ATC Procedures and Training Report

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Abstract

This document draws together results from the ATC real-time simulation exercise of an implementation of an LPV procedure at Glasgow and inputs from the contributing SESAR partners to assess the LPV procedures implementation impact on ATC and to propose and validate new LPV ATC procedures and training for controllers to implement LPV operations. It also summarises the results of the Glasgow simulation.

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Executive summary

The project Approach Procedure with Vertical Guidance (APV), P05.06.03, is organised into two phases. The first phase, LPV phase, supports actions towards the actual operational implementation of LPV procedures in European airports in line with the ICAO 36th Assembly resolution which recommends States to implement APV procedures at all Instrument Flight Rules rated runways by 2016. This report is an output of this first phase.

SESAR partners have contributed new LPV ATC procedures and training which will enable controllers to manage LPV operations. The validity of the new procedures and training is based on the results from a two day ATC real-time simulation activity which took place at Glasgow Airport on the 15th – 16th November 2011. Glasgow Airport had been selected as the UK airport for development in this project of an LPV procedure using the European satellite system EGNOS.

The basis of the Glasgow Procedure Design and the scenarios in which LPV approaches are introduced are described. Also the experience of the contributing partners in implementing RNAV procedures and the development of current training.

The Glasgow LPV design as used in the simulation is described along with the conduct of the simulation exercise. The simulation demonstrated that LPV approaches can be safely integrated into the operational environment with only a minor increase in controller workload.

The simulation also demonstrated that while ILS and LPV approaches can be safely integrated, the mix of the two procedure types can result in higher track miles flown, increased fuel burn, and, at an airport operating near capacity, possibly delays and reduced landing capacity; some recommendations are provided to mitigate these issues.

Based on the design of current ATC RNAV procedures, recommendations are given for the design of ATC LPV procedures.

Recommendations for LPV ATC training are given and backed up with the feedback from the training assessment made at the Glasgow simulation.

1 Introduction

1.1 Purpose of the document

This document draws together results from the Glasgow simulation LPV Validation Report and input from the contributing SESAR partners. It assesses the impact on ATC when implementing LPV procedures at an airport, the development of new LPV ATC procedures and training proposals, and summarises the results of the Glasgow simulation.

A summary of the Glasgow LPV simulation is taken from the LPV Validation Report [1] describing exercise EXE-05.06.03-VP-224. The exercise was conducted by NATS and used a real-time ATC training simulator and a procedure designed for a simple LPV SBAS approach to Glasgow.

The SESAR partners, Aena, ENAV, EUROCONTROL, NAV Portugal and NATS, have contributed to the definition and assessment of the exercise EXE-05.06.03-VP-224, and to deriving the LPV ATC procedures and training proposals.

1.2 Structure of the document

This document is organized as follows:

Section 1: introduce the document providing purpose, layout, intended readers, background and acronyms.

Section 2: gives an insight on how ATC procedures and training have evolved with the introduction of LPV procedures.

Section 3: gives the background to the Glasgow LPV SBAS simulation.

Section 4: describes the conduct, results and recommendations for the Glasgow LPV SBAS simulation.

Section 5: provides recommendations for new ATC procedures.

Section 6: presents recommendations for new ATC training.

Section 7: presents conclusions for LPV ATC procedures and training.

Section 8: gives references quoted in this document.

1.3 Intended readership

This document is mainly addressed to Air Navigation Service Providers who are intending to implement RNP APCH procedures to LPV minima.

The intended audience inside SESAR is:

1. WP 05.06.03 – as a potential input for the refinement and develop of other 5.6.3 deliverables.
2. WP 05.02 – Consolidation of Operational Concept Definition and Validation – to be informed of the integration and validation of LPV into the operational environment.
3. WP 05.03 – Integration and Pre-Operational Validation and Cross Validation – to be informed of the integration and validation of LPV into the operational environment.
4. WP 3 – Validation Infrastructure Adaptation and Integration – to be informed of the integration and validation of LPV into the operational environment.

1.4 Inputs from other projects

Very little material is found in previous projects regarding LPV procedures impact on ATC, and none where real time ATC simulations were carried out. Some feedback from controllers was found in projects:

- GIANT – GNSS introduction in the aviation sector (FP6 2nd Call GALILEO R&D Area 1A. Call number 2411), WP3 focusing on demonstration of the operational benefits of GNSS to airspace users.

- GIANT2 – EGNOS adoption on in the aviation sector (FP7 1st Call GALILEO 2007-1.04-01), WP4 collected feedback from Air Traffic Controllers at the occasion of flight demonstrations.

Also some inputs considered by EUROCONTROL for Safety Assessment are here taken into account.

1.5 Acronyms and Terminology

Term	Definition
ACPO	Aircraft Control Position Operator (pseudo-pilot)
AIP	Aeronautical Information Publication
AIR	Runway Controller (NATS ATC)
ANSP	Air Navigation Service Provider
ATC	Air Traffic Control
ATCO	Air Traffic Control Officer
ATM	Air Traffic Management
CAA	Civil Aviation Authority
CFIT	Controlled Flight Into Terrain
DH	Decision Height
DME	Distance Measuring Equipment
EFPS	Electronic Flight Progress Strips
EGNOS	European Geostationary Navigation Overlay Service
FAF	Final Approach Fix
FIN	Final Approach Controller (NATS ATC)
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HAL	Horizontal Alarm Limit
HAZID	Hazard Identification
IAF	Initial Approach Fix
IAP	Instrument Approach Procedures
IAS	Indicated Airspeed
IF	Intermediate Fix
IFR	Instrument Flight Rules

Term	Definition
ILS	Instrument Landing System
KPA	Key Performance Area
LNAV	Lateral Navigation (Capability)
LPV	Localizer Performance with Vertical guidance
LVP	Low Visibility Procedures
MAP	Missed Approach Procedure
MAPt	Missed Approach Point
METEO	Meteorology
MRA	Minimum Radar Altitude
NDB	Non Directional Beacon
NERL	NATS Enroute plc
NM	Nautical Miles
NPA	Non Precision Approach
NSL	NATS Services Limited
OFA	Operational Focus Areas
OSED	Operational Service and Environment Definition
PBN	Performance Based Navigation
PD	Procedure Design
PDG	Procedure Design Group
PoC	Point of Contact
R/T	Radio Telephony
RAIM	Receiver Autonomous Integrity Monitoring
RNAV	Area Navigation
RNP	Required Navigation Performance
RVR	Runway Visual Range
SBAS	Satellite Based Augmentation System
SESAR	Single European Sky ATM Research Programme
SJU	SESAR Joint Undertaking (Agency of the European Commission)

Term	Definition
TC	Terminal Control (NATS ATC)
VAL	Vertical Alarm Limit
VALP	Validation Plan
VALR	Validation Report
VALS	Validation Strategy
VCR	Visual Control Room
VFR	Visual Flight Rules
VOR	VHF Omni directional Range
VP	Verification Plan
VR	Verification Report

2 LPV ATC Procedures and Training

2.1 LPV Flight Procedure Design

Standardised rules for the construction of instrument flight procedures are published in ICAO Doc 8168 Procedures for Air Navigation Services – Aircraft Operations, the PANS-OPS. All of the States involved in this project apply the procedures design criteria published in the PANS OPS, the document consists of two volumes:

Volume I — *Flight Procedures* describes operational procedures recommended for the guidance of flight operations personnel and flight crew. It also outlines the various parameters on which the criteria in Volume II are based so as to illustrate the need to adhere strictly to the published procedures in order to achieve and maintain an acceptable level of safety in operations. Note that PANS OPS Volume 1 is not currently up to date and is in the process of a major review. It has not kept pace with the criteria that has been introduced in Volume II and does not include LPV operations.

Volume II — *Construction of Visual and Instrument Flight Procedures* is intended for the guidance of procedures specialists and describes the essential areas and obstacle clearance requirements for the achievement of safe, regular instrument flight operations. It provides the basic guidelines to States, and those operators and organizations producing instrument flight charts that will result in uniform practices at all aerodromes where instrument flight procedures are carried out.

The validation of Flight procedure designs is described in ICAO Doc 9906 – *Quality Assurance Manual for Flight Procedure Design*. Such a validation will include a verification of all obstacle data and navigation data and an assessment of the fly-ability of the procedure. The Validation of the GNSS signal-in-space should be done according to requirements in ICAO Doc 8071 – *Manual on Testing of Radio Navigation Aids*.

2.2 Scenarios and Situations

The ATC procedures and training referred to in the remainder of this section are discussed in terms of the following two airfield scenarios:

1. Airfield already operates an ILS landing system and in addition LPV approaches are added;
    - LPV approaches provide backup for ILS failures;
    - LPV approaches provide additional airport capacity allowing aircraft previously flying NPA to use LPV to approach to a near CAT I Decision Height of 250ft;
    - Regional, business and general aviation access to the airfield is improved and traffic may increase;
    - Safety will be improved with CFIT reduced if LPV replaces NPA on ILS failure;
    - Costs may be reduced as it may be possible to remove some ground navigation aids with the adoption of LPV.
2. NPA only were available but in addition new LPV approaches are added;
    - LPV approaches provide additional airport capacity allowing aircraft previously flying NPA to use LPV to approach to a near CAT I Decision Height of 250ft well below the NPA minimum descent altitude;
    - Regional, business and general aviation access to the airfield is improved in poor METEO conditions;
    - Safety will be improved with CFIT reduced as LPV replaces NPA;
    - Costs may be reduced as it may be possible to remove some ground navigation aids with the adoption of LPV.

The following benefits have been highlighted for GNSS (LNAV) procedure:

- This is in accordance with ICAO Assembly resolution 37-11 to replace conventional non-precision approaches by PBN procedures;

- Approaches can be used instead of conventional Non Precision Approaches (NPAs) based on ground infrastructure;
- Allow lower approach minima compared to some NPAs based on ground infrastructure;
- Approaches can be designed to keep approaches within boundaries of Controlled Airspace (CAS), other airspace boundaries and buffer zones;
- Does not require costly infrastructure to be installed and maintained;
- Allows Navigation Infrastructure rationalisation.

SBAS (LPV) procedures provide the following additional benefits:

- Provides vertical guidance independent of the Barometric Altimeter setting;
- Comparable minima to an ILS when the system reaches full operational capability;
- A continuous descent profile to the airfield;
- Reduced pilot workload;
- Improved situational awareness.

The Glasgow LPV simulation modelled the first scenario of an airfield with an existing ILS to which LPV approaches have been added. The NATS Glasgow simulation considered different levels of mixed ILS and LPV approaches, intermittent failure of LPV and different METEO conditions. Intermittent LPV failures were such as might arise from local jamming or failure of an aircraft's LPV equipment. Only simple LPV failure situations were considered, in that failure of the LPV was complete and there was no fallback to other GNSS landing modes. Failed LPV approaches resulted in the aircraft reverting to ILS, or, if too close to the FAF, the aircraft was required to do a missed approach.

Existing ATC procedures and training cover many but not all of the needs for LPV approaches and are described in this section; recommendations for new ATC procedures and training are described in sections 5 and 6.

2.3 ENAV ATC procedures and training

ATC Operational and Training aspects need to be investigated by an ANSP before implementing LPV Operations in the airspace under its jurisdiction. The main elements to be taken into account and which are derived mainly from a Safety analysis, are listed below

- Instructions allowing the aircraft to intercept the lateral LPV approach
- Altitude pressure setting (QNH), appropriate for the destination aerodrome.
- SBAS NOTAM in case of predictable SBAS outages affecting the aerodrome where LPV procedures are implemented.
- ATC missed approach tactical clearances in case of contingency (e.g. GNSS or SBAS Signal In Space failure).
- Multiple aircraft safely handling during contingency situations (lost of LPV capability and/or GNSS capability).

2.4 NAV Portugal ATC procedures and training

The procedures to be applied for LPV approaches must be as follows:

- Procedures in Controlled airspace;
- Procedures in Uncontrolled airspace.

In Uncontrolled airspace the primary service provided is information service gathered through AIS/AIM information for local GNSS service.

In Controlled airspace the ATC approach clearance does not imply an ATC monitoring minima for that flight.

Cleared for the LPV procedure via flyby point 'xxxx'' constitute clearance to complete and descend with the procedure.

Vectors for IF or FAF can be made available (attention should be made for MRA)

Mix mode operations (LPV and ILS) should be available only when traffic permits (monitoring traffic is the key issue).

2.5 NATS ATC procedures and training

2.5.1 ATC procedures

The ATC phraseology to be used in connection with LPV approaches is given below and is the RNAV phraseology from MATS Part 1, Appendix E, page 15 [6] and CAP 773 [9].

Pilots should request clearance to fly the procedure using the phraseology:

(Aircraft c/s), request RNAV approach, via (Initial Approach Fix Designator), runway xx

Where traffic conditions permit, air traffic controllers shall clear the pilot to follow the procedure using the following phraseology:

(Aircraft c/s), cleared RNAV approach, runway xx, (report at [Initial Approach Fix designator])

For traffic sequencing and to aid situational awareness, air traffic controllers may request the pilot to report when established on final approach track or to report at any other relevant point in the procedure. For example:

Report established on final approach track;

or

Report 2 miles from final approach fix

Air Traffic Controllers shall instruct the pilot to report at the final approach fix, using the phraseology:

(Aircraft c/s), report final approach fix

After reaching the final approach fix, the pilot will continue to fly the procedure towards the next waypoint (normally the runway threshold). At the appropriate time, the pilot will either continue with the air traffic clearance received or will execute the missed approach.

When Air Traffic Control is aware of problems with the GNSS system, the following phraseology shall be used:

(Aircraft c/s), GNSS reported unreliable (or GNSS may not be available [due to interference]) in the vicinity of (location) (radius) [between (levels)]

or

In the area of (description) [between (levels)] '(Aircraft c/s), GNSS unavailable for (specify operation) from (time) to (time) (or until further notice])

Following a RAIM indication, pilots shall inform the controller of the event and subsequent intentions:

(Aircraft c/s) GNSS unavailable (due to [reason e.g. Loss of RAIM or RAIM alert]) (intentions)

or

(Aircraft c/s) Loss of RAIM or RAIM alert (intentions).

MATS Part 1, Appendix E, also contains the Communications Technique and Standard Phraseology and List of Standard Phrases for NPA and ILS.

NATS ATC procedures for PBN, including LPV, are developed in accordance with the CAA Policy for the Application of Performance-based Navigation [7].

CAA and NATS have been proactively supporting APV stressing the safety and business benefits. APV Baro-VNAV has been implemented at London Heathrow, Gatwick and Belfast. At Southampton and Alderney, NATS have designed the LPV approach procedures and developed the requisite safety assurance material. The viability of Aurigny's route linking Alderney with the UK via Southampton will therefore be more assured. Alderney airport is the first airfield in Europe to use EGNOS to support scheduled passenger services

In terms of the two airfield scenarios given in 2.2, it would be expected that the NATS procedures and phraseology would be adaptable to the introduction of LPV into an airfield already operating ILS or an airfield operating NPA. The Glasgow simulation was of an airfield already operating ILS to which LPV traffic was added. The simulation demonstrated that the Controller could safely handle the mixed traffic but delays increased and extra track mileage was flown (see 4 ATC Simulation Results).

2.5.2 ATC training

NATS training can be divided into two phases 1) initial controller training at an approved college of ATC and 2) training given to a controller on joining an operational unit.

The initial basic training given to new recruits is based on the EUROCONTROL training package which is based on RNP principles and requires updating to PBN standards.

Unit training aims to teach the local procedures and to enable a controller to gain the skills required to become an air traffic controller at the Unit by building upon those skills gained during initial training. This Unit Training and Assessment Plan is approved by the CAA and is based on the European Manual of Personnel Licensing (Air Traffic Controllers) as set out in CAP 744 [8].

LPV approach training would be taught at the Unit level as part of the Unit Training and Assessment Plan. Training would consist of class lectures, simulation exercises, discussions, written and oral tests, competency assessment and licensing requirements. Unit training is broken down into three phases, Transitional, Pre-OJT (On the Job Training) and OJT.

2.6 Military needs

There are no specific military requirements for such approaches.

3 ATC simulations arrangements

3.1 Introduction

A simulation of a simple LPV SBAS approach to Glasgow was run using the real-time ATC training simulator at Glasgow. The results of the simulation exercise EXE-05.06.03-VP-224 are described in the LPV Validation Report [1] and are summarized in this deliverable. The two day validation exercise was conducted by NATS staff from the Validation Team, SESAR project team, NSL training, simulation support staff and a Glasgow ATCO. The exercise specification is given in the LPV Validation Plan [2] and also summarized here. The Procedure Design for the LPV SBAS approach to Glasgow was produced by NATS [3].

The objectives specified for the exercise were to a) support the validation of the integration of LPV into the operational environment, and b) assess the need for ATC training for use of the LPV procedures. The stakeholder's expectations defined in D05 Benefits Assessment of LPV [4] and in 05.06.03 PIR [5] form the basis of the exercise validation objectives.

3.2 Glasgow Procedure Design

The Glasgow LPV Procedure Design [3] produced by NATS is a draft design for RNAV (GNSS) approaches to runways 05 and 23 at Glasgow airport. Extracts from this document referring to the approach to runway 23 used in the simulation are reproduced below.

The final Glasgow LPV Procedure Design is in progress and will be fully reported in 05.06.03 D11, LPV Procedures.

Design Methodology

ICAO Doc 8168 PANS OPS Volume II (Fifth Edition) Amendment III Corrigendum II has been used as base design criteria.

Initial, Intermediate and Final Approach Segments

The procedures utilize a ‘T bar’ which has a standard initial and intermediate leg length of 5.0NM. In order to maintain this standard, a 220kt IAS restriction has been imposed.

Missed Approach

A requirement of this project was for a conventional missed approach segment rather than a full RNAV approach from IAF to MAP termination. Once aircraft have reached the required altitude or fix, navigation reverts to conventional means.

RWY 23 Missed Approach Instructions

“Continuous climb to 3000. Initially, straight ahead to 2500 or I-OO DME 2.6 (GOW DME 3) whichever is later, then climbing left turn to hold at VOR GOW or NDB(L) GLW at 3000 or as directed.”

Waypoints for RWY 23

Waypoint	Coordinate
IAF23A	56 05 51.42N 004 13 28.68W
IAF23A	56 05 39.06N 004 00 51.27W
IAF23B	55 58 35.70N 004 01 14.46W
IAF23C	56 02 13.71N 004 07 21.00W
IF23	55 58 48.03N 004 13 49.58W
FAF23	SDF 55 55 30.25N 004 20 01.54W
MAPt23	55 52 41.07N 004 25 18.42W
MAPt TURN POINT (ALT)	55 47 50.14N 004 34 20.60W

NB Format is (D)DD MM SS.SSx and coordinate system is WGS84.

RWY 23 RNAV approach

The figure below shows the LPV design including T bar and waypoints for the approach to Glasgow runway 23. For comparison, the Instrument Approach Chart for RWY23 is shown in Figure 2.

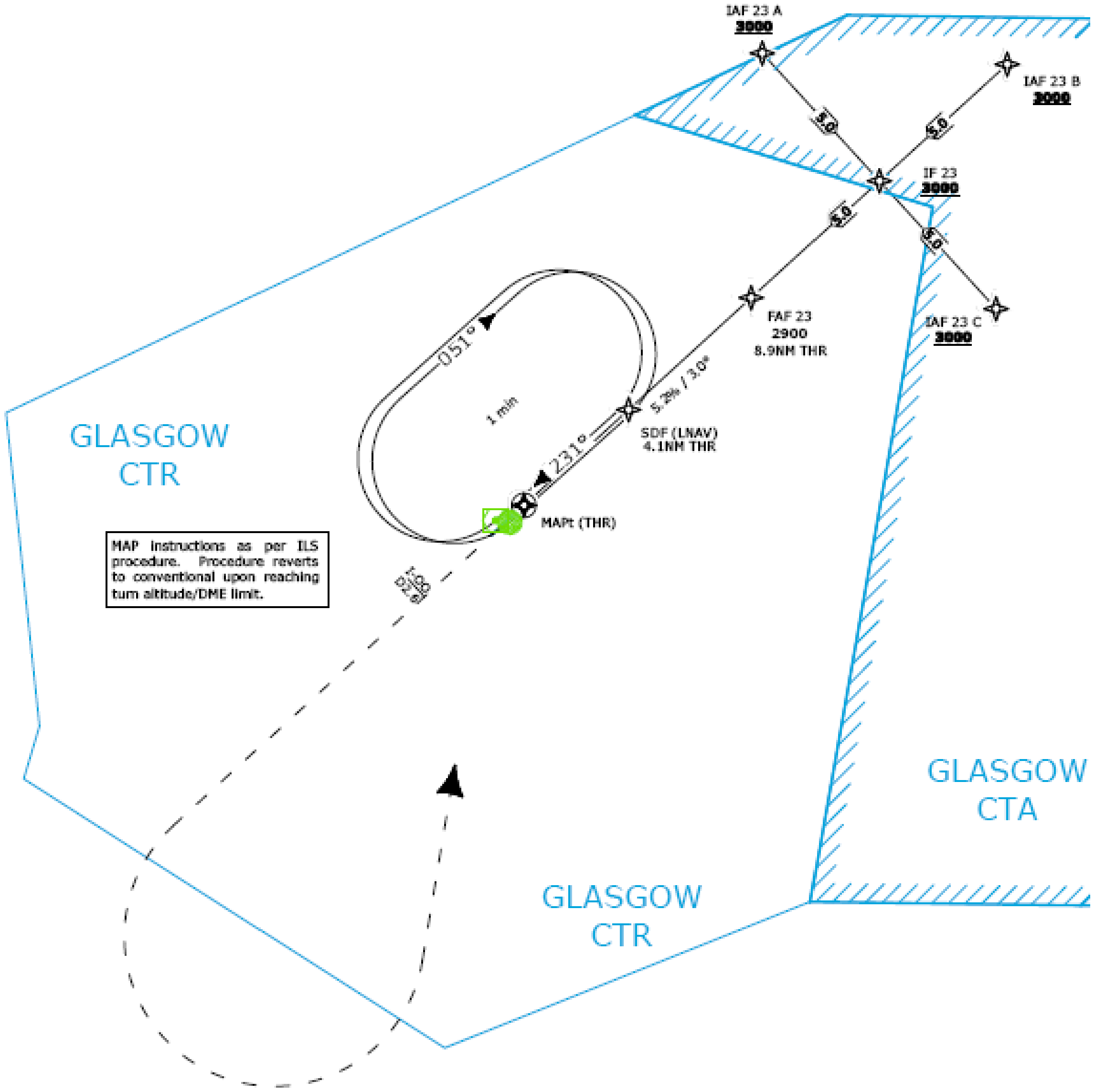

Figure 1: Glasgow RWY23 LPV procedure

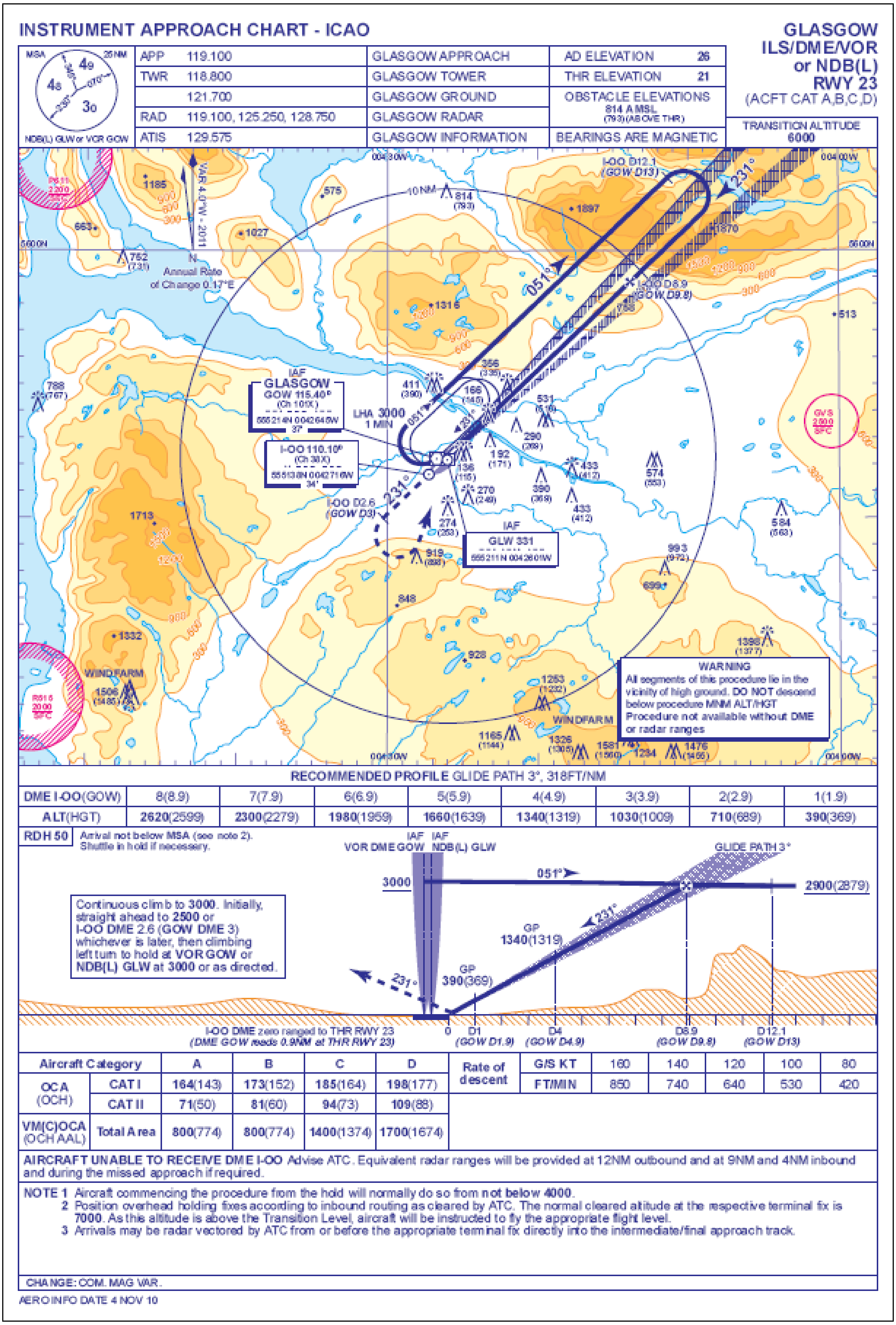

Figure 2: Glasgow RWY23 ILS Approach Chart

3.3 Simulation of the LPV ATC process

The Glasgow controller used the LPV ATC process very flexibly, sometimes vectoring aircraft to IF, IAF or to a point 2NM before the FAF, or sometimes directing aircraft to fly the procedure under their own navigation. This flexibility was used to achieve the correct spacing between aircraft flying ILS and LPV approaches and also to try and minimise delay and track miles. The LPV Procedure Design has a large effect on the controller's technique when handling mixed ILS and LPV traffic.

Prior to the exercise, the Controller and ACPO had a verbal briefing on LPV approach operations from Robert Spooner, NATS Manager Operations (Development). This was a high level briefing which gave the Controller freedom during the exercise to experiment and try different control techniques.

4 ATC Simulation Results

4.1 Conduct of Validation Exercise

The Glasgow airport approach training simulator uses a Micro Nav BEST simulator, comprising (for this exercise) one controller radar position and one pilot position. The system also utilises the EFPS (electronic flight strips) system currently in operation at Glasgow. The same controller was used for both days of the simulation.

Three standard training traffic samples were selected as providing suitably busy conditions as well as an appropriate mix of aircraft types and routes. These samples were then varied in terms of METEO conditions and also which aircraft were requesting LPV approaches. Scripts were prepared for each run whereby the METEO conditions were specified along with the approach type for each aircraft.

In this way each run of this exercise was structured to facilitate comparison between different combinations of LPV requests and weather conditions, along with equipment failures arising from simulated jamming of LPV signal.

Even though scripted, the request for an LPV approach from a given aircraft was dependant upon the pseudo pilot/simulator operator verbally making the request over the R/T. In practice this proved to be a straightforward technique which also allowed for the possibility of reviewing scripts and implementing changes in the short term.

4.2 Validation Scenarios

For details of the eight scenarios SCN-05.06.03-VALP-0010.0000 to SCN-05.06.03-VALP-0080.0000 see the Validation Plan, Ref. [2] section 3.5. A summary of the Validation Scenarios is:

Scenario id	**Scenario description**
SCN-05.06.03-VALP-0010.0000	Baseline. Current Glasgow ATC procedures. No equipment failures and a moderate headwind.
SCN-05.06.03-VALP-0020.0000	Maximise capacity. ATCO has full tactical autonomy and may clear to IAF or vector to IF as required. Moderate headwind. ILS 50%, LPV 50%.
SCN-05.06.03-VALP-0030.0000	Maximise capacity. ATCO has full tactical autonomy and may clear to IAF or vector to IF as required. Moderate headwind. ILS 80%, LPV 20%.
SCN-05.06.03-VALP-0040.0000	Maximise capacity. ATCO has full tactical autonomy and may clear to IAF or vector to IF as required. Moderate headwind. ILS 20%, LPV 80%.
SCN-05.06.03-VALP-0050.0000	ATCO controls according to PD and ATC Procedures. No ILS or LPV failures. Moderate crosswind. ILS 50%, LPV 50%.
SCN-05.06.03-VALP-0060.0000	Intermittent failure/jamming of GPS signal. Run without failure for 10 minutes, and then fail GPS for 5 minutes and intermittently during remaining 25 minutes. This is intended to cause go-arounds. Assumption is that failure of GPS will cause an aircraft LPV approach to revert to ILS if the aircraft is >15NM from the FAF, else the aircraft will execute a missed approach. Moderate headwind. ILS 20%, LPV 80%.
SCN-05.06.03-VALP-0070.0000	Medium fog causes occasional missed approaches due to poor visibility at Decision Height. Different airline operating procedures will affect the decision at the DH. Low wind. ILS 20%, LPV 80%.
SCN-05.06.03-VALP-0080.0000	Intermittent failure of GPS signal + moderate cross wind. Assumption is that failure of GPS will cause an aircraft LPV approach to revert to ILS if the aircraft is >15NM from the FAF, else the aircraft will execute a missed approach. ILS 50%, LPV 50%.

Table 1: Summary of Validation Scenarios

4.3 Exercise Results

Table 2 shows the results obtained regarding the validation objectives identified to validate the integration of LPV into the operational environment. All the validation pre-identified conditions and objectives were covered by the exercise.

The validation status denotes:

- OK: Operational objective is covered by a validation objective and achieves expectations.
- NOK: Operational objective is covered by a validation objective but does not achieve expectations.

Objectives rated as NOK are discussed below in 4.4, 4.5 and 4.6.

Validation Objective ID	Validation Objective Title	Success Criterion	Exercise Results	SESAR KPI	Validation Status per Objective
OBJ-05.06.03-VALP-0050.0010	Controller performance is improved or not adversely affected by the integration of LPV	Controller work load is within acceptable limits	Controller work load is within acceptable limits	Human Performance	OK
As above	As above	Controller R/T traffic is within acceptable limits	Controller R/T traffic moderately increased but is within acceptable limits	Human Performance	OK
As above	As above	Controller does not encounter additional safety incidents due to introduction of LPV	Controller did not encounter any safety incidents due to introduction of LPV	Safety	OK
As above	As above	Controller situational awareness is not reduced compared to current operations	Controller situational awareness is not reduced compared to current operations	Safety	OK
As above	As above	Controller debrief subjective responses are favourable to LPV	Controller debrief subjective responses were generally favourable to LPV	Human Performance	OK
As above	As above	Controller ability to maintain safe spacing is not adversely affected by the integration of LPV	Controller maintained safe spacing but controlling was more difficult with the integration of LPV	Safety	OK
OBJ-05.06.03-VALP-0070.0010	Airport performance is improved or not adversely affected by the integration of LPV	Airport landing rate is improved or maintained	Controller had some difficulty in maintaining an optimal landing rate with the integration of LPV, especially during the simulation of intermittent jamming of the LPV signal and during fog	Capacity	NOK
As above	As above	Airport landing rate is maintained if ILS replaces LPV during LPV outage	Reverting from LPV to ILS caused delays and the Controller had difficulty in maintaining	Capacity	NOK

			an optimal landing rate		
OBJ-05.06.03-VALP-0080.0010	Airline diversions to alternative airports are reduced or not increased with LPV	Airline diversions to alternative airports are reduced or not increased with LPV	No diversions to alternative airports were required	Capacity	OK
OBJ-05.06.03-VALP-0090.0010	Community environmental is improved or not adversely affected by the integration of LPV	Environmental benefits result from reduced fuel burn or noise footprint over current operations	Fuel burn was increased as longer track mileages tended to be flown during the LPV approaches compared to ILS. Noise footprint was not evaluated.	Environment	NOK

Table 2: Validation Objectives Analysis Status in this exercise

4.4 Simulation Observations

4.4.1 Track mileage and integration of LPV and ILS approaches

During the simulation it was clearly apparent that the application of the LPV procedure, as designed for Glasgow airport for use in this activity, tended to cause aircraft to fly a greater distance during an LPV approach compared to an ILS approach, and risked either a delay and/or an increase in track miles for a following aircraft on an ILS approach.

The procedure design for the Glasgow LPV approach to RWY23 places the FAF at 8.9NM from touchdown. In addition, the procedure calls for an aircraft to be established on the LPV approach 2NM before the FAF. Thus an aircraft on LPV approach has to intersect the runway centreline, at the latest, at 10.9m.

The Procedure Design for the LPV approach to RWY23 is shown in Figure 1 and, for comparison, the Instrument Approach Chart for RWY23 is shown in Figure 2.

Normal ILS operations at Glasgow are for aircraft approaching from the south to aim for an 8NM final approach. Therefore the aircraft turns on at 8NM to normally intersect the ILS between 7 and 8NM. The minimum for a short approach is 6NM. Aircraft approaching from the north intercept the ILS at 12NM.

In contrast, aircraft requesting an LPV approach from either south or north turn in at around 12NM to intersect the procedure at around 11NM and this enables the aircraft to be established 2NM before the FAF which is at 8.9NM from threshold. This is necessary as the LPV chart will have LNAV reversion which may be flown by aircraft equipped with either ETSO-129 or ETSO-145/6 receivers. The earlier ETSO-129 needs to be within 45° of the centreline 2NM from the FAF in order to carry out a RAIM check which determines whether the LPV can be flown or the aircraft should revert to LNAV. Aircraft with the later ETSO-145/6 receiver can be turned in closer to the FAF but flight trials would be required to verify the receiver behaviour should the aircraft turn in after the FAF.

Normally, because of the runway alignment, there would be fewer penalties for LPV approaches from the north with the exception that an LPV approaching aircraft would be unable to accept a short final.

ILS	LPV

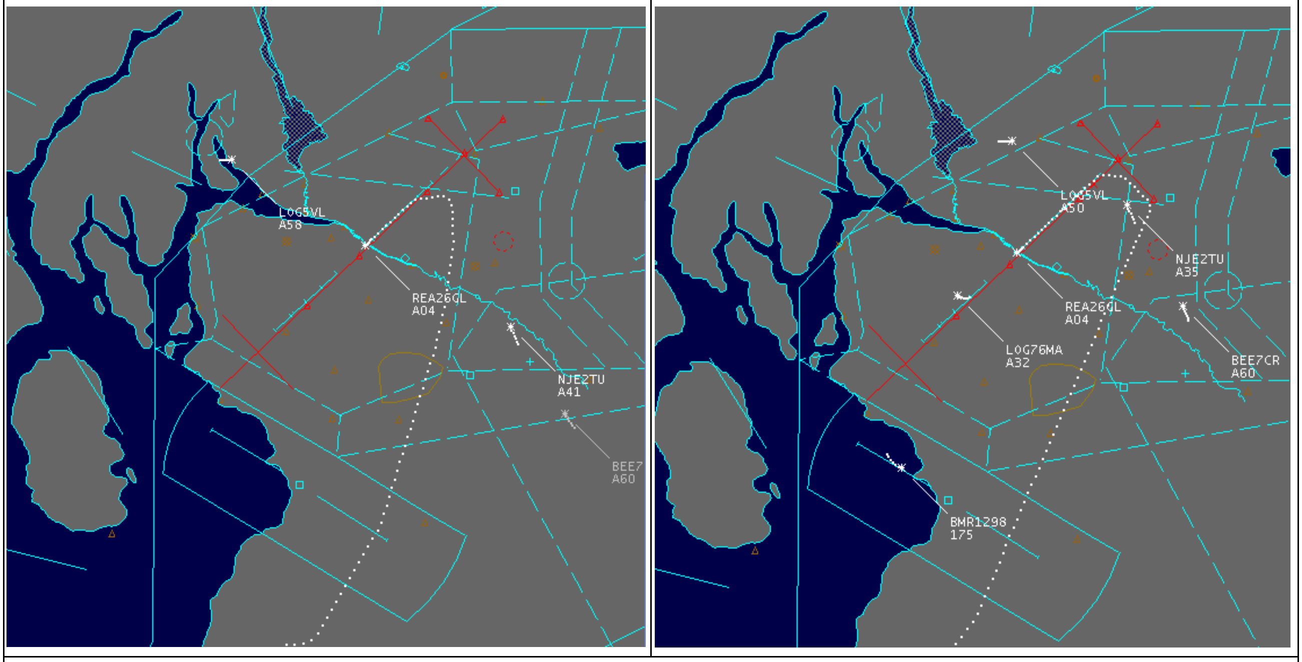

Figure 3: REA26GL AT72 comparison of ILS and LPV

In practice, this caused an approaching aircraft (on LPV approach) either to be vectored further to the east in order to accommodate the wider turn onto the centreline, or to be routed direct to one of the IAF or IF points, therefore taking an even wider turn onto the centreline.

It was subjectively apparent that the necessity for these manoeuvres resulted in an increase in the length of the approach and, therefore, in the track miles flown. Further, the wider turns necessary for the LPV approach caused any following aircraft on ILS approach to be potentially delayed and made to also follow the wider turn.

This resulted in the controller rejecting some requests for LPV approaches due to the risk of delaying following aircraft that were likely to request an ILS approach. A following LPV approach would naturally follow a similar route to the aircraft ahead. Thus the difficulty was with the integration of the two types of approach when an aircraft on ILS approach was following an aircraft on LPV approach. If an aircraft on an ILS approach was in the lead and being followed by an aircraft requesting an LPV approach, this presented no difficulty. This was most prevalent for aircraft arriving from the busier routes from the south, due to the tighter turn onto the ILS being available.

Aircraft arriving from the north and west (typically Loganairs from the Scottish Islands and, therefore, likely candidates for LPV approaches) were much less likely to be refused their request for an LPV approach as there was much less likelihood of affecting following aircraft. Even so, the technique that was typically applied by the controller for those flights was to initially route the aircraft direct either to IAF23A or IF23, when the aircraft first called in. This put the aircraft onto a more northerly track, slightly further away from the airport. As the aircraft got closer the controller often chose to vector the aircraft more tightly toward 12NM intersection, shortening the approach as far as was possible.

Instances were also observed where the controller refused a request for an LPV approach due to the presence of a following aircraft even before becoming aware as to which type of approach the following aircraft required. It will be necessary to establish local operational procedures to direct controllers as to how ILS and LPV approaches are handled in a mixed environment. For simulation purposes, failed LPV approaches resulted in the aircraft reverting to ILS, or, if too close to the FAF, the aircraft was required to do a missed approach (see section 2.2).

An example screenshot, Figure 3, show an instance of an aircraft being routed to IAF23C to follow the LPV procedure on own-navigation. The comparison of the same aircraft from two different runs shows the longer track mileage difference between a vectored ILS approach and an own-navigation LPV approach. The difference in track length between the two types of approach was less when an LPV approach was manually vectored toward the 10.9NM point on the centreline.

The controller, therefore, had the choice as to whether to send an aircraft direct to any of the outlying fixes on the procedure and then for the aircraft to proceed on its own navigation (resulting in a longer track flown) or to manually vector the aircraft toward the 10.9NM point for the shortest possible LPV approach.

4.4.2 Controller issues

It is of note that the 10.9NM point is not an actual fix on the LPV procedure, so the controller cannot send an aircraft directly to that point under its own navigation; it has to be manually vectored.

Due to the relative immaturity of the design of the procedure for use in this simulation, no names had been ascribed to the LPV fixes i.e. points IF23, IAF23A, IAF23B, and IAF23C. These were all points to which the controller could choose to send an aircraft directly under its own navigation. This lack of names caused some difficulty with R/T phrasing.

Particular difficulty was presented to the controller (and also the pseudo-pilot) during Run 7 with the fog conditions. The introduction of fog caused the declaration of Low Visibility Procedures, “LVP” over the R/T. Each aircraft that called in had to be informed of the “LVP” conditions. Some of those aircraft then requested LPV approaches but did so using incorrect phraseology, referring to LPV rather than RNAV GNSS. This caused considerable confusion in the communication between controller and pilot and prompted the comment from the controller “LVP v LPV - approach name needs changing”. This illustrated the importance of using the correct phraseology.

It was apparent from observations and from comments from the controller that his familiarity with the new procedure increased during the activity. This increased fluency with the new procedure is supported by the workload scores which can be seen to be decreasing during the second day of the activity during runs where the controller was dealing with more awkward situations e.g. fog and jamming of the GPS signal.

The detailed analysis of the workload and situational awareness score sheets and the general questionnaires can be found in the full LPV Validation Report [1].

4.5 Environmental Analysis

The simulation scenarios were not designed to facilitate a comprehensive environmental comparison of ILS versus LPV approaches. The comparison between the two types of approach is limited by the context of the simulation. Factors which affect the comparison are:

- The Procedure Design for the Glasgow LPV approach to RWY23 places the FAF at 8.9NM from touchdown whereas the norm for a vectored turn on for an ILS approach is between 6-8NM. In addition, the procedure calls for an aircraft to be established on the LPV approach 2NM before the FAF.
- Operation of the LPV procedure can be very varied as Controller has options for vectoring to different fixes in addition to authorising the aircraft to fly the procedure under its own navigation.
- Aircraft selected to fly LPV were the turboprops and small jets.
- The eight scenarios had different proportions of ILS and LPV, wind conditions, and equipment failures intended to produce missed approaches.
- Controller technique was flexible due to experimentation and learning.

Three examples of comparable ILS and LPV aircraft tracks are analysed below in Table 3 and an example of the routes flown is shown in Figure 3. The tracks were produced by replaying scenarios recorded during the simulation using the Micro Nav BestPlayer. The fuel burn was estimated by feeding the digitised track data through the Kermit environmental software. Table 3 summarises the fuel burn for the example aircraft.

Given the Procedure Design where the FAF is 8.9NM from touchdown and the vectored turn on for an ILS approach is between 6-8NM, the LPV approaches generally flew a higher track mileage. The aircraft shown are only examples and not statistically significant. The track mileage flown is dependant on the approach type and is also affected by the differing scenarios which have varied traffic mix, Controller vectoring, METEO and simulated equipment failures. The KLM45J is a F70 jet and shows a much greater extra fuel burn than the two turboprops.

		ILS		LPV		Extra track NM	% increase track NM	Extra fuel burn kg
Call sign	**Type**	**Track NM**	**Fuel kg**	**Track NM**	**Fuel kg**			
BEE2XR	DH8D	40.0	91.5	41.8	99.5	1.8	4.4	8
KLM45J	F70	37.3	132.0	49.2	229.9	11.9	31.7	98
REA26GL	AT72	44.1	67.5	51.1	73.4	7.1	16.0	6

Table 3: Comparison of example ILS and LPV tracks

4.6 Simulation Conclusions and Recommendations

4.6.1 Summary

These conclusions apply to this simulation activity and should be considered in conjunction with the limitations described previously.

- Situational Awareness remained high
- Aircraft on LPV approaches could be integrated into the operational environment with only a minor increase in controller workload
- Longer track mileage is flown during LPV approaches
- Risk of delay to aircraft following an LPV approach
- Some increase in R/T usage
- Effects of METEO more pronounced during an LPV approach

4.6.2 Controller Workload

With increased familiarity the controller's workload remained low despite the simulation of problem conditions. Workload was not increased during LPV approaches as the amount of vectoring remained similar to that required by an ILS approach. No aircraft were instructed to route directly onto an LPV approach and then allowed to complete the approach entirely under their own navigation; the Controller always intervened with some vectoring.

4.6.3 Controller Situation Awareness

The controller's Situation Awareness was not adversely affected by the integration of LPV approaches.

4.6.4 Integration of LPV approaches

Aircraft on LPV approaches could be integrated into the operational environment with only a minor increase in controller workload. This increase was seen to reduce with added experience.

4.6.5 Landing Rate

Landing rate as a measure of airport performance was assessed by question 10 of the questionnaire given to the Controller at the end of each simulation run. Question 10 asked the Controller to assess on a scale of 1 to 7 "Landing rate is reduced…… Landing rate is maintained or improved with the integration of LPV". No scores are available for the first four runs representing Day 1 of the activity. Of the scores for Day 2, runs 6 and 7 both show scores of '3' showing some reduction in landing rates during the simulation of intermittent jamming of the LPV signal and during the fog. Runs 5 and 8 show improved scores but still suggesting difficulty in maintaining an optimal landing rate.

The Glasgow simulation was of a busy period but the airport was not at full capacity. The delays were absorbed without having to hold or divert aircraft.

4.6.6 Track Mileage

Due mainly to the requirement for aircraft on LPV approaches to be on the centreline 2NM before the Final Approach Fix, longer track mileages tended to be flown during the LPV approaches compared to ILS approaches. This was not always the case as there were occasions when the streaming of traffic required an ILS approach to be turned on at a similarly early time.

However, in order for an aircraft to overfly any of the LPV procedural fixes would necessarily mean an increase in track mileage, as no situation was observed that would require an ILS approach to follow such a path.

It may be conjectured that aircraft performing an LPV approach entirely on their own navigation may present less interference with ILS approaches and, thus, avoid some of the possible delay. This was not performed during this activity and thus is recommended for a future activity.

The manual vectoring of LPV aircraft towards the centreline 2NM before the Final Approach Fix caused the controller to assess the possibility of delay to a following aircraft. Because of this, some requests for LPV approaches were refused.

4.6.7 R/T

Both observations and questionnaire responses indicate that R/T usage was moderately increased with the integration of LPV with ILS approaches. This was somewhat ameliorated with increased familiarity but was more apparent during problem conditions such as LPV failure and fog.

It may be further conjectured that R/T usage may also be ameliorated when an aircraft completes a LPV approach under its own navigation.

R/T confusion was experienced between ‘LVP’ and ‘LPV’ during simulated low visibility conditions.

4.7 Simulation Training Assessment

The training review conducted during the simulation is included below in section 6.5.

5 ATC Procedures recommendations

5.1 ENAV ATC procedures

- ATCOs shall provide an instruction allowing the aircraft to intercept the lateral LPV approach path at least 2Nm before FAF (for controlled aerodrome and when vectoring to intercept the LPV final approach path is provided)
- Prior to the final approach, ATCOs shall provide the flight crew with the altitude pressure setting (QNH), appropriate for the destination aerodrome.
- ATCOs shall receive SBAS NOTAM in case of predictable SBAS outages affecting the aerodrome where LPV procedures are implemented.
- Whenever applicable and feasible, the ATCO shall indicate SBAS unavailability while providing the approach clearance.
- ATCOs shall be able to handle safely multiple aircraft which have lost their LPV capability and/or GNSS capability in the terminal area.

5.2 NAV Portugal ATC procedures

- NOTAMs issued to inform of GNSS outages should be made available to ATS;

- Attention shall be made to R/T due to confusion that can occur between 'LVP' and 'LPV'.

5.3 NATS ATC procedures

5.3.1 NATS LPV and RNAV Procedures

NATS are implementing an LPV approach to Southampton airport. The procedure utilises the standard phraseology as described previously in section 2.5.1. A HAZID and a safety case have been prepared and flight trials with an Aurigny Trislander are planned.

NATS has implemented RNAV procedures for BaroVNAV approaches at London Heathrow and Gatwick.

The following section summaries a RNAV approach procedure implemented by NATS at Gatwick Airport.

5.3.2 Gatwick RNAV Approach Procedure

5.3.2.1 Overview

Pilots will 'Request RNAV Approach' on first contact with Gatwick Director. TC may offer or react to a request for RNAV final approach procedures from all operators. Aircraft do not need to indicate P-RNAV approval on flight progress strips to utilise RNAV final approach procedures.

The IF and FAF waypoints have been established for RNAV approaches to Runway 26L and 08R and are defined in terms of the extended runway centre-line and the range. An example is:

OLEVI is the Intermediate Fix (IF). (Defined as 26L extended centre-line, range: 10.6DME)

Both procedures commence at altitude 3000ft and contain a 'fly level' segment of 2NM, and at 8.6DME descent is commenced to maintain a 3° glide path. The APV procedures for Gatwick are based on GNSS and are defined by lateral navigational accuracy of ±0.3NM.

5.3.2.2 Co-ordination with Gatwick ADC

The Gatwick AIR controller must be informed whenever an aircraft is conducting an RNAV approach.

5.3.2.3 Weather Minima

The procedure shall not be offered when the temperature at Gatwick is below -10°C. (PANS OPS specifies this as the minimum temperature below which altimeter accuracy is not good enough for a BaroVNAV approach).

5.3.2.4 ATC Procedures: Radar Vectors to RNAV Approach

At an appropriate time to make good the required spacing, TC Gatwick FIN shall clear an aircraft for the RNAV approach, using the following example phraseology:

'(Aircraft c/s), route direct OLEVI / ABIBI, cleared RNAV approach runway 26L / 08R QNH'

When clearing an aircraft on an RNAV approach, it is implicit in the instruction that the aircraft is cleared on the vertical and lateral profile of the procedure. Therefore, it may be necessary to instruct aircraft initially to OLEVI / ABIBI without clearing the aircraft to fly the vertical profile.

For example:

'(Aircraft c/s), route direct OLEVI, maintain 4000ft'

Then subsequently:

'(Aircraft c/s), cleared RNAV approach runway 26L QNH'

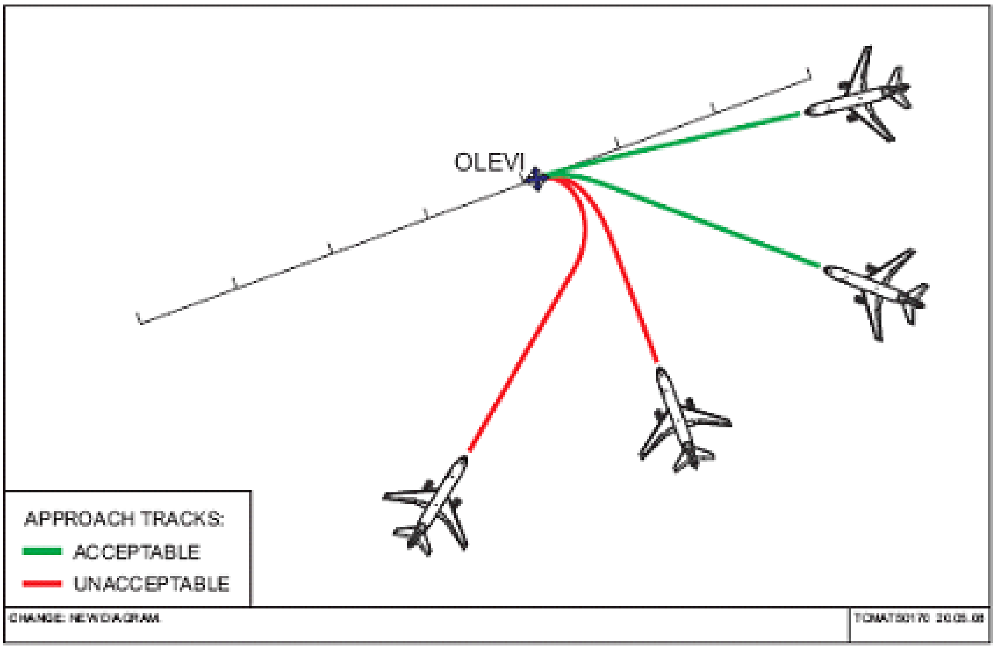

Figure 4: Radar Vectors to RNAV Approach

When released on own navigation, the track to OLEVI / ABIBI (Intermediate Fix for RNAV approach runway 26L / 08R) should be within 45° of the final approach track (as indicated in Figure 4 - red tracks are unacceptable approach tracks). It will be necessary to vector an aircraft onto the final approach track at a range in excess of 10.6NM, prior to passing a clearance to fly the RNAV procedure. As per ILS operations, to ensure that the aircraft's FMS can correctly capture the 3° glide path, FIN shall ensure that the vertical profile of the flight is such that 3000ft is achieved by the Intermediate Fix. No speed restrictions are specified as part of the APV procedures.

5.3.2.5 Radar Monitoring of Aircraft on Final Approach

It is the responsibility of TC Gatwick FIN to radar monitor traffic that is conducting an RNAV approach. In the event that an aircraft is seen to deviate significantly from either the nominal lateral or vertical profile, controllers must take appropriate action. The AIR Priority telephone line must be used when coordinating a plan of action with the Gatwick AIR controller. It is a requirement that the Gatwick ATM and DA telephone lines are serviceable before an aircraft can be permitted to fly an RNAV approach.

5.3.2.6 Strip Marking by TC Gatwick for RNAV Arrivals

When an aircraft requests to fly an RNAV approach on first call with the TC Gatwick INT and is offered the approach, 'R/RNAV' must be marked above the day of month / sector number in the right hand box of the approach format strip. When an aircraft is cleared to fly an RNAV approach, 'RNAV' must be ticked above the day of month / sector number in the right hand box of the approach format strip to confirm clearance on the procedure.

5.3.2.7 RNAV Equipment Failure

In the event that the required RNAV equipment fails, the flight crew shall advise ATC that they are unable to accept the procedure, with the phraseology;

'Aircraft c/s, GNSS unavailable due to (reasons).'

In such an event, TC Gatwick shall provide radar vectors and descent instructions in accordance with standard procedures. In the event of a reported issue with RNAV equipment or navigation accuracy, radar vectors must be utilised instead of following the prescribed procedure or associated missed approach procedure.

5.3.2.8 Radio Failure

In the event of RTF failure whilst flying an RNAV approach, it is expected that the pilot will follow the standard notified Radio Failure procedure as listed in the UK AIP.

5.4 Air Traffic Controllers preferences

In preparation for the Safety Assessment EUROCONTROL held discussions with Air Traffic controllers to discuss their recommendations for the implementation of RNAV Approach operations down to LPV minima. The following list of requirements has been proposed as input to the local safety assessments:

1. **All RNAV instrument approach procedures should include LNAV-only descent minima.**

Because the instrument approach chart might contain several minima lines it is preferable for ATC that the descent minima selected by the crew remains transparent so the controller does not have to differentiate between different RNAV capable aircraft. It has therefore been recommended that the least demanding minima line should be available on all RNAV approach charts.

2. **Information to be entered into the flight plan regarding aircraft capabilities should be limited to the ability of the aircraft to fly to the LNAV-only minima line.**

In the LPV case it is assumed that whenever a pilot wants to conduct an RNAV GNSS approach, he will request it. By requesting the approach, the pilot implicitly tells ATC that he is capable of performing the approach. ATC will provide approach clearance in accordance with the pilot’s request.

3. **On RNAV approaches ATC shall distinguish individual aircraft capabilities solely on their ability to execute RNAV IAPs to LNAV-only minima.**
4. **Flight Crew selection of the descent minima shall remain transparent to ATC.**

The above requirements are all linked to the recommendation to have the LNAV minima available on all charts wherever possible. The pilot will request the procedure using the title of the chart which is “RNAV approach RWY XX”. The controller does not need to know whether he is flying to the LNAV, LNAV/VNAV or LPV minima. This is because the track of the procedure is identical for each minima line. It is only the Decision Height or Minimum Descent Height that changes. In that way the approach only becomes unavailable when the LNAV only procedure is not possible (due to a GPS outage for example).

5. **RNP APCH certification material shall provide provisions to ensure that aircraft and aircrew are capable of intercepting the final approach track from a radar vector in a manner transparent to ATC.**

This requirement ensures that all aircraft performing RNAV approaches can be radar vectored. For LPV operations the Vector to Final function is included in the minimum avionics standard so all LPV capable aircraft can be vectored. It may not be the case for those aircraft only capable of flying to the LNAV minima.

6. Indications of the operational status of the navigation infrastructure supporting the IAPs shall be limited to stating that the procedures are available or not-available.

This is a request from the ATC community that any information provided to them about the status of the navigation service should be kept at a very basic and simple level. Indeed there is no specific requirement for real-time GNSS status information to be provided to ATC. There are NOTAMs issued to inform of GNSS outages and these NOTAMs are available to ATC.

6 ATC Training Recommendations

6.1 EUROCONTROL Training Recommendations

Air traffic controllers, who provide control services at airports where RNP approaches have been implemented, should have completed training that covers the items listed below (proposed in the ICAO PBN Manual Doc 9613):

Core training

How area navigation systems work:
- include functional capabilities and limitations;
- accuracy, integrity, availability and continuity including on-board performance monitoring and alerting;
- GPS receiver, RAIM, FDE, and integrity alerts;
- waypoint fly-by versus flyover concept (and different turn performances);

Flight plan requirements;

ATC procedures;

- ATC contingency procedures;
- separation minima;
- mixed equipage environment;
- transition between different operating environments; and
- phraseology.

Training specific to RNP APCH

a) Related control procedures:
   - radar vectoring techniques (where appropriate);

b) RNP approach and related procedures:
   - including T and Y approaches; and
   - approach minima;

c) Impact of requesting a change to routing during a procedure.

Some items of the training are general. Local considerations may be added as result of the local safety assessment.

6.2 ENAV Training Recommendations

- A training programme for ATCOs, which are appointed to manage LPV flight operations (in a mixed environment where ILS or NPA operations can be performed at the same time), has to cover the following aspects:

  Basic Concepts

  - RNAV concept overview
  - PBN concept overview
  - On-board DB and FMS

  Operational Aspects

  - Aircraft status monitoring before issuing RNAV/RNP instructions
  - Mixed-mode (Equipped and Not-Equipped aircraft) operations management
  - Phraseology aspects
  - Aircraft monitoring during RNAV/RNP operations
  - Instructions to Aircraft in case of separation infringement, loss of GNSS/SBAS capabilities or significant deviation from the nominal path

- ATCOs shall be trained adequately on the provision of appropriate radar vectoring to intercept the LPV final approach path, for airports with radar coverage and when pilot follows radar vectoring.
- ATCOs shall be trained adequately to provide ATC missed approach tactical clearances in case of contingency (e.g. GNSS or SBAS Signal In Space failure).

6.3 NAV Portugal Training Recommendations

The training programme should provide sufficient knowledge and training on the aircraft's different operations, such as, LPV approaches, including:

- Instrument approaches;
- Principles of GNSS
- General GLS concepts;
- Principles of Procedures LPV;
- Additional facilities accessories for LPV Approaches;
  - include functional capabilities and limitations;
  - include accuracy, integrity, availability and continuity including on-board performance monitoring and alerting;
  - Meteo, Visual Lights, Power Supply Require; etc
- LPV Procedures Charts for selected airports (ILS 03 and 21 on Lisbon Airport);
- ATS Procedures for LPV Operations;
- Phraseology and NOTAM used during a LPV operation;
- Simulation LPV Procedures for selected airports (ILS 03 and 21 on Lisbon Airport);
- Flight Certification of LPV Procedures for selected airport (ILS 03 and 21 on Lisbon Airport);
- Human Factors;
- Monitoring System and ATC Status Display;
- Flight Procedures
  - Flight Plan;
  - Pre-flight preparation;
  - In flight procedures;

Preparing for landing procedures.

6.4 NATS ATC Training Recommendations

Training is required to ensure that LPV procedures are safely and efficiently managed by ATCOs.

EUROCONTROL have proposed to update the PBN training, the recommendations below are draft recommendations that should be included. It is planned to review the recommendations with the NATS Training College and EUROCONTROL.

This looks to make a generic set of training suggestions based on the information from the Glasgow validation and the Southampton HAZID.

Observation 1: RNAV (GNSS) approach procedures cover a range of approach types and will require the introduction of new ATC phraseology.

There are a range of RNAV approach types that can be flown:

- **Training Recommendation 1A:** show approach types that can be flown (LNAV, LNAV/VNAV, and LPV).

- **Training Recommendation 1B:** detail what equipments are required for the different approach types -> EGNOS required for LNAV, LNAV/VNAV, and LPV; BaroVNAV required for LNAV / LNAV/VNAV; and GPS required for LNAV.

- **Training Recommendation 1C:** Show the different approach profiles

- **Training Recommendation 1D:** highlight how minima and RVR can vary dependant on system performance (VAL, HAL) and operator capability.

In the UK CAP 493 specifies the ATC phraseology for these procedure and CAP 413 show the pilots interactions:

- **Training Recommendation 1E:** the training material should highlight the new phraseology.

- **Training Recommendation 1F:** clarify that this is generic phraseology that covers a range of approach types.

- **Training Recommendation 1G:** This shall include a briefing on the limitations associated with generic phraseology for GNSS (LNAV) and SBAS (LPV) procedure (i.e. do not know approach type or minima that will be followed).

CAP 493 and CAP 413 also contain phraseology for actions that are already carried out by ATC units. The joining of these phraseologies is key to the use of the RNAV operations.

- **Training Recommendation 1H:** the training should show that existing phraseology for things such as rejecting approaches and vectoring will still be used.

Observation 2: highlight that standard ATC procedures for sequencing and separating aircraft will apply at all times during RNAV approaches.

- **Training Recommendations 2A:** the operational responsibility during an approach should be highlighted (monitoring if surveillance is available, points when ATC and pilot interact)
- **Training Recommendations 2B:** entry points (include waypoint types [flyby, flyover] and approach angles) to the GNSS (LNAV) and SBAS (LPV) procedures shall be covered in the training. Lateral (and vertical) capture areas for the waypoint should be highlighted.
- **Training Recommendations 2C:** The turn anticipation in-built into the aircraft avionics will result in range of approach path to the different waypoints dependant the angle of approach. Show this in examples related to approach angle of the different procedure transition points.
- **Training Recommendation 2D:** tactical vectoring to increase track mileage can be used to ensure that spacing is maintained. Tactical vectoring with IAFs, IF and 2NM from FAF should be shown.
- **Training Recommendation 2E:** speed control can be used to ensure that spacing is maintained. Examples of the use of speed control with IAFs, IF and 2NM from FAF should be shown.
- **Training Recommendation 2F:** the training should leave some prompts that information in the above should be appended with specific needs for an airfield so controller knows when to use these spacing techniques.
- **Training Recommendation 2G:** vectoring to alternative downwind legs can help aircraft stay within designated airspace and help with spacing. Give examples of this use.
- **Training Recommendation 2H:** include information related to the handover with tower control (unless there is specific need this will not change)

- **Training Recommendation 2I:** there may be speed restrictions on an approach. Controllers should be aware of this and methods to adhere to these should be in place.
- **Training Recommendation 2J:** Provide examples of how sequencing can be affected in multimodal operations. This should show that there may be different length track miles in the varied approaches. Show how existing vectoring for ILS may change for the RNAV procedure. Insert a warning so that controller are aware of the risk of mixing up approach types

Controllers should only permit the use of the RNAV procedures when there is workload capacity to manage the most labour intensive iteration of the approach

- **Training Recommendation 2K:** highlight this in the training and include other possible reasons for not carrying out a procedure and actions required. (see 1H for phraseology)

Observation 3: there is a range of ways that aircraft can transition onto approaches. The differing transition methods can impact sequencing. In addition to this the flight path of the aircraft may not be obvious.

- **Training suggestion 3A:** show the different transition methods that can be used, including transition to IAF, IF or vectoring.
- **Training suggestion 3B:** Highlight when aircraft is under own navigation, this could be done by showing when normal ATC interventions would be needed i.e. what the aircraft will do when cleared for approach or transitioned.
- **Training suggestion 3C:** show typical aircraft tracks for approaches with different transitions.
- **Training suggestion 3D:** ensure any constraints related to transition are clear, this should include angles that aircraft can approach transition points and safe distances that controller will need to issue instructions to pilots so they have time to prepare for the different transitions.
- **Training suggestion 3E:** highlight the phraseology that will be used for the different transitions (cleared to IAF, or requested IF) or vectoring. Show how vectoring and RNAV phraseology fit together. (see 1E)

- Controllers shall vector aircraft onto the final approach track, or onto a heading to close the final approach track at an angle not greater than 40° offset from the final approach track.
    - **Training suggestion 3F:** ensure vectoring points on the procedure are clear (including 2NM point before FAF that the integrity check is performed)

Observation 4: the operational unit should consider impact on flight progress strips when using RNAV procedures.

- **Training Recommendation 4A:** include information of how these operation will impact flight strips

- The positioning of the type of approach identified as RNAV on the associated pop-up needs careful thought.
    - **Training Recommendation 4B:** The training should show a suggested location this information could be input on both electronic or paper flight strips
- Thought must also be given to adding the ability to input ‘flyby’ points via the heading pop-up for when such items are included in the instructions issued.
    - **Training Recommendation suggestions 4C:** The training should suggested where this information could be input on both electronic or paper flight strips

Observation 5: System and equipment performances are not absolutely ensured.

Controller should only transfer aircraft from RNAV procedure through reacting to pilot requests or as a result of other failure (e.g. RAIM holes)

- **Training Recommendation 5A:** include details of the system performance and the impact of performance shortfalls such as a continuity outage or integrity events. The impact on ATC of the shortfalls should be highlighted.
- **Training Recommendation 5B:** Training shall include possible reasons for not carrying out the procedure and actions required
- **Training Recommendations 5C:** the training should highlight the phraseology used to communicate outages (see 1E)
- **Training Recommendations 5D:** the training should include information how known outages or bad performances are communicated to users after a report is received by ATC. Details of anticipated pilot actions should also be included.
- **Training Recommendations 5E:** during an approach procedure if an integrity event or service outage is stated the pilot must either discontinue the approach or switch to another approach. Recommend the cut-off point where controllers should not authorise transfer onto a different procedure type e.g. after FAF is sequenced, due to pilot workload.

Missed approach procedures will be flown in accordance with local practices. It may be necessary in the event of a total loss of GNSS that the MAP needs to be flown using guidance from ATC

- **Training Recommendation 5F:** give an example of how an ATC managed MAP will be carried out. In the event of a total loss of GNSS the MAP shall be flown using guidance from ATC
- **Training Recommendation 5G:** Show an RNAV MAP in accordance with a published chart

Aircraft deviations can occur either due to system performance or pilot issues

- **Training Recommendation 5H:** Suggest that controller may ask “report deviation from procedure” to ensure that this is noticed and pilots are clear that they shouldn’t deviate.

Observation 6: RNAV holds

- **Training Recommendation 6A:** RNAV holds will be designed along with the approach procedures. Note that these can only be used when GNSS is available. Also show how these will be flown and anticipated ATC intervention.

6.5 Glasgow Simulation Training Report

6.5.1 Context of Training Assessment

The training review was conducted by Denise Armstrong, NATS Airports Operations and Training Advisor, during the LPV trial at Glasgow on the 15th/16th November 2011. This review was to appraise the training requirements for implementation of LPV type approaches at UK airports.

Observations were taken from across the two days of simulation when eight scenarios were run comprising varying mixes of ILS vs. LPV approaches.

Prior to the exercise, the Controller had a verbal briefing on LPV approach operations from Robert Spooner, NATS Manager Operations (Development). This was a high level briefing which gave the Controller freedom during the exercise to experiment and try different control techniques.

6.5.2 Equipment

The exercise was run on the Glasgow ATC training simulator which was equipped with EFPS [Electronic Flight Progress Strips] and this raised its own training needs.

Input of data, reflecting instructions issued to strips, is by touch pen or mouse via a series of preformed pop-ups. Users of the system become very adept at muscle memory and become almost subconscious in action for the regular data inputs i.e. they know where the position of the word 'ILS' is on the pop-up without even looking. The positioning of the type of approach identified as LPV on the associated pop-up needs careful thought.

Thought must also be given to adding the ability to input 'flyby' points via the heading pop-up for when such items are included in the instructions issued.

The aircraft and avionic equipment being used for the procedure needs to be clarified in a briefing to student controllers, especially to clarify that this is a 'precision' approach as opposed to a non precision approach.

6.5.3 Naming

In relation to the data input requirements above, and to avoid confusion of data entry, the name of the type of approach needs to be considered as reflective of the actual technical approach i.e. adopting the generic 'precision' word LPV to accommodate this type of approach does not reflect the actual type of precision approach that is being performed and any reactive action needed by the controller in the event of a change of circumstances i.e. a go-around or break off. The NATS / UK CAA recommended name is RNAV (GNSS), see 2.5.1.

There is room for confusion and tongue tying during LVP [Low Visibility Procedures] operations if using the LPV process name.

Also, naming must be given to the target points within and to which the ATCO is able to vector.

6.5.4 Phraseology

During the exercises the Controller was searching for phraseology within his current ATC vocabulary to meet the different requirements of the LPV approach being conducted. Phraseology 'sets' need to be determined in order for training to be implemented as standard.

The Controller developed with practise across the exercises his own pattern of phraseology to suit the needs he felt were to be met e.g. 'Direct routing to 12NM, cleared for the procedure, report Final Approach Fix' – not necessarily inaccurate but lacked precision of meaning. **Training objective** – to use a standard pattern/set of phraseology.

Should the ATCO be trained in dropping the necessity to quote track miles within a sequence when it is the LPV system approach that determines more accurately the track miles? It was observed to be better if left as a number in the sequence. **Training Objective** – standardise phraseology.

6.5.5 Process

The exercises demonstrated that training would have to include an awareness of the approach vectoring needs, and why the LPV approach has to use a capture distance of >8NM since the ATCO norm is between 6 to 8NM. Also where within the procedure in terms of reference points could the ATCO provide vectors or clearance to? **Training Objective** – to include defined parameters, awareness and multiple opportunities to practise.

To begin with the Controller lacked a full understanding of the difference between flying own navigation to rather than as a flyby of set target points. Did the flight have to go outside or inside the 'flyby' points? **Training objective** – to include awareness of the difference.

The Controller also demonstrated that the process was initially difficult to adapt to and as a result 'refused' some of the approaches when operating under mixed mode since he believed that it impeded/delayed other fights behind it in the sequence. **Training objective** – clarify phraseology to refuse. **Training objective -** practise at mixing types of approaches.

The Controller was unsure as to whether the procedure was considered as 'own navigation' or 'locked on heading' for the purposes of separation against other traffic. Would 'Cleared for the LPV procedure via flyby point 'Alpha'' constitute clearance to complete and descend with the procedure? – This is at variance with the current ILS procedure where the pilot reports established before then being cleared for the descent. **Training objective** – to include definition of standard operational responsibility whilst conducting this procedure.

Procedure to follow if LPV is not captured, how does the pilot report 'established' and at what point would the controller be able to transfer to the VCR for clearance to land? **Training objective.** Training would also be needed in the actions needed to be followed in the event of a loss of signal (this relates to proof of separation whilst conducting the procedure as mentioned earlier).

6.5.6 Training Assessment Recommendations

The simulation scenarios chosen allowed an assessment of the type of exercises needed to support the controllers in learning the LPV process. The NATS NSL Training Advisor recommended a minimum of four hours of exercises that included a mix of standard and LPV approaches in order for the student to become familiar with both the different flight patterns and change to vectoring styles in order to accommodate this type of approach.

Exercises should start with multiple repetitions of the LPV approach to assimilate the behaviours exhibited during vectoring and flight, before then providing an element integrating ILS and LPV. Adapting a long term embedded pattern of behaviour takes repetitive practise. After the eighth exercise the Controller was much more comfortable in accommodating these approaches within the flow of traffic, although remaining hesitant since to do so would compromise the following aircraft in terms of delay to touchdown.

7 Conclusions and Recommendations

7.1 LPV ATC Procedures

7.1.1 LPV Procedure Design

ICAO Doc 8168 PANS OPS Volume II is used as the basis of the LPV Procedure Design and can be expected to result in uniform practices at all aerodromes where instrument flight procedures are carried out. The Glasgow LPV approach used in the simulation was produced according to these standards. The simulation demonstrated that while ILS and LPV approaches can be safely integrated, the mix of the two procedure types can result in higher track miles flown, increased fuel burn, and, at an airport operating near capacity, possibly delays and reduced landing capacity. The reduction in efficiency results from the LPV approach being longer in order to accommodate a 2 Nm straight segment before the FAF. The ILS approach does not have this restriction and the Controller can vector aircraft on to the ILS and so minimize the track miles flown. When implementing LPV procedures to runways that have ILS the procedures design should try to ensure that the flown track of the LPV procedure is as close to that flown by aircraft flying the ILS procedure. In Glasgow there was a particular issue of terrain to the north of the airport which meant that the FAF could not be placed closer to the threshold. This may mean that in other locations this problem can be reduced. In any case, the default approach will be the ILS approach and the LPV procedure is only normally going to be used when the ILS is unavailable.

7.1.2 LPV Procedures

The recommended LPV ATC procedures are described in sections 5.1 to 5.3 and are summarised as follows:

- A standardised phraseology shall be provided for communication between controllers and pilots.
- Controllers shall receive NOTAMs issued to inform of predictable GNSS outages.
- Pilots will ‘Request RNAV Approach’ on first contact.
- Prior to the final approach, controller shall provide the QNH pressure setting.
- Controller shall indicate SBAS unavailability before providing the approach clearance.
- Controller shall clear an aircraft at an appropriate time to make good the required spacing.
- Controller shall mark the strip or EFPS to indicate that an aircraft is flying an RNAV approach.
- When clearing an aircraft on an RNAV approach, it is implicit in the instruction that the aircraft is cleared on the vertical and lateral profile of the procedure.
- When released on own navigation, the aircraft track should be within 45° of the final approach track.
- Any controller vectoring instruction shall allow the aircraft to intercept the lateral LPV approach path at least 2NM before FAF.
- Where there are surveillance systems, ATC shall monitor the descent path in order to inform the crew if their approach path is not normal.
- In the event that the required RNAV equipment fails, the flight crew shall advise ATC that they are unable to accept the procedure.
- If more than one pilot reports a complete or partial loss of the GNSS LPV signal, then the controller shall decline further aircraft requests for RNAV GNSS approaches until the controller is satisfied that the service has been restored. It is not known what would be the way the controller could decide on the service restoration.
- In the event of GNSS failure, controller shall provide radar vectors and descent instructions in accordance with standard procedures.
- In the event of R/T failure, it is expected that the pilot will follow the standard notified Radio Failure procedure.
- In mixed mode environment where ILS and LPV procedures are available at the same time it will be necessary to establish local operational procedures to direct controllers as to how ILS and LPV approaches are handled.

The LPV ATC procedures should be implemented to include the six Air Traffic Controllers’ preferences in section 5.4 which are listed below:

1. All RNAV instrument approach procedures should include LNAV-only descent minima.
2. Information to be entered into the flight plan regarding aircraft capabilities should be limited to the ability of the aircraft to fly to the LNAV-only minima line.
3. On RNAV approaches ATC shall distinguish individual aircraft capabilities solely on their ability to execute RNAV IAPs to LNAV-only minima.
4. Flight Crew selection of the descent minima shall remain transparent to ATC.
5. RNP APCH certification material shall provide provisions to ensure that aircraft and aircrew are capable of intercepting the final approach track from a radar vector in a manner transparent to ATC.
6. Indications of the operational status of the navigation infrastructure supporting the IAPs shall be limited to stating that the procedures are available or not-available.

7.2 LPV ATC Training

7.2.1 Training Recommendations

The recommended LPV ATC training is described in sections 6.1 to 6.3 and is summarised below.

Air traffic controllers, who provide control services at airports where RNP approaches have been implemented, should have completed training that covers the items listed below (proposed in the ICAO PBN Manual Doc 9613):

<u>Core training</u>

How area navigation systems work:

- RNAV concept overview
- PBN concept overview
- Instrument approaches
- Principles of GNSS
  - include functional capabilities and limitations;
  - accuracy, integrity, availability and continuity including on-board performance monitoring and alerting;
  - GPS receiver, RAIM, FDE, and integrity alerts;
- waypoint fly-by versus flyover concept (and different turn performances).

Flight plan requirements;

- On-board DB and FMS
- Flight Procedures
  - Flight Plan;
  - Pre-flight preparation;
  - In flight procedures.

ATC procedures;

- Principles of LPV procedures;
- ATC contingency procedures;
- separation minima;
- mixed equipage operations;
- transition between different operating environments;
- phraseology;
- NOTAM relating to LPV operations;
- Radar monitoring of an LPV approach;
- METEO, Visual Lights, Power Supply Require etc.

<u>Training specific to RNP APCH</u>

a) Related control procedures.
b) Radar vectoring techniques to intercept the LPV final approach path.
c) Instructions to Aircraft in case of separation infringement, loss of GNSS/SBAS capabilities or significant deviation from the nominal path.

d) ATCOs shall be trained adequately to provide ATC missed approach tactical clearances in case of contingency (e.g. GNSS or SBAS Signal In Space failure).
e) RNP approach and related procedures:
   - including T and Y approaches; and
   - approach minima.
f) Impact of requesting a change to routing during a procedure.
g) LPV Procedures Charts for selected airports.
h) Simulation LPV Procedures for selected airports.
i) Management of mixed ILS and LPV operations when they can be performed at the same time.

7.2.2 Glasgow Simulation Training Feedback

The two day Glasgow LPV simulation was observed by the NATS Airports Operations and Training Advisor and her report is included in section 6.5. The report supports the training recommendations contained in this report and specific observations are summarised below.

The EFPS used by the Controller needs to be carefully designed in order to facilitate efficient input of data. Thought must also be given to adding the ability to input ‘flyby’ points via the heading pop-up for when such items are included in the instructions issued.

It is essential that standard phraseology is defined and used. Additional new phraseology may need to be developed to cover specific LPV situations.

The exercises demonstrated that training would have to include an awareness of the approach vectoring needs, and why the LPV approach has to use a different capture distance to the ILS approach. How does the pilot report ‘established’ and at what point would the controller be able to transfer to the VCR for clearance to land? Also where within the procedure in terms of reference points could the ATCO provide vectors or clearance to?

The Controller also demonstrated that the process was initially difficult to adapt to and as a result ‘refused’ some of the LPV approaches when operating under mixed mode since he believed that it would delay other fights behind it in the sequence. An ATC unit would need to develop a procedure detailing mixed traffic operations.

The NATS NSL Training Advisor recommended a minimum of four hours of exercises that included a mix of standard and LPV approaches in order for the Controller to become familiar with both the different flight patterns and change to vectoring styles in order to accommodate this type of approach.

8 References

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