QA Document 9906, Volume 5, Flight Validation of Instrument Flight Procedures

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BACKGROUND: The International Committee for Airspace Standards and Calibration (ICASC) was created following the 8th International Flight Inspection Symposium (IFIS) and exists to supplement the biennial (every two years) formal symposiums by promoting continuity in the exchange of regulatory, technical, operational and commercial information in flight inspection. The committee functions as an advisory group that researches topics of interest to the flight inspection and aviation community and provides technical input to the International Civil Aviation Organization (ICAO). Membership of the committee is intended to represent the worldwide flight inspection community, and is a reflection of industry, academia, and government interests. At the eighth meeting of its 186th Session, on March 9 2009, Representatives of the Council to the International Civil Aviation Organization included ICASC in the list of international organizations that may be invited to attend suitable ICAO meetings.

Following this recognition, ICAO tasked ICASC with defining the competency framework for flight validation pilots. During the initial workgroup meetings held in Montreal in June 2009 the need arose to actually describe the PROCESS that is associated with the work that a flight validation pilot will have to perform prior to developing pilot competencies and training requirements. The “flying aircraft components” of it was relatively clear, but we needed to identify (by defining a process) what additional qualifications would be required. This resulted in a decision to expand the project by developing two new volumes to the Quality Assurance Procedure Design Series of guidance material. Volume 5 would describe the Flight validation of Instrument Flight Procedures and Volume 6 would address the Flight

Validation Pilot Training and Evaluation. This is the reason why the manual Volume 5 only addresses the activities that are performed by the Flight Validation Experts.

Difference Between Flight Inspection and Flight Validation: For the purpose of quality assurance in the procedure design process, flight inspection, and flight validation are separate activities that may or may not be accomplished by the same entity. "Flight Inspection" is used in reference to an in-flight evaluation of a navigation system or ground-based navigation aid(s) to ascertain or confirm the ability of the navigation aid/system upon which the procedure is based to support the procedure in accordance with the standards in Annex 10 – Aeronautical Telecommunications and guidance in the Manual on the Testing of Radio Navigation Aids (Doc 8071). Flight inspection is not meant to verify the accuracy of space-based navigation systems, but provides a means to evaluate signals in space for local degradation and interference. The term "Flight Validation" is part of the Procedure Validation process and is concerned with factors other than the performance of the navigation aid or system that may affect the suitability of the procedure for publication. Flight Validation is a flight assessment of a new or revised instrument flight procedure to confirm that the procedure is operationally acceptable for safety, including required obstacle clearance, flyability, navigation database ARINC-424 coding, design accuracy, and required infrastructure (i.e., runway markings, approach lights, communications, runway lights, charting, etc.) with all supporting documentation. A procedure design organization may not have the expertise necessary to determine under which conditions flight inspection and/or flight validation may be necessary. For this reason, it is recommended that a review of the procedure by the flight inspection and flight validation organizations be included in the States procedure design process flow, following ground validation.

The Need for Flight Validation – Aviation is transitioning from ground-based NAVAID(s) and analog signals in space to computer-derived flight guidance completely dependant on accurate data. Flight Validation completes an End-to-End Process that connects the Virtual World to the Real World. Flight management System (FMS) and Simulator databases have varying degrees of accuracy and integrity to represent the real world environment. Flight validation verifies that the:

- Flight path clears obstacles and terrain safely,
- There is no significant local interference to the Global Positioning System (GPS) or SBAS signal
- The achieved flight path is the same as the one intended by the designer
- All data to be published are correct

Data Accuracy and Integrity. Procedural data accuracy is extremely important. Flight procedures utilizing ground-based NAVAIDS(s) (e.g., Instrument Landing System (ILS), Very High Frequency Omnidirectional Range (VOR), Nondirection Beacon (NDB)) can be referenced to a surveyed terrestrial fixed antenna location. In contrast, satellite based Area Navigation (RNAV) procedures deliver the aircraft to a point in spaced based on the WGS-84 geodetic datum. RNAV procedures consist of sequenced ARINC 424 coded path and terminators and waypoints. The combination of different ARINC 424 leg path and terminators provides the desired ground track and vertical path of a procedure. This requires very high integrity and accuracy of the survey data used in the flight procedure and the aircraft navigation database. It is mandatory that an appropriate quality assurance system covering all domains of data collection (surveys), processing, publication, and navigation database development be maintained (Ref. ICAO Annexes 4, 11, 14, and 15).

Data errors have several sources and can have critical effects to the procedure design process. Survey data is a common source of error in many countries. Terrain and obstacle data may be incomplete or just plain wrong. Ground-Based Augmentation System (GBAS) uses an earth–centered, earth-fixed (ECEF) reference system based on WGS-84. Conversions between geodetic data can also induce errors. Vertical datum difference between NAD-83 and WGS-84, for example, can result in positioning errors causing the actual Threshold Crossing Height (TCH) for SBAS LPV procedures being higher or lower than designed. Input errors, especially to the Final Approach Segment (FAS) Data Block, can result in significant changes to the flight path in relation to the runway. Additionally, data errors can be introduced by not using the appropriate “pending” data (e.g., when future changes to the airport will be realized by the time the procedure is actually published).

Particular attention should be paid to data accuracy in the precision FAS Data Block for Space-Based Augmentation System (SBAS) and GBAS flight procedures. Corruption of ellipsoid height data can have disastrous effects on the location of a glide path by displacing the glide path forward or aft along track of the intended design. All of these examples of data errors indicate a need to actually connect the virtual world of databases to the real world environment to assure safety of flight.

The Validation Process Overview– The validation of instrument flight procedures must be carried out as part of the initial certification of the procedure, or when an amendment is made to the procedure that has the potential to significantly affect the lateral or vertical flight path. The purpose of Validation is the verification of all obstacle and navigation data, and to provide an assessment of the flyability of the procedure. Validation and verification procedures are established which ensure that quality requirements (accuracy, resolution, and integrity) and traceability of aeronautical data are met. Validation normally consists of Pre-flight Validation, Flight Validation and Post flight analysis and documentation.

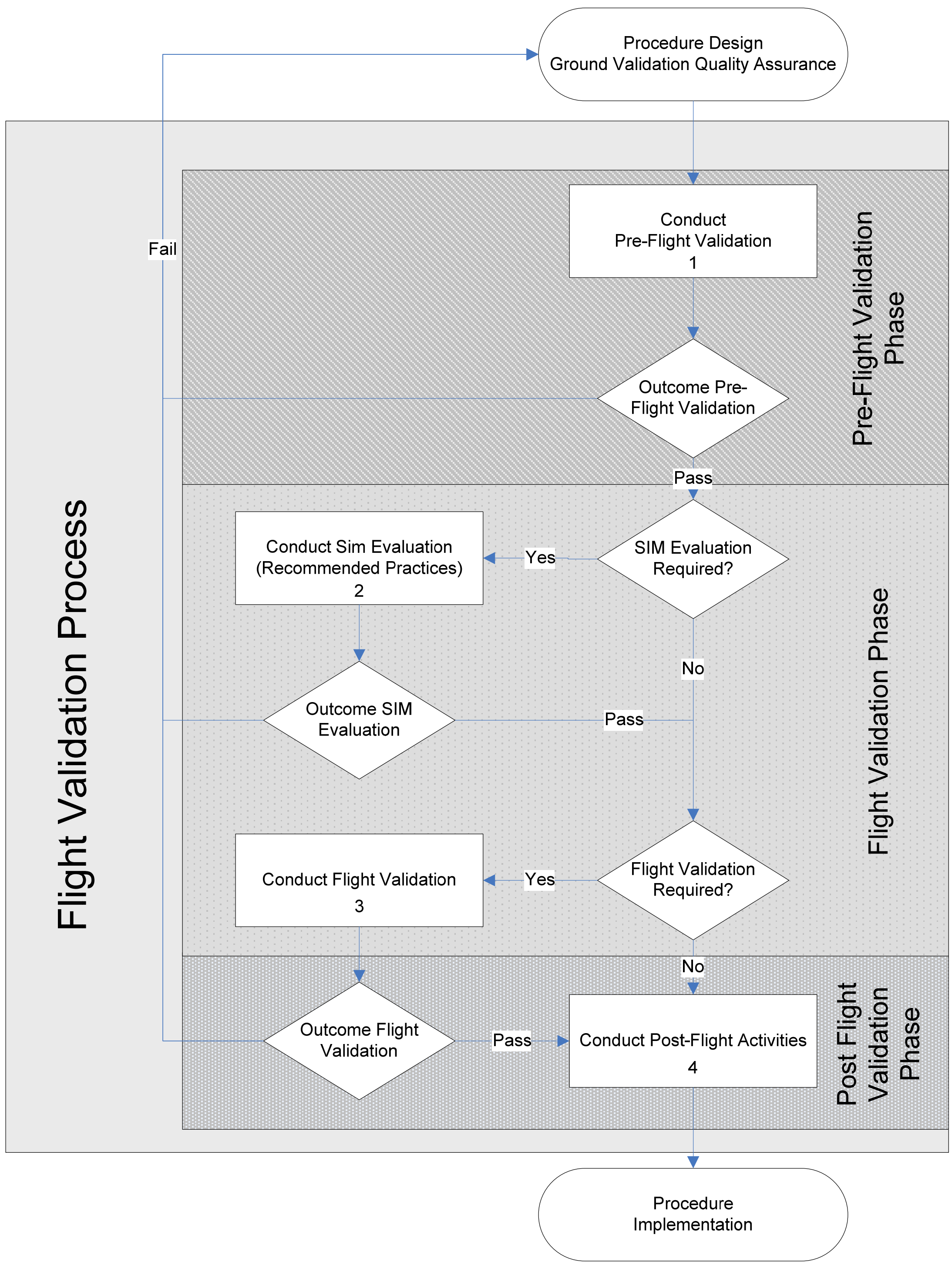
Prior to leaving the design phase, the instrument flight procedure should undergo a Ground Validation within the procedure design quality assurance process. It should encompass a systematic review of the steps and calculations involved in the procedure design.

Pre-flight Validation begins when the procedure package is received. In this phase of the process, the information provided is validated and potential errors in the procedure design are identified. Pre-flight Validation may include both a simulator evaluation and obstacle assessment.

Flight Validation requires a flight assessment in a properly equipped aircraft to confirm the procedure is operationally acceptable for safety, flyability, and design. The procedure must be flown in the relevant navigation mode required by the design. The objectives of flight validation include: flyability and overall safety; final assurance of adequate obstacle clearance; verification that the navigation data is correct and results in the designed flight path; verification that all required infrastructure is in place and operative; and the necessary signals in space are present and support the procedure. For complex procedures, additional flyability checks may be required in the proponent's aircraft or simulator.

Post Flight analysis and documentation finishes out the Validation process. Certain types of flight and navigational data must be recorded during the Flight Validation. Some of this data must undergo post-flight analysis to verify navigation data accuracy and integrity, as well as proper flight track performance, both laterally and vertically. A determination of satisfactory or unsatisfactory results should be made, along with ensuring the completeness and correctness of the procedure package. All recorded electronic data and the final report should be archived.

The validation process flow diagram



Pre-flight Validation Steps:

A Pre-flight validation review of the entire instrument flight procedure package should be completed by a person(s) familiar with procedure design concepts (see Doc 9906 Volume 6 for Flight Validation Pilot Competencies and Training) and with appropriate knowledge of flight validation issues. It is meant to identify deviations from criteria and documentation and evaluate prior to flight, to the extent possible, those elements that will be evaluated in the flight validation phase. Issues identified during the pre-flight validation phase should be addressed prior to the flight validation phase. Pre-flight validation determines the necessary subsequent steps in the flight validation process.

Before proceeding to the next step, it is recommended to resolve any known discrepancies with the designer.

Step 1: Conduct Inventory and Review Instrument Flight Procedures (IFP) Package

The Flight Validation Pilot must ensure that the IFP is complete and all necessary charts, data and forms are available. The goal is to familiarize and identify potential errors in the procedure design. The following minimum tasks should be performed:

- Ensure completeness of package (all forms, files and data included).
- Determine charts and maps are available in sufficient details to assess IFP during the Flight Validation (FV).
- Familiarize with procedure design constraints, requirements and intended users to determine the acceptability and geographical context to assist in the validation process.
- Discuss the procedure package with the procedure designer, as necessary.
- Verify procedure graphics and data from forms match.
- Compare the IFP design, coding and relevant charting information against the navigation database used for flight validation.
- Verify governing and secondary obstacles are properly identified (location, description, height).
- Determine need for flight simulator evaluation, especially where there are special or unique design considerations.
- Evaluate information provided concerning runway environment, airport markings and/or special local operations procedures (e.g., non-standard traffic patterns, lighting activation, airport lighting, noise abatement) in order to prepare for the FV.
- Review pertinent flight inspection and flight validation reports. Confirm that the applicable navigation systems support the intended instrument procedure. Check NAVAIDS, Global Navigation Satellite System (GNSS) availability and assess if flight inspection is required.
- Identify items that require flight inspection, such as new or amended fixes using ground-based navigation aids and Visual Glide Slope Indicator (BGSI) and other lighting systems requiring angle evaluations.

Step 2: Evaluate data and coding

For RNAV IFP, verify true course to next waypoint, distances, and altitudes reflect the flight procedure design. Leg segment data accuracy must be evaluated by comparison of the procedural waypoint data to the flight plan waypoint data. When evaluating RNAV Course to Fix (CF) legs, including holding lets, compare aircraft navigation performance with the instrument procedure design. Do not apply any tolerance to course-to-fix values. Confirmation of proper ARINC coding will be accomplished with either an appropriately equipped aircraft, or by a desktop evaluation of the current navigation database. Out-of-tolerance values or questionable ARINC 424 coding must be resolved.

For ground-based IFP, it is recommended to verify course, distances, and the Flight Path Angle (FPA) indicated on the IFP depiction and submission form of the procedure design. Where positive course guidance is required by the IFP design, confirm NAVAIDS performance meets all required flight inspection tolerances in conjunction with the Flight Validation.

Steps to evaluate data and coding:

- Prepare loadable data and coding.
- Compare true courses and distances for segments between data file and procedural data.
- Compare ARINC-424 coding for legs and path terminators between data file and procedural data.

Where the flight procedure design involves a complex new procedure or a significant change to existing procedures/ routes in a complex airspace, the State is strongly advised to liaise with the major commercial navigation data houses prior to promulgation. This liaison should provide the data houses with additional advance notice of the proposed changes and should allow them to review the proposed procedures, clarify any outstanding questions, and advise the state of any technical issues that may be identified. Advance notification of procedures should contain the following elements:

- Graphical layout of the procedure
- Textual description of the procedure
- Coding advice, when applicable
- Coordinates of fixes used in the procedure

Step 3: Review special operational and training requirements

- Review deviations from criteria and equivalent level of safety provided by waivers.
- Review safety case supporting the waver.
- Assess restricted procedures for special training and equipment requirements.

Step 4: Coordinate operational issues

- Consideration should be given to temperature and wind limitations, air speeds, bank, angles, climb/descent gradients, etc.

- Determine aircraft and equipment required to complete flight validation phase of the IFP.

- Determine airport infrastructure and NAVAID availability

- Check weather minima and visibility required for the flight validation phase. Initial assessment must be conducted in daylight conditions in Visual Meteorological Conditions (VMC) in each segment with visibility requirements sufficient to determine obstacle assessment.

Step 5: Conduct the night evaluation in the following circumstances:

- IFP developed for airport with no prior Instrument Flight Rules (IFR) services

- IFP to newly constructed runways or to runways lengthened or shortened

- Addition or reconfiguration of lights to an existing system already approved for IFR

Step 6: Coordinate with Air Traffic Services (ATS) and other stakeholders.

Step 7: Document the results of the pre-flight validation phase

- Assess whether the IFP is ready for further processing for simulator (optional) or flight validation.

- Provide a detailed written report of the results of the pre-flight validation phase (See Appendix C for fixed wing sample report forms. See Appendix XX for helicopter sample report forms)

Flight Validation

This step should always be carried out as part of the validation of initial and amended procedures. The state may determine that an actual flight with an aircraft may not be necessary under certain circumstances, such as (but not limited to) editorial changes to a published procedure or overlay to published procedures. However, a validation flight with an aircraft is required in the following cases:

- New procedures where there are no published procedures to the same RWY

- Procedures that contain non-standard design elements (deviation from criteria e.g. non-standard approach angles/steep approach, non-standard segment lengths, speeds, bank angles, etc.)

- When accuracy/integrity of data used in the IFP design and/or the Aerodrome environment is not assured.

This list is not all inclusive and may be expanded as appropriate by the state authority.

Flight validation should be included as part of the periodic quality assurance program as established by the individual States to ensure the procedure design process and its output, including the quality of aeronautical information/data, meet the requirements of Annex 15. It must be accomplished by a qualified and experienced flight validation pilot, certified or approved by the State.

The flight validation pilot must occupy a seat in the cockpit with visibility adequate to conduct the flight validation, and additional crew members must be briefed on FV requirements. Ground track path error performance varies with mode of flight guidance system coupling. It is recommended to evaluate new procedures coupled to the flight director and autopilot (when not prohibited). Evaluate for lateral and vertical disconnects from the autopilot/ flight director. Procedures design is based on TRUE altitudes. In-flight evaluation should be conducted at true altitudes with consideration for temperature variations from standard day. Lateral and vertical transitions from departure, en route, descent, and approach must produce a seamless path that ensures flyability in a consistent, smooth, predictable, and repeatable manner.

FV should be performed for all types of IFP described in PAN OPS. The procedure must be flown in the relevant navigation mode required by the design. For example, for RNAV (GNSS) IFP, ensure that only the GNSS sensor is utilized during the FV. All following required steps should be adapted to the specifics of each design and IFP.

The objectives of the flight validation of instrument procedures are to:

- Conduct an assessment of flyability to determine that the procedure can be safely flown.
- Provide the final assurance that adequate obstacle clearance has been provided.
- Verify that the navigation data to be published is correct.
- Verify that all required infrastructure, such as runway markings, lighting, and communications and navigation sources are in place and operative.
- Ensure the documentation of navigation systems confirms the applicable navigation system(s) (NAVAID, GNSS, RADAR, etc.) supports the procedure.
- Evaluate other operation factors, such as charting, required infrastructure, visibility, intended aircraft category, etc.
- Verify that waivers to standard design do not compromise safety.

Step 1: Verify data

It is essential that the data used in the procedure design compares to the charts, FMS data, or suitable navigation system data. The validation flights (simulator or aircraft) should be recorded with a collection/recording device that archives the procedure and aircraft positioning data (see Paragraph 7.3.6 Record flight validation). The procedure development package, charts, and airport data must match. It is recommended that RNAV/RNP procedures are packed and loaded electronically into the FMS or suitable navigation system without manually coding the ARINC 424 path/terminator data. Integrity measures such as Cyclic Redundancy Check (CRC) should be used to assure that data are not corrupted. This allows the flight validation process to evaluate the data as it was developed, without manipulation. If the procedure waypoint data must be manually entered into the FMS, it must be compared to the procedure data to ensure the data points match.

Steps to data verification:

- Ensure the data from the flight validation database matches that used in the procedure design.

- Ensure the data produces the desired flight track.

- Ensure that the final approach course/glide path deliver the aircraft to the desired point in space.

SBAS/GBAS FAS Data Requirements:

For SBAS and GBAS FAS data, the LTP/FTP latitude and longitude, the LTP/FTP ellipsoid height, glide path angle, DCH, and the FPAP latitude and longitude contribute directly to the final approach alignment. Corrupted data will skew lateral, vertical, and along track alignment from the intended design. Flight validation using a flight inspection system or post process analysis that can perform the necessary evaluations in a documented, quantitative fashion is required. It is recommended that at least the following IFP characteristics be evaluated as means of validating the FAS data elements defining LTP Lat/Long, LTP Ellipsoid Height, FPAP Lat/Long.

Horizontal Course Characteristics:

- Misalignment type, linear or angular

- Measure angular alignment error in degrees (when applicable) and linear course error/offset at the physical runway threshold or decision altitude point.

Vertical Path Characteristics:

- Achieved/measured DCH

- Glide path angle

Step 2: Assess obstacles

Detailed guidance regarding obstacle assessment is contained in Appendix A. In general, obstacles should be visually assessed to the lateral limits of the procedure design segment. The aircrafts should be positioned in a manner that provides a good view of the obstacle environment that is under consideration. This may require flying the lateral limits of the procedure protection areas in order to detect if unaccounted obstacles exist. The controlling obstacle should be verified for each segment of the IFP. Should unaccounted obstacles be observed, further investigation by the Flight Validation Pilot is required.

Step 3: Assess Flyability and Human Factor

Fly at least one on-course/on-path flight evaluation of the proposed procedure in an appropriate aircraft capable of conducting the procedure. See Appendix B for more detailed human factors information. The objectives of flyability assessment of instrument flight procedures are:

- Evaluate aircraft manoeuvring areas for safe operations for each category of aircraft for which the procedure is intended.

- Review the flyability of the instrument procedure as follows:

    - Fly each segment of the IFP on-course and on-path.

    - Validate the intended use of IFP as defined by Stakeholders and described in the conceptual design.

    - Evaluate other operational factors, such as charting, required infrastructure, visibility, intended aircraft categories, etc.

    - Evaluate the aircraft manoeuvring area for safe operations for each category of aircraft to use the IFP.

    - Evaluate turn anticipation and the relationship to standard rate turns and bank angle limits.

    - Evaluate the IFP complexity, required cockpit workload, and any unique requirements.

    - Check that waypoint spacing and segment length are suitable for aircraft performance.

    - Check distance to runway at Decision Height/Decision Altitude/Minimum Descent Altitude that are likely to be applied by operators and evaluate the ability to execute a landing with normal manoeuvring.

    - Evaluate required climb or descent gradients, if any.

    - Evaluate the proposed charting for correctness, clarity, and ease of interpretation.

Step 4: Evaluate Ground Proximity Warning System (GPWS) warnings.

The flyability assessment must be flown at speeds and aircraft configurations consistent with the normal IFR operations and meet the design intent (Aircraft Category). The Final Approach Fix to Threshold of an instrument approach procedure must be flown in the landing configuration, on profile, on speed with the GPWS active. Flyability should be evaluated with the aircraft coupled to the autopilot (to the extent allowed by the aircraft flight manual or SOP(s)) and may require additional evaluation by hand flying.

Aircraft category restrictions might be published and must be confirmed acceptable. In every case, the pilot is required to pay particular attention to the general safe conduct of the procedure and efficiency of the flight for the intended aircraft category.

Note: It is recommended that if different minima are provided for the same final segment (e.g. LNAV, LNAV/VNAV, LPV), that the evaluation of the final segment is accomplished on separate runs.

Step 5: Conduct associated validation tasks

The following associated flight validation tasks may be performed in conjunction with the obstacle or flyability assessment as required:

- Verify that all required runway markings, lighting, and communications are in place and operative.
- Verify that any required NAVAID(s) have been satisfactorily flight inspected to support the procedure design.
- Ensure the VGSI angles appear as intended or charted when evaluating vertically guided procedures.
- Air/ground communications with Air Traffic Control (ATC) must be satisfactory at the initial approach fix or intermediate fix minimum altitude and at the holding fix. Satisfactory communications coverage over the entire Minimum Vectoring Altitude, airway or route segment (in controlled airspace) at the minimum en route IFR altitude must be available with an ATS facility.
- Ensure radar coverage is available for all portions of the procedure, where required.
- Indicate any GPWS warnings or alerts. Record details of the alert to include lat/long, aircraft configuration, speed, and altitude.
- If night evaluation is required, determine the adequacy of airport lighting systems prior to authorizing night operation. Conduct night evaluations during VMC following appropriate daytime evaluation.

Step 6: Evaluate the light system for:

- Correct light pattern as charted
- Local lighting pattern in the area surrounding the airport to ensure they do not distract, confuse, or incorrectly identify the runway environment.

Step 7: Verify that waivers to standard design do not compromise safety.

Step 8: Verify chart depiction and details

- Check to ensure the chart has sufficient detail to safely navigate and identify significant terrain or obstacles.

- Ensure that the chart accurately portrays the procedure and is easily interpreted. Ensure flight track matches chart and takes aircraft to designated point.

- Verify true and magnetic course to next waypoint indicated on the FMS or GPS accurately reflects the procedure design. (Magnetic courses displayed by the FMS/GPS navigator may be dependent upon the manufacturer's software processing of magnetic variation.)

- Verify segment distances indicated by the aircraft navigation system accurately reflect the procedure design.

- Verify the FPA indicated on the FMS or GPS accurately reflects the procedure design.

- Check that waypoint spacing and segment length are sufficient to allow the aircraft to decelerate or change altitude on each leg without bypassing.

Step 9: Record flight validation

A recording device should be used that is capable of the following: IFP storage, time and 3-dimensional position in space with an acceptable sampling rate (not less than 1 Hz), and ability to post-process recorded data.

Record and save the minimum following flight data:

a. Processing date and time
b. Maximum number of satellites
c. Minimum number of satellites
d. Average Position Dilution of Precisions (PDOP)
e. Maximum Observed Horizontal Dilution of Precision (HDOP) [SBAS Procedures only]
f. Vertical Protection Level (VPL) [SBAS/GBAS Procedures only]
g. Horizontal Protection Level (HPL) [SBAS/GBAS Procedures only]
h. Maximum Observed Vertical Dilution of Precision (VDOP) [SBAS Procedures only]
i. For each segment, the maximum and minimum altitude, ground speed, climb rate, and climb gradient
j. A printed graphic or an electronic file of sufficient detail that depicts the flight track flown referenced to the desired track of the approach procedure, including procedure fixes

Post Flight Validation

Post Flight analysis and documentation finished out the Validation process. Certain types of flight and navigational data must be recorded during the Flight Validation. Some of this data must undergo post-flight analysis to verify navigation data accuracy and integrity, as well as proper flight track performance, both laterally and vertically. A determination of satisfactory or unsatisfactory results should be made, along with ensuring the completeness and correctness of the procedure package. All recorded electronic data and the final report should be archived.

Step 1: Assess the results of the flight validation:

- Review all aspects of the flight validation process to complete the assessment.

- Make a determination of satisfactory or unsatisfactory results based on criteria established by the State.

- For satisfactory flight validations, complete the IFP processing:

    - Ensure the completeness and correctness of the IFP package to be forwarded.

    - Confirm that required flight inspection of navigation aids and/or lighting, if any, has been completed.

- For unsatisfactory flight validations, return the IFP to the procedure designer(s) for corrections.

    - Provide detailed feedback to the procedure designer(s) and other stake holders.

    - Suggest mitigation and/or corrections for unsatisfactory results

Step 2: Document the results of flight validation

- Complete a detailed written report of the results of the flight validation.

- Ensure any findings and operational mitigations are documented

- Forward uncharted controlling obstacle position and elevation data to procedure designer(s).

- Ensure recorded data is processed and made available for archiving.

Next Steps to ICAO Implementation – QA document 9906 Vol. V is now finalized and ready for final deliberation during the next International Flight Procedure Panel (IFPP) meeting to be held at the ICAO headquarters in Montreal in October 2010. Adjustments and fine tuning of details are expected to keep this volume consistent with the others in the 9906 series. Publication is expected by mid 2011.