LORAN AND GPS

IN AVIATION

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I. WHY A TERRESTRIAL AVIATION NAVAID?

GPS was originally thought to be suitable as a sole means of navigation. Now we realize this is not acceptable for safety. Why?

(1) GPS is a "single thread" system critical to safe flight. The basic safety rule is: no single event (such as loss of GPS signal) should cause aircraft to risk crashing. This rule is independent of success of anti-jamming work.

(2) GPS is extremely vulnerable to interference. The satellites are at least 11,000 miles away. Transmitting power from the satellite is one (1) watt. Signal strength received on earth is 1^{-16} watt (one ten quadrillionth of a watt), i.e., less than background electronic noise. There are two types of jammers…

Noise Jammer. They are very easy to make ($50 of parts at Radio Shack). The range of 5 watt noise jammers: 200 kilometers. Aviaconversia, a Russian company, was selling noise jammers at the '99 Paris Air Show.

Spoofing Jammer. A spoofer imitates the GPS signal but with erroneous data – it confuses the receiver. A one (1) watt spoofer on Logan Airport, Boston, disrupts GPS signal for 300 miles (Source: Lincoln Labs).

The US military rejects GPS sole means in all applications. In a recent event, the US Navy, with access to all top secret technology, seeks proposals for alternate (i.e., backup) systems.

Also, the US Government has the switch to turn off or degrade GPS. The 1996 Presidential Decision Directive (PDD) specifically reserves

this authority to President, as do subsequent US statutes, as does 1999 Federal Radionavigation Plan.

GPS is a supplemental, not a primary, system of navigation.

II. SOLUTION: A HYBRID NAVIGATION SYSTEM

GPS must be teamed with a non-single thread (i.e., primary) navigation system for all phases of flight. Here are the simple choices:

En Route Flight/Terminal Maneuvering

- VOR/DME or DME/DME. These are the basic nav systems with which all aircraft are equipped. Both are very safe as primary (stand alone, sole means) systems.

VOR/DME navigation is safe but laterally inaccurate. VOR based systems are obsolete in modern, efficient air-space and should be abandoned, as Eurocontrol plans.

DME/DME navigation is safe and highly accurate, with lateral accuracy of ¼ mile. All modern air carrier aircraft are DME/DME equipped. Since so many air carrier aircraft rely on DME/DME navigation, these systems should be retained for some time. But DME systems are line-of-sight systems and provide poor coverage at low altitudes. They are also expensive to install and maintain (there are 1,000 sites in the US).

- LORAN. The great value of the LORAN system lies in the nature of its signal. The LORAN signal follows the surface of the planet (land and water) and is therefore available at low altitudes for terminal maneuvering and for non-precision approach. It is also a very long range signal and therefore cheap to operate. All of the North

American land mass is covered by 29 LORAN stations. LORAN is the en route navigation system of the future.

Precision Approach

Precision approach (vertically guided) to very low altitudes (200 feet or less) is mandatory for safe flight in bad weather.

- ILS is the standard, worldwide precision approach system. ILS is one of the great aviation safety technologies and will continue in service for the foreseeable future. All IFR aircraft have ILS.
- MLS is also an excellent precision approach aid. MLS has not been widely adopted because, at most airports, MLS is no better than ILS. But MLS's freedom from multipath interference make it superior to ILS at some crowded urban airports such as London Heathrow.

III. GPS AUGMENTATIONS

The growing awareness of the unacceptability of GPS sole means has completely changed the value of the various GPS augmentation systems for safety of life applications such as aviation (and marine) navigation. Under the earlier assumptions of GPS sole means, all ground based navaids would be scrapped. Usage of GPS augmentations would obviously be 100%. Cost savings to governments (no navaids) and operators (fewer avionics on aircraft) would be substantial.

The requirement to carry a redundant system in all phases of flight has changed everything because the augmentations are mostly, though not entirely, duplicative of systems that must continue to be operated by governments and carried by airplanes.

Wide Area Augmentation

The US WAAS program is complicated and expensive and has recently encountered cost overruns and schedule delays. Nevertheless, given sufficient money and time there is a good chance that the technical goals can be met. But is it worth $3 billion?

FAA's most recent study, "Sat Nav Investment Analysis Report," 25 September 1999, attempts to recalculate the costs and benefits of WAAS. Two pages of this report deserve close consideration: page 60, benefits, and page 86, program risks.

A detailed discussion of this study is outside the scope of this paper. However, one point on page 86 should be repeated. "… in aircraft equipped with a FMS, WAAS will not provide substantial added economic or operational value to them beyond what unaided GPS can provide, or beyond what they can achieve with RNAV – capable FMS equipment." Virtually all US air carrier aircraft are, on soon will be, RNAV capable with FMS. US air carriers are now re-evaluating their support for WAAS.

One benefit of WAAS is not in dispute. WAAS can provide a precision, vertically guided approach to small airports not equipped with an ILS. This is a significant benefit to general aviation and may also help small airports served by the new regional jets. Developing countries with few ILS's would also benefit.

Local Area Augmentation

Local area augmentation systems, LAAS, are simple short range ground based line of sight transmitters sending correction and integrity messages to airborne receivers in the immeidate vicinity of an airport.

LAAS can provide CAT I, II, & III approaches. Unlike ILS, LAAS systems are GPS-based and therefore are very vulnerable to interference. ILS must still be available on the ground and on aircraft.

Private Augmentation

Private, non-governmental GPS augmentation systems are of little interest to aviation but are mentioned because of their widespread use in non-safety of life applications. Container and truck tracking, surveying (to an accuracy of 3 inches), precision agriculture, backpacking, motor vehicle navigation, etc., all use GPS or augmented GPS. The vulnerability of GPS is not significant here because the loss of GPS does not threaten life. No redundancy is needed. Ninety to ninety five percent of GPS usage is not in aviation.

IV. SELECTIVE AVAILABILITY

The US Department of Defense distorts the civil GPS signal accuracy with SA (selective availability). The 1996 PDD requires that SA be terminated by 2006. Beginning in 2000 the DOD must annually report why it needs to continue SA. Insiders predict that SA will be turned off well before 2006, perhaps as early as 2001.

Basic civil GPS accuracy with SA is 100-300 meters. With SA off, accuracy improves to 2-10 meters. The differential role of WAAS corrects current GPS to this level of accuracy. Basic civil GPS will soon be as accurate as GPS/WAAS.

V. LORAN

This paper to the ANC has focused on the limitations of GPS because the need for LORAN, or any terrestrial nav system, depends

on GPS. If GPS alone, GPS sole means, is a complete navigation/approach system, no other system is needed.

Unfortunately, GPS has been over-promised for safety of life applications. In aviation a teamed, hybrid system is needed for every phase of flight. The task before ICAO and the world aviation community is to select the best systems to team with GPS.

I believe that LORAN is unquestionably the best partner for GPS from every point of view: accuracy, coverage, and cost. Rather than repeat my views, I attach a paper delivered in November to The Royal Institute of Navigation in London.

Before I close, let me advise the ANC of a development just last month in the US. The Automatic Blink system (ABS) of LORAN passed its last test for approval by FAA and the Coast Guard. ABS is an integrity channel which monitors the LORAN signal and advises the pilot if the signal suddenly becomes unusable. This safety system now fully qualifies LORAN as an instrument non-precision approach aid. LORAN is now a complete, certifiable, sole means aviation navigation and NPA system like VOR/DME and DME/DME. Formal certification by FAA is expected immediately. Manufacturers are already developing a certifiable receiver. I hope and expect that ICAO will add LORAN to its list of navigation systems soon.

Next you will hear Dr. Wolfgang Lechner of Germany who is a leading technical expert on radionavigation. From my perspective as a user, the most interesting part of his paper is how elegantly GPS teams with LORAN to provide a low cost, secure, host country controlled partner with GPS.