Verification of the New Standard Instrument Departure routes for Malacky Airport Using Flight Simulator

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***Abstract*— The article points to new approaches in the verification of new flight procedures using computer simulations. In the first part, the article deals with the need for the design and construction of new standard instrument departure routes for Malacky- Kuchyňa airport. The second part of the article contains a description of the newly designed tracks. The Materials and Methods section describes the software that helped us create new flight procedures and their subsequent verification. The final part points to the practical outputs from flight simulator, the application of progressive technologies in the creation of new flight procedures with an emphasis on minimizing costs during verification and minimizing the carbon footprint during testing, as software tools were used to verify the designed routes.**

Keywords*— *Standard instrument departures, simulator, verification, software, analysis

I. Introduction

Standard Instrument Departures (SID) are one of the main and safest ways to depart from airports around the world. The need for the creation of new Standard Instrument Departures and the innovation of already existing Standard Instrument Departures become a matter of course when the airspace becomes overcrowded. Each proposed standard instrument departure must meet high safety and economic criteria.

There are many factors that influence the creation of Standard Instrument Departures (SID). The influence of weather and weather phenomena is essential due to the various flight parameters and flight conditions [1]. The level of noise during the creation of new procedures must be considered at the highest possible level because it can have a negative impact on the population located near the airport [2,3]. According to the forecasts of the leading air carriers, the intensity of airspace use will increase by about 2-3 times by 2025. The requirements to increase the capacity and efficiency of airports in some world and European airports are high and are still increasing, especially to increase the throughput of the runway from the point of view of air traffic management. Runway capacity and efficiency is often directly related to the minimum longitudinal separation between approach phase operations and final approach or departure operations [4]. The current growth of air traffic requires finding more efficient ways of guiding aircraft through the Terminal Maneuvering Area (TMA), which connects the airways on the route to the ground, to avoid congestion. The solution is proposals for new departure and arrival procedures that consider several constraints, including obstacles around the airport, limited pitches, and yaw angles, and the need not to combine Standard Instrument Departures [5]. The airport is both the starting point and the final point of air transport. The sharp increase in the orderly flow of air traffic directly causes traffic congestion in the Terminal Maneuvering Area (TMA), which affects the optimal operation of flights. Optimization of departure and arrival procedures is therefore crucial for air traffic flow regulation. The design of several Standard Instrument Departures according to the instruments (SID) is one of the possibilities of solving the problem in the Terminal Maneuvering Area (TMA) with optimal lengths [6,7]. In addition to the Control Zone (CTR) and Terminal Maneuvering Area (TMA), the classic air traffic control system also includes a network of flight paths for conducting civil air traffic flights in the airspace and they are closely connected [8]. Standard Instrument Departures (SID) are used at many airports around the world. Standard Instrument Departure provides safe execution of the flight from the end of the runway to the network of flight paths on the route. Flights flown under Standard Instrument Departures contain many operational advantages, both for the pilot and for air traffic controllers [9]. Small deviations from the assigned Standard Instrument Departure occur on almost every Standard Instrument Departure flown. This is quite normal and does not pose an immediate threat to flight safety. However, large deviations from the assigned Standard Instrument Departure or an incorrectly flown Standard Instrument Departure can be dangerous and can result near terrain or an obstacle and proximity to other aircraft [10]. The ability to apply reduced spacing to Standard Instrument Departures increases efficiency and introduces a single-spacing rule concept, the Unified Departure Operation Spacing (UDOS) concept, where the same reduced initial spacing is generally used regardless of whether the departure

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paths diverge or not [11]. The effects of capacity constraints at airports with increasing flight traffic can be reduced by operational changes. To better solve this problem, the Single European Sky Air Traffic Management (ATM) Research (SESAR) and the Next Generation Air Transportation System (NextGen) program suggest Performance Based Navigation (PBN) as a solution. The Area Navigation (RNAV) and Required Navigation Performance (RNP) belong to the group of PBN procedures [12]. These procedures enable more efficient use of airspace by reducing en-route distances, fuel consumption and the perception of aircraft noise. The advantages of PBN systems compared to conventional navigation procedures based on devices are indisputable, but also economically more expensive [13]. Therefore, airports with conventional navigation devices use already existing procedures or create new procedures using traditional navigation devices. Some reconfigurations of standard departure routes at airports can bring significant reductions in fuel consumption and noise levels. This can be done either by introducing modern radio navigation aids for Terminal Maneuvering Areas or by removing restrictions on flying over cities and populated areas and designing low noise procedures for those areas. These operational solutions have been implemented at Henri Coanda International Airport in Bucharest and have other important benefits, such as reducing the workload of air traffic controllers and reducing the overall flight time [14]. At Kunovice airport, new Standard Instrument Departures were designed according to the Performance Based Navigation (PBN) concept and benefits such as increased airspace capacity, flexibility or reduced workload of air traffic controllers are expected [15].

After being inspired by the articles, Standard Instrument Departures at Malacky Airport were created in a conventional way, as the airport has conventional newly purchased navigation equipment. At the airport, there is a need for the creation of new Standard Instrument Departures, mainly from an economic point of view. Standard Instrument Departures are designed with maximum emphasis on safety, economy, and environmental impact. It is assumed that fuel consumption and flight time should be significantly reduced in the initial phase of flight in the Terminal Maneuvering Area (TMA).

II. Materials and Methods

A. Routes Creation

The creation of the SID (Standard Instrument Departure) routes began with the designation and analysis of airport obstacle area constraints, Obstacle surfaces and Noise contour model using the PHX system. The PHX instrument flight procedure design software package is a set of tools that can be used by a professional procedure designer to design instrument flight procedures. The PHX procedure design software is Not an automated system but is a “tool based” procedure design software package [16].

For the correct creation of maps, it was necessary to study the areas of CTR (Control Zone), TMA (Terminal Maneuvering Area) with an emphasis on MSA (Minimum Safe Altitude) shown on figure 1, available radio navigation devices and their working frequencies.

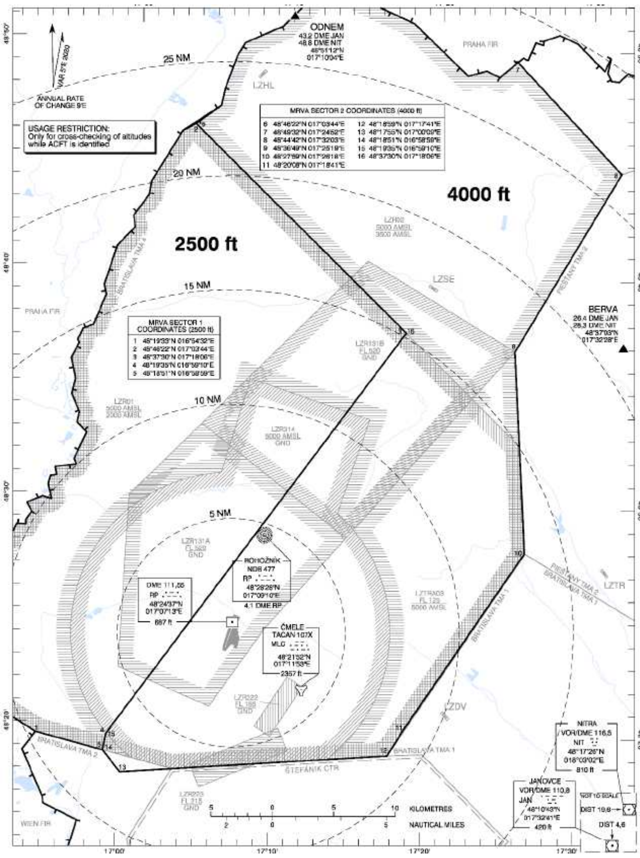

Fig. 1. Example of Minimum Sector Altitudes

The output of the PHX software is a set of SID maps, which had to be verified using flight verification.

Using the PHX software we created SID routes for RWY (Runway) 01 shown on figure 2.

TOVKA 1Z

The TOVKA 1A track is designed for departure southeast from runway 01 at LZMC airport to TOVKA. After take-off, the aircraft is required to maintain the course of the runway up to the RP point, which is defined by a non-directional NDB radio beacon. As for the vertical profile, the aircraft needs to reach an altitude of 3500 feet at the latest on NDB RP. RP can also be defined in the form of radial and course from the omnidirectional beacon VOR JAN, the specific value is R315 and DME distance 23.6NM from VOR JAN. After reaching the RP point, the aircraft turns into course 180, that is, exactly south until the moment of flying course 216 from the NDB RP. Subsequently, the aircraft maintains this course until the TOVKA point, where the departure route segment ends.

JAN1Z

The design of line JAN1A was created as the primary departure direction from runway 01 to the southeast, specifically to the JAN point defined by the VOR JAN device. Similar to the departure of TOVKA 1Z. After takeoff, it is necessary for the aircraft to maintain the course of the runway up to the RP point, which is again defined by the NDB omnidirectional radio beacon As for the vertical profile, the aircraft needs to reach an altitude of 3500 feet at the latest

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on the NDB RP, similar to the previous case of departure to the TOVKA point. Following the flyover of RP NDB, it is necessary to pour radial 328 onto VOR JAN, which we maintain until arrival at VOR JAN.

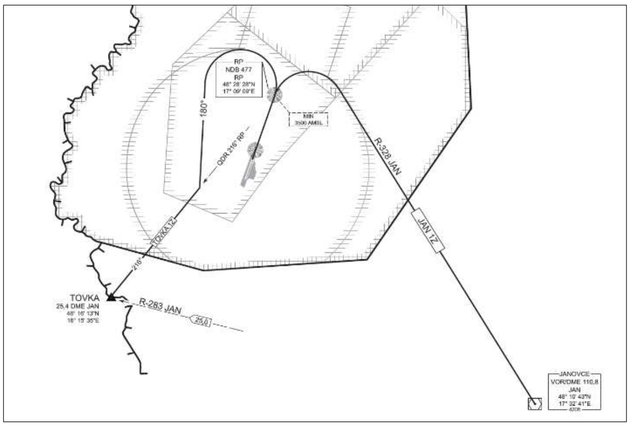

Fig. 2. SID router for runway 01 at Malacky Airport

Using the PHX software were also created SID routes for runway 19 shown on figure 3.

JAN 1A

The design of line JAN1A was created as the primary departure direction from runway 19 to the southeast, specifically to the JAN point defined by VOR JAN equipment. After takeoff from runway 19, it is necessary to maintain the course of the runway until the moment of reaching an altitude of 1200 feet. Subsequently, it is necessary to pour course 038 to the NDB device marked RP. The length of the line section is approximately 7NM to the FP point and it is required that the aircraft has an altitude of 3500 feet and reaches it no later than the FP point. The RP point can also be defined in the form of radial and course from VOR JAN, the concrete value is R 315 and DME distance 23.6NM from VOR JAN. After passing the RP point, it is necessary to pour radial 140 from the VOR JAN device and maintain this course until reaching the JAN point.

TOVKA 1A

The TOVKA 1A line is designed for departure southeast from runway 19 at LZMC airport, specifically to the TOVKA point. Like the departure route JAN1Z, it is necessary to maintain the course of the runway after take-off from runway 19 until it reaches an altitude of 1200 feet. After that, it is necessary to pour the course 038 again to the NDB device marked RP. The length of the line section is approximately 7NM to the FP point and it is required that the aircraft has an altitude of 3500 feet and reaches it no later than the FP point. The RP POINT can again be defined in the form of radial and course from VOR JAN, the concrete value is R 315 and DME distance 23.6 NM from VOR JAN. After reaching the RP point, the plane turns into course 180, that is, exactly south until the moment of flying course 216 from the NDB RP. Subsequently, the aircraft maintains this course until the TOVKA point, where the departure route segment ends.

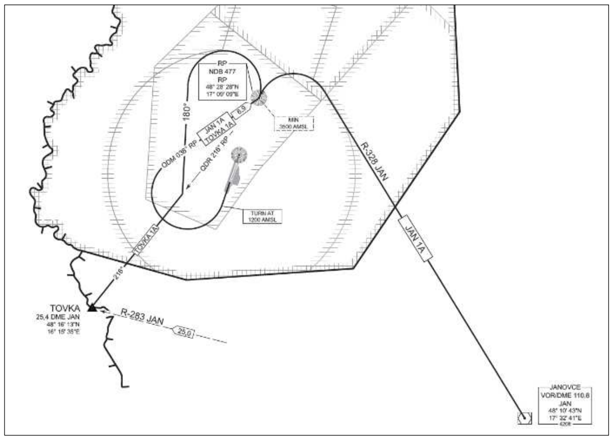

Fig. 3. SID router for runway 19 at Malacky Airport

B. *Flight Simulator for Routes Verification*

For Routes verification the Elite Flight Simulator was used, Approved by EASA (European Air Safety Agency) for BITD (Basic Instrument Training Device). The Elite BITD (see figure 4) is an EASA entry level flight simulator offering some credits towards training, but predominantly a great tool for educational purposes and most importantly it is affordable. The ELITE S612 BITD features a single pilot, fully enclosed spacious cockpit with a separate detached instructor's station. Part of the package is an EASA CS-FSTD A (Airplane Flight Simulation Training Device) factory acceptance along with relevant qualification test guide documentation for the flight model Beech Baron Be58. The S612 BITD is also approved under FAA (Federal Aviation Administration) regulations as AATD (Advanced Aviation Training Device) and under CASA (Australian Civil Aviation Safety Authority) regulations as a Level B FSD2 (Approved flight Training Device) training device.

Fig. 4. Elite S612 BITD ME Simulator with flight model Beech Be58

Flight verification took place on the S612 BITD ME simulator, specifically on the flight model, which represents the BEECH Be58 aircraft.

Description of aircraft and model

The flight model has the following navigation instrumentation: 2x COMM NAV radios with HSI and CDI stations, 1x DME for both navigation radios, RMI display also for both navigation radios and 1x ADF. The flight model is also equipped with a simple GPS GARMIN Apollo GX50, which, however, does not allow use for the PBN area.

ELITE PILOT 8 software

The ELITE S612 BITD ME flight simulator is equipped with software called Elite PILOT 8. The software enables advanced control of the simulator itself while respecting all requirements for simulation of different flight modes, including the possibility of adjusting weather conditions. Complete map coverage of the European area is also available, including a database of airports, radionavigation equipment and points within the region of Europe.
An equally important part of the program is a panel called MODIFICATION, (see figure 5) where the software allows the creation of a new airport, point or radio navigation equipment of all others. For the conditions of our flight verification, this was an important part of the program, as Malacky-Kuchyňa LZMC airport is a NATO air base, which means that the airport and its components were not included in a valid database with all its equipment.

It was necessary to create new points into the databases, respectively new radio navigation devices such as NDB, new ILS frequencies, and so on. Figure 4 shows the environment of ELITE PILOT 8 Software in MODIFICATION mode.
Thanks to the advanced flight model, the accuracy and response of the instruments corresponds to reality, that is, this flight simulator is suitable for performing said flight verification.

C. *Creation of equipment in softvare Elite PILOT 8*

For the needs of verification flights on the ELITE Beech Baron B58 pilot simulator, it was necessary to modify Malacky airport in the simulator software environment and add some radio navigation equipment. For the correct verification of standard instrument departure routes, it was necessary to create points:

- NDB R with coordinates N4825266 E01707643, variation E04.6, station elevation 715 ft, working on frequency 231.0 kHz, and range 60 nautical miles.
- NDB RP with coordinates N4828466 E017091510, variation E04.6, station elevation 673 ft, working on frequency 477.0 kHz, and range 60 nautical miles.
- ILS RP with coordinates N4823124 E01706628, variation E04.6, station elevation 659 ft, working on frequency 111.55 MHz, magnetic localizer bearing 193°, glide slope angle 3°.

Example of radionavigation devices creation is shown on figure 5.

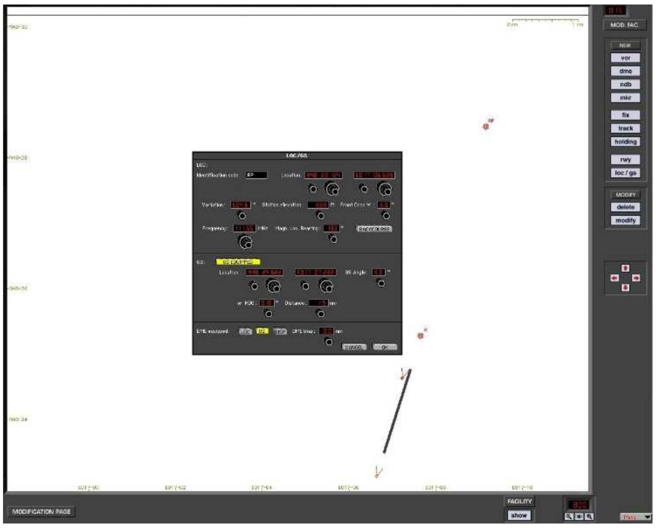

Fig. 5. "MODIFICATION" Menu in software Elite PILOT8

The output of the ELITE Beech Baron B58 simulator is also a horizontal and vertical flight profile also in text form and „saved"graphic history which is shown in the figures 6 and 7. PILOT8 saves the flying route in a .pth file format that only PILOT8 can read. For research and diagnostic purposes, ELITE solutions provide a software tool to compress a .pth file into .txt format. And the subsequent data can then be read from a clear table in a time sequence of one second. For example, the modified output provides the following data: Latitude, longitude, altitude of IAS VS, Radial Ground speed and many other parameters such as damper position, chassis position, identification of data on display devices, etc.

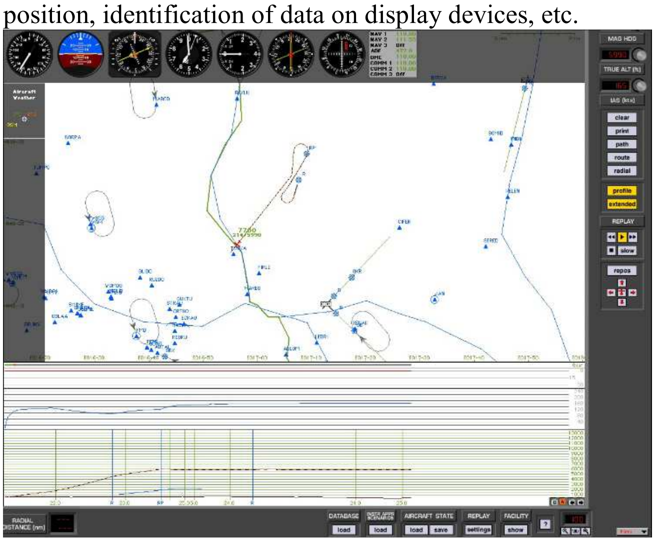

Fig. 6. Aircraft state and path menu nin sofrtware Elite PILOT8

Lat	Lon	Nav_Dist		Alt	IAS	HDG	DME_Dist		GS_Alt	GS_Alt_High		GS_Alt_Low		Radian	Gear	Flaps	VSpeed	Path_Ty
48.391335	17.113333	-9999.000000	694	0	13	-9999	-9999	-9999	-9999	-9999	2	0	0	0	99	-		-4
48.391335	17.113333	-9999.000000	694	0	13	-9999	-9999	-9999	-9999	-9999	2	0	0	0	99	-		-4
48.391335	17.113333	-9999.000000	694	0	13	-9999	-9999	-9999	-9999	-9999	2	0	0	0	99	-		-4
48.391335	17.113333	-9999.000000	694	0	13	-9999	-9999	-9999	-9999	-9999	2	0	0	0	99	-		-4
48.391335	17.113333	-9999.000000	694	0	13	-9999	-9999	-9999	-9999	-9999	2	0	0	0	99	-		-4
48.391335	17.113333	-9999.000000	694	0	13	-9999	-9999	-9999	-9999	-9999	2	0	0	0	99	-		-4
48.391335	17.113333	-9999.000000	694	0	13	-9999	-9999	-9999	-9999	-9999	2	0	0	0	99	-		-4
48.391335	17.113333	-9999.000000	694	0	13	-9999	-9999	-9999	-9999	-9999	2	0	0	0	99	-		-4
48.391335	17.113333	-9999.000000	694	0	13	-9999	-9999	-9999	-9999	-9999	2	0	0	0	99	-		-4
48.391335	17.113333	-9999.000000	694	0	13	-9999	-9999	-9999	-9999	-9999	2	0	0	0	99	-		-4
48.391335	17.113333	-9999.000000	694	0	13	-9999	-9999	-9999	-9999	-9999	2	0	0	0	99	N	RP	-4
48.391335	17.113333	-9999.000000	694	0	13	-9999	-9999	-9999	-9999	-9999	2	0	0	0	99	-		-4
48.391335	17.113333	-9999.000000	694	0	13	-9999	-9999	-9999	-9999	-9999	2	0	0	0	99	-		-4
48.391335	17.113333	-9999.000000	694	0	13	-9999	-9999	-9999	-9999	-9999	2	0	0	0	99	-		-4
48.391335	17.113333	-9999.000000	694	0	13	-9999	-9999	-9999	-9999	-9999	2	0	0	0	99	-		-4
48.391335	17.113333	-9999.000000	694	0	13	-9999	-9999	-9999	-9999	-9999	2	0	0	0	99	-		-4
48.391335	17.113333	-9999.000000	694	0	13	-9999	-9999	-9999	-9999	-9999	2	0	0	0	99	-		-4
48.391335	17.113333	-9999.000000	694	0	13	-9999	-9999	-9999	-9999	-9999	2	0	0	0	99	-		-4
48.391335	17.113333	-9999.000000	694	0	13	-9999	-9999	-9999	-9999	-9999	2	0	0	0	99	-		-4
48.391335	17.113333	-9999.000000	694	0	13	-9999	-9999	-9999	-9999	-9999	2	0	0	0	99	-		-4
48.391335	17.113333	-9999.000000	694	0	13	-9999	-9999	-9999	-9999	-9999	2	0	0	0	99	-		-4
48.391342	17.113337	-9999.000000	694	4	13	-9999	-9999	-9999	-9999	-9999	2	0	0	0	99	-		-4
48.391376	17.113352	-9999.000000	694	10	13	-9999	-9999	-9999	-9999	-9999	2	0	0	0	99	-		-4
48.391434	17.113380	-9999.000000	694	16	14	-9999	-9999	-9999	-9999	-9999	2	0	0	0	99	-		-4
48.391521	17.113422	-9999.000000	694	22	14	-9999	-9999	-9999	-9999	-9999	2	0	0	0	99	-		-4
48.391636	17.113476	-9999.000000	694	28	14	-9999	-9999	-9999	-9999	-9999	2	0	0	0	99	-		-4
48.391773	17.113543	-9999.000000	694	34	13	-9999	-9999	-9999	-9999	-9999	2	0	0	0	99	-		-4
48.391937	17.113619	-9999.000000	694	39	13	-9999	-9999	-9999	-9999	-9999	2	0	0	0	99	-		-4
48.392124	17.113705	-9999.000000	694	45	13	-9999	-9999	-9999	-9999	-9999	2	0	0	0	99	-		-4
48.392334	17.113800	-9999.000000	694	50	13	-9999	-9999	-9999	-9999	-9999	2	0	0	0	99	-		-4
48.392567	17.113907	-9999.000000	694	55	13	-9999	-9999	-9999	-9999	-9999	2	0	0	0	99	-		-4
48.392818	17.114025	-9999.000000	694	60	13	-9999	-9999	-9999	-9999	-9999	2	0	0	0	99	-		-4
48.393093	17.114153	-9999.000000	694	64	14	-9999	-9999	-9999	-9999	-9999	2	0	0	0	99	-		-4
48.393383	17.114294	-9999.000000	694	68	14	-9999	-9999	-9999	-9999	-9999	2	0	0	0	99	-		-4
48.393700	17.114449	-9999.000000	694	72	14	-9999	-9999	-9999	-9999	-9999	2	0	0	0	99	-		-4

Fig. 7. Decoded text form of aircraft path in sotware Elite PILOT8

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III. DISCUSION AND RESULTS

Flight verification of all routes was carried out in accordance with standard flight simulation using the above-mentioned flight simulator. The flight on the route was in "on hand" mode, so the flight did not use an autopilot. As for meteorological conditions, these were set to CAVOK weather with no wind, the airport pressure QNH was set to 1013HPa. During the simulations, the biggest problem seemed to be stabilizing the aircraft on the desired course when pouring pointers from non-directional radios. A relevant comment in this case would be the use of procedures using PBN, but this is the subject of our further research.

At the end of the research, using available software information, the output of the performed simulations was created in the form of a map base using the Google earth environment and with the "tracking line" of the given flights. The source of data for the creation of the "tracking line" was the above-mentioned software tool from Elite. Thanks to which we obtained coordinates and altitude in second intervals. The following illustrations show the simulation flows embedded in the Google earth environment (see figures 8 to 11)

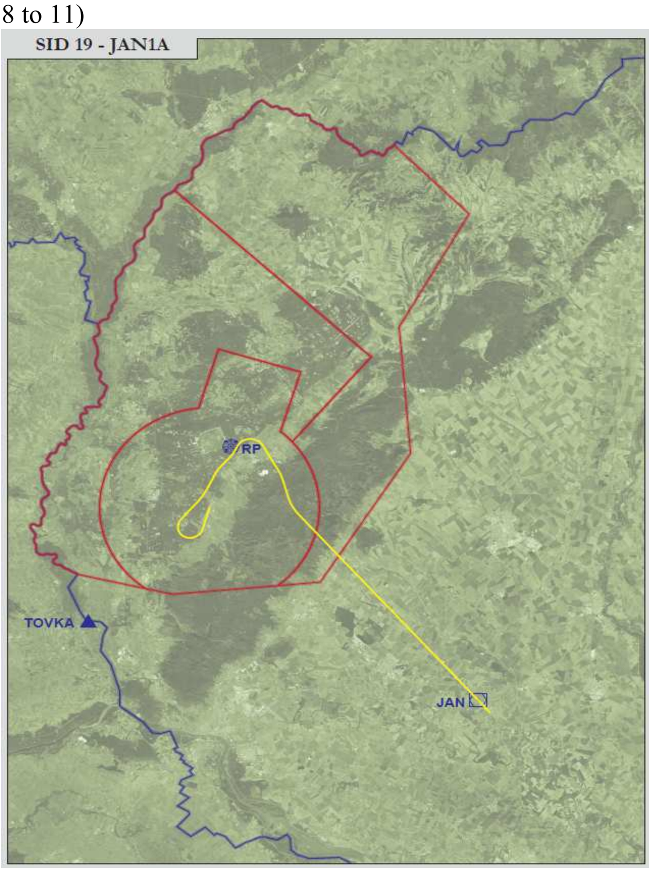

Fig. 8. Simulated flight on route JAN 1A

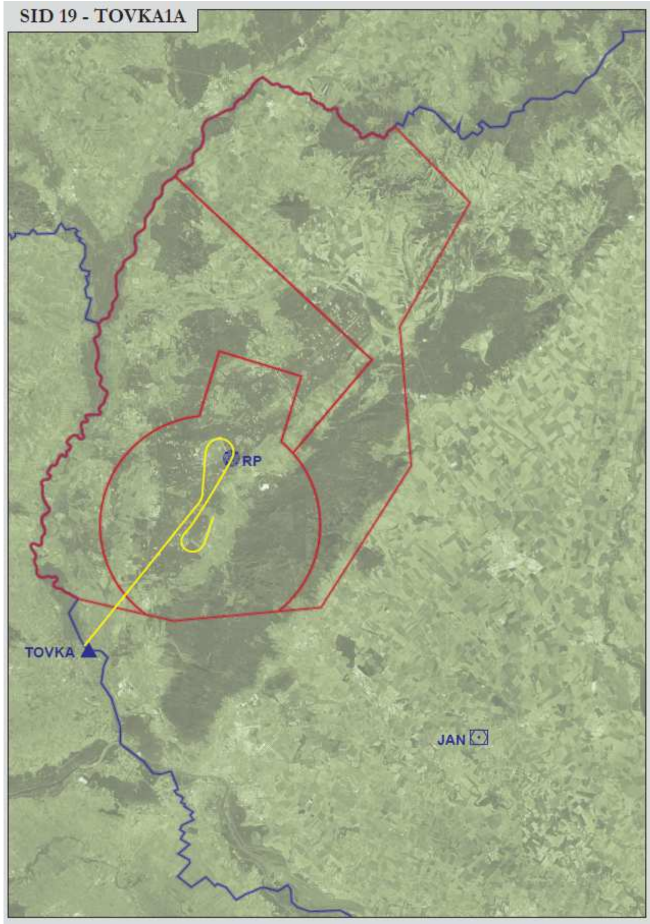

Fig. 9. Simulated flight on route TOVKA 1A

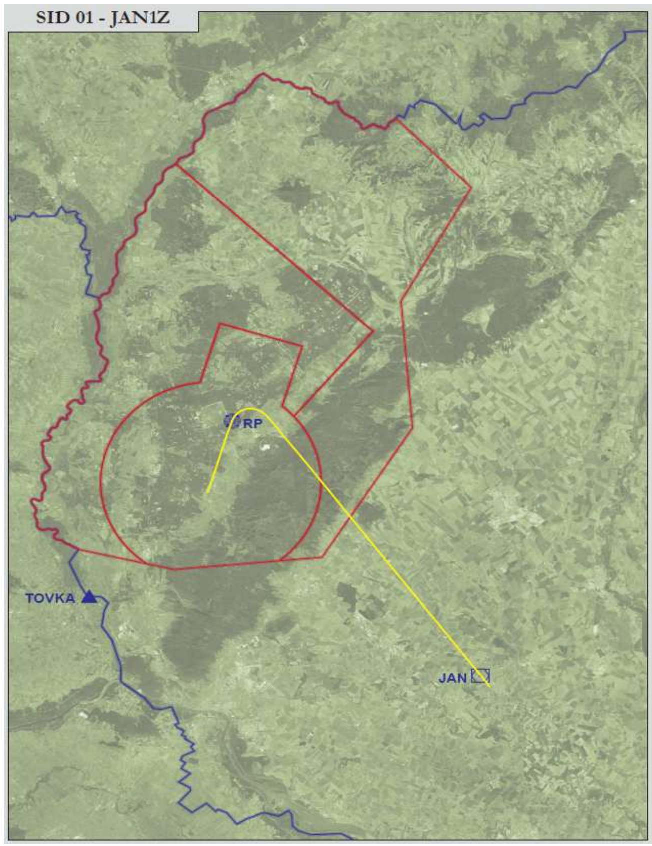

Fig. 10. Simulated flight on route JAN 1Z

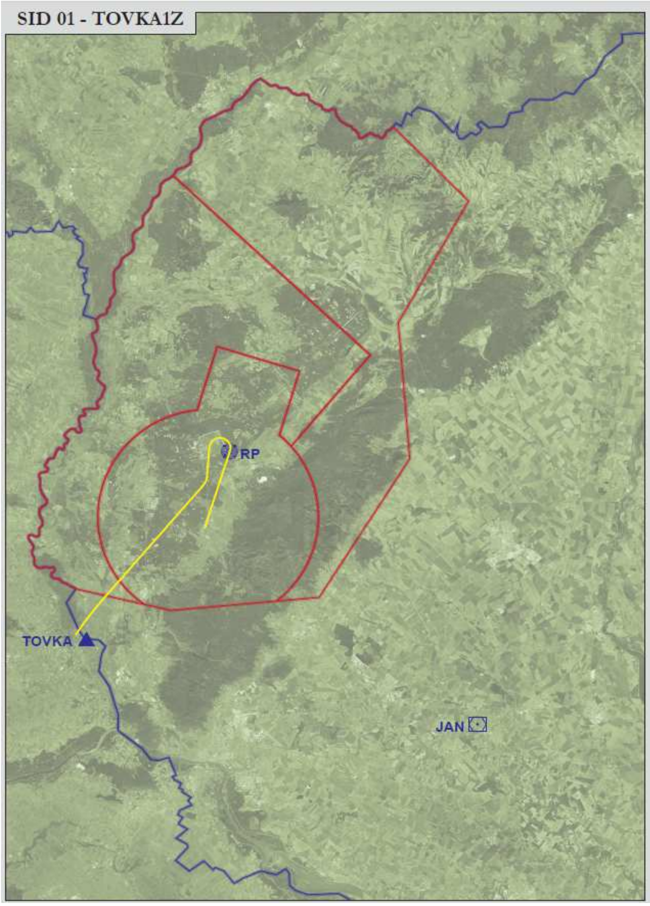

Fig. 11. Simulated flight on route TOVKA 1Z

IV. Conclusion

The article points to the verification of the eligibility of constructed SID departure routes for the Malacky - Kuchyňa airport. As a result of the research, the proposed routes comply with the parameters for the categories of aircraft with which the lines were laid. Of course, further continuing research includes the ambition to create arrival routes STAR from TOVKA and JAN points also for both directions of runway 01 and 19. The subsequent procedure will again be flight verification using simulation on the S612 BITD ME flight simulator. For comparison, the authors plan to perform a flight verification simulation using simulation on another type of flight simulator available to the Faculty of Aeronautics, namely the ELITE S612 BITD SE installation, which includes the flight model of the C172RG aircraft. This trainer is also upper, as it simulates an airplane from the same category. Successful verification on flight simulators will also be followed by flight verification in real conditions using the Diamond DA-20 and LET L-410 Turbolet.

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