_m). \qquad (6)$$

If consider, that

$$\mu = \mu_0 \mu_r, \qquad (7)$$

where μ is the total permeability and μ_0 is permeability of vacuum, from (5) we can obtain following expression [2]:

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$$\mu = \frac{B}{H}. \quad (8)$$

From the (7) it is obvious, that for magnetorquers application ferromagnetic cores are preferred over paramagnetic due their higher permeability, which leads to substantial reduction in power consumption. However, the ferromagnetic materials have magnetization curves which exhibit nonlinearity and hysteresis [6].

There are two main types of ferromagnetic materials: soft and hard magnetic materials. Hard ferromagnetic materials have a high remanence magnetization and high hysteresis loses. They retain a large value of magnetization so the high magnetic field must be applied to demagnetize them. On the other hand, soft ferromagnetic materials have lower remanence magnetization and lower hysteresis losses, makes them preferred core materials. Due to their small value of coercivity can be easily magnetized and demagnetized, which leads to smaller power consumption and almost negligible remaining dipole moment produced by the magnetorquers after it is turned off [6].

The magnetic flux density $\vec{B}$ generated by the ferromagnetic core material is given by

$$\vec{B} = \mu_0\vec{M} + \vec{H}_d, \quad (9)$$

where $\vec{M}$ is the current state of magnetization of ferromagnetic core and $\overrightarrow{H_d}$ is the demagnetization field.

Inserting ferromagnetic core into the solenoid, the magnetic field inducted by running current magnetized it, therefore the effect of cores magnetization must be taken int the account to estimate total magnetic flux $\vec{B}_{tot}$, which is given by the sum of (9) and (4) (in case of long solenoid) [2]:

$$\vec{B}_{tot} = \mu_0\vec{H}_0 + \mu_0\vec{M} + \mu_0\vec{H}_d$$

$$\vec{B}_{tot} = \mu_0(\vec{H} + \vec{M}) \quad (10)$$

where $\vec{H}_0$ is magnetic strength generated by solenoid and $\vec{H}$ is the resulting magnetic strength given by the sum of $\vec{H}_0$ and $\vec{H}_d$. Since $\vec{M} = \chi_m \cdot \vec{H}$, the (10) can be transformed to the following form:

$$\vec{B}_{tot} = \mu\vec{H}. \quad (11)$$

It is necessary to realized, that μ holds constant value only for linear dependence of $\vec{B}$ and $\vec{H}$. Otherwise, if the material is subject to hysteresis (i.e. ferromagnetic materials), μ is a complex function of the magnetic strength $\vec{H}$ and the previous state of magnetization, so $\vec{B}$ cannot in general be calculated according to (10) [3].

C. Demagnetizing field

The presence of an external magnetic field around the ferromagnetic sample of final dimensions causes, in addition to its magnetization, the formation of demagnetization field inside the sample. The direction of this demagnetization field is opposite to the direction of the applied external field, so its tries to reduce it, and thus the magnetization of sample. The emergence of the demagnetizing phenomenon inside the sample is caused by the bounded magnetic dipoles concentrated in the area of the sample edges [3]. Since the density of bounded magnetic dipoles is proportional to the magnetization of sample, the attenuation of strength of the applied magnetic field can be expressed by the following equation [3]:

$$\overrightarrow{H_d} = -N_d\vec{M}, \quad (12)$$

where $\overrightarrow{H_d}$ is the magnetic strength of demagnetizing field and N_d is the dimensionless coefficient called demagnetizing factor, the size of which depend only on the shape of the sample. According to (12), the resulting magnetic field strength is given by

$$\vec{H} = \overrightarrow{H_0} + \overrightarrow{H_d} = \overrightarrow{H_0} - N_d\vec{M}, \quad (13)$$

and thus [3]

$$\vec{H} = \frac{\overrightarrow{H_0}}{1 + N_d\chi_m} \quad (14)$$

Substituting (14) into (11), the total magnetic flux density $\vec{B}_{tot}$ is given by

$$\vec{B}_{tot} = \frac{\mu_0\mu_r\overrightarrow{H_0}}{1 + N_d\chi}. \quad (15)$$

Based on (15) the magnetization must be expressed to obtain magnetic dipole moment of core $\vec{m}_c$, which is related to magnetization via

$$\vec{m}_c = \int \vec{M}dV, \quad (16)$$

where dV is the volume element [3]. From (10) and (15), the magnetization of core can be calculated according to:

$$\vec{M} = \left(\frac{1}{\mu_0} - \frac{1}{\mu}\right) \cdot \vec{B}_{tot}$$

$$\vec{M} = \left(\frac{1}{\mu_0} - \frac{1}{\mu}\right) \cdot \frac{\mu_0\mu_r\overrightarrow{H_0}}{1 + N_d\chi}$$

$$\vec{M} = \frac{\overrightarrow{H_0}(\mu_r - 1)}{N_d(\mu_r - 1) + 1}. \quad (17)$$

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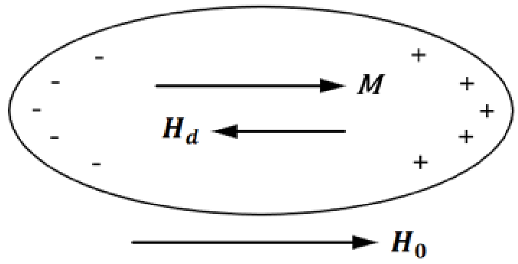

Figure 1. Magnetic fields inside magnetized sample

Integrating (17) with respect to volume, the magnetic dipole moment generated by core is obtained:

$$\vec{m}_c = \int \vec{M} dV = \frac{NlS(\mu_r - 1)}{N_d(\mu_r - 1) + 1}, \qquad (18)$$

where expression NlS is the magnetic dipole moment of solenoid given by following expression:

$$\vec{m}_s = \int \vec{H} dV = \int \frac{NI}{l} dV = Nl\vec{S}, \qquad (19)$$

Now, the total magnetic dipole moment generated by magnetorquer can be expressed as the cross product of (18) and (19):

$$\vec{m} = \vec{m}_c \times \vec{m}_s, \qquad (20)$$

As can be seen from (18), the magnetic dipole moment of core depends not only on permeability of material, but also on the shape of core, the impact of which is determined by demagnetization factor N.

In general, the calculation of the demagnetization factor is a relatively complex process. Assuming that the shape of the sample is irregular, the value of the demagnetization factor does not change continuously within individual parts of the sample volume. For many geometric objects, the exact determination of the demagnetization factor is not feasible. An unambiguous, and therefore the most accurate, calculation can be achieved in the case of homogeneously magnetized samples, which applies only to ellipsoids and their geometrically related bodies [2].

To determine the demagnetization factors of arbitrary shaped sample with non-homogenous field the numerical methods must be applied. According to these methods the demagnetization factors of the various shaped samples has been calculated [4]. The demagnetization factors of the objects, which geometrically correspond to the most used shapes of magnetorquer ferromagnetic cores, are listed in the table 1. For the purpose of calculation, the formula for prolate rotational ellipsoid is also listed.

Need to be mentioned, that the demagnetization factor of cylinder and rectangular prism calculated according to these formulas can only be considered as an approximation.

TABLE 1. Formulas for the demagnetization factors calculations

Prolate rotational ellipsoid	
$N_e = \eta(p)$	$\eta(p) = \frac{1}{p^2 - 1} \cdot \cdot \left[\frac{p}{\sqrt{p^2 - 1}} ln(p + \sqrt{p^2 - 1}) - 1\right]$
Cylinder, magnetized longitudinally	
$N_v \approx N_e \cdot k(p)$	$k(p) = \frac{1 + 2{,}35 \cdot \ln(1 + 0{,}137 \cdot p)}{1 + 2{,}28 \cdot \ln(1 + 0{,}284 \cdot p)}$
Plate, magnetized longitudinally	
$N_h \approx \approx \eta(p_{\eta\varphi}) \cdot k(p_{\eta\varphi})$	$p_{\eta\varphi} = \frac{L}{2} \cdot \sqrt{\frac{\pi}{S}}$

note: p is aspect ratio given by $p = \frac{L}{D}$, where L is length and D is a diameter in the thickest part of the ellipsoid. S is a base area of prism.

III. DESIGN AND PRODUCTION OF CORES

For the purpose of mutual comparison, the two types of cores have been designed. The first one is in the shape of prolate rotational ellipsoid. The body of this kind of shape has in its longitudinal direction the lowest demagnetization factor among all ellipsoidal shaped bodies, which is suitable for the magnetorquers core application. The main reason for that is of course the lower mass and power consumption of the magnetorquer. However, despite their benefits the ellipsoidal shaped ferromagnetic cores are not used due to their demanding production. There are certain limitations in the conventionally applied production method for making ferromagnetic cores from commonly used alloys. These technological limitations are related to complex quadratic surfaces of ellipsoids. The second one has been designed in the shape of right cylinder. It is the most common shape of core in the magnetorquers applications. Generally, the cylindrically shaped bodies have a little smaller value of the demagnetization factor than the prolate ellipsoids (in case of identical geometrical proportions) and much smaller than rectangular prism which is also quite common shape of the magnetorquer cores.

The all-important parameters of the designed cores are shown in table 2. As can be seen, the table 2 contains the values of the demagnetizing factors and the values of geometrical properties. In order to achieve higher authenticity, the geometrical properties of the designed cores were chosen to dimensionally match with the magnetorquer cores commonly used for the nanosatellite application.

The demagnetizing factors for both cores were calculated using formulas from table 1. and

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geometrical parameters listed in table 2. Due to their geometrical proportions the calculated value of the demagnetization factor of the prolate ellipsoid gains smaller value than demagnetizing factor of the right cylinder so the demagnetizing field of ellipsoidal shaped core must reach lower value as well, therefore its generated magnetic dipole moment must be higher. Based on the parameters from table 2. CAD models of the cores were created. For this purpose, the Creo parametric software was used. Consequently, both models were printed using three-dimensional printer- Prusa i3 MK3S. In order to obtain the best magnetic properties a magnetically detectable filament was used. The printed cores are shown in the Fig 2.

As can be seen in Fig 2. on both cores there are visible filament layers made during printing process. It can be considered as structural inhomogeneity, which may cause magnetic shape anisotropy and must be taken into the account during analysis of measurement results. This undesirable structural condition is from the most part given by printer features related to its nozzle.

TABLE 2. Parameter of ellipsoindal and cyllindrical shaped cores

Parameter	Values	
	Ellipsoidal shaped core	**Cylindrically shaped core**
Length L [m]	0,070	$0{,}040\,m$
Diameter D [m]	0,005	$0{,}080\,m$
Volume V [m^3]	$1{,}806 \cdot 10^{-6}$	$2{,}010 \cdot 10^{-6}$
Demagnetization factor N_d [-]	0,004	0,015

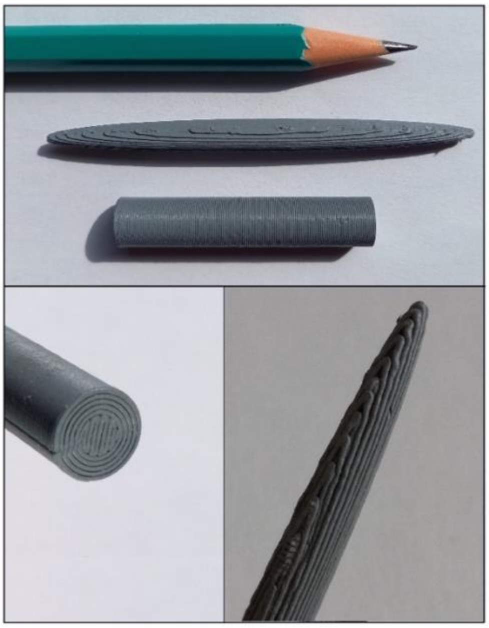

Figure 2. 3D Printed ellipsoidal and cylindrical core

IV. MEASUREMENT OF MAGNETIC CHARACTERISTICS

In order to determine the magnetic properties of produced cores the several measurements were performed. The main goal of the measurement was to obtain hysteresis model of the printed samples, better known as the hysteresis loop, which defined the dependance of magnetization or flux density on the applied magnetic field strength. According to this well-known graphical characteristic the magnetic properties such as hysteresis loses, magnetic saturation, coercivity force and remanence of the measured magnetic material can be obtained.

For this purpose, the stray field measurement method was used. The essence of this method is to measure stray magnetic field of the magnetized sample. Both cores were magnetized in their longitudinal direction by the time-varying magnetic field generated by solenoid, in which the currently measured core was stored during measuring process. With each change of the applied magnetic field, the value of the stray field was sensed by a probe. Based on the measured stray field, known demagnetization factor, geometrical properties and position of the sample with respect to the probe, the magnetizations of cores were calculated. The applied magnetic field strength was calculated based on the properties of coil and time varying current value.

The measurements and calculations were performed automatically by four channel magnetometer VEMA-04 with parameters presented in [5].

The measurement results are shown in the Fig 3. and Fig 4. as the dependence of magnetic polarization P on the applied magnetic field strength H_0. Interdependence between magnetic polarization and magnetization is given by

$$\vec{P} = \mu_0 \vec{M}. \qquad (21)$$

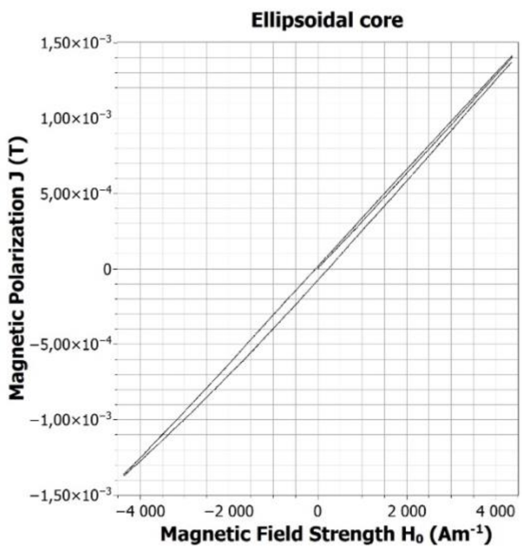

Figure 3. Magnetic Polarization vs. Magnetic field Strength for ellipsoidal core

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As can be seen in both figures there are not expected hysteresis loops typical for ferromagnetic cores. From Fig 3. it is obvious that measured characteristic of the ellipsoidal shaped sample has patterns of magnetic material so the most magnetic properties can be determined. However, its behavior is not acceptable for magnetorquers application due to small values of magnetization.

In case of cylindrical shaped sample, the measured values of magnetization are in comparison with ellipsoidal shaped sample smaller by three orders, therefore the whole characteristic is way more affected by the ambient noise (see Fig 4.). Consequently, its magnetic properties could not be determined unequivocally.

The primary reason for this unacceptable behavior of the used materials may be caused by a significant disproportion between the thermoplastic polymer and the ferromagnetic particles, which are randomly distributed in the volume of both samples. Based on this, it is obvious that during the magnetization process individual magnetic domains of the samples are not arranging in the preferred direction and consequently a single dominant domain in the entire sample volume is not created. The ferromagnetic particles are magnetized independently of each other hence it is not possible to measure the magnetization of the whole sample, only the combination of individual magnetic moments of these individual ferromagnetic particles and their concentrated clusters can be measured.

Its needs to be considered that these particles are mostly spherical in shape. Since demagnetization factor of the sphere is $N_s = 1/3$ there must be significant reduction of the total magnetic field. It may explain the small values of measured magnetizations.

For the sake of completeness, it should be mentioned that there is also noticeable contribution of the demagnetization field given by the geometrical properties of the whole bodies. Based on this statement, the smaller magnetization of cylindrically shaped sample can be caused by the demagnetization effect, functionally related to its body geometry. This is Because, as mentioned above, the demagnetization factor of cylindrical core is higher than the demagnetization factor of ellipsoidal core (see Table 2).

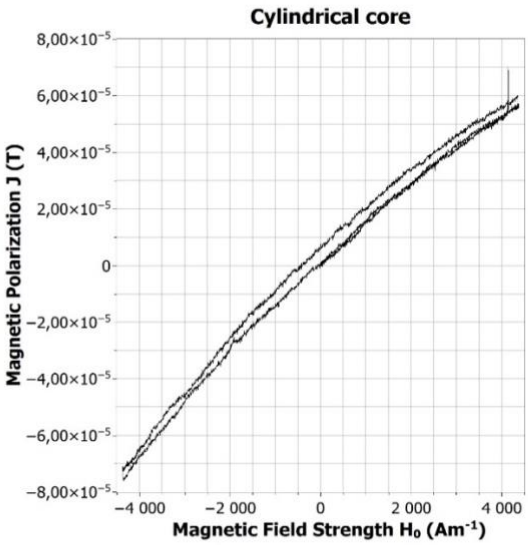

Figure 4. Magnetic Polarization vs. Magnetic field Strength for cylindrical core

CONCLUSION

This paper has demonstrated the potential use of the ferromagnetic filament for magnetorquers core productions. Ferromagnetic cores are generally one of the most crucial elements of the stabilization and attitude control subsystems. The efficiency of such systems strongly depends on the ability of the ferromagnetic cores to amplify the generated magnetic dipole moment, which interacts with geomagnetic field in order to achieve required satellite position. To obtain desired magnetic dipole moment the appropriate shape and material of core must be chosen. For this purpose, equations for magnetic dipole calculations were shown and discussed. According to these calculations, the two types of cores were designed and subsequently printed. The first one was printed in the shape of an ellipsoid and the second one in the shape of a cylinder. After the manufacturing process the several measurements was performed. Based on the measurements results the discussion with relation to the used material and geometric properties of produced cores was taken.

This paper has demonstrated that produced cores made of ferromagnetic filaments are inappropriate for magnetorquers applications, no matter of core shape and thus the accuracy of demagnetization field determination.

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Analysis of pilot properties when controlling an aircraft in the longitudinal plane

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***Abstract* - The article is focus on the analysis of the pilot's characteristics when piloting an aircraft in the longitudinal plane. The input signal of the pilot in the control circuit is the signal of deviation of the required position of the aircraft from its actual value, the output is the effort that the pilot must make to control the aircraft using the control stick. We can replace the properties of the pilot with a unit that eliminates the control deviation, that is, the mismatch between the instantaneous and necessary values of the controlled flight parameter.**

I. INTRODUCTION

The pilot plays a very important role in the aircraft control complex and is an inseparable part of the whole system. Analyzes of the pilot's ability to control the aircraft in the longitudinal plane are understood as a human analysis in control using sensory organs as a sensor and executive organs as muscular parts of the body that provide the required tasks. Therefore, it is important to understand the problem of the pilot as a human member in the system, and to design a mathematical model that will define as closely as possible the behavior of man in the process of aircraft control. [1] This behavior can be further analyzed according to the abilities, experience, education, age, and psyche of the pilot, but to simplify the mathematical model, we need to unify some of the properties.

The input signal is a sudden change or deviation of the desired position of the aircraft from its actual value, which is understood as a deviation or change in the position of the aircraft in the longitudinal plane. The output signal is thus the effort that the pilot must make to control the aircraft with the control stick in order to reach the desired state of the aircraft. The desired state of the aircraft is the state of either returning the aircraft to the position before the input signal, stabilizing the unstable aircraft back to a stable longitudinal plane, or adapting to a new stable position. This state is simulated in the MATLAB / Simulink simulation environment.

Values of different values were entered for the simulation, which show different properties of the pilots. The output of the simulation are values that show in what time pilots with different characteristics and experience are able to stabilize the position of aircraft in the longitudinal plane.

The stabilization of the aircraft in the longitudinal plane in the simulation system is understood as the complete attenuation of the noise with a smaller deviation, which was caused by the input signal and the subsequent signal configuration.

II. OBJECTIVE OF THE RESEARCH

When operating an aircraft, a person must record and process various information, including its transmission to the necessary movements to control the aircraft. [2] Real human behavior in performing the necessary tasks is difficult to determine in time, especially when fatigue and consequent loss of attention are taken into account. In addition, there are other tasks in which the pilot must adjust the method and strategy of the flight due to the change in aircraft dynamics over time. [3] The human pilot is affected by four main variables: task variables, environment variables, operator (pilot) variables, and process variables.

First are the task variables, which include the inputs of systems that enter control but without the help of a pilot. These systems are displays and manipulators that have a very large impact on the pilot.

The second type is environmental variables, which include factors such as ambient lighting, temperature, vibration, G load, atmospheric conditions, etc. [4] These factors can be very unpleasant to control an aircraft and can greatly affect the entire flight. In very poor environmental conditions, it is necessary for the pilot-in-command to have sufficient experience to be able to fly safely. The third type is aimed directly at the pilot or operator. There are important factors that must not be forgotten, and their importance must be taken into account. These factors include stress, fatigue, training, motivation, practice, and others. These factors can be expressed in units of time as a delay or response. [4] The fourth are process variables, representing practice, instructions, and necessary piloting commands.

The sum of all these above variables directly affects the pilot in the control of the aircraft, and are very

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important elements. For this reason, even when creating a mathematical model, it is necessary to take into account all these variables and transform them into numerical or temporal form.

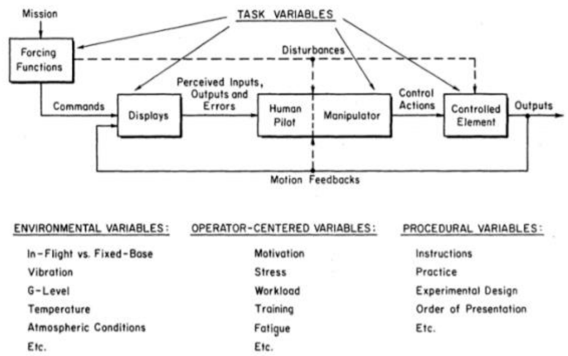

Figure 1. Factors affecting the pilot while control [4]

A. The neuromoscular system of the pilot

The pilot's nervous-muscular system is affected during the control of the aircraft. It has developed into a sophisticated sensor set that consists of natural sensory organs. The central nervous system is best suited for slight angular rotations of short duration also occurring on the ground. The system takes it for granted that it perceives reality, but often rotations with low intensity and long duration during flight occur. As a result, misperceptions occur, resulting in disorientation. This is perceived as a situation in which the pilot is not able to correctly determine the position of the aircraft and its movement.

The nervous system is based on the physiological activity of the human muscle. It represents two types of muscles: extrafusion and intrafusion.

Extrafusion muscles make up more muscle and are responsible for generating strength.

Intrafusion muscles, on the other hand, disperse throughout the muscle and provide a degree of feedback to the central nervous system. [5]

The pilot uses sensory organs to control the aircraft. In the central nervous system, the received information is processed, and in the muscular part, the required tasks are performed. By combining these two parts, the pilot can effectively control the aircraft. The movement of the muscle elements is directly proportional to the movement of the control stick, which subsequently deflects the control surfaces of the aircraft, which shows the output member from the control circuit. However, in order for the movement of the muscle parts to be performed at the right time and with the necessary force, it is necessary for one to use sensory members, which also function as feedbacks. One of the many important factors is that the pilot perceives more the effort he has to make to steer the aircraft than the movement of the steering stick itself. If the pilot's control effort is affected, a steering failure occurs.

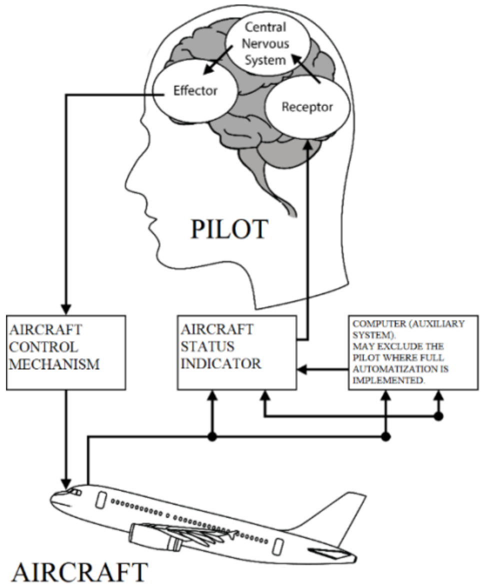

Figure 2. Pilot in the control of the aircraft

B. Visual system

It is the primary source of information needed to maintain orientation in space. The visual system serves mainly for spatial orientation and relies on certain stimuli. These represent movement, distance, inclination and tilt in three-dimensional space and a linear and aerial perspective. The biggest advantage and feature of the visual system is its ability to subconsciously process information and provide a stable perception of the environment over a large spatial range. [5] It achieves this ability by adding a low-frequency signal to the central nervous system, which can then determine the spatial orientation.

C. Vestibular system

The role of the vestibular system is to control and sense the movement of the body. The system is located in the inner ear of the human body and consists of otoliths and semicircular canals. [5] Otoliths give the pilot a feeling of tilt during the flight, which is caused by pressure. This feeling also arises during the long-term shooting of the aircraft and the subsequent launch of the aircraft on the horizon. The pilot feels that he is still tilted. Semicircular channels, on the other hand, serve the pilot to perceive the angular acceleration. [6]

The difference is visible especially when comparing the data of the pilot with the simulator and from the real flight.

III. MATHEMATICAL MODEL OF THE PILOT

The pilot's mathematical model is widely used in analyzes. From the result it is possible to find out the processing of flight characteristics, stability, control, behavior of the pilot - aircraft, considerations about the

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reactions of the pilot when changing information on displaying systems. To begin with, to create a pilot model, basic known information must be used, which are specific physical examples for setting up individual blocks in the system. If the values are entered correctly, the system should evaluate the control of the aircraft in the given situation, and the consequent expected intervention of the pilot in the control. These values are unique to each pilot due to the uniqueness of each human operator. The quality and completeness of the mathematical model depends on the number of flight data collected. [7]

The mathematical model represents all the above factors and the pilot's behavior in version of numbers or time. The creation of a mathematical model requires knowledge of human behavior in the aircraft control environment and the subsequent processes involved in the performance of control. Behavior is the use of auditory and visual signals to estimate the status of an aircraft at a given time. [8] When creating a mathematical model, this behavior must be translated into such a way that the individual activity of the pilot and the individual factors affecting the aircraft operator can be expressed. Subconsciously, visual, vestibular, and proprioceptive signals are processed as inputs to be able to provide position, angular, and linear acceleration estimates. [8]

It is very difficult to model the pilot's perception in a mathematical model. What is crucial is an accurate estimate of the dynamic response of the pilot's perception, especially when it comes to instrument flight. This is because the visual mode of the environment has little effect on the pilot's perception.

To create a mathematical model, the program MATLAB / Simulink was used. The quality of the control process depends on the accuracy of the mathematical model of the controlled system, including the transport delay. [9]

The mathematical model can be used as a separate element, which has its own input and output. This part of the pilot's model was created in the Simulink simulation environment, where the input to the system is a signal generator, which causes a rapid change in control using the displayed changed signal at a given time. This generator can be set to a part of the flight to produce any change in the position of the aircraft as a fault or sudden change in altitude or loss of altitude. This fluctuation can result in: turbulence, unwanted or accidental interference with operator control, engine failure and subsequent starting with position stabilization, and other aspects that can cause a sudden change.

The next part is the pilot delay block. Represents a delay in the pilot's response to an error. This means that the moment the aircraft changes position or drops its altitude, for example, the human operator would not be able to react at that immediate moment. [10] Therefore, it is important to enter a delay in the system to respond to the generated signal.

After a delay, the pilot gain factor must be entered in the system. The coefficient represents all pilot habits for the specified aircraft control types. If a situation occurs that it takes the pilot a long time to intervene in the control, the system could become unstable. This statement also applies if there is a sudden change in system reinforcement during the management process. [11]

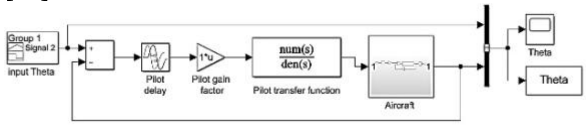

Figure 3. Pilot Behavior mod

The main part of the pilot model is the pilot transfer function. The transfer function includes time constants and time responses that are tailored to the operator and express his capabilities.

Subsequent parts of the model in Simulink, show the numerical expression of the aircraft in the longitudinal plane.

A. Pilot Mathematical Model Studies

The mathematical model is based on studies where the first of the mathematical models that laid the foundation for the expression of human behavior was designed by the scientist McRuer. To this day, his mathematical model of human behavior in aircraft control is used, as well as the connection between a machine and a human operator. McRuer's studies analyze the basic element of transmission from the point of view of automated control. They also focus on the analysis of human behavior, internal processes in receiving optical, sound and movement reactions. [12]

$$F_{(s)} = \frac{Y_{(s)}}{X_{(s)}} = K\frac{(T_3 s+1)}{(T_1 s+1)(T_2 s+1)}e^{-\tau s} \quad [10]$$

K - pilot gain factor

τ - pilot delay response to received signal

T_1 - Delay time constant related to learned stereotypes, pilot procedures and their implementation. Repeated situations of the pilot lead to his learned habits. This condition causes the pilot to gradually use brain activity.

T_2 - Nerve muscle time constant representing the pilot's delay in his activity. The delay is caused in a neuromuscular manner. This includes the muscles and sensory organs that work at the level of the spine.

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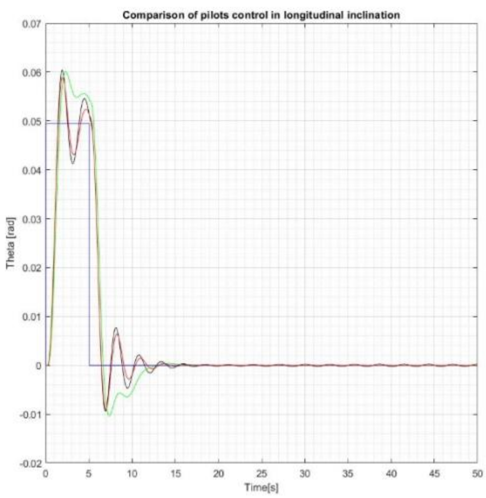
Using the spine (spinal cord), the brain can receive information and then respond to the external environment.

T_3 – Time constant related to the pilot's experience. Explains the pilot's ability to anticipate that something may happen. The ability to plan and take further action under any circumstances is possible by estimating or predicting the future situation. This is the highest level of situational awareness. [4] The pilot therefore has the ability not only to understand the current situation, but also to predict future situations. Pilots will acquire this ability through training and the amount of experience gained.

IV. ANALYSIS OF THE PILOT MODEL

The main part of the article is the analysis of the pilot model. The analysis of the model consists in the fact that the consciously set coefficients have obtained the necessary outputs. These outputs are obtained from the values and time coefficients set according to the previous part of the article. The coefficients represent a less skilled pilot, a skilled pilot and a pilot who has values set at the level of a fast-perceiving pilot, but with slow responses. The controlled parameter is the longitudinal inclination of the aircraft Theta in radians [rad], per unit time T in seconds [s].



Graph 1. Expexted/modeled reactions of pilots in longitudinal stability control

Graph 1 shows the reactions and values of a less skilled pilot. The value entered at the input shows the change in the position of the aircraft longitudinal inclination, and then shows the reaction of a less skilled pilot. It is marked in black. As graph 1 shows, the perception of an error and a change in aircraft position in longitudinal inclination is slow and delayed. The initial reaction, on the other hand, is aggressive and too skewed. Consequently, the response of the aircraft, which returned to its original position in longitudinal inclination, is not stable. The less skilled pilot intervenes late again, destabilizing the aircraft again. It is clear from graph 1 that the aircraft stabilizes only after a long time, but there may still be a situation where the aircraft will not be stable.

Another pilot is shown in red, where we can also see the perception and reaction to the situation. The graph shows that the operator responds very quickly to a change in aircraft position in longitudinal inclination, has a quick response and deflects the steering with sufficient force. The subsequent return of the aircraft to a stable position in longitudinal inclination is in a relatively short time.

Graph number 1 shows the reaction of the third pilot, who quickly perceives a change in the position of the aircraft in longitudinal inclination but does not yet have sufficient skills and abilities to be able to stabilize the aircraft as quickly and efficiently as possible and return to its original state in longitudinal inclination. It is marked in green. When the signal is deviated, it can be seen that the stabilization time of the aircraft is not as short as in the case of pilot number 2, but he performed the required task in less time than pilot number 1. The pilot is so skilled that he controls the aircraft's reactions at a high level.

By analysing all three graphs on one screen, the reactions, abilities, skills, and perception of system pilots are visible and comparable. The graph shows the differences and the importance of all factors, if even one factor changed, it immediately affects both the system and the human pilot.

The values shown in the graph represent the position and reaction of the aircraft in the longitudinal inclination to the deflection of the control stick controlled by the pilot.

CONCLUSION

The article describes, displays, and analyses the systemic human mathematical model of the pilot. The first pilot, shown in graph 1, has inferior abilities according to the mathematical system because if this system is tested and compared, he will choose a human operator who has actually flown zero or minimum flight hours. Pilot number 2 represents the pilot in the graph, who has already flown considerable hours, can assume and react appropriately to the situation. Pilot number 3 shows and will be compared with a pilot who has actually flown very few hours and masters the basic theory and is already accustomed to the behaviour of the aircraft.

The analysis that has been performed at a longitudinal inclination, can also be used for further research. It is proposed to analyse the system pilot in comparison with the human pilot. This would represent a comparison of the outputs from the flight simulator.

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LUQA airport before and during the COVID-19 pandemic

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***Abstract*— The current Covid-19 pandemic has hit airports and airlines around the world. A pandemic lasting more than a year has forced several carriers to close down. Many countries and airports have been completely closed to passenger air traffic and the situation is not at all favorable for the coming months. A recent study by Eurocontrol states that by 2024, air transport should reach 2019 numbers in early 2025. However, this is due to the fact that the population will start to be vaccinated against covid-19 as early as 2021. the general crisis did not escape even the popular holiday state of Malta and Luqa Airport. The aim of the article is to analyze the effects of the COVID-19 pandemic on air transport at the mentioned airport. A major challenge for Luqa Airport in a time of pandemic is how to deal with an emergency for canceled routes and a loss of passengers. The article is part of a research aimed at identifying the negative effects of a pandemic on the world's aviation industry.**

I. INTRODUCTION

Luqa Airport on the island of Malta as the only international airport in the state of Malta. It is located south of Italy and the nearest international airport is Catania. The airport belongs to the Wien group, which includes the Swechat airport in Vienna itself and the third is the airport in Košice, Slovakia. Malta is a popular holiday destination and is visited annually by more than 8 million passengers, mostly to this picturesque island by air. In the second world pandemic, it caused not only million damage to Luqa Airport but to all airports around the world. Many have addressed the question of how to proceed and how to deal with this pandemic. Edib Ali Pehlivanlı began writing a several-page study like all this in her article. The year 2019 was a year that no one will forget and in modern history they have marked people all over the world. Air transport suffered the most, which was completely paralyzed in places and, apart from cargo flights, it was almost non-existent. [1].

The aim of this article is how a small airport on the island of Malta, washed by the Mediterranean, was able to cope with the lockdown and the ban on flights for several weeks and months, with a decrease in passengers and a reduction in flights. The article is focused on the load factor and average seating capacity, but also on the cargo flights themselves. The information itself was obtained from the official website of the Vienna Group and its annual reports.

II. AIR TRANSPORT AT LUQA AIRPORT

Codeed by the International Association for the Improvement of Airports IATA - MLA and by the International Civil Aviation Organization ICAO - LMML, Luqa Airport is the second largest airport in the Wien group with passengers and cargo carried. It opened its gates on March 25, 1992 with 1 terminal for passengers. Compared to Košice Airport, it handles 12 times more passengers a year with an average number of 6.8 million. The holiday season in Malta is long, but travelers visit the island throughout the year. Basically, until the first two months of the year, the airport is under a surge of passengers. The airport connects 64 cities mainly in Europe and North Africa, which can be reached either by regular or charter flight. Due to the fact that Malta is an island in great demand, there is a demand for cargo transport, either on board flights with passengers as cargo, but mainly on separate cargo flights. The demand for freight transport increased dramatically in 2018 and this trend continued for another year. The airport is a base for the domestic airline Air Malta and the low-cost carrier Ryanair. These two carriers also carry the most passengers on their aircraft and fly to the most destinations. The already mentioned carrier Rynair's unit on the Luqe in a close line is behind us Air Malta and together they have over 35% share on all flights.

Figure 1. LUQA Airport [2]

EasyJet, Lufthansa, Wizzair and Turkish airlines are far behind them. Top destinations are Gatwick Airport in London and Fiumicino in Italy. As a result of the pandemic, the promising airport was hit hard, and like all airports in the world, they also had to think as far as possible how to use the airport as efficiently as possible.Since 2016, the airport has grown by a double-

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digit percentage increase every year, and 2019 was the highest in the entire history of the airport, with 7.3 million passengers carried. The biggest impact on the airport was in 2020 and the decline itself, which began in March due to the pandemic, continued throughout the year. As can be seen in the picture, the airport fell by 76% compared to 2019 by more than 5.5 million passengers to 1.74million passengers. They have not had such a result in the last 20 years of the airport's operation [2].

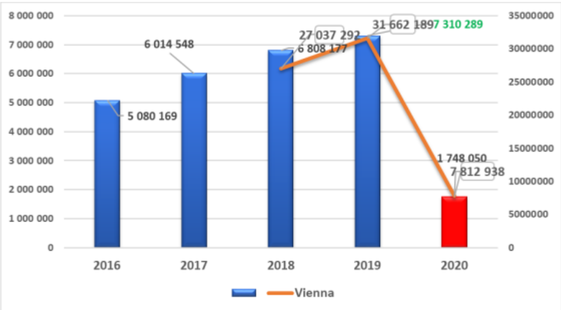

Figure 2. Total number of passengers at LUQA airport from 2016-2020 (self processing)

One of the factors in the increase in the number of transported persons was the increase in all flights. In 2017, the growth was the highest by up to 20%, which had a significant impact on the increase in the number of passengers by 18%. On the other hand, the load factor decreased slightly, which ultimately also had an impact on economic indicators, namely the negative ratio of flight growth to passenger growth [3]. The following year it was balanced and as the number of flights grew, so did the number passengers. 2019 was a turning point for Luqa Airport, as the best and balanced increase in the number of passengers and flights slightly increased the load factor. From an economic point of view, it was a success, as the aircraft were, on average, slightly fuller than in the past.

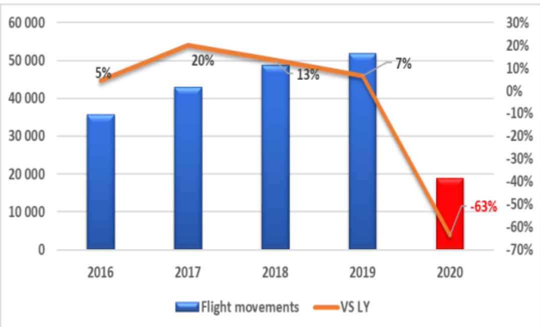

Figure 3. Movements of all flights at Luqa airport in the years 2016-2020 (self processing)

At the beginning of 2020, air traffic was still at the level of previous years, but began to decline gradually in March, and this downward trend continued until the end of 2020. It was the worst year in 20 years for the airport.

They were forced to react immediately to the situation and the decline in passengers due to restrictions due to the

pandemic and bans on civil flights [4]. As can be seen in the graph below, they managed to react quickly to the change and the mentioned load factor fell by only 35%. On the other hand, the number of flights decreased by 63% and the total number of transported passengers fell by as much as 76%.

It is a high number that has a big impact on the economy and the airport will recover from this loss for a long time. The International Civil Aviation Association estimates that it will be at least 5 years or more [5]. The airport had to look for alternatives and the decision was made to focus on freight cargo transport, which is crucial and important for the entire island state. Most of the goods are transported to the island of Malta by air, as evidenced by the quantity that is transported through the airport. On average, it is more than 16 thousand tons per year. Compared to Košice Airport, which on average transports only 60 tons of cargo per year, a huge number. Since 2016, freight transport has grown. The airport recorded significant growth in 2018 and immediately thereafter in 2019 with a total of 16422 tonnes [6].

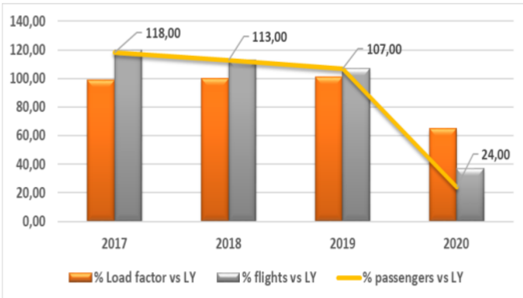

Figure 4. Load factor compared to the number of flights and passengers (self processing)

Freight transport was expected to decline during the pandemic, similar to civilian transport, but only at a slower pace. The opposite was true, as the airport reached the level of 2018 in 2020 and decreased by only 4% year on year. It was the freight that helped Luqa Airport economically. In 2021, it is expected that air transport will continue to grow significantly. This is also indicated by the predictive linear method.

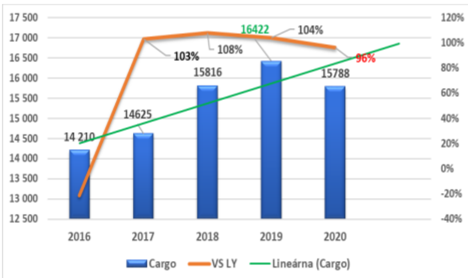

Figure 5. Total Cargo at Luqa airport since 2016-2020 (self processing)

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III. DISCUSION

Based on the information and data of the Wien group, of which Luqa Airport is a part, it is clear that the pandemic also affected them and they did not avoid the historically highest declines and losses in civil aviation. 2020 was not only the worst for Luqa Airport, but for many airports around the world. They fought the pandemic bravely and were remarkably able to use the situation for themselves and focus their forces on freight transport. The graph below shows that freight traffic at Luqa Airport will develop rapidly in the coming years, and even the 2020 pandemic did not slow it down. It is remarkable how they coped with the pandemic and maintained the trend before this period, which began at the end of 2019. The airport used the situation to its advantage and quickly adapter to the market and demand in freight transport.

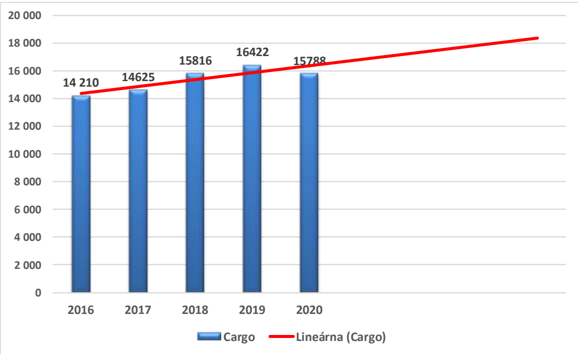

Figure 6. Development of Cargo at Luqa airport with a 5 year forecast (self processing)

Very few airports in the world have been able to maintain this trend, and many have fallen by tens of percent in freight traffic. Therefore, even in the future, the airport will be able to better respond to current challenges, which may recur in the future and thus may be better prepared to handle them immediately and respond immediately. As the only one in the whole group, they decreased by only 4% year-on-year. Schwechat Airport alone fell in freight transport by 23% and Košice Airport by as much as 87%. Regarding the decrease in passengers, all 3 airports were at a loss level from 75% to 82%. The situation is still not improving as expected and with the advent of the second wave of the pandemic in Europe, it does not look good for the coming months. The European and American Aviation Agencies predict such a pandemic situation until 2025. For the next period of air transport in Malta, it remains to be hoped that international traffic will revive at least by summer 2021. If such a scenario continues, several mainly charter but also charter network carriers not only in Europe will have existential problems.
Conversely, civil aviation will suffer for several years. Malta is a very popular holiday destination and all air traffic in Malta is dependent on charter flights, when in the summer months the onslaught at the airport is greatest. The best months of the year are from June to September. The hope will be covid passports that will allow people to travel and refuel airline planes.

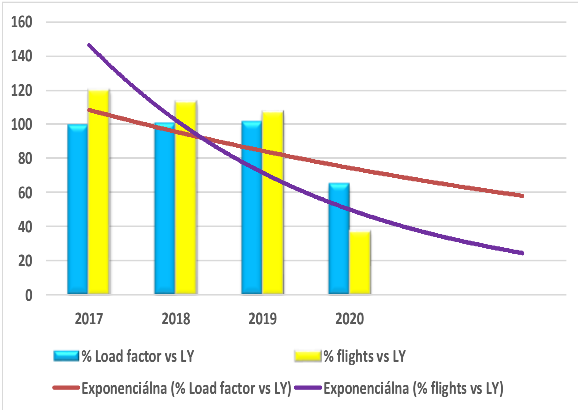

Figure 7. Development of Cargo at Luqa airport with a 5 year forecast (self processing)

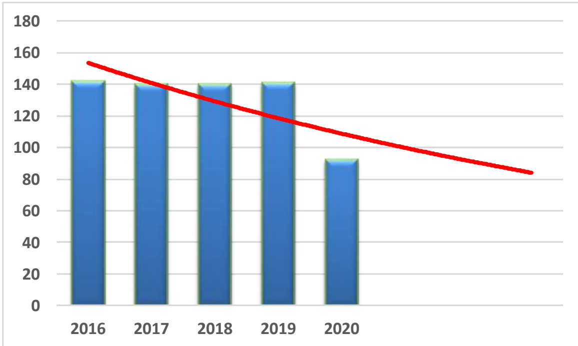

Figure 8. Load factor at Luqa airport with a 5 year forecast (self processing)

It remains to be hoped that this pandemic will soon pass and that everything will gradually return to normal before the pandemic period. The forecast for the next period is cautious and the development will depend on the pandemic. The exponential curve on the graph shows the gradual growth of civil transport.

CONCLUSION

It is clear from this investigation that Luqa Airport has handled the pandemic very well. They reacted very quickly to the drop in passengers and made flights more efficient in a very short time, either by reducing and canceling or changing the frequency. Thus, they managed to keep the load factor at an acceptable level. On the other hand, they made very good use of the potential of Cargo transport.
It is noteworthy that compared to other airports, they managed to maintain the trend from the previous year and fell by only 4%. This is the best result within the Wien group. This is also due to the fact that the island is dependent on the supply of goods and most of the goods pass through Luqa Airport. The vision for the future in civil transport is uncertain and the preconditions for a return to the years before the pandemic are in the horizon of 5 years.

A similar assumption has been published by the International Civil Aviation Organization (ICAO). For freight transport, the growth trend will be much more and it is assumed that in 2021, even with the partial revival of civil transport, it will exceed the numbers from 2019. Not only Luqa Airport, but the whole world will be recovering from this pandemic for several years, and it will depend on each airport how it can react to the re-imposition of measures and get closer to the numbers before the pandemic as soon as possible. At the same time, after the collapse of some airlines, it will depend on which of the current airlines will fill the free space of slots at airports.

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Concept of optimization of UAV operators training and evaluation

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***Abstract*— The paper presents a concept of a system for optimizing the training of operators of unmanned aerial vehicles and their objective evaluation by the measurement of onboard control signals and real-time tracking of the vehicle position. The system for the control signal measurement consists of a programmable logic device and a microcontroller with wireless communication. For the tracking of the vehicle a position system using ultrasound was considered. The article describes the current methods for practical training of UAV operators and the proposed changes for the optimization of the training processes by the evaluation of the collected flight data from the measurement and tracking systems based on a human model.**

I. INTRODUCTION

Unmanned aerial vehicles (UAVs) are currently very popular and are used in various industries. In the past, these drones were used only in the military, but today UAVs also find more and more civilian use. They are used, for example, in video production, photography, surveying, science and research, or in various other sectors [1], [2], [3], [4]. Our department also conducts research into the use of unmanned aerial vehicles equipped with magnetometers for the purposes of non-destructive archeology [5].

There is currently a worldwide amendment in process to the legislation on unmanned aerial vehicles, where great emphasis is placed on defining different categories of operation according to the size (weight) of UAVs and to the qualifications of remote pilots and operators.

As the technology of commercial drones is still relatively new and constantly evolving and the number of their users is growing around the world, there are obvious differences in the legislation and rules of flying in different countries. There are also countries in the world where they have not yet begun to address this issue or are just beginning, and also countries where flying with unmanned aircraft is completely banned. These major differences in rules can also be seen in the European Union.

Therefore, efforts have been made for a long time to harmonize legislation between EU Member States in order to avoid such large differences in rules and legislation when flying a drone in different states.

The new regulation of unmanned vehicles in the European Union has been in force since 31.12.2020 and divides their operation into three categories: *Open, Specific* and *Certified* [6]. The most common category is the *Open* category, which includes most operators and remote pilots of unmanned aerial vehicles. The *Specific* category is for riskier operations that are not included in the Open category. To operate in this category, an operating permit for drone operators from the relevant national aviation authority where they are registered is required. The *Certified* category corresponds to the operations with the highest level of risk. Future drone flights with passengers on board, such as air taxi services, will fall into this category. The approach used to ensure the safety of these flights will be very similar to the approach used for manned aviation.

The *Open* category is further divided into three subcategories - A1, A2, A3 - which can be summarized as follows: A1 – flying over people, but not over assemblies of people; A2 – flying close to people; A3 – flying far away from people.

Each subcategory has its own sets of requirements. Therefore, in the *Open* category, it is important to identify the subcategory of operations to which the current flight activities fall, in order to determine which rules apply to us and the type of training that needs to be completed. It is important to identify the type of drone by checking the class identification plate (C0, C1, C2, C3, C4) if it is a new generation of drone, or alternatively by checking its weight.

For flights in subcategories A1 and A3, which are considered the least dangerous, as with category A1 only very small UAVs can be operated and with category A3 flights can be performed only outside of inhabited areas, only theoretical exams are mandatory, which can be performed on-line. These exams consist of topics about the legislation, technical and meteorological concepts for UAV operation and human factors.

For category A2, as it enables operation of mid-sized drones in close proximity of uninvolved people, a stricter theoretical exam needs to be performed at the respective aviation authority and also a practical exam, where the remote pilots have to demonstrate their abilities in a safe operation of the UAV. However, at present there are no measures involved for the objective evaluation of the flight performance of these pilots, they are only subjectively evaluated based on the instructor's experience.

The aim of this work is therefore to present the concept of a system for monitoring the pilot's control inputs to the UAV combined with a commercial system for tracking the drone mid-flight with the purpose of objective evaluation of the pilots.

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II. THE PRACTICAL TRAINING OF REMOTE PILOTS

There are numerous standard exercise maneuvers used for the training of the remote pilots, starting with basic movements of the UAV, for example takeoff and landing and small movements in each direction. If the candidates are already acquainted with the basics of UAV control, simple maneuvers follow, so far only in one direction, but at relatively greater distances. The first such sequence of maneuvers is a takeoff with the drone at a distance of 10 meters from the operator and subsequent forward and backward movements and landing at the take-off site. Then, in the next exercise, it is possible to make a landing at a place other than the take-off point and a subsequent flight back to self. If the remote pilots are already able to control the unmanned vehicle safely during these basic maneuvers, they proceed to more complex ones, where all these movements are combined.

The first more complicated maneuver is a flight along a square figure, which is shown in Figure 1. The pilot takes off with the drone close to himself and flies forward to a certain distance. He then stops at that point and flies the same distance to the side. From that point, he flies backwards parallel to the first flight segment and then, in a lateral motion, arrives at the take-off point and lands. In the basic version of this exercise for ease of control, the drone is oriented all the time with the back side to the pilot, so it always moves in the direction in which the lever on the controller is deflected.

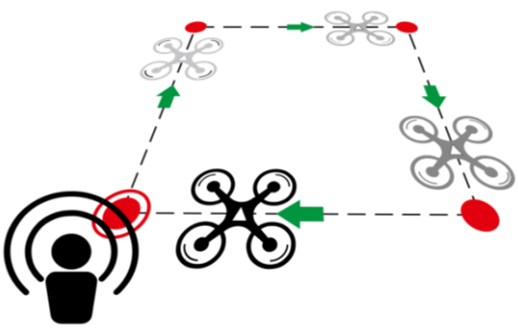

Figure 1. Flight along a square figure

Another exercise is flying around a circle, shown in Figure 2. This maneuver is more complicated because the pilot has to move the control levers smoothly at all times to achieve the correct circular trajectory. However, it is still only necessary to use the levers for elevator and aileron control and the drone always moves in the direction in which the levers are deflected.

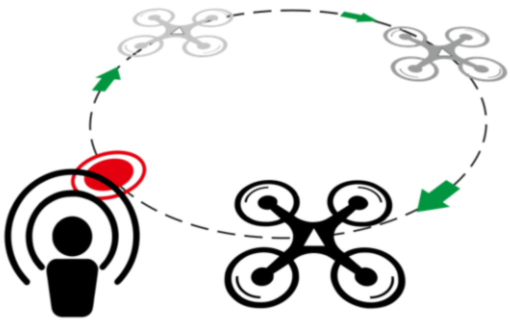

Figure 2. Flight along a circle

If the operator is already able to perform these two exercises correctly, their complication follows by turning the drone forwards to him. In this case, all the controls become inverted from the pilot's point of view, so he must also consider the orientation of the UAV.

Another possible variation is when the drone points always in the direction of flight. Then the pilot must manage the unmanned vehicle differently for each segment of the trajectory. In this case, the circle flight also complains that the operator must continuously regulate all four control axes at all times.

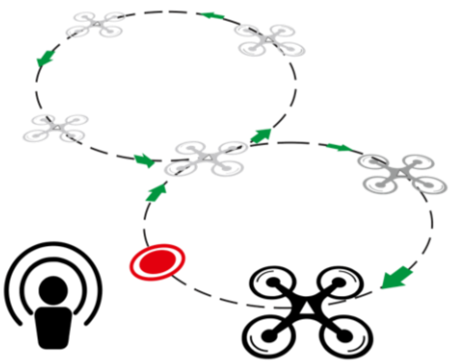

Figure 3. Flight along a figure 8 pattern

The last standard exercise for multicopter flight is the flight along the pattern 8, shown in Figure 3. It is basically a flight in two circles, with the direction of flight changing at the midpoint. With this exercise, the remote pilot trains turning in both directions.

III. SYSTEM FOR EVALUATION OF PILOT PERFORMANCE

The maneuvers presented in the last chapter can be also used for the objective evaluation of the pilots' performance if the UAV is equipped with a system for precisely monitoring the control inputs and also with a system for tracking the UAV's position.

Since the most widespread UAV autopilot systems like ArduPilot or PX4 support logging of all flight data including control inputs and aircraft position based on GNSS systems, we could consider this as a solution for this problem [7]. However, the logging rate of these systems is

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relatively low (maximum at 25 Hz), which is inadequate for the precise measurement of the control inputs. The other problem is that due to reasons concerning safety and legislation, the training of the operators should be carried out indoors, where is no GNSS coverage, so an indoor tracking system should be used.

The proposed solution for these problems is the use of a complex monitoring system consisting of a custom system for the measurement of the control inputs and a commercially available ultrasound-based system for the UAV tracking.

A. *Control signals measurement system*

The most popular signals for transferring control inputs from the remote pilot to the flight controller are PWM (pulse-width modulation) and CPPM (cumulative pulse-position modulation). Pulse-width modulation is a form of digital signal in which data is expressed in pulse widths and the repetition frequency of the signal is constant and equal to the sampling frequency. The pulse width to the corresponding analog sample is usually expressed by the relation

$$t_P = a \cdot x + b, \quad (1)$$

where t_P is the pulse width, x is the value of the analog sample, a is the multiplicative constant expressing the sensitivity and b is the additive constant of the signal offset. The constant a can have both positive (direct proportionality of the input signal and pulse width) and negative (indirect proportionality) value. The b constant ensures the offset so that the pulse width value is always positive. Pulse-position modulation is a form of digital signal where data is expressed by the position of the pulse within a period. For servo signals in unmanned vehicles, a special type of PPM signal (also called PPM-Sum or CPPM) is used, in which a sequence of PWM channels (maximum 8) are combined into one PPM channel.

The system for the control signals monitoring is based on the measurement of these PWM and CPPM signals. The part for the PWM measurement was already completed, the CPPM part still needs further development. We used two main hardware components: a field-programmable gate array (FPGA) and a microcontroller platform. The FPGA is used for the measurement of signal parameters and the microcontroller for further calculations, communication through Bluetooth, and data storage on SD card.

The measurement system operates on the basis of independent measuring channels of the PWM signal created in the FPGA, which consist of counters, registers with averaging filters and control circuits. Several such channels (in the basic version 8, but it is possible to extend) are connected to a common clocked register for output synchronization and then to a communication module, which controls the data transfer from the gate array to the microcontroller.

Table 1. shows the basic technical parameters of the measuring system. It is capable of measuring eight channels of PWM signal simultaneously. To extend the measurement system with CPPM signal measurement channels, it is necessary to slightly modify the structure of the measurement chain in the FPGA by creating one eight-channel controlled register, into which a pair of counters enters (for measuring pulse time and gap time). The input is switched to the next channel at each pulse and back to the first after the eighth pulse. The output from this eight-channel register can then proceed to a common clocked register with the PWM channels and subsequently to the communication module.

B. *Indoor UAV tracking*

There are several solutions for tracking objects in interiors. The simplest such systems work on the basis of Wi-Fi or Bluetooth connection of the tracked object with several static stations [8]. However, these solutions are mainly used to determine the presence of an object in a given room, they are not intended for accurate location.

Other solutions use ultra-wideband (UWB) radio signals [9] or ultrasound signals for the time-of-flight measurement of distances between the tracked object and the static stations. For our purposes, the use of an ultrasound-based system is the most suitable as it gives a real-time accurate position of the UAV with sufficient sampling rate, while being cheaper than UWB systems and less susceptible for interference.

From the commercially available indoor positioning systems we chose the Marvelmind Super Beacon system which consists of several ultrasound beacons which can act as static base stations as well as the mobile tracked beacon.

TABLE 1. Technical Parameters of the PWM Measurement system

Parameter	Value	Unit
No. of PWM channels	8	
Supply voltage	5	V
Input signal voltage	3.3	V
FPGA clock frequency	50	MHz
Sampling rate with Bluetooth	200	Hz
Sampling rate with SD card storage	500	Hz
Total weight of the measurement system	150	g

The precision of this system is ±2 cm with sampling rates up to 100 Hz. A connection to at least 4 stationary beacons is required to pinpoint the location of the mobile beacon (similar to the GPS system). However, the Marvelmind system also offers advanced modes designed specifically for accurately determining the position and orientation of unmanned vehicles using multiple beacons [10].

The first special mode is the precise determination of the flight altitude. If all stationary beacons are located in the same plane (x, y coordinates), the determination of the z coordinate of the mobile beacon will be less accurate if it is close to the plane of stationary beacons as the geometry of triangulation implies. The solution to this problem is to use two more auxiliary stationary beacons, which are located at a different height in a common plane with a pair

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of stationary beacons from the basic group, but perpendicular to the plane of the basic four beacons. This second level ensures the exact determination of the z coordinate of the monitored object [11].

The second special mode is to determine the orientation of the UAV. For this, a pair of mobile beacons are placed on the monitored object next to each other at a distance of 10-15 cm. The mutual position of this pair of mobile beacons is then defined in the control software and the orientation of the monitored object is determined from the difference of their measured position.

Fig. 4. illustrates the concept of the beacon layout in a hall for testing unmanned vehicles and training their operators using these two special modes of operation. Using this or a similar configuration will allow the complete and accurate determination of the position of the unmanned vehicle in all three spatial axes as well as the rotation about the z axis.

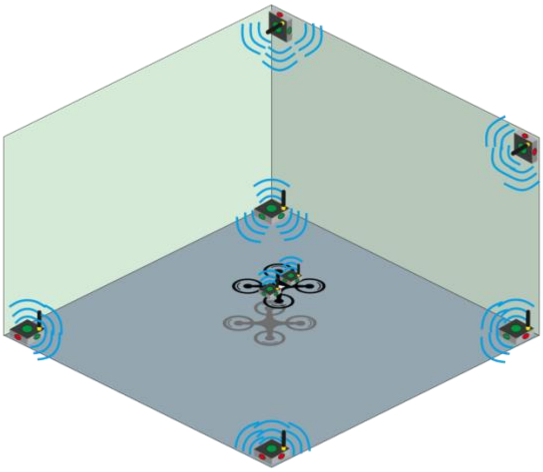

Figure 4. Concept of Marvelmind beacons placement

C. Evaluation of the pilots based on the human model

In order to achieve greater objectivity in the evaluation of remote pilots, they should be considered as regulators of a control system and the parameters of their cybernetic model should be addressed [12].

The basic equation describing the mathematical model of human behavior using elements of automatic control, which can be understood as a basic mathematical model of dynamic properties of the pilot, is the following [13]:

$$F_{(s)} = \frac{Y_s}{X_s} = K \cdot \frac{T_3 \cdot s + 1}{(T_1 \cdot s + 1) \cdot (T_2 \cdot s + 1)} \cdot e^{-\tau s}, \quad (1)$$

where K is a gain coefficient representing the pilot's habits for a given action, T_1 is the time constant indicating the pilot delay for the activity given by the neuromuscular system, T_2 is the time constant characterizing the readiness and dexterity of the pilot, T_3 is the predictive time constant related to the pilot's experience, τ is the time constant indicating the delay in the response of the pilot's brain to movement and eye perception and s is the Laplace operator.

From the data collected from monitoring the remote pilot’s control input and tracking the position of the UAV the parameters of the human model can be calculated. Based on these information, the performances of the remote pilots can be better compared to each other and a baseline can be set for their objective evaluation.

Also, other useful information of the pilot’s behavior can be collected. By monitoring the pilot during the flight around the square pattern, for example, it is possible to find out how much the control uncertainty increases when the UAV is oriented with the front side to the pilot (and lateral movements are practically inverted) compared to when the drone is oriented with the rear.

In another variation, when the aircraft is always pointing in the direction of flight, it is possible to determine whether the pilot is always aware of its orientation. Similar information can be collected when flying in a circle or pattern 8, and the pilot must continuously regulate the orientation of the UAV. From the sequence of such exercises, it is possible to reveal exactly which maneuvers the pilot has the greatest problems with and to adjust the training so that he focuses more on these areas.

CONCLUSION

Unmanned aerial vehicles are currently widely used in various industries and applications and are increasingly available to the general public. In order to ensure the continuity and especially the safety of air traffic, despite the increasing number of users of unmanned aerial vehicles, efforts are being made to create appropriate conditions for their theoretical and practical training. Quality study materials and evaluation methods already exist for theoretical training, but practical training needs to be optimized by creating a technical solution and the right methodology for objective evaluation of the remote pilot’s performance.

In order to meet the stated goal, it was necessary to design a concept of a monitoring system that is able to measure control signals from the pilot to the flight control system and monitor the position and orientation of the unmanned vehicle. Based on this, a system was created for measuring PWM signals on board UAVs, which are the most common control signals, and also a commercial system for object tracking was chosen.

In the further continuation of this work, it will be necessary to create a superior system for the management of practical flight exercises, with which it will be possible to synchronize all components of the measuring chain and also to issue commands for performing maneuvers by pilots. This will make it possible to accurately measure the reactions of pilots in various flight situations and their performance in more complex flight maneuvers, on the basis of which it will be possible to objectively assess their performance based on the cybernetic human model.

An important task will be to perform test measurements with several pilots with different skills in the control of unmanned aerial vehicles from complete beginners to professional operators. This will make it possible to fine-

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tune the training methodology and performance evaluation and to create a standardized system for the practical training of unmanned aircraft pilots.

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The influence of COVID-19 on MRO processes

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***Abstract*— The Covid-19 crisis has not only affected air traffic by decrease amount of flights, even at the beginning of its almost complete down. Maintenance organizations (MROs) were also affected following the suspension of traffic. The quick reactions and reorientation, with the aim of increased safety, had to be adapted to the then used work procedures for aircraft maintenance. The intention is to gather the measures which were implemented, which are constantly being improved in line with new knowledge on the transmission and spread of SARS – CoV – 2 virus. The implementation of measures to mitigate the effects of disease risks and its transmission had to be retrained and staff had to be supervised to ensure that safety risks were maintained in the aircraft maintenance process. Maintenance organizations have shifted to parking and storage policy, and with parking aircraft, it is possible to talk about conservation of aircraft technology at airports, which are already crowded.**

I. INTRODUCTION

In December 2020, the WHO issued an internal document compilation of findings on the spread of SARS CoV2. Evidence suggests that the virus spreads from an infected person in a drip from the mouth and nose to uninfected individuals in the vicinity of the infected person. The virus can spread through the air during talk, coughing, sneezing, these particles can be transmitted through microscopic droplets, we are talking about aerosols, through the mucous membranes in the nose in the mouth but also through the eyes.

During the work, the worker may encounter a direct or indirect way through the virus or contact with the carrier of the SASRS-CoV-2 virus. It is worth mentioning that the way we can get infected is caring for a person who is infected or quarantined, coming into contact with surfaces that have either not been disinfected or have been insufficiently disinfected. If we catch these objects and do not disinfect the skin of the hands by washing or a suitable disinfectant applied to the skin in the correct way. Even incorrectly applied, the most effective disinfection is ineffective if the application procedure is not applied correctly or is not followed. If there is a virus carrier nearby, the risk of a virus infection is greater. SARS-CoV-2 is able to spread in aerosol form, which means that it is a reduced droplet path. The aerosol can be transported over a greater distance than droplets. Not a small risk is staying in crowded places and places where many people stay, bad, weak, insufficient ventilation or air extraction from the area where people stay. The risk of spread increases in the case of community or one could say "cell" spread.

Employers should be in cooperation with health professionals in cooperation with health and safety staff so that they are constantly able to monitor the situation at the workplace in the company so as to constantly increase the safety of company staff. However, we must not forget the regular reporting system for monitoring and implementing the measures that have been taken to prevent the spread of the virus in the workplace. Implementation reports should be reported in case the effectiveness or ineffectiveness of a given measure has been established.

It is then described how the risk is distributed in the workplace due to the pandemic situation and fluctuations.

Lower risk - employment that does not require a high number of staff, limited contact with people who could be positive

Medium risk - work or tasks in which it is possible to potentially meet a crowd or small groups of people where an employee may come into contact with a possibly infected person.

High level of risk - when we know that in the group we came in contact with is a person who has already been in contact with a positive person on SARS-CoV-2.

Very high level of risk - work in which workers come into contact directly with the infected person or are close to the infected person when the level of risk of infection is very high through aerosols or direct contact.

The risk of the workplace regarding the transmission and spread of the virus should be at each workplace and adapted to the work performed so that it is in accordance with the description and scope of work.

Risk assessment should serve as an assessment or evaluation process in assessing the degree of infectivity in order to reduce the incidence in the workplace or zero. The above-mentioned degrees of risk serve for the primary categorization of the risk in the workplace, this matrix does not yet include the impact of vaccination.

The use of protective equipment is highly recommended. The need to use PPE is highly recommended, not only in healthcare but also in other sectors of the industry. Over time, as the virus "evolved", measures and restrictions reflected its behavior and direction. often the limits were reduced to almost zero when we were almost free.

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Figure 11. Parked aircraft

The incidence of cases also decreased during the summer period. This was due to the fact that penetrating sunlight, dry weather and prolonged sunshine created the conditions and mitigated the spread of SARS CoV2[3][4].

Some companies have abolished employee rotations and created smaller working groups of workers in order to prevent dissemination and transfer in larger groups. in practice, this means that the working group consists of 2-5 employees. If one of them has symptoms, then the whole working group is sent for testing and in case of positivity of one of the members within the working group, then the whole group will undergo domestic quarantine. this prevents the transfer and there is no need to trace contacts and trace as much as it would in a free shift. Another measure in the fight against a pandemic in the workplace is the introduction of wearing PPE (breathing masks, respirators, drapes), some employers handed out face masks to FFP3 employees in the first wave. Employees were separated from the personnel matrix, who, after each major transfer to the workplace, early boarding, breaks, cleaned the handles and often touched, caught areas.

Another measure that employers have introduced in connection with pandemic measures at work is the measurement of the temperature at the start of the work shift. This measurement is performed at the entrance to the building or to the place of work. If an elevated body temperature above 37 ° C is detected, the employee is sent home and then to perform the test.

Figure 2. Social distancing

Commonly used measures in MRO to minimize risk passed between colleagues hand washing with hot water and soap. Placed enough paper towels to dry hands after washing. Also proper promotion of hand sanitizing by responsible managers or by shift leaders. The facilities should be under a cleaning process at minimum twice per a day. It impacts workflow because of interruption of work. Social distancing interrupts workflow and workloads. Workers should work at minimum with 2 meters gap or 6,5 feet. If it is not possible to perform tasks by one employee to keep the minimum social gap 2 meters PPE has to be used, face masks and gloves or face shield should be worn. Social distancing reduce scheduled works in shift pattern, this measure prolonged work and caused overpriced maintenance.

The year 2019 was a record year and 2020 was also a record year but an infamous record. While in 2019 a record was recorded in the number of aircraft in the air at one time 2020 returned to aviation time. Air traffic has gone back 40 to 50 years. Practically, the transport of people did not work, so it was canceled. Only repatriation flights and air freight operated. EASA issued a document to STC holders allowing conversion of the aircraft to cargo aircraft [9]. Airlines and maintenance companies each had to deal with the situation caused by the Covid-19 virus in their own way. Austrian airlines grounded 80 aircraft at Vienna Airport [1]. Some types of aircraft were moved to Bratislava. Some of the grounded aircraft are similar to the conversion to basic equipment and are being prepared for return to leasing companies [10]. The opinion of Lufthansa Technik is that in these turbulent times they cannot give a clear prediction of returning to the normal state before the pandemic in 2019. The main problem is the turbulence of the development of the pandemic and the market as such [11]. Lufthansa Technik's optimistic estimates are at the end of 2023 or the beginning of 2024. According to Chief Lufthansa Technik, the crisis has shut down or decommissioned older aircraft, as well as more economically demanding aircraft such as fuel economy. Also, large aircraft with 4 engines are slowly being taken out of maintenance or production has stopped. These aircraft are the A380 and B747. Decommissioning will not be a problem for operators but for mechanics with a type rating for this aircraft. The decommissioning of these aircraft will help to reduce the volume of work and this will lead to a reduction in the revenues of maintenance companies. On the other hand, they will be replaced by B777 and A330 aircraft. Undoubtedly, A320 family and B737NG aircraft will maintain their positions in operation. The year 2020 is described as the most difficult in the company's history. The company's losses were huge. LHT swung to a € 383 million ($ 454 million) adjusted operating loss, from a € 463 million profit in 2019. Revenue declined 43%, to € 3.75 billion. The revenue shortfall was global, but the biggest shortages were in Europe. LHT claims that, especially in the whole region, it has suffered from declining revenues from engine and component support activities, where capacity utilization has temporarily fallen "well over half".

While in the Americas and Asia-Pacific regions the decrease in sales was smaller in relative terms - revenues in the Americas fell by 39% to EUR 821 million and in Asia by 25% to EUR 430 million - the LHT was particularly affected by the crisis in its home region. Sales in Europe, the Middle East and Africa fell by 45% to EUR 2.55 billion.

The LHT network, which includes facilities jointly operated with partners, has made more than 3,000 redundancies - including around 1,900 temporary staff. As regards internal staff, the number of staff fell by 5% year-on-year to 22,745 at the end of December, according to LHT. [2]. Just as Lufhansa Techniques expected growth in

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2020, many other companies also expected profit growth. The main problem that the companies had to deal with was the parking / grounding of the aircraft.

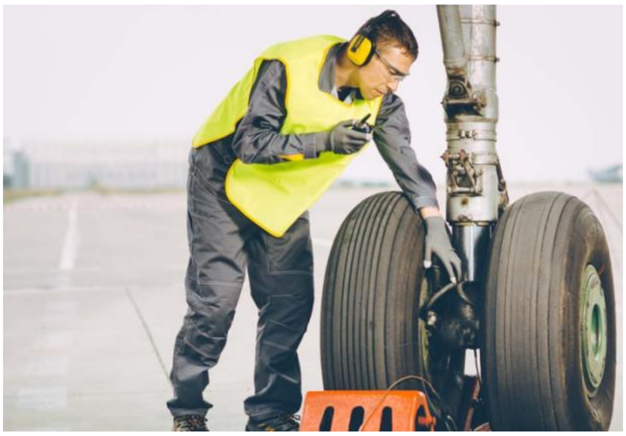

Figure 3. Check of hydraulic lining [7]

An emerging problem with aircraft parking was the lack of material needed to park and preserve aircraft. When parking, it is important to follow the manufacturer's manual with the correct aircraft registration. Only then is it ensured that everything is done correctly.

The facts point to the recovery of air traffic and thus to the recovery of maintenance organizations. For example, European MROs engaged in aircraft engine maintenance based on the compound annual growth rate (CARG) predict a 4% increase. This assumption is based on the fact that the fleet of air operators has a higher average age. One of the highest in the European region. The expected development has two directions. One possibility is the growth of maintenance companies. This fact is not indicated by the flight path 2050 strategy and emission reductions. It is expected to eliminate older models with high fuel consumption and economic costs of maintaining airworthiness. Maintenance companies will switch to newer types of aircraft with more economical propulsion units. This will require the training of maintenance personnel involved in aircraft maintenance [6].

Figure 4. New type rate rating [7]

Additive production is expected to bring even greater profits in the next decade and potentially change the environment for the parts market and the supply chain. As AM technology evolves, Boeing's CMO report predicts that the non-critical parts solution will come to the forefront in the delivery and production of high-quality on-demand parts. This process of being able to provide the "part you need when you need it" should significantly reduce costs and lead times.

CONCLUSION

After the crisis breaks, the impact of strong digitization is expected. In the coming years, companies will invest in digitization, which will bring benefits when storing and ordering spare parts. MROs are expected to respond proactively rather than reactively. While this trend offers clear opportunities for airlines, it also presents challenges for smaller MRO providers and parts providers who have a hard time matching the resources and technologies of the larger OEMs.

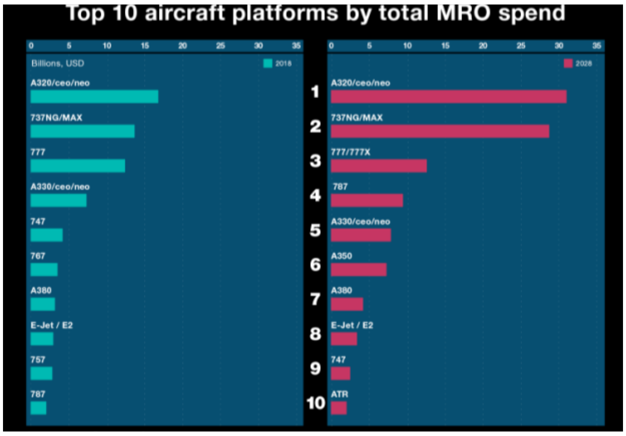

Figure 5. Future development after Covid-19 [7]

We can expect as the aviation aftermarket increases its efforts in data analysis, modeling and automation in coming years, we can expect to see more partnerships or consolidations — moving the aftermarket towards more universal standards and processes.

OEMs and the big airframers like Airbus and Boeing entering into the aircraft aftermarket, can be seen as either a good or a bad thing. For airlines it provides an opportunity for access to service packages span across activities that take place in the hanger: such as maintenance, technician training, e-solutions, and system upgrades. As well as material management services like spares and tooling [7]. 2020 was a year like no other, and not just for the aviation industry. The COVID-19 pandemic and the global recession it created have affected everyone. This year has also taught us that the world can change in the blink of an eye and thus our predictions for the MRO and aftermarket industries are just that – educated guesses that may look much different in another year's time.

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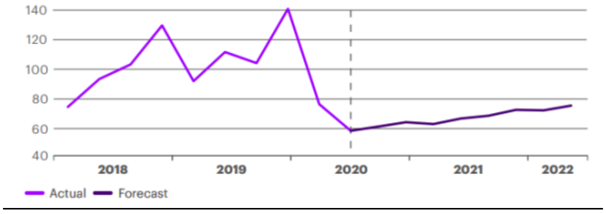

Figure 6. Europe commercial aerospace index

But some of these challenges we have seen coming for quite some time now. COVID-19 has accelerated industry trends and made them more pressing than ever. For MROs, the crisis could prove to be a catalyst for change that betters prepare the industry for both the eventual return in global demand and a more sustainable, high-tech future.

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[11] https://www.lufthansa-technik.com/ltt
[12] https://www.easa.europa.eu/sites/default/files/dfu/guidelines_for_de-storage_aircraft_scenario_covid19.p

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Structural perception of Safety Management System (SMS) in the context of Civil Aviation Authorities

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***Abstract*— Safety is generally characterized as the state of being "safe", the condition of being protected from harm or other non-desirable consequences. Aviation safety determines the form of an aviation system or organization in which risks connected with aviation activities are reduced and controlled to an acceptable level. One effective way of how to achieve it is to implement a safety management system (SMS). Safety management system should be seen as an aggregate strategic aspect of standard business management, understanding its high priority to safety. This article aims to provide a structural comparison of the system within individual Civil Aviation Authorities (CAAs) and its perception and reflection in the adopted regulations and recommendations. This article is mainly based on datasets publicly available through the International Civil Aviation Organization, Transport Canada, Civil Aviation Safety Authority Australia, Federal Aviation Administration and UK Civil Aviation Authority websites.**

I. INTRODUCTION

Many authors characterized safety as the state in which the chance of harm to persons or property damage is decreased and maintained at or under an acceptable (adequate) level within continuing hazard identification and risk management [27]. Air safety and its improvement have constantly been the highest priority for the airline industry, and becoming an adequate air safety record are essential to an airline's success [24]. Aviation Safety Management System (SMS) is becoming a regulatory requirement. Civil Aviation Authorities (CAAs) need to find methods to manage safety management activities to achieve means to show compliance with actual regulations [25]. The International Civil Aviation Organization (ICAO), Transport Canada (TC), Civil Aviation Safety Authority Australia (CASA), Federal Aviation Administration (FAA) and the UK Civil Aviation Authority (UK CAA) have made significant progress in the development, implementation, and refinement of SMS. This safety system is created to continuously improve safety by identifying hazards, managing and examining data and continually evaluating safety risks. The SMS attempts to proactively check or mitigate threats before they appear in aviation accidents and incidents. It is a system that is comparable to the organization's regulatory obligations and safety goals [26]. ICAO characterized SMS as a "systematic approach to managing safety, including the necessary organizational structures, accountabilities, policies and procedures" [5].

II. CIVIL AVIATION AUTHORITIES (CAAs)

INTERNATIONAL CIVIL AVIATION ORGANIZATION (ICAO)

The International Civil Aviation Organization (ICAO) was founded in 1947 and it is a specific agency of the United Nations. To ensure safe and organized development, it modifies the principles and techniques of international air navigation and promotes international air transport planning and development. The ICAO Council adopts guidelines and recommended practices for international civil aviation in air traffic, facilities, flight inspection, unlawful intrusion prevention, and border-crossing procedures [1].

The Safety Management Manual (Doc 9859), which was published in 2006, is intended to assist ICAO Contracting States in fulfilling the specifications of Annexes 6, 11 and 14 regarding introducing SMS by operators and service providers. In the guidance manual, ICAO suggests individual and proper steps for combining the different elements into a unified SMS as a beginning and operating an effective process for safety management [4]. The manual's primary objectives are to help States transition to a performance-based safety approach; put in place safety-related information-protection tools, and achieve the goals set out in the Global Aviation Safety Plan (GASP). The latest edition of the Safety Management Manual (SMM) is 4th and is complemented by the unique website (www.icao.int/smi). The website contains some examples and resources from the third edition of the SMM and additional practical examples, tools, and instructional materials that will be compiled, revised and updated regularly [5], [6].

Safety Management System (SMS) is the topic of Annex 19, which was first published in July 2013 (and became effective in November 2013) [3]. Annex 19 presents standards for implementing and maintaining a State Safety

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Program (SSP) by States and providing a Safety Management System (SMS) by relevant service providers included in the various services and industries in aviation [2]. Annex 19 applies to safety management functions that are directly connected to or facilitate aircraft's safe operation. It lays out a broad collection of specifications that aren't specific to any aviation role, service provider, or organization. Per ICAO Annex 19, Edition 2, Chapter 4, the Safety Management System of a service provider shall be established following the framework elements and be proportional to the service provider's size and the complexity of its aviation products and services [3].

TRANSPORT CANADA (TC)

The Department of Transport was formed in 1935 by Canada's government to understand Canada's changing transportation environment. Transport Canada is the department in the Government of Canada accountable for developing regulations, policies and services of all transportation types in Canada. It merges transportation departments: road, rail, marine, aviation and transportation security in general. It is a federal institution responsible for transportation policies, systems and programs. They support secure, safe, effective and environmentally responsible transportation. Transport Canada is accountable for licensing pilots and other aviation professionals and registering and inspecting aircraft. Additionally, it is responsible for the safety certification and constant safety oversight of most commercial operations. Transport Canada's Civil Aviation (TCCA) Directorate is Canada's civil aviation authority [8].

Since the 2000s, Canada's Commercial and the Aircraft Maintenance and Manufacturing Branch have published corrections to the Canadian Aviation Regulations (CAR) requiring SMS establishment in certain operations types [4]. In 2001, the first material related to Safety Management System (SMS) was published as Introduction to SMS (TP13739 E) [9]. The guidance material Safety Management Systems for flight operations and aircraft maintenance organization (TP13881 E) was published in 2002 to explain the recommended regulatory requirements' purpose and use [10]. The practical guide to the implementation of Safety Management Systems for small aviation operations (TP14135 E) was published in 2004 to explain SMS in simple operations [11]. These materials are designed as operational guidelines for defining, developing and implementing an SMS within the flight, maintenance operations and small aviation operations. In 2008, Advisory Circular (AC) No. 107-001 - Guidance on Safety Management Systems Development was published as guidance on SMS's ways to be implemented in large, complex organizations. This guidance material interprets the application of the SMS regulatory requirements. It contains valuable examples and models of how the elements that make up an SMS might be achieved and gives an evaluation tool for understanding whether an organization reaches the minor regulatory requirements [12]. In 2016, Advisory Circular (AC) No. 107-002 - Safety Management System Development Guide for Smaller Aviation Organizations was published to help small-sized aviation organizations implement an SMS. It has the same content as a guide for large organizations but related to small ones [13].

CIVIL AVIATION SAFETY AUTHORITY AUSTRALIA (CASA)

The CASA (abbreviation for Civil Aviation Safety Authority) is the national authority for civil aviation regulation in Australia. It was founded in 1995 when the air safety functions of the former Civil Aviation Authority of Australia were separated from air traffic control's other regulatory role. CASA is accountable for controlling and monitoring civil air operations in Australia, issuing proper licenses, enforcing and implementing safety requirements, and preserving the environment from aircraft use impacts. Its mission is to develop a positive and collaborative safety culture within a good, effective and efficient aviation safety regulatory system, supporting and helping the aviation community. CASA is a government organisation that manages aviation safety and the operation in Australia and aircraft overseas. CASA license pilots, list and register aircraft, manage safety and increase safety awareness in aviation. It is furthermore responsible for making sure that airspace is controlled and used safely [14].

Because of the importance of SMS, CASA published a draft AC119-165 in 2002 to help establish course criteria for the preparation and training of safety managers as required to implement and manage the Safety Management System (SMS). In 2005, an AC 172-01(0) was published to provide general principles and practical guidance to illustrate SMS requirements compliance. CASA also issued two guidance materials that described, more specifically, the work of CEOs in the implementation of SMS [4]. Recently CASA published Civil Aviation Advisory Publication (CAAP) as guidance material of Safety Management Systems for Regular Public Transport Operations CAAP SMS-01 v1.1 [15].

FEDERAL AVIATION ADMINISTRATION (FAA)

The Federal Aviation Administration (abbreviation FAA) is the biggest improved transportation agency and a governmental organisation of the United States to manage every aspect of civil aviation in that nation and over its neighbouring international waters. It was founded in 1958 and its capabilities cover the development and operation of airports, air traffic control, the certification of pilots, other professionals and aircraft, and the protection of assets during the launch or re-entry of commercial space vehicles [17], [18].

In 2006, FAA published Advisory Circular AC120-92 - Introduction to Safety Management Systems for Air Operators to introduce the SMS concept for the first time to airlines and other air transport operators and guide SMS improvement by aviation service providers. FAA indicates that a circular is not obligatory and does not create a regulation; e.g. the SMS implementing is optional [4]. This circular described SMS as an organisation-wide comprehensive and preventive method for managing and

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achieving safety. An SMS also ensures the overall safety performance of the organisation [19]. SMS presents an evolutionary method in operation safety and safety management. SMS is a structured method that forces organisations to maintain safety with the corresponding preference that other core business processes are handled. This applies to internal (FAA) and external aviation industry organisations (Operator & Product Service Provider) [21]. In 2020, FAA published ORDER 8000.369C - Safety Management System, which establishes policy and requirements. The requirements included within this order are meant to assist organisations in incorporating SMS into their organisations [20].

UK Civil Aviation Authority (CAA)

The UK Civil Aviation Authority (UK CAA) is a government corporation of the Department for Transport was founded in 1972. The UK CAA is the legal corporation that directly or indirectly oversees, regulates and manages all civil aviation aspects in the United Kingdom. As the UK's aviation regulator, CAA works to meet the highest safety standards in the aviation industry, to protect all costumers when they fly and to manages' security risks effectively. Most aviation regulation and policy are arranged worldwide to guarantee consistent safety and consumer protection levels [22].

The United Kingdom National Air Traffic Services (NATS) started introducing standard SMS in 1991, primarily because of the growing attention on safety concerns and airspace capacity from outside groups as the public, the media and UK Parliament. In 2002, the UK Civil Aviation Authority's Safety Regulation Group (SRG) published one of the first introductory Civil Aviation Publication (CAP) 712 – Safety Management Systems for Commercial Air Transport Operations as a guidebook. An SMS was described as an exact component of the corporate management respossibility which sets out a company's safety policy and determines how it intends to manage safety as an integral part of its overall business [4]. In 2015 was published Safety Management System (SMS) guidance for organisations - CAP 795. This document aims to guide the implementation of SMS. It has been developed to understand the SMS concept and develop management methods and processes to implement, manage and achieve a good SMS. It applies and implements to air operators, airworthiness management organisations and maintenance organisations, air navigation service providers, aerodromes and accredited training organisations. This guidance material meets ICAO Annex 19 requirements and is a UK CAA alternative to compliance for the European Union Aviation Safety Agency (EASA) management system requirements regarding safety management. SMS continues beyond compliance with prescriptive directions to a systematic approach where potential and possible safety risks are identified and controlled to an acceptable level. SMS uses a business-like approach to safety, safety plans, safety performance indicators and targets, and constant monitoring of its safety performance. It allows efficient risk-based decision-making processes over the business [23].

III. COMPARISON: SIMILARITIES AND DIFFERENCES

Modern SMS can be defined as a collection of activities considered necessary actions to fulfil responsibilities under the new age of self-regulation delegated responsibility [28]. The definitions of SMS in air transport differ depending on the system's approach and perception of CAAs (Table 1).

TABLE 1 definitions of SMS

ICAO	**systematic approach to managing safety, including the necessary organisational structures, accountabilities, policies, and procedures** [4]
TC	explicit, comprehensive, and proactive process for managing risks that integrates operations and technical systems with financial and human resource management for all activities [12]
CASA	**systematic approach to managing safety, including organisational structures, accountabilities, policies, and procedures** [15]
FAA	the formal, top-down, organisation-wide approach to managing safety risk and assuring the effectiveness of safety risk controls [20]
UK CAA	a systematic and proactive approach to managing safety risks [23]

It can be observed than SMS definitions differ significantly from each other, although the whole system's meaning and essence do not conflict. The definitions of ICAO and CASA, which are marked "**bold**" in (Table 1), are the most consistent and characterized SMS in the same way as systematic approach to managing safety. The UK CAA describes this system in direct relation to the risk management contained in it. TC and FAA define the system differently, which is reflected in the components and elements of this system.

The SMS structure is mainly based on the ICAO SMS guidance, consisting of four major components [15]. The universally held SMS framework includes principal components and twelve key elements describing SMS requirements.

The ICAO-specified system for implementing and maintaining an SMS has:

- a safety policy,
- safety risk management,
- safety assurance and
- safety promotion,

plus, a minimum of twelve elements. The system can be tailored to each organisation's company's complexity and

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nature [3], [7]. Every Civil Aviation Authority (CAA) explains the safety outcomes and the key components and elements of an SMS.

To sum up, results in similarities and differences present comparable SMS components based on various documents published by CAAs and organisations. A significant difference in the SMS components is shown by Transport Canada (TC), as it has a different structure than the classic ICAO framework and, at the same time, complements it with the emergency preparedness and quality assurance component. Plus, it is possible to see changes in the individual elements, which differ and complement the SMS depending on the countries' perception of safety and SMS definition.

The similarities and differences (Table 2) in the individual elements are shown in "**bold**", and a comparison is based on the ICAO standardized framework in given components which contains twelve elements.

Other elements were compared and that matched and highlighted in "*italics*". In result, this is above all a consensus on responsibility, training and communication.

All other elements that do not match present differences and these are highlighted in "red". TC and FAA have their own philosophy, which fulfils the requirement but extends it with some processes and activities, e.g. emergency preparedness and response or efforts to build a positive safety culture in all workforce levels.

TABLE 2 similarities and differences in the elements

ICAO (Doc 9859)	**management commitment; safety accountability** *and responsibilities*; **appointment of key safety personnel; coordination of emergency response planning; SMS documentation; hazard identification; safety risk assessment and mitigation; safety performance monitoring and measurement; management of change; continuous improvement of the SMS**
TC (AC) No. 107-001	safety policy; non-punitive safety reporting policy; roles, *responsibilities* and employee involvement; *communication*; safety planning, objective and goals; performance measurement; *management review*; identification and maintenance of applicable regulations; **SMS documentation**; records management; reactive and proactive processes; investigation and analysis; risk management; training; awareness and competence; operational quality assurance; emergency preparedness and response
CASA (CAAP SMS-01)	**management commitment** and *responsibility;* **safety accountability** of managers; **appointment of key safety personnel;** SMS implementation plan; third-party interface; **coordination of emergency response plan; hazard identification processes; risk assessment and mitigation processes**; **safety performance monitoring and measurement**; *internal safety investigation;* **management of change; continuous improvement of the SMS**, *training and education; safety communication*
FAA (Or. 8000_369C)	establishes senior **management's commitment** to improving safety regularly, defines the processes, methods and organisational structure needed to meet safety goals; defines the need for, and adequacy of brand-new or changed risk control based on the assessment of acceptable risk; assesses the sustained effectiveness of implemented risk control strategies; assist the identification of new hazards; *training; communication,* and other efforts to build a positive safety culture in all levels of the workforce
UK CAA (CAP 795)	**management commitment** and *responsibility;* **safety accountability; appointment of key safety personnel; coordination of emergency response planning; SMS documentation; hazard identification; safety risk assessment and mitigation;** *internal safety investigation;* **safety performance monitoring, measurement and** *review;* **management of change; continuous improvement of the SMS**, *training and education; safety communication*

CONCLUSION

This article aimed to point out the structural perception of the SMS system and compare the similarities and differences within individual Civil Aviation Authorities strategies.

TABLE 3 SMS structure adopted by CAAs

CAA	Components	Elements	Document
ICAO	4	12	Doc 9859
TC	6	17	(AC) 107-00
CASA	4	15	CAAPSMS-01
FAA	4	-	Or.8000_369C
UK CAA	4	12	CAP 795

Many aviation organizations and civil aviation authorities have made efforts to develop SMS and make it an official requirement. In this article, all significant Civil Aviation Authorities globally, such as ICAO, TC, CASA, FAA and UK CAA was selected and compared in components and elements in the SMS framework. The results show (Table 3) that the SMS structure is mainly based on the ICAO SMS guidance, consisting of four major components: safety policy, safety risk management, safety assurance and safety promotion. It is possible to see a notable difference in the Transport Canada components, supplemented by other features. The universally held SMS framework includes components and key elements describing SMS requirement —especially elements varying depending on the CAA strategy. Nevertheless, it can be concluded that the whole system, regardless of where it is used and applied, represents a new improvement direction for ensuring safety. SMS

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concentrates on maximising opportunities to improve the aviation system's overall safety continuously. The whole approach builds on current procedures, integrate with other management frameworks and shows good corporate practice by tailoring a compliant regulatory environment to the enterprise. A system is primarily proactive and predictive. It analyses the hazards and risks that affect the whole organisation and risk controls. Implementation of SMS describes a fundamental change in the way all organisations business. In conclusion, safety becomes an essential part of the organisation's operations. But, suppose SMS is to be a success. In that case, every CAA must establish a disciplinary and enforcement policy that promotes and rewards the behaviours for achieving it. The most positive benefit of the SMS is improving on current levels of aviation safety in the knowledge of the industry's continuing growth.

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Review of anti-pandemic measures at airport transport systems in the period of COVID-19

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***Abstract* — Doctoral student present a certain view of anti-pandemic measures at airports, based on a literature review. The aim of the article was to identify internationally and nationally applicable standards, norms, law and countermeasures which need to be taken into consideration in process of Health Security improvement at the airport terminals, with focus on airport transport systems. Current pandemic has a significant impact on research & development of "Baggage handling" system, its construction and protection. Nowadays, the smooth, safe, secure and biological protection of luggage handling is one of the most fundamental issues. Airports cooperate with national and international organizations to ensure the safest service possible to passengers and to protect their employees**

I. INTRODUCTION

In order to limit the spread of COVID-19, airports cooperate with national and international organizations to ensure the safest services possible to passenger and to protect their staff. Airports around the world restrict access to airport infrastructure only to employees and passengers (or, for example necessary escorts), introducing increased levels of cleaning and disinfection, HVAC (Heating, ventilation, and air conditioning) is designed to reduce the risk of airborne transmission, by ensuring a high level of air exchange and an adequate level of humidity. Employees and passengers are subject to health screening (mainly body temperature control and a questionnaire) and are required to wear a mask. Suitable passengers are allowed to check-in. Last but not least, the measures help health-concerned passengers and employees to feel safer.

According to Steven Moore, Head of ATM Network Operations, EUROCONTROL for exploration of the challenges facing the European airports as they prepare for the recovery these questions need to be answered:

- What challenges do we face at Airports in Europe?
- Are we ready and able to meet them?
- What lessons have been learned from summer 2020?
- What preparations are underway?
- What can we do about lack of harmonization of restrictions and rules by the states?
- What needs to be prioritized to deal with recovery?
- How can we build up better aviation in Europe from the airport perspective, with a view not just of short but also perhaps the medium and long-term future? [1].

II. INTERNATIONALLY AND NATIONALLY APPLICABLE STANDARS AND LAW

In the context of the fight against COVID-19 and other infectious diseases in the future, it is necessary, in the conditions of the EU and the Slovak Republic, to know the basic standards, regulations and recommendations and to build on them:

- SIB 2020-07R2 : Progressive Restart of Aerodrome Operations after Complete or Partial Closure [2],
- SIB 2020-02R5 - Safety Information Bulletin: Coronavirus COVID-19 Pandemic - Operational recommendations [3],
- SIB 2020-13 - Provision of Groundhandling Services at Aerodromes [4],
- SD SD-2020-01 - Safety Directives: SUPERSEDED BY EASA SD-2020-03 [5],
- SD SD-2020-02 - Safety Directives: SUPERSEDED BY EASA SD-2020-04 [6],
- Measures related to civil aviation due to communicable disease COVID-19 [7],
- Civil flights in FIR Bratislava in relation to the communicable disease COVID-19 [8],
- Measure of Ministry Health Management Office [9],
- Regulation (EC) No 300/2008 of the European Parliament and of the Council of 11 March 2008 on common rules in the field of civil aviation security and repealing Regulation (EC) No 2320/2002 [10],
- Commission Implementing Regulation (EU) 2015/1998 of 5 November 2015 laying down detailed measures for the implementation of the common basic standards on aviation security [11],
- Act No. 143/1998 Coll. on Civil Aviation (Civil Aviation Act) and on Amendments to Some Acts as amended by later regulations [12],
- ICAO Annex 14 [13],
- Commission Regulation (EU) No 139/2014 of 12 February 2014 laying down requirements and administrative procedures related to aerodromes pursuant to Regulation (EC) No 216/2008 of the European Parliament and of the Council [14], etc.

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III. MEASURES AT AIRPORT TRANSPORT SYSTEMS

Airports around the world restrict access to airport infrastructure only to employees and passengers (or, for example necessary escorts), have introduced increased levels of cleaning and disinfection, HVAC (Heating, ventilation, and air conditioning) is designed to reduce the risk of airborne transmission, by ensuring a high level of air exchange and an adequate level of humidity. Employees and passengers are subject to health screening (mainly body temperature control and a questionnaire) and are required to wear a mask. Eligible passengers are allowed to check-in. Last but not least, the measures help to health concerned passengers and employees to feel safer.

In 2020 Eurocontrol created Impact assessment of COVID-19 measures on airport performance [1]. The objective of the analysis was at first to determine what degree of the measures impact on passenger journey times through a terminal. How much of additional space might airport need in key zones that are most affected by COVID measures. Given the impacts of those measures, at what percentage of 2019 traffic volumes will airports reach a saturation capacity?

TABLE 1 Additional space for deparute flow [1]

Additional space	Process/Area
50%	check-in
100%	security control
35-50%	boarding gates

The results are that, up to 10 minutes additional time for departing passenger. In terms of space, 50% of additional space was required in check-in to maintain certain social distancing (see table 1). On the Arrival process the journey time increased between 5 to 20 minutes depending on the setup. In baggage reclaim area additional space of 30 to 50% increase was needed (see table 2).

TABLE 2 Additional space for arrival flow [1]

Additional space	Process/Area
30-50%	baggage reclaim
100%	Immigration

Key conclusions they found in the study: The maximum saturation capacity at just 60-75% of the 2019 traffic volumes.
The important problem is that restrictions measures have not been implemented in sufficient harmonize way. Each country is implementing their own testing strategy, health screening, quarantine policy, self-isolation strategy, etc. Good example is difference between Netherland, Germany and Italy (information valid for the first half of March) [1]. Passengers younger than 30 years are not required to have tests in Netherlands, In Germany only younger than 6 and in Italy only younger than 2. In Netherlands you need to have not only PCR but also an antigen test 4 hours before entering Netherlands [1].
According to Sergio Fernandez; IATA [1], this has created confusion. Passengers are not allowed to boarding because they are not able to comply with the requirements. Airlines are requested to do extra checks regarding required documentation. That may result in the creation of queues, passengers dissatisfaction, and risky environment.

It is necessary to harmonize measures in a better way across air transport net because quick movement and smooth processes are essential.

A. Social distancing

Airports must put in place all necessary measures to comply with the new rules. It should be noted that when designing the optimization, the additional distance reduces the system capacity (the problem may occur at peak times) of each of the subsystems of the terminal.

B. Masks and respirators

The mask and respirator significantly reduce the risk of airborne transmission. It could be said that it complements "social distancing". The primary principle of the spread of COVID-19 is exhaled droplets (especially when coughing, sneezing or loud talking from face to face), by secondary contact with a surface infested, for example, by the deposition of these droplets. The mask or respirator forms a physical barrier against the exhalation of droplets and aerosols.

C. Testing, Immunity Passports and Vaccination

At the moment, several countries are planning and trying to introduce an immune passport confirming the presence of antibodies to COVID-19. Passengers and employees may also be asked to prove themselves by a negative test. The aim is to prevent the infected person from boarding and entering the country. It is also used as a part of a process such as secondary health screening.

An interesting possibility is the detection of antibodies. It can be used to indicate that someone is able to work and travel without the risk of infection or transmission of infection. This, together with vaccination, can be used in the future to obtain the so-called Immune passport allowing free movement. Granting privileges to those who have antibodies or have been vaccinated could motivate people to get vaccinated.

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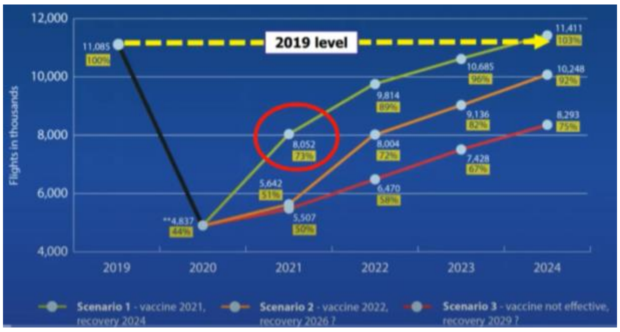

Figure 1. Eurocontrol statfor 5-year forecast [1]

In the late November 2020, the Eurocontrol startfour team issued the 5 year forecast for Europe based on the null intelligence. At the beginning of November was just before vaccination strategies started across the states of Europe. In forecast there were 3 scenarios. Scenario 1 indicates potentially 70-75 of 1019 traffic as an average in 2021 (see Fig. 1), if Europe population will be successfully vaccinated in the current year.

D. Entry/exit Health screening

Entry / Exit screening consists of public health measures implemented at points of entry and exit at an airport. It is also suitable for the continuous control of the health, discouragement from the arrival of sick staff and passengers, prevention of the spread of the disease. The most common Principe is temperature measurement. Good example of such a device is IR screening system from Incoff LTD. (see Fig. 2).

Figure 2. IR screening system TSG-1 from Incoff LTD. [15]

E. Simulation

Simulation programs allow developing and designing solution configurations by selecting different building blocks to meet the specific requirements of a particular airport or a part of it.

According to Guilian Preud'homme from Brussels Airport [1], simulation of airport model is used to benchmark internal study to see if it is possible to close parts of infrastructure. Another reason is to identify, if was possible to reduce the runway configuration system in any way to improve efficiency.

Figure 3. Airport model: Airside [1]

Simulation of terminal is crucial, because it is important to see entire airport system as a whole. It allows studying the passengers motion from the airspace into the car park and vice versa, to see if the social distancing measures can be adhered, etc.

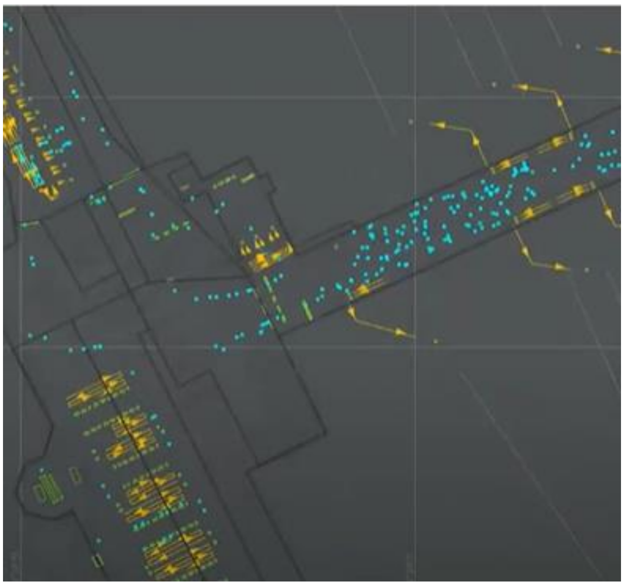

Figure 4. Airport model: Terminal [1]

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F. New technologies

The movement of passengers, staff and goods must be smoother with limited human contact. For effect elimination of queues and gathering people a new technologies can be used: BIM (Building Information Modeling), Contact Tracing Apps, Artificial Intelligence (AI), Digital Twin, Web/Mobile Applications, Contactless Touch Panels, Passenger Tracking and Alerts, Passenger Flow Monitoring (PFM), Passenger Dynamic Simulations, Smart Restroom Technology, home app check-in, digital boarding passes, boarding pass activated entry gates, check-in kiosks, Automated baggage drop-off, automated boarding gates, etc. [16].

G. Dissinfection

The secondary principle of the spread of COVID-19 is by contact with a surface infested. To reduce the risk airport operators should enhance disinfection procedures (see Fig.5).

Figure 5. Cleaning and Disinfection [16]

CONCLUSION

As we head from the second wave, world airports facing various challenges. Building on experience of specialists from the entire air transport network (e.g. airports, airlines, air navigation service providers, e.tc.) is needed. Exploration of challenges facing airports is necessary for the recovery preparation. It is necessary to harmonize measures in a better way across air transport net because quick movement and smooth processes are essential.

Current pandemic has a significant impact on research & development of “Baggage handling” system, its construction and protection. Nowadays, the smooth, safe, secure and biological protection of luggage handling is one of the most fundamental issues. It is important to invest in touchless technology and make travelling more fluent for accumulation prevention of large numbers of travelers and employees. According to study, in baggage reclaim area additional space of 30 to 50% increase was needed.

From perspective of airport transport systems optimization it is necessary to consider not only anti-covid measures. Authors note, from long-term, incorporation of innovative technologies and procedures for tools comparison, product quality evaluation, service quality evaluation and process quality evaluation will be needed [17, 18, 19, 20, 21, 22, 23].

Better results in the fight against COVID-19 can be achieved if all airports and anti-pandemic measures across countries are more efficiently coordinated.

ACKNOWLEDGMENT

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Geographic information system (GIS) landing assistance in emergency situations for General Aviation operators of Ultra-light aircraft

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***Abstract*— A wide range of GIS data is publicly available, covering many different types of functions. The level of detail of each data is different as the age and accuracy of the data. GIS has the possibilities which allow us to display individual layers and read the data such as terrain relief, slope, area type, length. After evaluating the requirements that the aircraft needs to be able to safely land and stop the aircraft without seriously damaging the integrity of the fuselage or endangering the safety of the crew, we can use the various GIS functions to speed up the process of finding a suitable area for landing.**

I. INTRODUCTION

During an emergency situation when the pilot has no other option and is forced to make an emergency landing in to the terrain, he must perform a certain number of actions. The pilot is obliged to adjust the approach speed to a suitable gliding speed and start looking for a landing spot with a large number of criteria and characteristics to consider, perform a series of maneuvers and safely land the aircraft by avoiding obstacles and minimizing danger to persons on board and on the ground.

Although these procedures are based on a large scale of risk management analysis performing an emergency landing is a mentally exhausting and complex process. Pilot must perform multiple tasks at once in a very short time, ranging from minutes to seconds. Automation some or all of these tasks with a computer system will reduce the pilot's workload so that he can focus on the most critical tasks

II. METHODOLOGY

The methodology was based on collection and analysis of available literature, summarization and synthesis of personal knowledge based on own experience as a pilot and professional consultation with experts in the field. Summarization of available data and correct formulation and interpretation of own opinion to obtain the possible image of interpreted data.

III. RESULTS

To identify the capabilities of GIS in the general aviation we have to discuss the data that we can read from the system and requirements for desired landing area.

A. Landing area requirements

An emergency landing is a landing of the aircraft in emergency. This does not necessarily happen on the runway. Emergency landings can be made in to the terrain, water and forest areas. If no engine power is available during an emergency landing, the aircraft is gliding at the gliding speed to maintain control. During the glide, the pilot begins to evaluate the situation and perceive the individual factors that are necessary for the successful landing of the aircraft on a suitable surface. [1]

The direction of the wind is important because it is desirable to land in the wind direction to minimize speed. Smoke or vapor emissions can be useful in determining the direction and speed of wind.

In terms of surface conditions, the most desirable is a runway or paved surface, with the next one being an uphill slope grass area. If the plowed field is the only option, it is necessary to land parallel to the rows. Landing down the hill is also unfavorable.

In hilly terrain, landing over a slope or uphill is more appropriate. Obstacles can be dangerous such as fences, along with power lines throughout the area. When flying with a single-engine aircraft, the best way to ensure the availability of suitable landing spots is to create a route structure so that the pilot avoids flying over mountainous terrain, densely wooded areas or large areas of water, if possible. It is a hostile environment for an emergency landing, which complicates search and rescue efforts.[5]

If it is necessary to fly over these areas, it is advisable to choose a reasonably high altitude to improve the glide range and improve landing options. A lonely dirt road may be fine if people or power lines are not visible. Another option is landing on a busy road or highway, it is a generally unfavorable option where there are many dangerous factors such as: power lines, billboards, traffic, bridges, overpasses. Both for normal landing and emergency landing, the key is the approach speed. It is the speed of the aircraft that affects the total length needed to

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stop the aircraft completely. Different surfaces have different characteristics. [5]

The weight of the aircraft is one of the basic factors that determines the landing distance required of the aircraft. The kinetic energy increases significantly as the weight of the aircraft increases, and the brakes must absorb this greater energy, increasing the pressure on the aircraft's braking system. A decrease of air density leads to a reduction of the aircraft performance.

Airports with high altitude are characterized by low pressure and high ambient temperatures. The headwind reduces the landing distance of the aircraft. Landing in the headwind reduces ground speed and increases the lift coefficient. This is beneficial for pilots as well as for air traffic controllers.

An aircraft landing in the headwind will require a smaller runway and will be able to leave the runway sooner. If the headwind decreases near the ground, the flight speed of the aircraft will decrease and it will tend to decrease. The tailwind increases ground speed and therefore a longer distance will be required for the aircraft to land. Landing in the tailwind could cause the aircraft to overshoot the runway and hit objects or terrain.

Runway conditions affect the performance of an aircraft during take-off and landing. The runway can be made of concrete, asphalt, gravel or grass. The landing distance required by the aircraft is much greater for low friction runways that do not allow effective braking.

Aquaplaning is a phenomenon in which directional control is lost due to the presence of a water between the tires and the runway surface. The uphill landing will allow the aircraft to land a shorter distance. The runway down the slope will require a greater landing distance. The high flap setting helps the aircraft increase aerodynamic drag and reduce the stall speed so that the aircraft can fly safely at low speeds.

Packages included in the GIS increasingly provide analytical tools that are built-in as standard. The increased availability of resources has created a new dimension, called spatial intelligence. GIS as a whole system can be described as a conversion to digitization process. [2]

GIS can recognize and analyze spatial relationships that exist in digitally stored data. These topological relationships allow complex spatial modeling and analysis. Topological relationships between geometric objects traditionally include proximity (what they are adjacent to), retention (what they attach to), and proximity (how something is close to something else). [2]

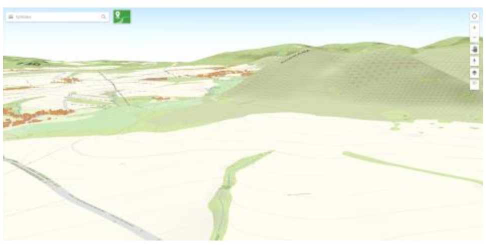

Figure 1. GIS 3D terrain display
Source: zbgis.skgeodesy.sk

The display of data on the map will improve the overall capabilities of the pilot and also increase his safety. It is important to note that these maps should be seen as secondary systems. Due to the time required to collect GIS data, the layers used do not reflect the current state, but rather the state as it was during the last survey. In addition, data obtained from multiple sources are likely to be of different timeliness. Thanks to the available tools, it is possible to apply any function to the map layers in order to achieve the results that are best suited for a specific scenario.

B. Designated landing area

Aircraft landing process consist of 4 stages. Approach, flare, transition and full braking segment. When the aircraft glides down its approach angle is constant and varies with actual situation. Considering this is an emergency landing there could be no thrust power. Speed corrections will be only done by changing the angle of approach. [3]

Evaluation of the terrain is the key to recognize terrain surface, slope, obstacles and altitude. Terrain surface affects the landing distance. Required landing distance varies with type of terrain. We have to apply a factor for each type of the terrain so we can estimate the stop distance. [3]

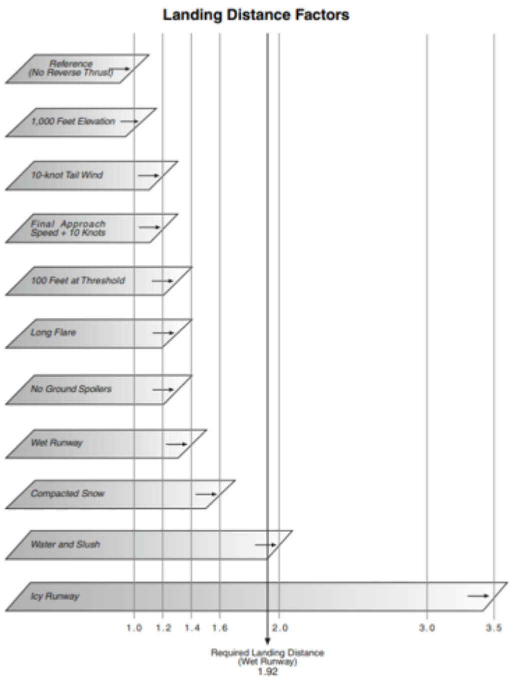

Figure 2. Required landing distance factor
Source: Flight Safety Foundation Approach and Landing Accident Reduction (ALAR)

For calculation of landing distances, we have to use these formulas:

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Required runway length (dry) = Actual landing distance (dry) x Landing distance factor

Required runway length (wet) = Actual landing distance (wet) x Landing distance factor

The aircraft landing mass, surface wind and temperature, runway slope and condition of the aircraft are being considered already in required length. Since the ultra-light aircraft are much lighter and allow pilot for more maneuverability. With such information on board pilot can prepare himself for a certain situation he is facing. By recognizing the terrain type he can estimate the stopping distance. [5]
Pilot has to distinguish if the desired landing area is wet or a dry, then he has to distinguish the terrain type. Wet surfaces generally provide less tire friction. There are aswell different lengths of grass that affects actual stopping distance. The ideal condition for landing would be dry paved surface.

C. Possible scenario

In the figure below we see ultra-light plane on final approach into the terrain. Pilot has to evaluate designated area for landing. First, he has to configure his aeroplane for landing then starts the evaluation of the terrain.

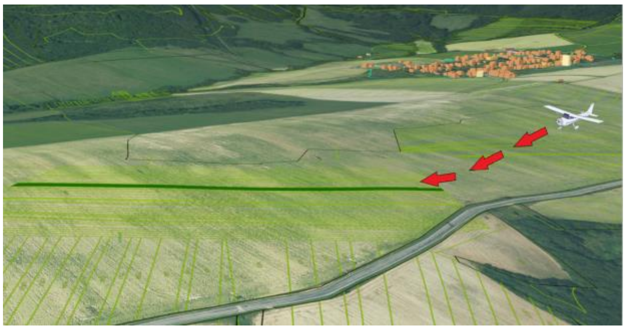

Figure 3. Ultra-light plane in final approach

From the figure above we see that desired area for emergency landing has a slight uphill slope. This condition will help pilot stop the plane a and reduce the required distance for full a stop. Another figure shows the same situation but from different perspective.

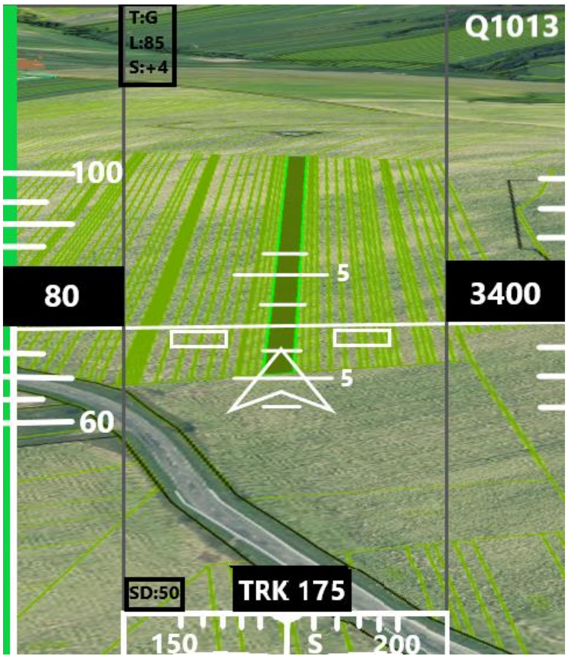

Figure 4. Possible HUD overlay

HUD overlay shows possible implementation of Geographic information system directly in to the primary flight display or additional system. GIS is capable of displaying buildings and structures and other relevant geographic information. All of this is helpful in reduced visual conditions still applying VFR rules. For the pilot not trained for IFR flying. When the pilot selects actual landing area the additional data will show up. This data is represented in figure above in top left corner and bottom left corner. [4]

T – terrain type (grass, concrete, arable land)
L – length of the landing area (in meters x 10)
S – slope of the terrain (+ for positive)
SD – stopping distance after evaluation of the landing distance factor (in meters x10)

If we would like to apply elevation of the terrain applying geographical altitude into primary flight system where the altitude is barometric could cause a confusion of the pilot and misevaluate actual height. If we would like to enhance actual GPS system on board or any other supplementary system, we could implement even elevation data.
The problem with altitude is that we would have to estimate the average terrain elevation. With terrain slope information pilot could estimate its rough terrain and overall elevation.

IV. DISCUSSION

The suggestion part of this paper is based on summary of the landing factors, data provided by GIS and pilot actions. We had to evaluate those measures, by implementing we could increase the safety of ultra-light pilots.

1. Landing area aspects – Direction of the wind, terrain type, terrain slope and obstacles are aspects

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that have to considered in evaluation of suitable area for landing. The most desirable condition for emergency landing is paved surface. If the pilot has no other option than land into the terrain, he has to choose grass field with short grass preferably with uphill slope. If there are obstacles or no availability of such areas, he has to perform landing in current condition he is facing. If its plowed field it is required to land in line with the plowed lines. Landing perpendicularly with plowed lines could endanger safety of the crew. The plowed lines would cause constant bouncing of the aircraft that could overstress front landing gear and cause it to collapse and dig into the terrain with propeller.

2. Landing factors – We have to take into consideration different types of terrain where we have to apply a landing factor to estimate landing performance of the aircraft. Depending on terrain condition whether it is dry or wet different rules apply. By wet condition of the terrain the stopping distance is much longer so the landing performance decrease and landing factor increase.
3. Implementation of data – Displaying a possible scenario with figures made by author where pilot is forced to land into the terrain shows a possible implementation of GIS system either directly into the primary flight display or as a supplementary display expanding terrain information such as a terrain type, length, slope, estimated stopping distance. Estimation of the stopping distance would be done by applying landing factor for a certain terrain type.

CONCLUSION

This research focuses on GIS systems in general aviation, which can increase the safety during emergency situations or any other dangerous situations. The idea was to increase awareness for General aviation flights safety.

During the research, it was found that the information provided by GIS could be implemented directly in to the existing system or as a supplementary device. Expansion of actual systems with information collected from GIS could improve overall safety. When there are sudden changes of visual flight conditions or decreased visibility and emergency situations occurs.

Every additional information assisting the pilot in emergency situation improves his chances for successful landing. For less experienced pilots or for pilots in training flying their initial solo flights, would such a system expansion encourage them and make them feel more confident about their flying experience. We can assume that the given area constantly needs to be researched to solve various tasks which confirms the topicality of the issue.

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Basic overview of COVID-19-associated changes in lung tissue

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Abstract - **The pandemic spread of the SARS-CoV-2 virus causing COVID-19 disease is one of the most watched aspects of today. At our Department of Forensic Medicine and Pathological Anatomy, the Health Care Surveillance Authority, in Prešov we have performed since 2020 – 2021 126 autopsies of deceased patients with COVID-19 disease confirmed by PCR. Examined COVID-19 patients aged 28-95 underwent complete or partial autopsies with emphasis on the histopathological examination of the lung tissue. The hallmark findings were proliferation of type II pneumocytes (caused by the cytopathic effect of the virus), presence of microthrombi in small and medium-sized blood vessels, formation of hyaline membranes in alveoli and extensive regressive changes of the lung tissue. The gained experience will be used in the analytical part of the dissertation on the topic Database of selected medical data of aviation personnel for forensic purposes in aviation medicine and the information model for risk assessment in a forensic medical expert opinion.**

I. INTRODUCTION

Coronavirus disease 2019) caused by SARS-CoV-2 virus (Severe Acute Respiratory Syndrome-Associated Coronavirus-2) has been officially declared a world pandemic by the World Health Organization in March 2020 [1]. The disease was first reported in the Chinese province of Hubei in December 2019, and the first officially confirmed case in Slovakia was in March 2020. More than 95 million people worldwide have already been infected and more than 2 million died (more than 5500 deaths in the Slovak Republic) [2].

COVID-19 can also be characterized as a complex, multisystemic, inflammatory vasculopathy with a significant risk of mortality. Critical patients make up about 5 % of the infected population. The etiological agent causing COVID-19 is a RNA virus called SARS-CoV-2 from the Betacoronavirus genus. Its characteristic feature is the use of ACE2 (angiotensin-converting enzyme 2) as the entry receptor into cells. ACE2 is expressed in lung alveolar cells, respiratory epithelial cells, and vascular endothelial cells. Therefore, these tissues are the entry points for the virus and are the places where the intracellular infection starts and the virus multiplies. The virus is spread through droplets, aerosols or contact with contaminated objects [2,3].

Clinical signs of COVID-19 demonstrate high inter-individual variability. The clinical presentation of SARS-CoV-2 infection generally ranges from mild rhinitis to severe viral pneumonia with potentially fatal ARDS. Typical symptoms include nonspecific symptoms of airway inflammation, i.e., fever, chills, dyspnea, cough, sore throat, nasal congestion, dizziness, muscle and joint pain, general weakness, chest tightness, excessive mucus production with expectoration. Loss or attenuation of smell and taste perception is an uncommon symptom that appears in higher frequency in COVID-19 patients [3]. Other uncommon symptoms include headache, diarrhea, abdominal pain, vomiting or pain when swallowing. In approximately 90 % of cases, patients experience more than just one of the symptoms [4]. Serious complications include multiorgan failure, septic shock, and venous thromboembolism [8].

The leading cause of death in COVID-19 patients is respiratory failure, i.e., acute respiratory distress syndrome (ARDS). However, there are large differences between countries in mortality among infected patients (China 69 %, Iran 8 %, France 19 % and Germany 13 %) [2].

Men are more often represented among critically ill patients (52 to 84 % of critically ill patients) and these patients are mostly elderly people with comorbidities such as hypertension (41-63 %), diabetes (13-46%) and obesity [8].

Because SARS-CoV-2 has an affinity for endothelial cells, their damage leads to significant negativeoutcome in the more severe course of the disease and causes hypercoagulability, with a consequent higher risk of venous thrombotic and thromboembolic complications. The result is generalized small vessel vasculitis with massive capillary thrombi formation. These factors lead to disseminated intravascular coagulopathy which significantly increases mortality. 25 % of critically ill COVID-19 patients are reported to develop venous thromboembolism and 40 % of them die. The immune response induced by SARS-CoV-2 infection has two phases. Already during the incubation period and the initial

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symptomatic manifestations, a specific immune response is induced, which tries to eliminate the virus and prevent the progression of the disease to pulmonary phase. However, SARS-CoV-2 preferentially attacks the lower respiratory tract due to the high concentration of ACE-2 receptors on type 2 pneumocytes.

In the pulmonary phase of the disease, viral replication and viral load is a decreased, but a large amount of pro-inflammatory cytokines is released and pulmonary infiltrates are formed.

Produced inflammatory cytokines (IL-6, IL-8, TNFα) stimulate cell apoptosis in lungs, liver, kidneys and other tissues, which further activates coagulation and can lead to multiorgan dysfunction.

Patients with severe COVID-19 develop thrombosis rather than bleeding, that typically appears in disseminated intravascular coagulation. Pathogenesis of severe pulmonary involvement in COVID-19 includes:

Hyperinflammation (cytokine storm), a phenomenon when T lymphocytes and macrophages become abnormally activated and damage the lungs, heart, kidneys and other organs.

Hypercoagulable state - dysregulated immune system destroys the endothelium which leads to blood clotting and consequently to the formation of micro- and macrothrombi.

ACE-2 receptors are also present on platelets, which may contribute to their massive aggregation and impaired blood flow. This microangiopathy predominantly affects the pulmonary and cerebral circulation.

Severe hypoxemia - oxygen failure in pneumonia and microthrombosis is caused by impaired oxygen transport through the alveolar–capillary barrier.

COVID-19 treatment consists of oxygen supplementation in the non-invasive form, i.e. high flow nasal oxygenation (HFNO) and non-invasive ventilation (classic mask, full face mask or helmet). If the non-invasive oxygen supplementation is insufficient or if patient is in a condition requiring emergency intubation from the beginning invasive artificial lung ventilation is used.

As already mentioned, COVID-19 infection causes marked platelet activation, which contributes to a severe prothrombotic condition and an increased inflammatory response [6]. Although aspirin is currently not generally recommended for COVID-19 patients, according to some clinical studies it could be effective in preventing blood clots formation in patients with this disease [7]. In one study the use of aspirin in the first 24 hours after admission or in the 7 days before the start of hospitalization was associated with significantly lower need for artificial ventilation, admission to the ICU and hospital mortality, but not with lower thrombosis incidence [8]. Therefore, aspirin has been included in the therapy of COVID-19 in various clinical departments and can be used as a part of at-home treatment.

II. METHODOLOGY, RESULTS AND DISCUSSION

Over the period of the years 2020 – 2021, we performed at our department 126 autopsies of patients with COVID-19 disease confirmed clinically during patients' life by PCR. The deceased patients underwent a pathological-anatomical autopsy with a focus on the examination of the airways and lung tissue. Because COVID-19 is highly contagious disease (viral antigens have been demonstrated to be present in bodies for up to 10-14 days after death), it was necessary to take measures to protect autopsy staff from getting infected.

Certified protective equipment was used during autopsy to prevent the transmission of infection to humans. Clothing and equipment consisted of disposable medical scrubs, full-body waterproof overalls, two pairs of disposable gloves, a face respirator with a replaceable FFP4 filter, goggles or shield, shoe covers and a rubber apron.

Figure 1. Protective equipment used during autopsies of bodies with confirmed or suspected infectious disease.

After autopsy, the clothing was decontaminated with chemical disinfectants at the autopsy room, and then placed in a box intended for the disposal of biological waste, which is sealed after it is filled and consequently disposed as biologically hazardous waste by a specialized company.

After autopsy, the autopsy room was disinfected with antiviral disinfectants and ultraviolet germicidal lamps.

Formalin-fixed and paraffin-embedded tissue sections were stained with hematoxylin and eosin.

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Examination of lung tissue during autopsy consists of two consecutive steps. The first is a macroscopic gross examination of organs of the respiratory tract including description of the appearance and consistency of the lungs and parts of the lower respiratory tract. The second step is microscopic histological examination of lung tissue and respiratory tract tissue. Lung tissue specimens were collected according to a standardized procedure for pathological autopsy. Tissue specimens were taken from both lungs from the upper and lower lobes and pulmonary hilum. For topographical identification the taken specimens were partially cut with dissecting scissors in different ways. For example, the specimens taken from the right lower lobe were partially cut once and the specimens from the left lower lobe were partially cut three times. The specimens taken from the right upper lobe were uncut. This procedure allowed us to identify parts of lung that were most severely affected with the disease.

The examination of patients with the confirmed COVID - 19 infection included the collection of autopsy tissue specimens from lungs, bifurcation of the trachea and spleen. Taken specimens were after collection inserted into special collection sets consisting of a test tubes with saline and then sent to Regional Public Health Authority in Košice where they were tested for the presence of SARS-CoV-2 by PCR. The same procedure was followed in cases of sudden, unexpected deaths of individuals who were known to have symptoms of respiratory disease and the SARS-CoV-2 positivity was not ruled out. At present, antibody or antigen rapid tests are used to preliminary rule out SARS-CoV-2 presence in cases of unknown death circumstances.

The macroscopic appearance of the lungs is characterized by marked focal or diffuse consolidation of the tissue with an increase in the average lung weight, sometimes above 1300 g. [1]. No typical lung predilection site (as is common in some pneumonias, e.g., tuberculosis) of COVID-19 involvement was found. This finding is consistent with radiological findings and descriptions of bilateral injury [8]. Grossly, cut lung tissue is congested and composed of darker and paler areas and focally or diffusely of areas with firmer consistency (Fig. 2). Grossly and on palpation, it may resemble solid and non aerated liver tissue. In the vascular system there are signs of hemostasis with the presence of thrombi in large sized vessels. In the airways there are signs of acute bronchitis with marked congestion and in some cases small ulcerations.

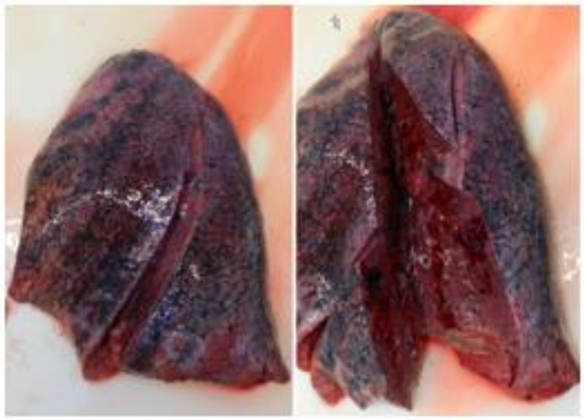

Figure 2. Gross appearance of left lung with typical morphological signs of COVID-19. Dominant changes are edema and consolidation of lung tissue.

Three morphological parts of the lung tissue (airways, pulmonary alveoli and interstitium) are microscopically examined. The description consists of the characteristics of the airways, histopathological changes of the pulmonary alveoli and the interstitium.

The dominant finding in the alveoli is hyperplasia and detachment of lining epithelial cells, especially pneumocytes II. type, with their subsequent accumulation and formation of clusters in the alveoli. Other findings are large epithelial multinucleated cells originating from the alveolar lining and hyaline membranes (Fig. 3 - narrow arrow).

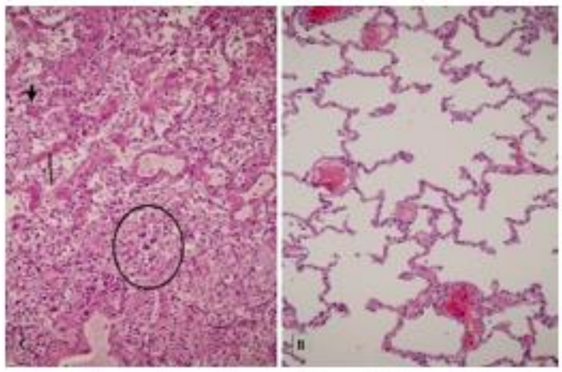

Figure 3. Comparison of the morphology of inflamed (A) and healthy (B) lung tissueAtypical type 2 pneumocytes (circle), hyaline membranes (thin arrow) and capillary microthrombi (wide arrow) can be seen.(HE, 200x)

Pneumocytes lining the inner surface of the pulmonary alveoli may be enlarged and show cytonuclear atypia and syncytial change (Fig. 3 - circle). Sporadically basophilic granules can be present in the cytoplasm of pneumocytes. The respiratory epithelium in the airways shows regressive changes, with evident detached epithelial cells accumulating in the lumen.

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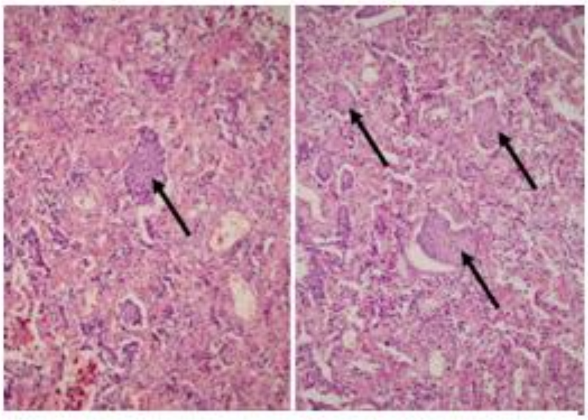

Figure 4. Microscopic appearance of squamous epithelial metaplasia.(HE, 200x)

In secondary bacterial or mycotic superinfections neutrophil infiltrate also appears in alveoli. In up to 43 % of cases the squamous metaplasia of respiratory epithelium can be observed (Fig. 4) [1]. In the interstitium, there is microscopically a marked edema with lymphocyte and plasma cell infiltration.

The changes in the lung vascular system typically include small vessel (with lumen diameter ≤ 1 mm) microthrombi (Fig. 3 - wide arrow) and often thrombosis of large vessels Histological examination often also reveals generalized vasculitis with chronic inflammatory infiltrate in the vessel wall.

In the late stages of the disease, the lung tissue is affected by interstitial fibrosis (Fig. 5). Increased amount of collagen in interstitium reduces the elasticity of lung tissue. This significantly worsens the recovery potential of lung tissue and is a possible cause of post-infectious complications.

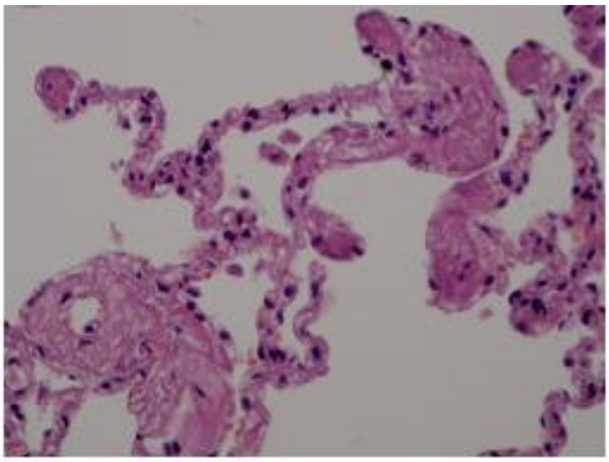

Figure 5. Microscopic image of lung interstitial fibrosis. (HE, 400x)

CONCLUSION

Inflammatory lungs diseases can be a life-threatening process requiring intensive medical care. The described histomorphological changes have a serious effect on the vital functions of lung parenchyma. Massive inflammatory infiltration leading to respiratory obstruction and edema reduces the respiratory capacity of the lung tissue. Changes in the interstitial space lead to the firmness change of the tissue with the loss of important organ elasticity [4]. Vascular microtrombi are the cause of severe pulmonary hypertension leading to overload of the right ventricle that can even manifest as acute pulmonary embolism. These morphological changes together often exceed the compensatory capacity of the organism and lead to failure of vital functions with lethal consequences. Severe COVID-19 is manifested by fever, cough and difficult breathing. Critical COVID-19 is manifested by the presence of ARDS, sepsis or septic shock. Great importance in the fight against this modern disease is given to the vaccination of the population and application of anti-epidemic measures. The future will show if populations are ready to face this and similar challenges.

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The Impact of the Pandemic on the Airline Industry – A Year with Covid-19

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***Abstract*—In this paper, we will evaluate the year with the covid-19 pandemic and its impact on air travel and the airline industry around the world. The paper will be a concise effort to analyze the impact of shut borders and dramatic restriction on travel in the past year and look into some predictions for the travel and tourism industry. We saw a small increase in air travel especially during summer when the restrictions significantly decreased in Europe and elsewhere in the world. However, covid-19 had an unprecedented impact on air travel and many of the main carriers are hit by substantial losses and need a bailout from the local/national governments or bank loans to survive. In the first part, we assess the revised data on performance and economic cost to the airline industry and travel & tourism sector. In the second part, we look at whether the predicted U-shaped scenario will last longer or whether we are on the path to normal recovery of the aviation industry in the next year or two.**

I. INTRODUCTION

The negative impact of the Covid-19 on all aspects of society and the economy is well known and documented. Aviation has been particularly impacted, accumulating shocks from previous events like 9/11, SARS or the global financial crisis in 2008 into one so-called "black swan" event which will have far-reaching implications on the industry in the coming years. The impact on the aviation industry during the year 2020 was unprecedented. Amid the worst global pandemic, the forecasted drop of passengers is around 50.6% in 2020 when compared to the year 2019 [1]. At the peak of the stoppage around April 2020, there was a drop in passenger traffic by 94% compared with April 2020, which includes a 98.9% drop in international passengers and a 90.7% drop in domestic travellers [2]. This in turn had a significant negative impact on the frontline companies operating in the aviation industry and the rest of their supply chains. However, the previous shocks have lasted short and were always followed by a strong rebound in business and traffic. There must be substantial support from the governments which have to ensure that the air transport will have strong guidelines and ability to restore their operations to the full extent as soon as possible. Otherwise, they will need further financial assistance to survive prolonged restrictions on travel among countries. This situation is unprecedented in the modern era of flight transportation as we have not experienced absolute widespread of any virus before, although there were SARS and MERS since early 2000 but only in certain regions.

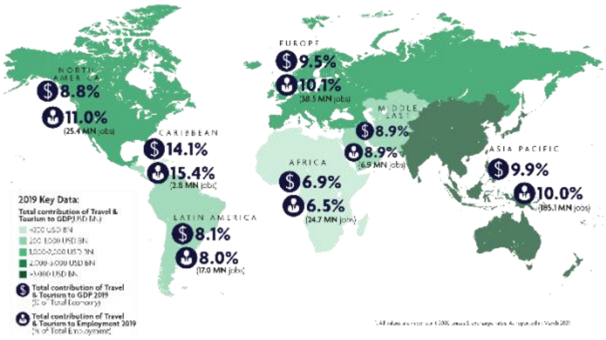

Figure 1 . Total Contribution of Travel and Tourism to GDP (% of Total Economy; dollar sign) and Employment (% of total employment; person sign) in 2019. All values are in constant 2020 prices and exchange rates as reported in March 2021

II. AVIATION INDUSTRY AND TRAVEL AND TOURISM SECTOR

The aviation industry has massive spillovers on wide aspects of the economy in countries around the globe. One of the most visible shocks was to tourism. According to the World Travel and Tourism Council, tourism is a huge global business with 10.6% of direct and indirect global employment and accounts for more than 10% of global GDP (10.4% to be exact in 2019) with international visitor spending amounted to US$1.7 trillion which is 6.8% of total exports or in other words 27.4% of global services exports [3]. As you can see in figure 1, darker areas mean more total contribution in real terms. In the darkest area of South East Asia and Pacific + Australia, the total financial contribution towards GPD in the region was greater than US$ 3 trillion.

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If we look at the data from 2020, in figure 2, we see a dramatic slump in every region with the highest impact on the Caribbean region with a 58% decrease in total financial contribution to GDP and almost 25% of the total workforce in the industry being laid off. The least impact on the financial contribution to GDP was in Latin America whereas the least impact on the workforce in the industry was in Europe. One can argue, that Latin America is lacking the popularity of other regions among tourists with their concerns for safety and lack of developed resorts. Moreover, the impact in Europe on the workforce was definitely minimised through a variety of anti-covid employment programmes which positively impacted employment and led to only 9.3% redundancies in the sector. One can ask what was the total negative impact or suffered loss in the travel and tourism sector in 2020 and how the spending decreased compared to 2019?

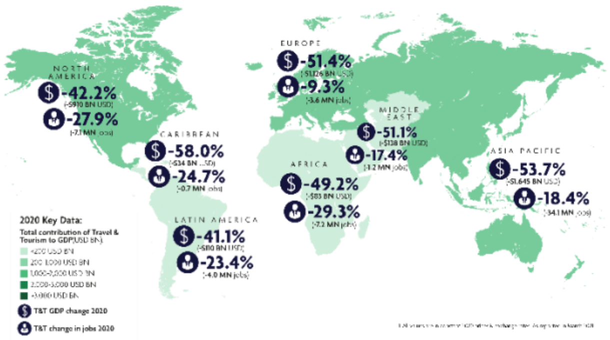

Figure 2. Total change in travel and tourism to GDP in 2020 in % (dollar sign) and to change in jobs in 2020 in % (person sign). All values are in constant 2020 prices and exchange rates

In 2020, there were 62 million jobs lost in the travel and tourism sector which accounts for 18.5% redundancy in the industry and tourism sector along with a drop in total GDP contribution of the sector by 49.1% to only 5.5% (it was 10.4% in 2019). In total values, the GDP contribution of the travel and tourism sector decreased from around US$ 9.2 trillion in 2019 to US$4.7 trillion in 2020 and total jobs in the sector went from 334million (1 in 10 jobs in the world) of employed people to 272 million jobs (1 in 11 jobs) [4].

From the same report and data, we can see that business spending decreased by 61% in 2020 compared to the year 2019, whereas leisure spending decreased by 49.4% in 2020 when compared with the previous year. One interesting aspect is domestic vs international spending. We can see a significant difference between the decrease in international spending which fell by 69.4% in 2020 and domestic spending which contracted by 45%. Domestic spending accounted for 71.7% of total spending in 2019 by the tourist on leisure and business trips whereas domestic spending accounted for 82% of total spending in 2020. This shows that people travelled predominantly during summer months for trips to local destinations by vehicles on their own or with the family in order to prevent catching covid-19 and therefore decreasing demand for air or rail travel during last year. The highest share of domestic travel of total travel and tourism spending among G20 countries were Japan, Brazil and the United States with the share of 94.6%, 94.4% and 93.9% respectively whereas the lowest share had Turkey, Spain (permanent invitee to the G20) and Saudi Arabia with the share of 47.2%, 63.2% and 66.2% respectively in 2020 [4]. Lastly, more than 58% of tourists arrive at their destination by air regularly and this will harm GDP benefits from air travel-related tourism which suffered a loss of over US$ 630 billion alone, with loss of direct aviation jobs of 4.8million or a 43% reduction compared with the pre-COVID situation [5].

III. AVIATION INDUSTRY AND ECONOMIC MEASURES IN 2020

Impact on the airlines is directly linked to the performance of the global economy as airlines help global trade and movement of people and goods across borders. According to the Organisation for Economic Co-operation and Development (OECD), the World GDP decreased by 3.4% in 2020, whereas the GDP of the Euro area fell by 6.8%, the USA by 3.5% and the United Kingdom by 9.9% [6]. The United Nations Conference on Trade and Development in March 2020 predicted the impact of the Coronavirus to be around US$ 2 trillion and global GDP growth will come at around 1.7% [7]. This clearly shows the expectations of global authorities on the impact of covid on the global economy and that almost no one, at the very beginning, expected it to be worse than the infamous impact of the sub-prime crash and consequent global financial crisis which resulted in a 2% GDP decrease within a year. Also, even the European Investment Bank expected the global economy to rebound in the second half of the year 2020 and predicted the fall of the world GDP to be around 2.8% for the whole year [8]. This shows the seriousness of the covid-19 impact on the global trade and economy.

However, as countermeasures were applied and many of the government programs were passed to protect the economy through various fiscal stimuli and to keep employment as high as possible with the least impact on a workforce, we see significant potential for improvement in GDP growth in the future with a forecasted global growth ranging from 4.5% to 7% in 2021 and 2.75% to 5% in 2022. The upside scenario and higher GDP growth in the next two years take into account faster progress in deploying effective vaccines around the world and a wide take-up amongst the eligible population that would enhance the pace at which containment measures can be relaxed and provide a stronger boost to the confidence of consumers and companies whereas on the other hand, downside scenario takes into account the speed of vaccine production and deployment will not be fast enough to stop the transmission of the virus, especially if there is a wider emergence of new mutations that require new or modified vaccines and currently we see serious differences across

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economies in the timing of downside shocks with many emerging-market and developing economies having slower-then-expected vaccine rollout being an immediate concern that could dampen spending and consumer confidence hurting spending on travel and tourism sector together with less demand for air travel [6]. This could further lead to greater financial problems in the future for airlines operating in such economies and consequently would require more economic stimulus compared to airlines in the developed world, where there is an expectation of vaccination rollout and satisfactory coverage of the population by the third quarter of 2021.

IV. FINANCIAL PERFORMANCE OF AIRLINE INDUSTRY

Airlines were hit strongly in 2020. We saw a dramatic decline of 65.9% in global revenue passenger km (RPKs) which is the largest decline since the second world war although we expect the global RPKs to grow forecasted 50% in 2021 compared to the year 2020 [9]. Moreover, we experienced a cargo capacity shortage due to the lack of passenger aircrafts which led on average to around 25% less cargo capacity in 2020 when compared to the same months in 2019 depending on the region with North American airlines rebounding and strongly growing since June 2020 and finishing the year with 20% growth year-on-year (YoY) in December 2020 whereas Latin America was on 80% of the 2019 capacity the whole year [10]. If we look at the revenue for airlines, we see a pattern such as passenger revenues collapsed by 68.9% from US$607 billion in 2019 to US$189 billion in 2020 while cargo revenues were up 27.8% in 2020 from US$100.8 billion to US$128.2 billion [11]. This dramatic decrease will have a prolonged impact on the return on invested capital (ROIC) which was -17.7% in 2020 compared to 5.8% in 2019 with the expectation of -6.8% in 2021[9].

Airlines tend to usually hold less liquidity on their accounts due to the nature of the business activity, predominantly among traditional airlines such as Lufthansa Group or Air France-KLM although this tendency is less true for low-cost carriers such as Ryanair or Wizz Air. To put it in the perspective, Ryanair and Wizz Air had the highest liquidity amongst all European airlines' groups with over 47% of total revenue as liquid assets in 2019 whereas Air France-KLM held around 22% of its revenue in liquid assets and Lufthansa Group held only 12% of its global assets liquid such as cash in 2019 [12]. The most important question here is, why is it important to have a certain significant % of your revenue in form of liquid assets? The significant importance of liquidity emerges when a business in any sector faces an unexpected need to finance its operations but does not have immediate access to finance capacities.

This is what happened in the aviation industry from March 2020 onwards. Airlines groups had significant overheads due to the nature of their business and plenty of ground and back-office staff which support the main function of airlines which is the movement of customers and goods among cities and states. They had to access the banks' loans or quickly liquidate the illiquid assets to meet their business obligations. This led to various bailouts from governments around the globe. For example, Air France-KLM group has recorded a historical loss in 2020 at about 7.1 billion euros and received a bailout from the French and the Dutch government in the forms of loans and guarantees of 10.6 billion euros. Another example would be the Lufthansa group which got an 11 billion euros bailout from the German government in form of the German getting a 20% stake with the option to boost that by an additional 5% in the future. On the other hand, low-cost carriers did not get similar help from their respective governments like these national carriers. One can argue, how effectively and efficiently are these national behemoths run and whether they operate at the highest efficiency when their low-cost counterparts are able to survive such a significant negative impact without the need for governmental bailouts. This could lead to a serious negative impact on the future of the competition among airlines if there are some players too big to fail who can count on help from the government when needed. An argument can be that they employ a plethora of people and their lay-offs would cost the government more in form of social benefits and re-education. On the other hand, that is how the free market and capitalism work and these companies should be able to survive on their own or die. For the information, the overall loss to European airlines was 22.2 billion euros in 2020 while airports have lost 33.6 billion euros in foregone revenues [13].

V. ROAD TO RECOVERY

In the previous paper [14], we discussed two potential scenarios or path to recovery. The first one was the V-shaped path to recovery for the aviation industry where this scenario is a normal shape for a recession, with a quick drop and a brief period of contraction followed by a smooth recovery and positive growth which some experts predicted at the beginning of covid-19 in March and April. Their predictions were based on the previous local pandemics which were V-shaped with impact on aviation lasting between six to twelve months, such as the outbreak of the SARS or MERS. There was a limited impact on RPKs with an annual reduction of only 8% in the region. So far, we saw the reduction in global RPKs to be at 65.9% in 2020 which has a far more drastic impact on the airline. If we take into account demand condition such as consumer confidence in air travel and supply condition, we are more likely to see a U-shaped recovery.

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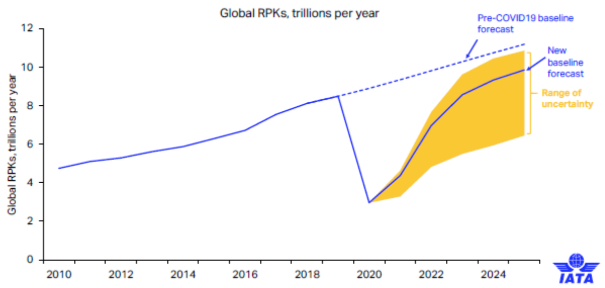

Figure 3. Global revenue per kilometres in trillions per year

As it can be seen in figure 3, the prediction from the International Air Transport Association (IATA) predicted the recovery to pre-covid levels in the aviation industry to be in late 2024 – early 2025 although the OECD predicted a strong recovery for global GDP growth at around 5.5% in 2021 meaning the world economy will likely shake off the effects of covid-19 by the end of 2021 [6]. U-shape scenario brings a variety of challenges to the recovery in the industry, especially slow recovery in RPKs which has in turn a direct impact on revenue and ROIC. The main prediction from the IATA expects the RPKs to be around 57% in 2021 from the pre-covid situation in 2019, as there was a weaker start to this year for business and leisure passengers due to the surge in virus cases, travel restrictions and significant delays in vaccination -> International RPKs started the year at 14% of pre-crisis levels versus 24% average in 2020 but we expect, in the second half of the year, a rise to 34% of pre-crisis level which implies zero international air travel growth in 2021 over 2020 [15].

On the other hand, domestic RPKs will be much stronger driven by a buoyant global economic growth, accumulated savings of consumers, pent-up demand and the lack of travel restrictions within borders that should lead to a 48% rise over 2020, taking domestic RPKs in the second half of this year to 96% of pre-crisis levels which will produce relatively better financial performance among airlines and especially in regions with large domestic markets – more than 66% of North America airlines RPKs are domestic, South America 48% or the Asia Pacific of 45% but this will be weak for Europe where airlines have only 11% of RPKs from domestic flights with the Middle East being only 3% [15]. We could see regional discrepancies and financial problems (with the need for further bank loans or governmental stimulus) for airlines focusing on international travellers among which you can count biggest airlines from Europe such as Air France – KLM or Lufthansa Group and from the Middle East such as Emirates Airlines or Etihad Airways which are global hubs for flights connecting international travellers, whereas the majority of flights in North America happen within the states such as the USA or Canada and recovery for the aviation industry is expected to smoother and faster.

CONCLUSION

The goal of this paper was to assess the crisis in the aviation industry in 2020, its impact on the travel and tourism industry which are closely related to the aviation industry, meaning one impact another and vice versa, and look at the potential recovery in the next two to three years. From the presented analysis, we see that we can expect the U-shaped recovery path which means the problems for the aviation industry will last longer than predicted at the beginning of the covid-19 pandemic in March 2020. We can expect faster recovery for airline companies that operate more domestic flights compared to international ones while the rate of vaccination will play a significant role in the return of the customers. In the vaccination rollout and take-up, there are currently dominant European countries with North America and we could see a gradual return to normal life for people by the end of the third quarter of 2021 depending on the demand conditions. Moreover, the structure of paying customers could change as business trips are more likely to stall while companies will start using more online meetings which are similarly effective in terms of working together on projects or consultations but makes significant cost savings in terms of paying for transport/flight and accommodation and employees could save more time by doing meetings from their office or home without the need to travel around the globe.

Furthermore, airlines and the whole aviation industry are significant employers and pay a lot in terms of tax revenue to governments. Airlines typically pay governments US$111 billion per annum in tax revenue whereas they needed Covid-19 support in form of governmental aid totalling US$173 billion [9]. Costs remain a serious challenge to airlines trying to stop cash burn in 2021 because according to the IATA economic brief, there is an expectation of much higher average jet fuel in 2021 by 31.2% due to stronger global economic growth pulling energy prices higher and also non-fuel costs rose 17.5% in 2020 as fixed costs had to be spread over a dramatic smaller capacity but this will partially reverse in 2021 due to capacity growth as well as because of the cost-cutting efforts of airlines [15].

To conclude, the aviation industry is one of the most strategic sectors of national and global economies as it is essential for trade, business, tourism and economic growth. We will very likely see a prolonged recovery within the industry with a return to the normal levels in 2024 and 2025. It will depend on the specific market and region in which those airlines, airports and support companies operate and on the consumer confidence in the safety of flying with the level of restrictions playing a significant role in the selection of the mode of transport.

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Utilisation and implementation of Fatigue risk management in aviation safety

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Abstract— **Fatigue is a daily part of the pilots life in the commercial air transport environment. But what is fatigue? Fatigue described by ICAO : "A physiological state of reduced mental or physical performance capability resulting from sleep loss or extended wakefulness, circadian phase, or workload (mental and/or physical activity) that can impair a crew member's alertness and ability to safely operate an aircraft or perform safety related duties." A team of health experts from Mayo Clinic described fatigue as follows "Nearly everyone is overtired or overworked from time to time. Such instances of temporary fatigue usually have an identifiable cause and a likely remedy. Unrelenting exhaustion, on the other hand, lasts longer, is more profound and isn't relieved by rest. It's a nearly constant state of weariness that develops over time and reduces your energy, motivation and concentration. Fatigue at this level impacts your emotional and psychological well-being, too." So let's set the term as prolonged and extensive tiredness, which can and is affecting the thinking and reactions of the pilots in the cockpit during flight.**

I. INTRODUCTION

Fatigue is a well known factor in aviation and the first one who addressed the consequences of long duty periods without sleep was Charles Lindberg himself. So we can say that the first historical mention of fatigue dates back in 1920s. The first mention of the negative impact of time zone changes to quality of sleep were known as early as the 1930s so basically that's the introduction of the term Jet lag. Apart from the invention of the terms the impact of tiredness on the pilot's performance was known as well. In comparison with rested people the tired ones think and move slowly, make more mistakes and have memory difficulties. These symptoms may inadvertently lead to aviation errors and accidents.

The most common reasons for the developing fatigue in long-haul pilots were circadian disturbances in combination with time zone transitions. For short-haul pilots were night flights, jet lag, early wakeup, time pressure, multiple flight legs and consecutive duty periods without sufficient time for quality sleep and recovery.

Fatigue is a safety threat and therefore Fatigue Risk Management should be implemented to a bigger unit called Safety Management System. It is also an ICAO requirement.

Fatigue is a multidimensional phenomenon related to sleep need and internal biological rhythms of the individuals. Despite its complexity its operational causes are strikingly consistent across the various flight operations. Also the consequences of fatigue.

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Fatigue is a multidimensional phenomenon related to sleep need and internal biological rhythms of the individuals. Despite its complexity its operational causes are strikingly consistent across the various flight operations. Also the consequences of fatigue. A study was made with an outcome documenting on inflight and simulator experiments as well that fatigue impairs the central nervous system functionality. This study demonstrated that in the long haul operations the pilots were susceptible to vigilance losses during the low workload parts of the flight i.e. the cruise phase. The same study showed us that the pilots were 9x more likely to have micro-sleeps and vigilance losses during night flights than the same length flights during day. Another study carried out by NASA showed that out of 1424 short haul pilots 87% felt asleep for an unknown time, the other correspondent group was executive pilots and in that group 71% of the 1488 pilots admitted that they have fallen asleep at certain moment of the flight. Keeping in mind that both operations are multi-pilot in commercial aviation that shouldn't be a major safety threat, but now we need to look at the possibility of both pilots sleeping at the same moment. It's hard to calculate it mathematically because we know too little

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information from the survey but we can state for sure that this situation happened. At that moment the safety of the flight and the passengers was jeopardised. One of the aims of the FRM is to enhance safety and prevent situations like that to develop.

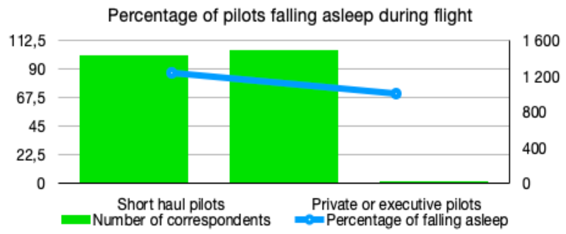

Figure 1. Percentange of pilot falling asleep during flight

Fatigue Risk management is : A data driven means of continuously monitoring and managing fatigue-related safety risks, based upon scientific principles and knowledge as well as operational experience that aims to ensure relevant personnel are performing at adequate levels of alertness. This is the definition of FRM by ICAO. FRM is trying to reach a realistic balance between safety, productivity and costs. Lately the scientists around the world understood that a more proactive way of Fatigue Risk management is needed. They need to look at the habits of the pilots, and they need to measure real sleep instead of the length of the rest opportunity. They also need to evaluate the sleep quality according to the phase of the day when the sleep was earned that is driven by the daily cycle of the circadian biological clock in the brain.

One of the outcomes of the FRM programme is the flight time limitation table of the aviation authority being EASA in Europe, the FAA in the United States and CASA in Australia in many smaller countries without major airlines the controlling authority is still the ICAO with its SARPS. Although we would expect a unified approach we can see major differences between the flight time limitations of the above-mentioned countries. The maximum annual flight time in the USA is 1400 flight hours while in Australia and the EU is 900 flight hours in the UAE this limit is as much as 2000 flight hours. Which shows that in USA a standard pilot can fly up to 64% more hours yearly than his colleagues in EU or Australia keeping the same safety standards.

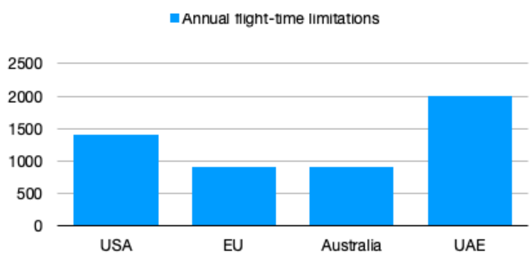

Figure 2. Annual flight-time limitations

The above-mentioned flight time limitation represents a somewhat simplistic solution for increasing the safety "the inside of the Table makes the operations safe and being outside of the predetermined numbers makes it unsafe" and this table represents only a defensive strategy. While this table was a huge improvement in the area of safety and it is adequate for some operations it still stays a one-size-fits-all approach that does not take in account the operational differences between airlines or the differences between the crew-members. So We can see that the first outcome of the FRM study was the flight time limitations table designed by each Civil Aviation Authority.

IV. II. INTRODUCTION TO SLEEP SCIENCE

At the beginning of this chapter I would like to have a different look at Fatigue as a phenomenon which in this context is closer to sleep deprivation. *Fatigue results from an imbalance between the physical and mental exertion of waking activities and recovery from that exertion which requires sleep.* According to this definition we can approach the reduction of crew fatigue by reducing the amount of work or improving their sleep. There is a widespread belief in the world of business that sleep time can be traded off to increase the amount of time available for waking activities in a busy lifestyle however sleep science has proven the sleep is not a tradable commodity. To put it in other words you need to gain back energy for the oncoming activities by solid sleep.

The science of looking at brain during sleep is called polysomnography and is a combination of measurements of electromagnetic waves is various parts of the head and the body. It comprises of measuring the brainwaves EEG, eye-movements EOG and the muscle tone EMG. Using this scientific method we can distinguish Two different kinds of sleep.

Non rapid eye movement sleep. Compared to waking brain activity non-REM sleep shows slower brainwaves with a slightly higher amplitudes. The brainwave amplitude becomes larger because the flow of neurons in the brain is synchronised. The heart rate and the breathing is slow and regular. People woken from this phase of sleep don't recall much mental activity, e.g., it is the wrong phase of the sleep to be woken up from during work or shortly before a demanding mental activity. To explain the dynamics of sleep, the longer the person is awake the more slow wave sleep will he require in his next sleep period. During a sleep period the proportion of time spent in slow wave sleep decreases. Even in slow wave sleep the brain is still working about 80% and capable of cognitive processing. Slow wave sleep is essential for the consolidation of some types of memories and is therefore necessary for learning. Operationally slow wave sleep is important because the brain can have

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difficulty transitioning out of it when someone is woken up suddenly this is called sleep inertia. This is sometimes used as an argument against the use of in-flight nap. However various studies proved the the probability of entering non-REM sleep in less than 40 minutes is improbable. So the recommendations for in flight nap are to limit the available nap time to 40 minutes.

During rapid eye movement sleep brain activity measured by polysomnography shows similar brain activity as during waking. Operationally that means that wakening a person from a REM phase of sleep results in fast regaining of his situational awareness.

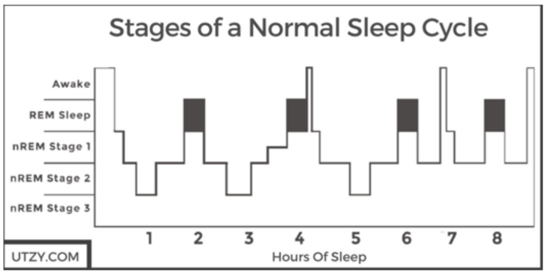

Figure 3. Stages of a Normal Sleep Cycle

Sleep quality is determined by uninterrupted non-REM/REM cycles. Rest periods should include defined blocks of time during which crew-member are not contacted except for emergencies. These protected periods shall be known to the flight crew and also the other crew-members. For example the scheduling department shouldn't contact the crew-member in this period because they may disrupt their sleep and the consequences can have negative impact on the safety of the ongoing flight duty.

Another huge factor of the sleep quality is the circadian rhythm of a person. The circadian body clock is a timepiece in the brain that is sensitive to light through a pathway from the eyes. It generates a more or less 24hours cycle to help the person stay awake during the day and get good quality sleep during the night. Almost every aspect of body functioning undergoes the cycle of the circadian body clock. The daily minimum body core temperature corresponds to the time in the circadian body clock cycle when people feel most sleepy and are least able to perform mental and physical tasks. This period is called the WIndow of Circadian LOW (WOCL) and this time period represents a high risk of fatigue related errors.

How to mitigate fatigue induced safety risk? This question has been addressed for a long time, and many companies tried to identify the minimum rest period that needs to granted to pilots before duty. From the sleep science perspective the answer is not a single universal number, but a good answer can be built up using a few factors:

a) The first one is recent sleep history. A well rested crew-member is more prone to fatigue than a person who already accumulated some sleep debt.
b) The individual sleep need of a person, which varies with crew-members.
c) The quality of the earned sleep, dependant mostly on the aspects of the crew-members housing and environment.
d) the length of the uninterrupted sleep the crew-member gets, also dependant on the home environment if the crew-member is involved in household works after his duty.
e) The criticality of the tasks he had to manage during his duty.

From these factors we can seed that there is no single and 100% effective strategy. The crew-member and the airline need to share the responsibility in creating an environment and duty schedule that can grant enough quality sleep opportunity.

III. FRM POLICY DOCUMENTATION

The FRMS policy creates an umbrella that covers the FRMs operation. The FRMS policy must define the scope of the operation and list all its aspects which should be specified for the type of the Airlines operations. The ICAO defined the basic aspects that the FRMS of an airline should cover:

a) reflect the shared responsibility of the planning department and the crew-members.
b) state the safety objectives of the FRMS.
c) be signed by the CEO of the airline.
d) be communicated to all departments of the organisation
e) declare the management's commitment to effective safety reporting.
f) declare the management's commitment to the provision of adequate resources for FRMS, and its continuous improvement.
g) set up clear lines of responsibility and accountability from management down to each crew-member.
h) set review periods to ensure the FRMS remains relevant and appropriate.

After setting up a FRMS the company needs to identify and assess the risks. A Very easy and graphical way to do so is the ICAO fatigue risk assessment matrix.

Fatigue Risk						
Risk Probability		Risk Severity				
		Catastrophic A	Hazardous B	Major C	Minor D	Negligible E
Frequent	5	5A	5B	5C	5D	5E
Occasional	4	4A	4B	4C	4D	4E
Remote	3	3A	3B	3C	3D	3E
Improbable	2	2A	2B	2C	2D	2E
Extremely Improbable	1	1A	1B	1C	1D	1E

Figure 4. Fatigue RIsk

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After setting up the matrix we need to set up the rules of usage and understanding it. And a very easy and comprehensive explanatory table is the risk tolerability matrix. With these 2 tools the airline can achieve higher safety standards also in the FRMS.

Suggested Criteria	Assessment Risk Index	Suggested Criteria
Intolerable Region	5A, 5B, 5C 4A, 4B, 3A	Unacceptable under the existing circumstances
Tolerable Region	5D, 5E, 4C, 4D, 4E, 3B, 3C, 3D 2A, 2B, 2C	Acceptable based on risk mitigation. May require management decision
Acceptable Region	3E, 2D, 2E, 1A 1B, 1C, 1D, 1E	Acceptable

Figure 5. Source see list of used literature

The outcome of the FRMS should be a well organised friendly and safe environment where the responsibility is shared between the various departments of the airline and the crew member. The environment should be open for any safety inputs and requests where the crew is rested enough to conduct challenging tasks during their flight duty.

CONCLUSION

Todays airline and air-transport environment is very dynamic business oriented and if a company wants to stay-in-the-game it needs to adopt to the pace set up by the other competitors. A very common business-model is a long term sustainable grow especially adopted in Europe where the leading roles in the airline sector are taken by Ryanair and EasyJet. Another very important aspect of the future in airline business is the environmental sustainability, the airlines try to be greener and more environmentally friendly. You need to be faster, cheaper, safer and it is really hard to achieve. One of your tools to achieve this goal is the FRMS because by adapting its rules and recommendations You can utilise your workforce to the maximum while staying 100% safe, and at the end of the day that matters. Safety is the major promotion force in aviation, an airline needs to have a 100% clean reputation in terms of safety to survive. And by having a well designed FRMS and safety culture in the airline, You can create a well balanced working schedule for your crew kepping in mind their essential needs and keeping their physical and mental alertness and prodictivity on a high level, what helps You to have efficient operations. Your crew will be happy well rested, feel safe and that will make them to stay with the company, they will be part of a bigger entity with safety in their mind and do their best to help the company grow. The rostering as we know it today had to evolve for several decades to approach it's present form. It's evolution was based on several attempt's to achieve a well balanced work environment, and over the time they could observe the system's faults. The FRMS scientist took all the mistakes and used them to form a new and better system well understood and tailored for achieving hogher efficiency in operations along with a comfortable and well balanced life quality for the crew. There were various roster patterns from 6/1/6/7 to 6/2 for comuting pilots being 14/7 or 20/10, and in all roster pattens we can find some pro's and cons. As the flightcrew is composed of human beings we can imagine that every roster pattern has it's likers and dislikers. There is a very important organizational note however, if an airline nwants to stay efficient the worst way to achieve it is using mixed roster patterns for flight crew scheduling. So the best way to stay efficient is to avoid this kind of operations. Today's most wide spreadly accepted roster pattern amongst Europe's low cost carriers is a 5/4 pattern which is effective and comfortable for the crew as well for the company. While it utilises the workforce efficiently it gives opportunity to he crew member to make long term plans with their family and so have some home-spent quality time. Again the stability in the individuals life rhythm makes his life better. After all a happy crew is a good and efficient crew.

In my opinion today's airlines try to take the most out of their employees, which can sound harsh but the EASA tries to oversee these questions in real life. The national Civil Aviation Authorites do the same. They have succesfully set up sets of rules for rostering which have become a good base for the FRMS. I think that the FRMS is a very good and efficient tool for crew planning. Of course the management of the company has to be comitted to it. To answer some of the questions concerning Fatigue Risk Management although the companies try to push the limit of the crewmembers flight time, there is a very well promoted safety culture in europe so it would be very inconvenient for them to go against the rules. I think the aviation is really safe in europe and we can be 100% sure that everything is done to keep it that way.

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