Enabling the LAAS Differentially Corrected Positioning Service (DCPS)

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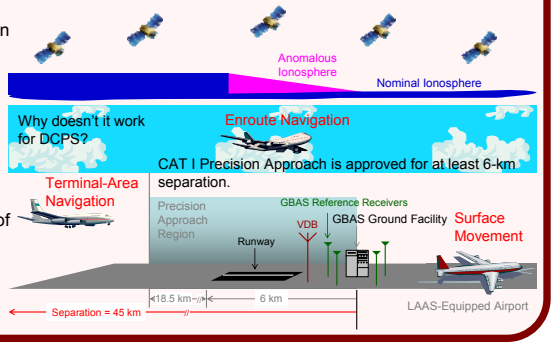
Introduction

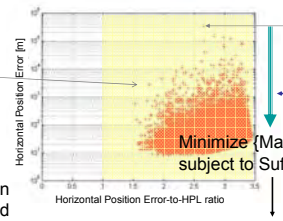
Local Area Augmentation System (LAAS) is primarily focused on supporting precision approach but it can also be used for a variety of other applications that are known as DCPS. DCPS includes all potential airborne uses of horizontal position and velocity that are not included in CAT I precision approach.



Goal

DCPS Integrity

The current LAAS requirements for DCPS integrity are that position error should be bounded by the corresponding protection level to the 10^{-7} -per-hour probability level, and cannot be met by CAT I LAAS.



Minimize {Maximum Unprotected Error} subject to Sufficient Availability

Design and Requirements Alternatives

1) Integrity requirements change:
Max. Unprotected Error = currently 0 ⟶ Nonzero
2) MOPS change to lower max. unprotected error

Airborne Geometry Screening Rules

- Limited subset geometry
  - All-in-view only (M = 0)
  - Drill-down to 1-satellite out (M = 1)
  - Drill-down to 2-satellites out (M = 2)
  - : Constellation Dependent
- Limiting Maximum absolute value of the range-to-position scalar ($|S_{horizontal}|$)
- Combinations of airborne geometry screening rules
- RAIM with combinations airborne geometry screening rules

Simulation Procedure

Generate all in view, all 1-SV out, all 2-SV out, etc., down to all 4-SV subset geometries

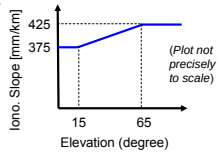
- 1 day
- 5-minute updates
- 24-SV constellation (all SV's healthy)
- 11 major U.S. Airports

Loop through all independent individual satellites

1-SV Impact

D_{max} = 45 km
$V_{aircraft}$ = 70 m/s

CONUS CAT-I Ionospheric Anomaly Threat Model



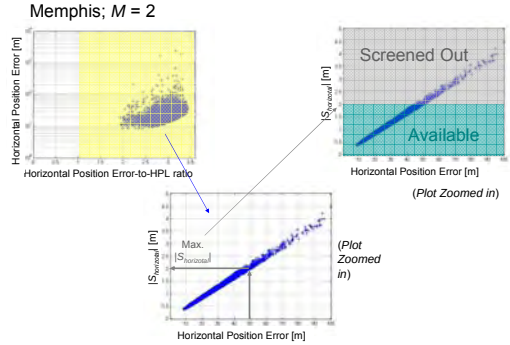
$V_{aircraft}$ = 70 m/s
σ_{vig} = 4 mm/km

Compute worst-case Position Error *, Protection Level *

* Horizontal component only

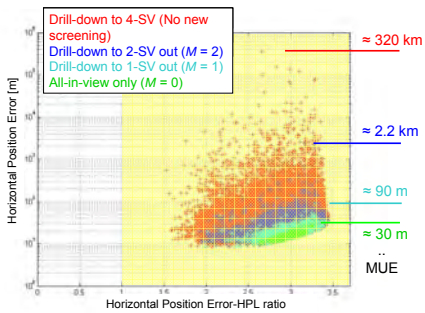
Airborne Geometry Screening

Memphis; M = 2

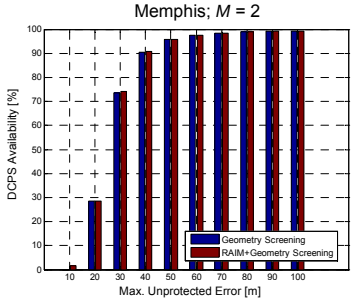


Results

Screening Based on Limited Subset Geometry: Memphis



Comparison of DCPS Availability between Airborne Geometry Screening alone and with RAIM: Memphis; M = 2



Screening Based on Maximum $|S_{horizontal}|$ Only: Memphis

Max. $\lvert S_{horizontal}\rvert$	MUE (m)	DCPS Availability (%)
6.0	150	95.3
5.2	130	94.5
4.0	100	92.5
3.2	80	89.8
2.0	50	78.6
1.2	30	48.8
0.4	10	0.05

Summary of MUE with approx. 95 % Availability: Memphis

Airborne Implementation		MUE	Availability (24 Healthy SV's)
No new screening		~ 320 km	> 99.9 %
Screening based on 2-satellites-out (M = 2) rule only		2.2 km	> 99.9 % (for benign aircraft dynamics)
Screening based on max. $\lvert S_{horizontal}\rvert$ only		140 m (max. $\lvert S_{horizontal}\rvert$ = 5.6)	95.0 %
Combinations of M satellite out and max. $\lvert S_{horizontal}\rvert$	M = 0	25 m	96.2 %
	M = 1	35 m	96.4 %
	M = 2	50 m	95.6 %
RAIM with screening	M = 0	0 m	> 99.9 %
	M = 1	35 m	96.8 %
	M = 2	50 m	95.7 %

Conclusions

Four key conclusions have been drawn from the DCPS analyses conducted in this research:

(1) Changes to both the DCPS integrity requirements definition and the requirements on LAAS avionics are needed to make DCPS usable.

(2) A change to the impact component of the CONUS LAAS ionospheric anomaly threat model, from 2-satellite to 1-satellite impact, is necessary when this threat model is applied to DCPS.

(3) Once a non-zero value of MUE is allowed by the DCPS integrity requirement, the use of multiple screening rules and, optionally, the use of RAIM for DCPS makes it possible to achieve an MUE for DCPS of about 50 meters (for D_{max} = 45 km) with approximately 95% availability. Further significant reductions do not appear to be possible unless the maximum-gradient bound in the ionospheric anomaly threat model is reduced significantly. However, defining availability more conventionally, in terms of the all-in-view geometries only, would result in significantly lower MUE values at 95% availability.

(4) Because performance differences among the most-helpful options are relatively small, there does not appear to be one clearly "best" choice of additional airborne screening and monitoring. Therefore, the optimal selection depends highly on the specific flight and ground operations to be supported by DCPS and the constraints imposed by existing LAAS airborne equipment.

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