APPENDIX

MLS — THE CASE FOR INSTALLATION AT SPECIFIC AIRFIELDS CASE STUDY — LONDON HEATHROW

1. INTRODUCTION

1.1 ILS continues to be the primary global precision approach system and new civil aircraft are delivered with an ILS capability, often to the most stringent Category III requirements.

1.2 ILS has provided a very good service in the past, and is likely to continue in operational use for many years, however it does suffer from some limitations as has been witnessed at London Heathrow airport which is used as a case study for the purposes of this paper.

2. ILS LIMITATIONS

2.1 ILS limitations have been well documented and include:

a) vulnerability to multipath interference from building developments on or around an airport and from aircraft and vehicle movements. This was the case with London Heathrow 27L ILS as described in this case study;

b) the landing rate in low visibility conditions is constrained due to the need to protect the ILS signal from multipath interference from other aircraft;

c) the signal is vulnerable to interference from various sources, such as. Electro Magnetic Interference (EMI) as may be caused by commercial broadcast FM radio (note this type of interference has caused down-grade of Dubai ILS); and

d) a requirement for a level ground plane in front of the radiating antennas to achieve an acceptable course structure and meet coverage criteria.

2.2 In practice these limitations have not proved to be significant at the vast majority of locations throughout the world. However, there are a small number of locations where ILS performance has deteriorated due to multipath interference from building developments. In addition, the reduction in landing rate in low visibility conditions is also a serious constraint at many international airports where capacity of operation is at a premium.

3. LONDON HEATHROW AIRPORT (LHR) CASE STUDY

3.1 Effect of buildings and aircraft movements on Heathrow ILS

3.1.1 In 1996 a new cargo centre was built to the south of Runway 27L at London Heathrow. Given the lack of available real estate at the airport there was little choice regarding the location of the new building. Prior to construction of the cargo building, the ILS 27L signal was well within limits, which is shown in Figure 1.

ILS Localiser 27L before BA Cargo Centre Built

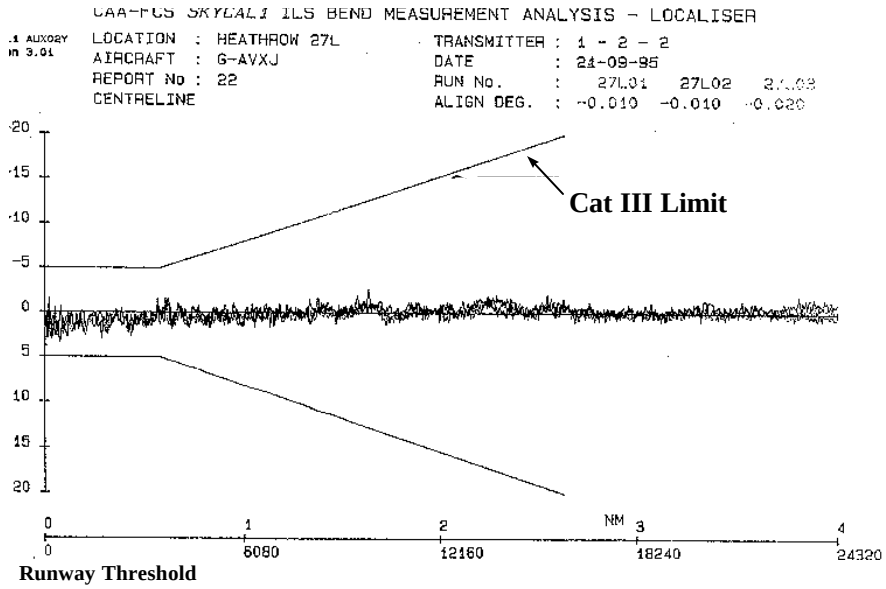


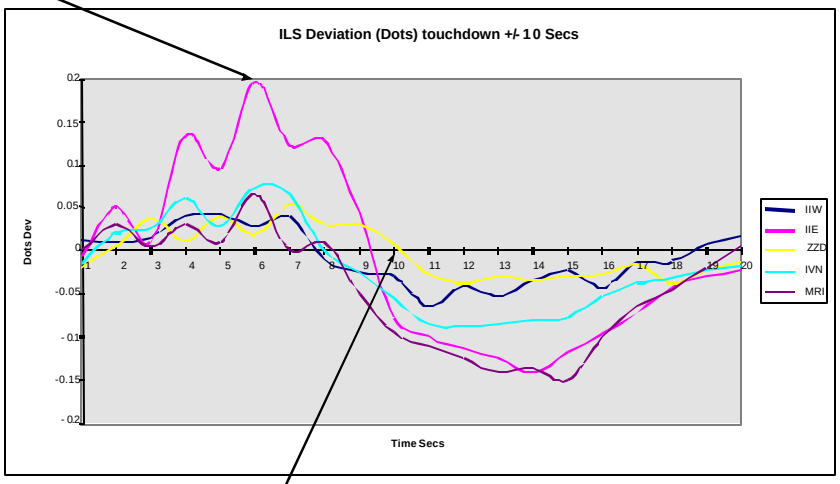
Figure 1.

3.1.2 Before construction, analysis was carried out to assess the potential impact on the ILS localiser. This analysis suggested that the multipath interference would remain within acceptable limits.

3.1.3 However after construction of the cargo building, the ILS remained within Cat III limits although a beam bend was identified during roll-out and in January 2002 a number of significant beam bend events were reported by crew landing whilst low visibility procedures (LVPs) were in force. These beam bends are shown in Figure 2 for five different aircraft landing during this period. This resulted in a temporary down-grading of the ILS.

LHR 27L ILS Downgraded Jan 2002

= Approx 35 ft Fly R



Touchdown

Figure 2.

3.1.4 In October 2002, a new state of the art ILS was installed on 27L as part of the Heathrow ILS replacement programme. Flight check of the new ILS revealed that the beam bend still existed but remained within Cat III tolerance, as can be seen in Figure 3, provided no aircraft are parked on stands south of the runway.

27L ILS Oct 2002 (New ILS)

Close to Cat III Limit with no aircraft on X-Ray Stands

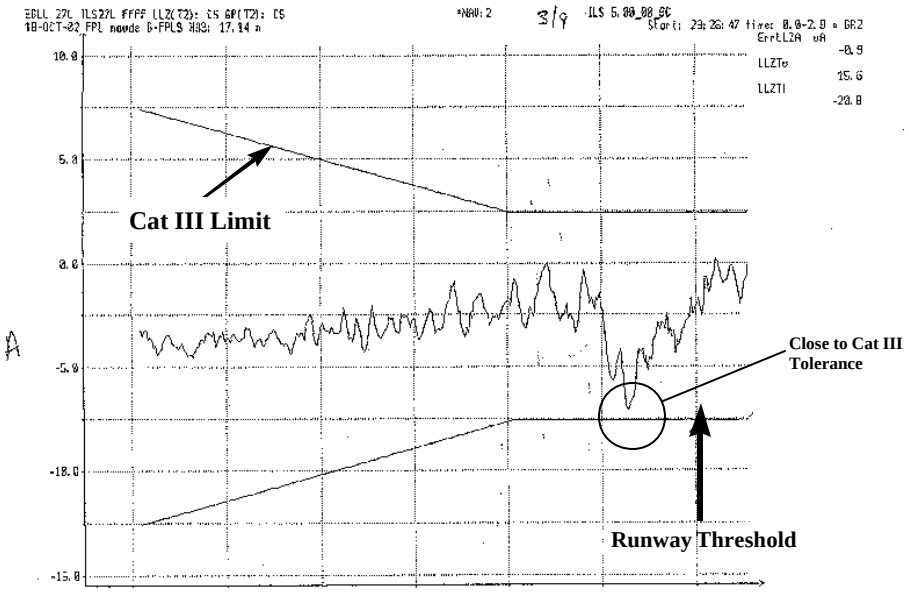


Figure 3.

3.1.5 In November 2002 during another period of LVPs, further beam bend events were reported as can be seen in Figure 4. These were similar in waveform to those reported in January 2002.

B777G-RAES ILS Beam Bend Event (25 Nov 02 07.31 Hrs)
- one of 6 events reported through a two hour period of fog.

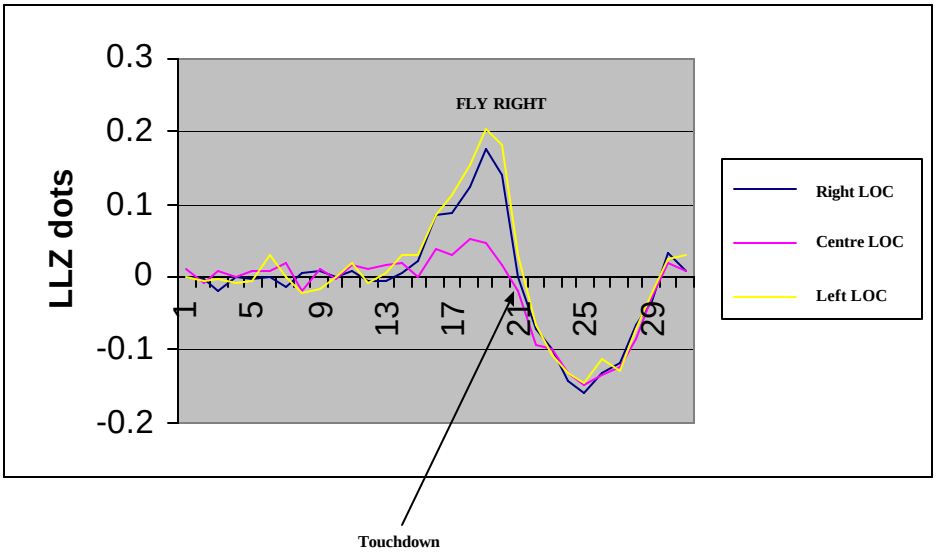


Figure 4.

3.1.6 Review of the surface movement radar screen capture revealed that during the event shown in Figure 4, aircraft movements around the X-Ray stands may have contributed to the multipath interference as can be seen in Fig 5. Since these events, flight check results have confirmed that the beam bend is outside Cat III limits with aircraft on these stands and potentially when taxiing along the southern taxiway. In June 2003, 27L was again downgraded whilst the manufacturer evaluates potential changes to the localiser to mitigate the effects. Whilst the beam might be protected by limitations on use of the stands and taxi-way, these could not be tolerated by the operators at Heathrow due to the lack of available stands and the impact on ground movements.

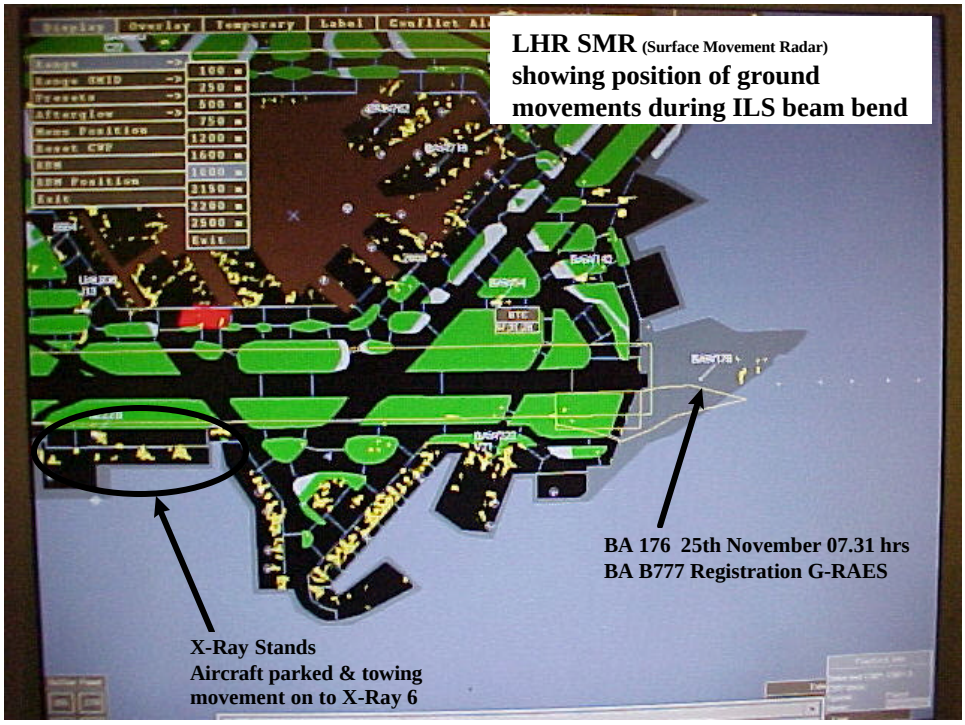


Figure 5.

3.1.7 In addition to the effect of the cargo centre, London Heathrow Terminal 5 is under construction and further development work around the airfield continue to threaten all of the ILS installations. This is not unique to Heathrow and has been demonstrated at Amsterdam Schipol airport and at Zurich.

3.2 ILS impact on landing rates at London Heathrow

3.2.1 Demand at London Heathrow is fairly constant throughout the day, as can be seen in Figure 6, and as a result, any large reduction in service rate from the standard good weather rate of 44 arrivals per hour cannot be recovered, resulting in disruption throughout the day. Introduction of low visibility procedures, primarily to protect the ILS, reduces the service rate to between 22-30 arrivals per hour, a shortfall of up to 50%. In the first part of the morning, this reduced service rate is almost entirely taken up by inbound long-haul arrivals, which are not subject to European flow regulations. As a result, departure slots are applied to all inbound European aircraft (shorthauls) by Eurocontrol Central Flow Management Unit (CFMU) to avoid an uncontrolled increase in airborne arrival holding.

3.2.2 Based on data from 1996 until 2001, low visibility procedures are implemented at Heathrow on an average of 19 days per annum. In the winter of 2001/2002 LVPs accounted for more than 93,000 minutes of slot delays, over 100 round trip cancellations and 19 diversion for British Airways alone.

3.2.3 Meteorological forecasting of runway visual range (RVR) is extremely difficult. UK Meteorological Office data for the same period indicates that LVPs are forecast but not implemented on 46% of occasions. On these occasions a precautionary flow rate is usually applied resulting in application of slot delays (ground holding) for all European inbound aircraft. This flow rate may not be lifted until it is clear that LVPs are not required, resulting in substantial ground delays to the inbound aircraft, particularly those departing from stations over an hour flying time from Heathrow. In addition, the same UK Meteorological

Office data states that LVPs fail to be forecast on 50% of occasions. When early morning fog occurs with RVR requiring the application of LVPs and is not forecast, arrival holding rapidly increases and may result in diversion of inbound long-haul aircraft.

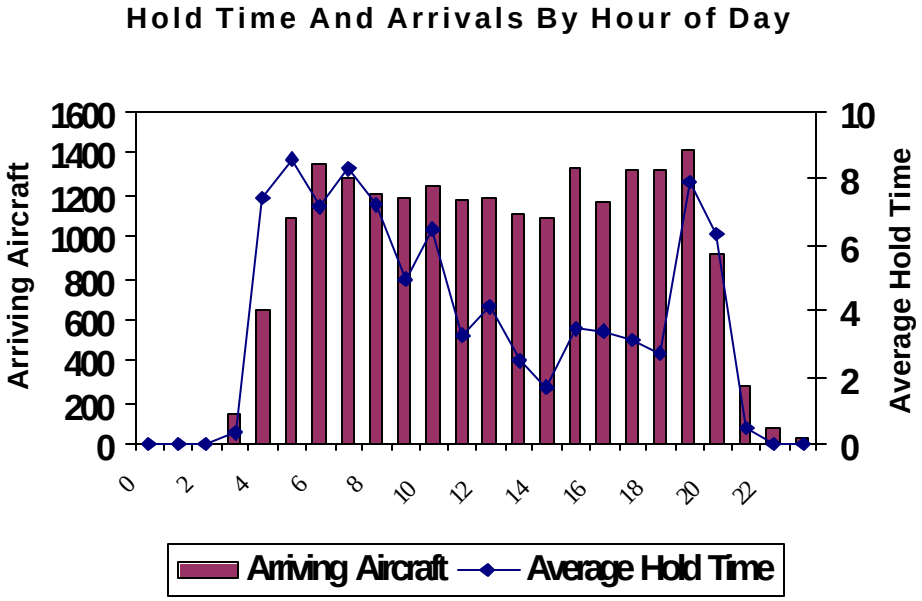


Figure 6. LHR hold times and arrivals per hour of day for 1 month period

3.2.4 The reduction in service rate in low visibility is to a large part driven by the need to protect the ILS Localiser and Glidepath from multipath interference and beam bends. For arrivals, the preceding aircraft has to be clear of the Localiser Sensitive Area (LSA) before the next arrival can be cleared to land, as can be seen in Figure 7. The large shaded area represents the Localiser Sensitive Area, which extends to 137m from the runway centreline. In addition, the preceding aircraft may cause disruption to the beam whilst on approach. The result is an increase in arrival spacing from a minimum of 2.5 nautical miles (medium to medium wake vortex category) to between 6-8 nautical miles.

LHR ILS/MLS Sensitive Areas

(Not to scale)

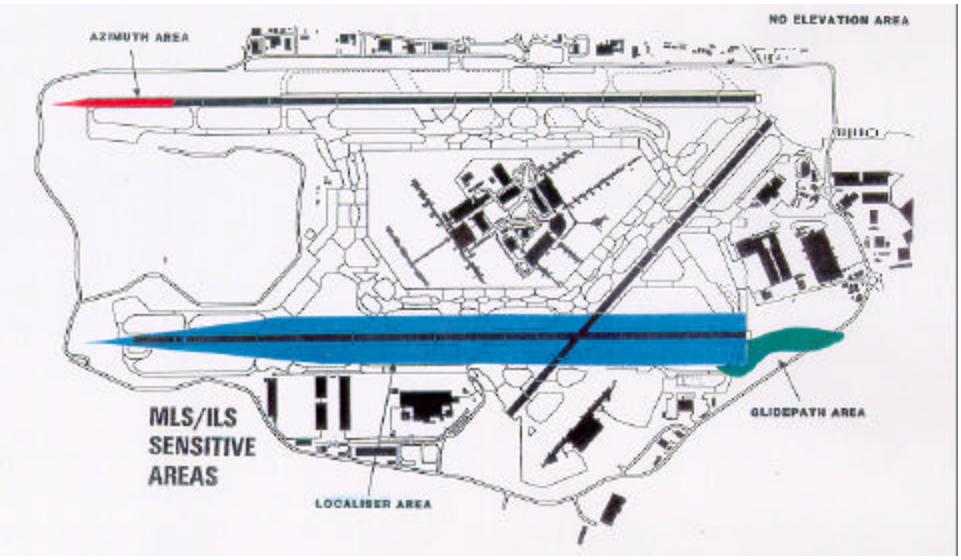


Figure 7.

3.2.5 Heathrow runways are usually operated in segregated mode that is a separate departure and arrival runway. When arrival holding reaches high enough levels the runways can be operated in a mixed arrival/departure mode (known as Tactical Enhanced Arrival Mode or 'TEAM'). When low visibility procedures are in force, additional ILS arrivals on the departures runway cannot be used to increase the arrival rate without substantial impact on departures as the departing aircraft must be clear of the localiser before an arrival is cleared to land. This implies that between 1.5 and 2 departures could be lost for each arrival. This may rapidly result in severe ground congestion.

4. THE CASE FOR MLS AT LONDON HEATHROW

4.1 MLS is, by design, almost immune from multipath interference and the Azimuth (MLS equivalent to the ILS localiser) sensitive area is very small in comparison to that of ILS.

4.1.1 With MLS it is possible during low visibility conditions for aircraft on final approach to be spaced closer with MLS than with ILS. This translates to an improvement in the landing rate in low visibility conditions depending on the number of aircraft equipped with MLS as can be seen in Figure 8.

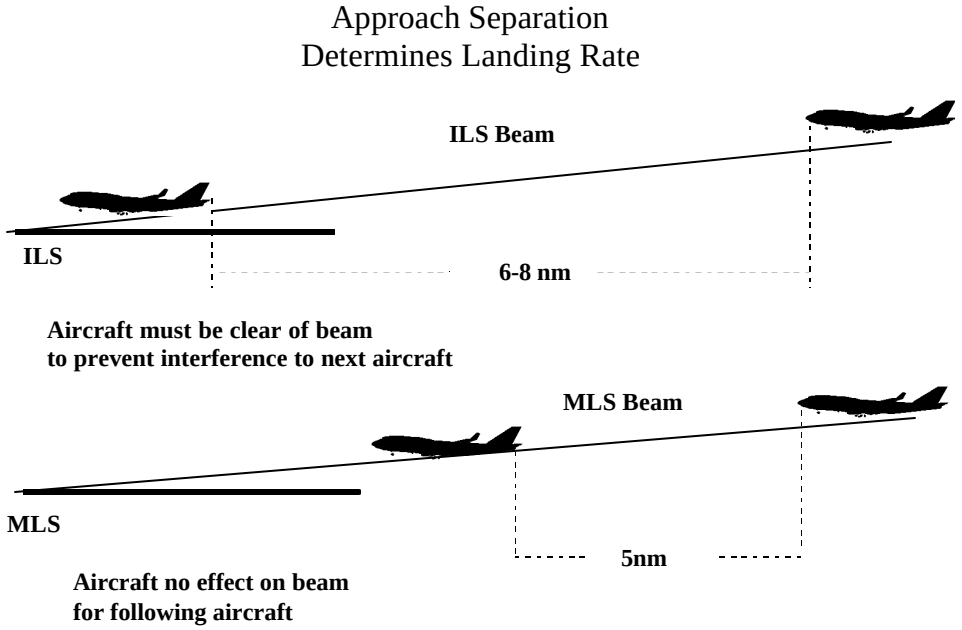


Figure 8.

4.1.2 In addition, aircraft can be cleared to land on a mixed mode (arrivals and departures) runway as soon as the departure has taken off rather than having to wait until it has flown beyond the localiser array as can be seen in Figure 9. Note that Heathrow has installed Mode S Multilateration based Advanced Surface Movement Guidance and Control System (A-SMGCS) which in addition to providing better awareness of surface movements, can be used to determine the point of lift-off for the departures to provide ATC with a clear cue for landing clearance for the inbound aircraft.

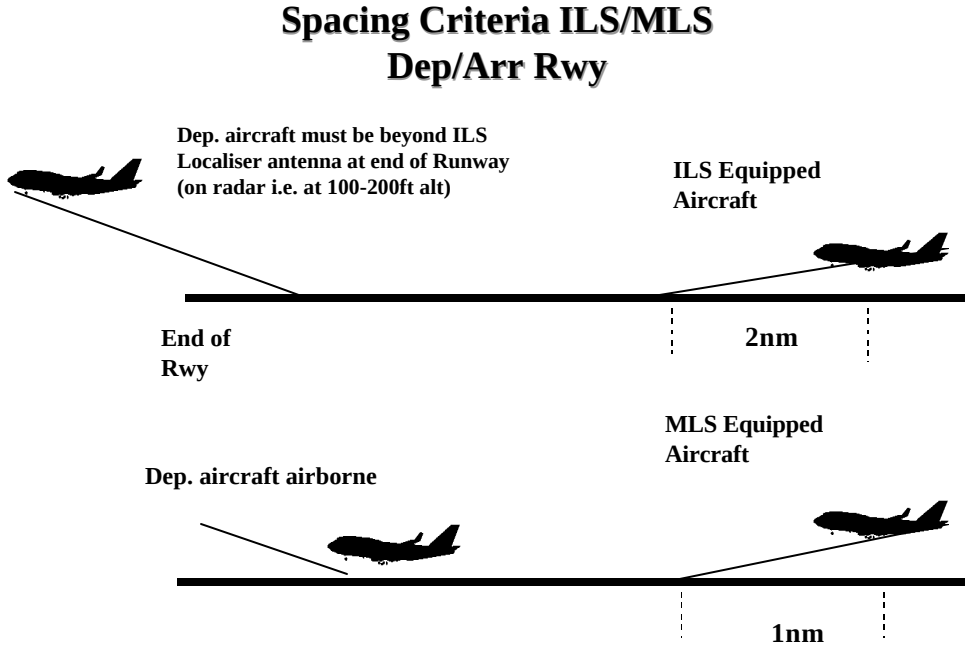


Figure 9.

4.1.3 As a result of this improved performance studies have shown that even with a 40% mix of MLS equipped arrivals, the airport arrival flow rate may be increased by over 20% in low visibility. In addition, an extra 6 MLS arrivals may be planned to land on the departures runway when low visibility occurs or is forecast thereby substantially decreasing the impact of actual or forecast low visibility procedures.

4.1.4 Heathrow MLS is co-located with the ILS, shown in Figure 10, and ILS services will be maintained to the highest category available. Given that the additional MLS flow rate reduces the unmet demand for all operators at the airfield, the benefit is to both ILS and MLS equipped aircraft.

Figure 10.

4.2 ATC mixed mode (ILS/MLS) procedures

4.2.1 ICAO Project Team LVP have developed the European LVP Manual which was approved in March 2003. It contains the procedures to be used by crew and Air Traffic Control to ensure that the correct separation and low visibility procedures are used for ILS and MLS aircraft in a mixed mode environment.

4.2.2 In brief summary the procedures are as follows:

a) MLS equipage is identified via a 'K' in item 10 of the ICAO flight plan;

b) inbound aircraft confirms intent for "Microwave" approach at first contact with ATC;

c) approach controller clears aircraft for ILS or "Microwave" approach;

d) crew report "established ILS" or "established Microwave";

e) landing clearance for Microwave approach can be given as late as 1 mile from threshold (ILS requires 2 miles);

f) landing clearance for arrival on the departures runway can be given as soon as departure is wheels off;

g) mechanism with flow management to enable MLS equipped aircraft to take up additional MLS arrival capacity, ILS flow controls no change; and

h) MLS azimuth and elevation still referred to as localiser and glideslope to simplify crew and ATC procedures.

4.3 Heathrow MLS implementation plans

4.3.1 MLS has already been installed on 27R-runway end at Heathrow and is radiating. By the end of Summer 2003 it will have been installed on 27L and 09R runway ends leaving 09L to be accomplished when the ILS is replaced in Spring 2004. All four runway ends are anticipated to reach Cat III by autumn 2004. In addition, an MLS has already been installed by STNA at Toulouse Blagnac and will be used for aircraft and ground system certification.

4.3.2 Airborne data collection begins on an in-service British Airways Airbus A320 in spring 2004. British Airways will then take delivery of the first Cat IIIb certified Airbus 321 in Autumn 2004 and expect to obtain MLS Cat III operational approval in Winter 2004. The MLS system is being certified as "ILS Look-a-like" at this time so there is no current intent to carry out curved and segmented approaches as these procedures will be accomplished through the use of the aircraft's Flight Management System. One other airline has also been involved in the Heathrow Airports Limited MLS project team at Heathrow and the decision to install MLS there. Once the system is being used on a daily basis, other major Heathrow operators may well follow suit and with more operators equipped, the benefit to the airport should increase from the initial 6 additional movements per hour of low visibility to up to 10 or more movements thereby greatly improving the robustness of the Heathrow operation.

4.3.3 Other airports such as Paris Charles DeGaulle and Amsterdam Schipol have also expressed interest as they face similar issues to London Heathrow, however, the decision will have to be taken on an airport by airport basis. London Gatwick may well follow if sufficient numbers of MLS equipped aircraft begin operation from it.

5. GNSS LANDING SYSTEM

5.1 Although GNSS should eventually support Category II and III precision approach operations this capability may not be generally available on new build and retrofit aircraft before the 2010 - 2015 timeframe. In the meantime ILS will continue to be the primary precision approach aid at most airports in the world. MLS is now an alternative option at those locations where it is no longer feasible to provide an ILS service, or where it may provide operational and economic benefits.

5.2 Given that ILS serves the majority of the busier airfields and the aircraft are already equipped, the key question may be whether there will be an operational or financial imperative for widespread replacement of ILS with a GNSS based landing system. Even with the introduction of the Multi Mode Receiver the costs associated with integration of a Cat III GNSS landing capability on to in service aircraft will be substantial. This may leave operators unable to substantiate the investment unless there are particular locations within their network where the system provides substantial benefits which cannot be supported by ILS, hence the ICAO general strategy is likely to remain in force. In fact it may require the large scale retirement of the in service aircraft before the GNSS landing system equipped fleet reaches a critical mass allowing for ILS retirement. In the interim and prior to GNSS Cat III approval, individual airports and their operators may decide that there remains a case for MLS installation.

5.3 The adoption of a general strategy rather than a mandatory transition plan means that the systems to replace ILS will be chosen on the basis of performance and cost benefit, and with the participation of all stakeholders. It is likely that ILS will continue to provide a valuable service for many more years at some locations and it is possible that the system design will be more than 70 years old before it is finally replaced. This, in itself, is a great testament to the engineers who designed and developed the system.

— END —