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Review article

IMPLEMENTATION OF SATELLITE TECHNIQUES IN THE AIR TRANSPORT

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Abstract

The article shows process of the implementation satellite systems in Polish aviation which contributed to accomplishment Performance-Based Navigation (PBN) concept. Since 1991 authors have introduced Satellite Navigation Equipment in Polish Air Forces. The studies and researches provide to the Polish Air Force alternative approaches, modernize their navigation and landing systems and achieve compatibility with systems of the North Atlantic Treaty Organization (NATO) and International Civil Aviation Organization (ICAO). Acquired experience, conducted military tests and obtained results enabled to take up work scientifically - research in the environment of the civil aviation. Therefore in 2008 there has been launched cooperation with Polish Air Navigation Services Agency (PANSA). Thanks to cooperation, there have been compiled and fulfilled three fundamental international projects: EGNOS APV MIELEC (EGNOS Introduction in European Eastern Region - APV Mielec), HEDGE (Helicopters Deploy GNSS in Europe), SHERPA (Support ad-Hoc to Eastern Region Pre-operational in GNSS). The successful completion of these projects enabled implementation 21 procedures of the RNAV GNSS final approach at Polish airports, contributing to the implementation of PBN in Poland as well as ICAO resolution A37-11. Results of conducted research which served for the implementation of satellite techniques in the air transport constitute the meaning of this material.

Keywords: *aviation, air transport, satellite systems, satellite techniques, PBN, GNSS, SHERPA, HEDGE*

1. Introduction

In 1979 an implementation of satellite techniques was initiated in Polish aviation. Then prof. Jan Stanisław Wereszczyński (1914-1991) as the manager of the thematic group navigation with exploiting satellite ”techniques of the Space Research Centre of Polish Academy of Sciences, remain a member of the Scientific Council of Higher Officers' Air School in Dęblin (The Polish Air Force Academy). In 1981 in WOSL the first Polish air team carrying out the project together with the navy "Implementation system TRANSIT to the navigational positioning". The subject taken up was on the time, because this system designed in 1967 was made available to civil users. Even though the TRANSIT system was used for the marine navigation, it was independent of the weather, but was composed by only a few available satellites and an included adopted method of outlining positional lines only several times for twenty-four hours. It made them impossible to use in air navigation. Therefore a successor to the TRANSIT system appeared, American military GPS-NAVSTAR system. Due to geopolitical issues, embargo on satellite technology, first applying this system in Poland had been hampered. Only after shooting down passenger plane of Korean lines in 1983 above territory the USSR, system the GPS was made available for civil applications, but with restrictions (SA and the A-S). Thanks to that undertaking further research associated with differencing satellite. Conception RTK DGPS technicians was possible within the framework of Polish Radionavigation Plan and with testing receivers on boards of Polish aircraft. Get results of military works scientifically – research and acquired experience allowed in years:

- 1992 – 2007 effecting of air-tests in the Polish Air Force basing on board air - satellite receivers. This stage is yet still realized but with smaller intensity, working out of foundations tactical and technical, effecting of investigations, researches and put into execution polish DGPS of system of permanent stations for needs of aviation, compatible with requirements: NATO;
- 2008 – 2014 has been launched cooperation with Polish Air Navigation Services Agency (PANSA). Thanks to cooperation, there have been compiled and fulfilled three fundamental international projects: EGNOS APV MIELEC (EGNOS Introduction in European Eastern Region - APV Mielec), HEDGE (Helicopters Deploy GNSS in Europe), SHERPA (Support ad-Hoc to Eastern Region Pre-operational in GNSS). The successful completion of these projects enabled implementation 21 procedures of the RNAV GNSS final approach at Polish airports, contributing to the implementation of PBN in Poland as well as ICAO resolution A37-11.

At the Prague Summit of January 1994, President Clinton offered a U.S. initiative for the regional airspace management modernization for Central and Eastern Europe (CEE). The offer was initially focused on Hungary, Poland, Slovakia, and the Czech Republic with a possible extension to other regional countries in the future. In light of the previous interest expressed by these four CEE countries in airspace management modernization, which includes active participation in the NATO Committee for European Airspace Coordination (CEAC), President Clinton selected this initiative as one which could be offered as U.S. assistance to foster regional cooperation. Specifically, the initiative offered assistance in designing a regional civil-military air traffic control and air sovereignty architecture which would emphasize joint civil/military resource sharing and regional cooperation to minimize the total costs of satisfying host country air traffic control and air sovereignty requirements. The intended objectives for air traffic control modernization are to realize the efficiency of regional cooperation and to achieve full compliance with European Air Traffic Control Harmonization and Integration Program (EATCHIP) standards. The existing navigation aid system are mostly Soviet-built. According to the Polish military officials, the performance of the existing nav-aid equipment meets their needs, but they plan to replace some of the equipment to achieve interoperability with NATO systems. The Polish government is currently evaluating several options to replace the existing "Eastern" aircraft with "Western" aircraft. Once the purchase of particular types of aircraft is finalized, they plan to make a decision regarding the use of specific avionics and compatible aircraft landing systems.

The implementation of satellite techniques in the Polish air transport was possible after the adoption of uniform military-civil aviation standards. The Electronic Systems Center's International Programs Office, ESC/IA and The Air Force and Defense Command, conducted a study of the navigation system upgrade requirements for the Polish military airfields selected for NATO operations. The study objectives were to pro-vide the Polish Air Force alternative approaches to modernize their navigation and landing systems and achieve compatibility with the North Atlantic Treaty Organization (NATO) and International Civil Aviation Organization (ICAO) Systems. The 6-month study was structured as a three-step effort involving collection of data on the existing Polish Nav-aid Systems, assessment of current capabilities compliance with the NATO/ICAO interoperability requirements, and formulation of modernization approaches to achieve compatibility. The study focus was to recommend a navigation systems modernization implementation approach to achieve minimum NATO/ICAO interoperability requirements prior to April 1999. Post April 1999 modernization recommendations are also presented to al-low incremental implementation of the state-of the-art navigation systems to achieve full compliance with NATO/ICAO.

Implementation of the modernization recommendations presented in this report will achieve compliance with the NATO/ICAO navigation and landing systems requirements. The recommendations are based on the adequacy of the existing capability to satisfy the applicable interoperability requirements for NATO/ICAO. The study considered the following six Navaid interoperability capabilities in formulating the recommendations:

1. Precision approach
2. Non precision approach
3. Enroute navigation
4. Avionics
5. Approach lighting system
6. Voice communications

2. GNSS implementation for Polish aviation 1992-2007

The Air Force Academy has executed in May 1992 first polish flight experiments, installed on board helicopters Mi-8, Mi-14, SOKÓŁ and airplane ISKRA (fig. 1), receivers of satellite technology: TRIMBLE, SEXTANT AVIONIQUE, SEL ALCATEL, KLN 89 (fig. 2). Then helicopters and airplanes flew along the route. As a results of flight tests with the GPS system in aviation applications to have got a 95 percent accuracy of 100 m. (horizontal) and 156 m (vertical), when the signals were intentionally degraded by selective availability. I thing that were very good results, because GPS in 1992 wasn’t operational capacity.

The Air Force Academy has executed the next experiment in 1993 year, installed on board airplane The GPS MAGELLAN NAV receiver. As a result of flight tests in aviation applications to have got a 95 percent accuracy of 100 m. (horizontal) and 156 m. (vertical), when the signals were degraded by S.A and A - S.

Fig. 1. The Polish aircraft TS-11 “Iskra” used for flight tests

Fig. 2. An on-board GPS receiver KLN 89 mounted in Polish aircraft TS-11 “Iskra”

From 26.07 to 27.07.1993, as a result of co-operation the Air Force Academy and the University of Agriculture and Technology, the pilot investigations were accomplished, which aimed at determination of navigation points of Deblin airport in global reference system. The obtained results of pilot experiment will be a base for further investigations which should take advantages of installing DGPS receivers on airplanes for modern navigational technique and optimisation of flights. The research project comprises two stages. At the first stage it is planned to perform flights over the points with co-ordinates determined during the pilot experiment and to compare values of stationary measured co-ordinates with values received during DGPS measurements taken during the flight of the airplane. At the same time the points with co-ordinates determined during the pilot experiment may serve as reference points. At the second stage of planned research works the co-ordinates obtained in stationary measurements will be put in the memory of DGPS receivers and a set of flights will be done. All sets of flights should be performed in different weather conditions, in day and at night, with different number of used satellites. For all these mentioned investigations it was necessary to connect the network in Dęblin airport to the global system of co-ordinates and determination, in stationary sessions, the co-ordinates of terrestrial navigational points in this system. In described experiment the terrestrial navigational points of Dęblin airport were tied up to the station Borowa Góra, which belongs to EUREF - POL 92 network. Four dual frequency Ashtech MD XII receivers were used for measurements. Computer elaboration of GPS measurements, adjustment of the network and accuracy analysis were done by the team from the Institute of Geodesy and Photogrammetry, Olsztyn University of Agriculture and Technology.

From 1994 to 1996, as a result of cooperation with: The University of Agriculture and Technology, The Commission of Satellite Geodesy of the Committee of Space and Satellite Research of Polish Academy of Science, the Air Force Academy has tested the GPS navigation equipment MAGELLAN, TRIMBLE, GARMIN, NAVI, SEXTANT AVIONIQUE. The Polish Air Force hasn't tested the ASHTECH GPS navigation equipment on board airplanes, because the Air Force Academy hasn't aircraft receivers of Ashtech.

Polish trainer jet called TS11 Iskra equipped with GPS hardware was used for the flight tests. The GPS observations were carried out with Ashtech GPS receivers (Ashtech Z-Surveyor, Ashtech Z-XII), for EGNOS corrections Javad Legacy receiver was used. Four GPS reference stations were taking part in the experiment, located along the aircraft route. The reliable - reference positions of the aircraft trajectory were determined as an average of four positions calculated independently on the basis of every reference station. Collected results during air experiments are presenting fig. 3, fig. 4, fig. 5. The GPS observations were carried out with Ashtech GPS receivers (Ashtech Z-Surveyor, Ashtech Z-XII), for EGNOS corrections Javad Legacy receiver was used. Four GPS reference stations were taking part in the experiment, located along the aircraft route. The reliable - reference positions of the aircraft trajectory were determined as an average of four positions calculated independently on the basis of every reference station. Experiment conducted during the final approach of the Su-22 plane provided with interesting results with the deck GG24 receiver with dual-capable GPS/GLONAS (fig. 6).

The implementation of GNSS operations requires that Polish aviation authority consider a number of elements including the following:

- planning and organization;
- procedure development;
- air traffic management (airspace and ATC considerations);
- aeronautical information services;
- system safety analysis;
- certification and operational approvals;
- anomaly/interference reporting;
- transition planning.

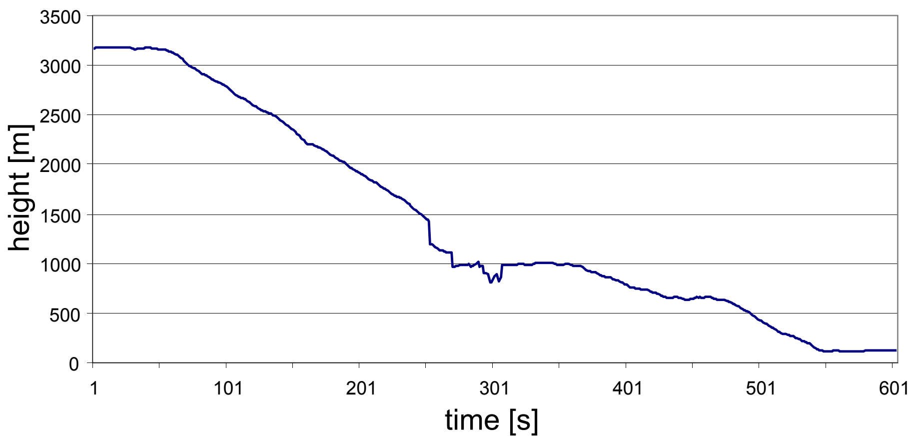

Fig. 3. Vertical plot of the TS-11 Iskra aircraft as a function of ellipsoidal height and GPS time

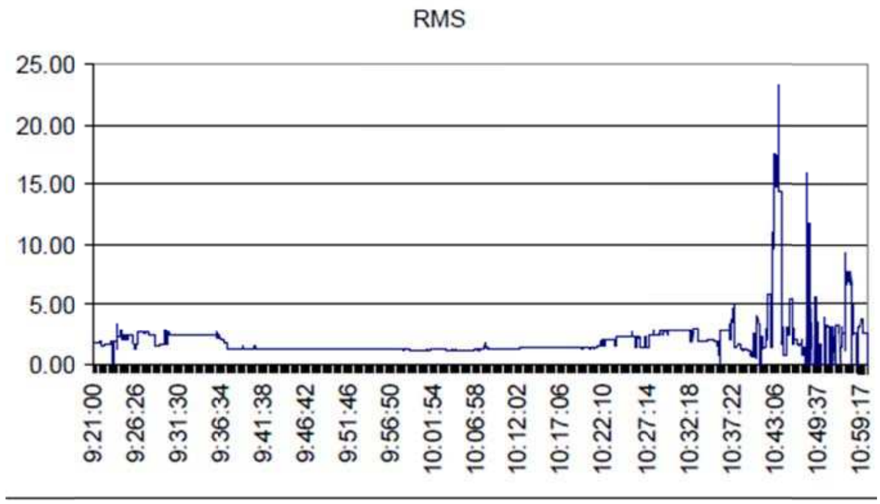

Fig. 4. Plot of mean geodesic co-ordinate errors during descent

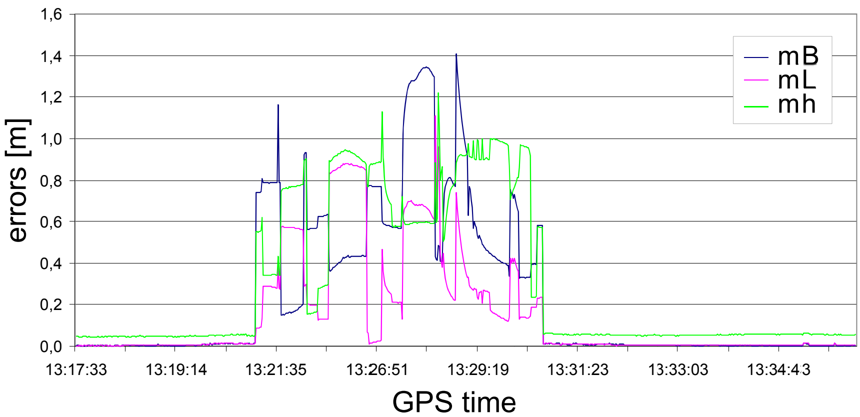

Fig. 5. Plot of mean geodesic coordinate errors during descent (illustrates mean geodesic co-ordinate errors during descent as well, but it is important to note, that these errors rose, when the aircraft executed approach descent flight with changing flight parameters, such as G-force, the angle of pitch, banking and the value of angle acceleration).

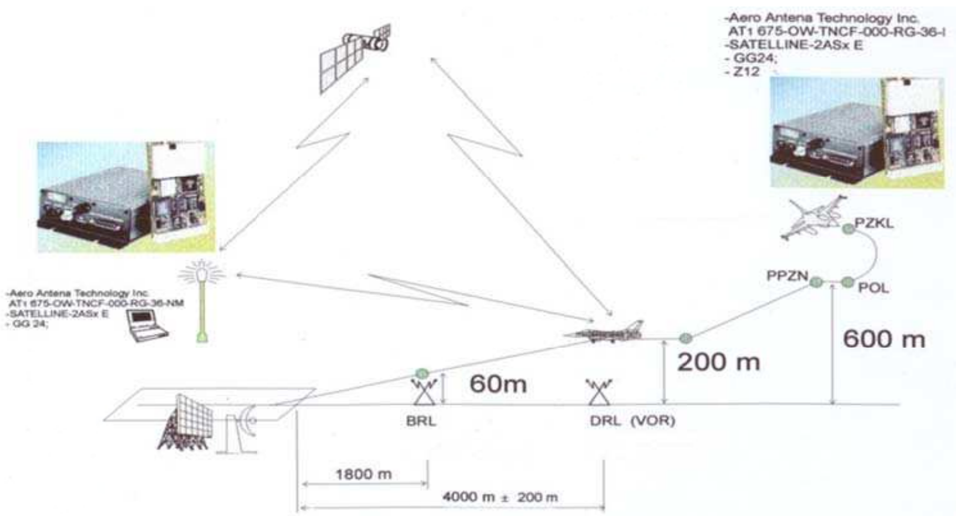

Fig. 6. The final approach of the Su-22 plane with GG24 receiver GPS/GLONAS

Considering the complexity and diversity of the global airspace system, planning can best be achieved if organized regionally and/or in wide areas of common requirements and interest, taking into account traffic density and level(s) of service required. Planning and implementation is a State's responsibility within FIRs where it provides air traffic services, unless States have agreed to jointly plan services in an area covering more than one State. Owing to the global nature of GNSS signals, it is important to coordinate the planning and implementation of GNSS services to the greatest extent possible.

While this objective is normally pursued through ICAO and its regional bodies, it should be supplemented by bilateral and multilateral coordination where necessary. The latter coordination should address detailed aspects not covered within the ICAO framework. Experience has shown that the decision to implement GNSS within States should be made at the highest level and coordinated regionally within the ICAO Regional Implementation Planning Groups. Successful implementation programmes usually involve cooperative efforts that include all departments and/or individuals who are affected by the possible outcomes, who will have the authority for committing resources to ensure completion of the programme.

There is a need for users, including air carriers, general aviation, and the military, to be included in the GNSS implementation team to allow them to communicate their specific requirements. Users will then be able to assist State authorities to develop an effective and efficient GNSS implementation strategy. A technical committee could be formed and given the responsibility for defining requirements and executing the implementation plan. Team composition may vary by State, but the core group responsible for the GNSS programme should include members with operational expertise in aviation, and could include:

- Operations (persons responsible for operational approvals, pilot training, and flight procedures);
- Airworthiness standards (persons responsible for approving avionics and installations);
- Aviation standards (persons responsible for developing instrument approach procedures and developing obstacle clearance criteria, etc);
- Aeronautical information service (persons who are involved in NOTAM, procedure design, databases etc);
- Air traffic services (persons responsible for developing ATC procedures and controller training);
- Aerodrome operator (persons responsible for developing aerodrome infrastructure to support approach operations);
- Engineering (engineers responsible for the design of systems and equipment);
- Airline representatives (personnel from flight operations and flight crew training);
- Other user groups (representatives of general, business, commercial aviation, unions, as well as other modes of transport that may use GNSS; surveyors, GNSS receiver manufacturing representatives etc);
- Military representatives;
- Other foreign civil aviation or ICAO officials (for educational purposes).

The plan should identify capabilities that should be in place in order to meet various requirements for each approval stage and steps needed for implementation, and should consider regional and global planning for CNS/ATM systems. The GNSS plan should include the development of a business case. The adoption of CNS/ATM systems has major economic and financial implications for service providers and airspace users. Business case development at the State level is essential in determining the effect of GNSS and also to choose the most cost-effective implementation strategy.

It is important to note that there are not regulation and certification concerning the utility of GNSS in Polish aviation. The transition to GNSS represents a significant change for aviation, so it requires new approaches to regulations, providing service and operating aircraft. A successful transition to GNSS requires a comprehensive orientation and training programme aimed at all involved parties. This program should keep pace as GNSS evolves. It is most important that the decision-makers in aviation organizations receive a broad appreciation of the capabilities and potential of GNSS to deliver service.

The GNSS transition path and timetable depends on a variety of factors, so the information provided to decision-makers should evolve accordingly. Staffs in regulatory and service provider organizations require background training to be able to appreciate how GNSS could affect their area of responsibility. This should include: the basic theory of GNSS operations; GNSS capabilities and limitations; avionics performance and integration; current regulations; and concepts of operation. This should be followed by job-specific training to prepare staff to plan, manage, operate and maintain the system.

For many pilots, GNSS represents the first exposure to avionics that require programming instead of simply the selection of a frequency. The wide variety of pilot interfaces dictates a new approach to training and the certification of pilots. Aircraft operators should develop manuals and other documents aimed at assisting pilots to use GNSS properly and safely. ATC training should include the application of GNSS to RNAV to ensure maximum use of this technology

3. Application of the Global Navigation Satellite System (GNSS) in air navigation

3.1 EGNOS Data Collection Network (EDCN, EDCN_Next) Projects

The EGNOS Signal-in-Space (SIS) Validation (ESV) Task Force has been established by the Eurocontrol Navigation Domain to coordinate (technical) activities necessary to assess the performance achievable with a Minimum Operation Performance Standards (MOPS) compliant receiver over the ECAC Countries.

In the frame of these activities Eurocontrol has established a standardized data collection environment to perform continuous EGNOS performance monitoring. Next to European Air Traffic Service Providers (ATSP), six universities, geographically distributed around Europe, are involved in the validation task. The added value of this work, in addition to the EGNOS system verification activities, lays in the independence of the data collection sites with respect to the Ranging and Integrity Monitoring Stations (RIMS) locations and a greater diversity of the receivers and analysis tools.

The actual achieved performance in each location is assessed (thereby using the accurately known location of the monitor station) and the performance is checked against the Required Navigation Performance (RNP) requirements (Accuracy, Availability, Integrity and Continuity of service). In addition any anomalies identified are analyzed in detail to assess the cause, the probability of re-occurrence and possible mitigation techniques from the user side.

PANSA's Monitoring Stations Network and EDCN: Equipment (GNSS Receivers 5xPolaRx2e, 2xPolaRx4Pro), Software (PEGASUS/EUROCONTROL, Magic Gemini GMV), Localizations (Warszawa, Rzeszów, Kraków, Gdańsk, Poznań)

3.2 EGNOS Introduction in European Eastern Region - APV Mielec and Helicopters Deploy GNSS in Europe (HEDGE) Projects

In Poland, the first flight trials of approach operations designed in accordance with APV specification based on EGNOS took place 14/15 March 2011 in Katowice and Mielec.

These trials were successful and they confirmed that EGNOS can be used to support navigation procedures in Poland. These pioneer flights were made in frame of APV Mielec and HEDGE projects. Deliverables collected during these projects like procedures, business case, safety case etc. were attached to a letter PANSA sent in December 2011 to the Polish CAA to get a permission to implement GNSS in Poland.

Fig. 7. Aircraft "Seneca" after first LPV GNSS flight tests in Poland at the airport Katowice (14-15.March 2011) and and routes of test flights.

3.3 Helicopters Deploy GNSS in Europe (HEDGE) Next Project Goal

GNSS based approach procedure design, flight validation, safety analysis and implementation for helicopters (Point in Space – PinS). Project is made in cooperation with the Polish HEMS, Pildo Labs at Babice Airport. It is founded in frame of 7FP from GSA.

3.4 Support ad-Hoc to Eastern Region Pre-operational in GNSS (SHERPA) Project Goal

Support to European Eastern Region countries by organizing regional working groups and workshops to improve understanding of preoperational activities which should be undertaken by individual entities engaged into a GNSS implementation process (ANSPs, NSAs, airport and airlines operators etc.).

Preparation of EGNOS implementation plans which should be part of national PBN strategies.

- Consortium: ESPP, Pildo Labs, PANSA, EANS, BULATSA, DHMI, HCAA.
- This project bases on lessons learnt from HEDGE and APV_Mielec experiences.

Cooperation:
Domestic cooperation: PANSA, Silesian University of Technology, Civil Aviation Authority, Polish Helicopter Emergency Medical Service.
International cooperation: ICAO, Eurocontrol, GSA (European GNSS Supervisory Authority), ESSP (European Satellite Service Provider), Pildo Labs, Helios, GMV, Other ANSPs.

Performed and planned undertakings:
LPV GNSS procedures introduction at controlled airports (ILS overlay) – April 2014 (Warszawa, Katowice – October 2013). EWA Agreement between PANSA and ESSP was signed 28.02.2013. In circumstances of a lack of the national regulations connected with implementation of GNSS as a navigation sensor in Poland a decision was made that GNSS can be implement using rules described in 1035/36 EU Regulation and should be treated as a change to the Functional ATM System. It means that PANSA has to prepare all documents connected with implementation of GNSS procedures with a GNSS sensor as a navigation sensor for them and to propose solutions which can be accepted by the Polish CAA. These documents should, between others describe exploitation rules for GNSS sensor and operational rules for using GNSS procedures and the role of the Polish CAA is approve or not documents like these. So more, it means that Polish CAA is not going to strictly approve GNSS as the navigation sensor but a procedure based on GNSS.

- NPA GNSS Procedures Procedure design in accordance with ICAO Doc8168 and relevant documents. (done).
- NPA GNSS Approaches – operational rules – published in Polish AIP (done).
- Safety assessment (done) and Flight validation, etc. (done)
- GNSS data logging for after accident and incident investigation purposes. There is a LoA between PANSA and Head Office of Geodesy and Cartography which operates an ASG EUPOS net. (done)
- RAIM prediction – there will be obligation for pilots to check availability of the GNSS/GPS sensor using AUGUR and relevant NOTAMS. PANSA has a LoA with DFS which offers a service regarding RAIM prediction. Relevant NOTAMS will be published. (done)
- Ongoing actions and future plans National PBN Plan – prepared by PANSA and sent to CAA to coordination and approval (December 2012).
- LPV GNSS procedures – PANSA made a decision that the right way to introduce GNSS is to implement GPS based NPA procedures first because they should be treated as a first back-up level for LPVs in the future (done).

LPVs will be designed as an overlay procedures on the ILS procedures with appropriate corrections. This activity should be very simple so the first Polish LPV procedures should be published in October 2013 (Katowice, Warszawa) and rest of the Polish controlled airports should get their LPV procedures till April 2014 . EWA with ESSP has already been signed.

EPBC (Babice) – Project HEDGE NEXT – PinS procedure for rotorcrafts. It should be suitable for fixings. Babice airport is managed by Ministry of the Interior and it is main base of the Polish HEMS. This airport is the bigest Polish uncontrolled airport.

Experience in SHERPA work done and lessons learned:
In circumstances of a lack of the national regulations connected with implementation of GNSS as a navigation sensor in Poland a decision was made that GNSS can be implement using rules described in 1035/36 EU Regulation and should be treated as

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Identified difficulties and lessons learnt

- No National PBN Implementation Plan and no regulation for GNSS at State level cause that implementation of any GNSS procedure depends on individual decisions of National CAA.
- Specific environment of Polish aviation. Big transport airplanes are not equipped in EGNOS avionics. Only part of small GA aircrafts are prepared to make LPV procedures but they operated mainly from airports without instrument runways.
- SBAS procedures flight validation
- Bussiness case? How to implement LPV procedures? Basing on economic or political decisions? Who should be first? Aircraft avionics or approach procedure?
- In case of Poland, there is a filling that a decision to implement NPA GNSS procedures before LPVs is a good way because we have experience how to do it now. Implementation of LPVs should be much easier

Ongoing actions

- National PBN Plan – prepared by PANSA and sent to CAA to coordination and approval. PANSA was answered that Polish CAA is going to use this document to prepare their own version of PBN National plan.
- LPV procedures introduction at all cotrolled airports (as ILS overlay) in 2014

In the framework of the SHERPA project prepared:

- Doc: SHERPA-PANSA-NMA-D11EP "EGNOS POLAND MAKET ANALYSIS;
- Doc: SHERPA-PANSA-NSR-D21EP "Polish National Scenario Report
- Doc: SHERPA-PANSA-ENIP-D22EP "EGNOS National Implementation Plan

4. PBN Implementation Plan POLAND

In future aviation concepts developed within SESAR and NextGen, the use of Performance Based Navigation (PBN) is considered to be a major ATM concept element. ICAO has drafted standards and implementation guidance for PBN in the ICAO Doc 9613 "PBN Manual". The PBN concept represents a shift from sensor-based to performance based navigation connected with criteria for navigation accuracy, integrity, availability, continuity and functionality. Through PBN and changes in the communication, surveillance and ATM domain, many advanced navigation applications are possible to improve airspace efficiency, improve airport sustainability, reduce the environmental impact of air transport in terms of noise and emission, increase safety and to improve flight efficiency.

It is evident that the application of GNSS will become even more common within the next decade. This calls for a preparation of the corresponding navigation infrastructure as well as (inter)national regulations and policy to facilitate the use of (augmented) GNSS during all phases of flight.

At the 36th General Assembly of ICAO held in 2007, the Republic of Poland agreed to ICAO resolution A36-23 which urges all States to implement PBN. States are therefore requested to produce a PBN plan by the end of 2009. The second part of the ICAO resolution calls for specific navigation applications, referred to Approach Procedures with Vertical guidance (APV), to be implemented at relevant instrument runways by 2016.

The implementation of PBN as a design tool is principally a matter for the applicant sponsoring the airspace change. However, choice of an appropriate ICAO PBN specification and its application is critical to maximizing the benefits to cost ratio and to the ordered evolution of the airspace system. For that, appropriate regulatory policy and implementation guidance is required to set the parameters around which PBN may be used.

This document contains the Policy for the Application of PBN in Republic of Poland. It provides a base on which PBN concept may be applied and providing the regulatory mechanism for the change that will have to be undertaken by the respective Air Navigation Service Providers (ANSPs) in order to realize the projected benefits.

In the global context, PBN is on the forward path for both the Future Air Traffic Management Concept envisaged by ICAO and is consistent with the recent ICAO Assembly Resolution (A37-11). In Europe, PBN is an essential component in the Single European Sky Air Traffic Management Research programme (SESAR). The policy and implementation will require both the political will and commitment to make the necessary changes to modernize the ATM system. This policy has been developed under the auspices of the Polish Civil Aviation Office and national ANSP – Polish Air Navigation Services Agency (PANSA) in agreement with LOT Polish Airlines and Aero Club of Poland.

The primary purpose of the PBN policy is to set out a specific regulatory framework and support to ANSPs and operators to help facilitate development and implementation of airspace changes. The policy should therefore take account of the requirements of the ANSP i.e., those responsible for management of the airspace and be consistent with our international obligations.

It is considered appropriate to outline a PBN Policy to ensure interoperability at global level and common understanding between PANSA, operators and Polish Civil Aviation Office. In view of the above, this policy addresses the application of PBN polish airspace where area navigation techniques is used for operation on ATS routes, SIDs & STARs and Instrument Approach Procedures (referred to as the policy in this document).

The Performance-based Navigation (PBN) concept specifies that aircraft RNAV or RNP system performance requirements be defined in terms of accuracy, integrity, continuity and functionality required for the proposed operations in the context of a particular airspace concept, when supported by the appropriate navigation aid (NAVAID) infrastructure. Compliance with WGS 84 and data quality prescribed in Annex 15 are integral into PBN. It’s a shift from sensor based to performance based navigation.

PBN is one of the enablers of an airspace concept. Communications, ATS surveillance and ATM are also essential elements of an airspace concept. PBN relies on the use of area navigation and comprises of three components: The Navigation Application which identifies the navigation requirements resulting from the Airspace Concept such as ATS routes and Instrument Flight Procedures; The NAVAID Infrastructure which refers to ground and space-based navigation aids;

The Navigation Specification which is a technical and operational specification that identifies the required functionality of the area navigation equipment. It also identifies how the navigation equipment is expected to operate in the NAVAID Infrastructure to meet the operational needs identified in the Airspace Concept. The Navigation specification provides material which Poland can use as a basis for developing their certification and operational approval documentation.

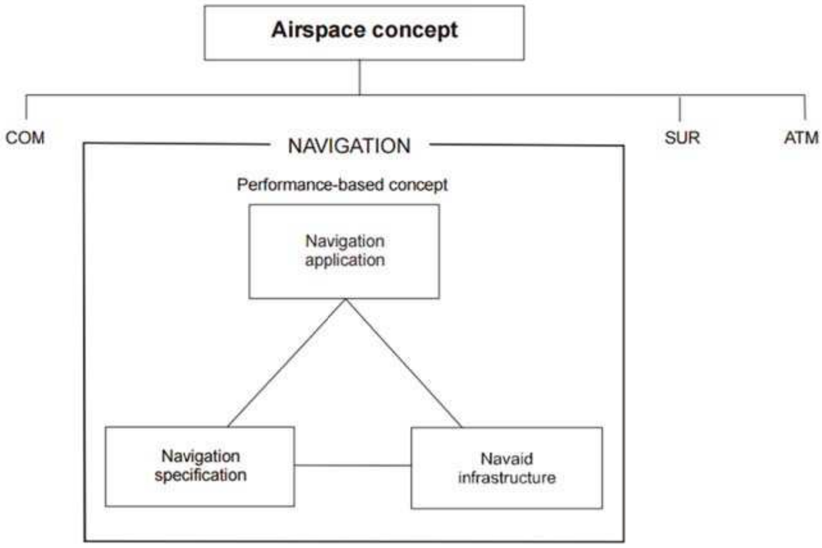

Fig. 8. Performance-based Navigation Concept (Doc. I.C.A.O. 9613, 2008)

A navigation specification details the performance required of the RNAV or RNP system in terms of accuracy, integrity, and continuity; which navigation functionalities the RNAV or RNP system must have; which navigation sensors must be integrated into the RNAV or RNP system; and which requirements are placed on the flight crew. A navigation specification is either an RNP specification or an RNAV specification. An RNP specification includes a requirement for on-board performance monitoring and alerting. RNAV specification does not include this requirement.

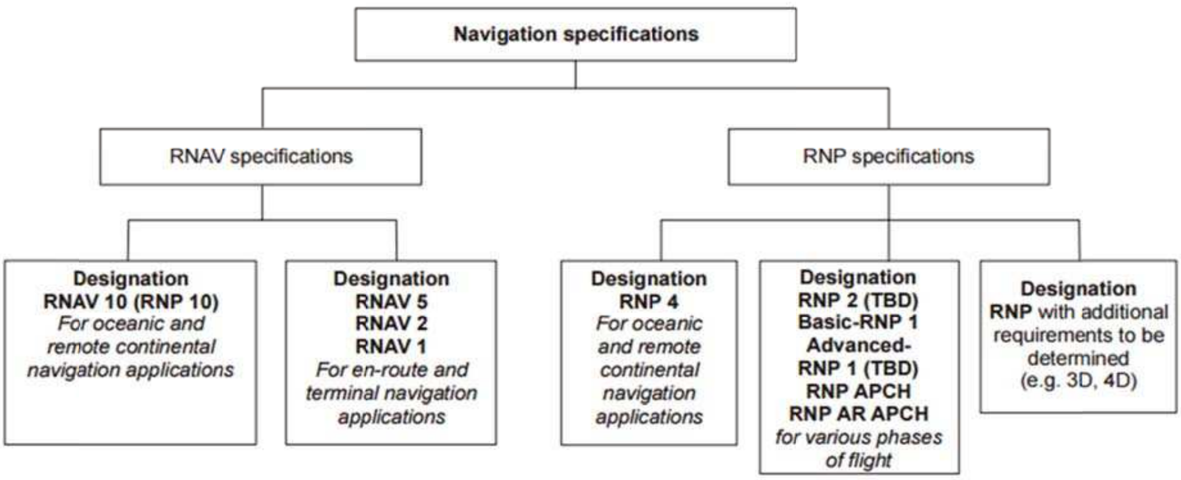

Fig. 9. Navigation specification designations (Doc. I.C.A.O. 9613, 2008)

The NAVAID Infrastructure refers to ground or space-based NAVAIDs. Ground-based NAVAIDs include i.e. DME and VOR. Space-based NAVAIDs include GNSS elements as defined in Annex 10 — Aeronautical Telecommunications.

A navigation application is the use of a navigation specification and associated NAVAID infrastructure to ATS routes, instrument approach procedures and/or defined airspace volume in accordance with the airspace concept. An RNP application is supported by an RNP specification; an RNAV application is supported by an RNAV specification.

Tab. 1. Overview of navigation specifications by flight phase and associated EASA material (Source: PBN Implementation Plan POLAND perform in SHERPA project)

Navigation Specification	Flight Phase								EASA Material
	En route		Arrival	Approach				Departure	
	Oceanic/ Remote	Continental		Initial	Intermediate	Final	Missed		
RNAV 10	10								AMC-20-12
RNAV 5		5	5						AMC-20-04
RNAV 2		2	2						To be developed
RNAV 1			1	1	1		1	1	To be developed
RNP 4	4								To be developed
RNP 2	2	2							To be developed
RNP 1			1	1	1		1	1	To be developed
A-RNP	2	2 or 1	1	1	1	0.3	1	1	To be developed
RNP APCH				1	1	0.3	1		AMC-20-27 AMC-20-28
RNP AR APCH				1-0.1	1-0.1	0.3-0.1	1-0.1		AMC-20-26
RNP 0.3		0.3	0.3	0.3	0.3				To be developed

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