



ARAIM FD Availability Performance

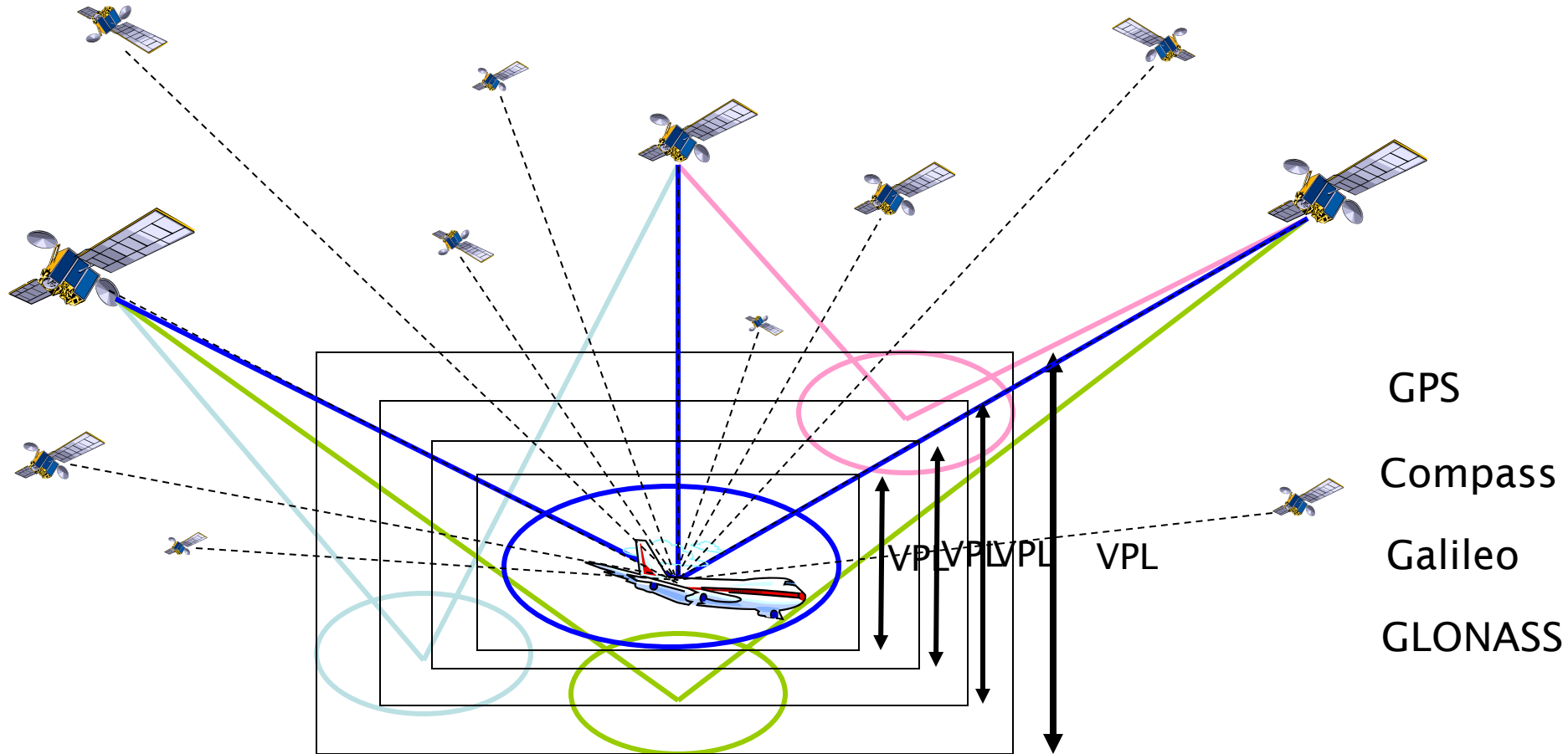
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**EU-U.S. Cooperation on Satellite Navigation,
Working Group-C on Next Generation GNSS**

**ARAIM Outreach Event
Toulouse
7 April 2017**



Exploiting multi-constellation for integrity: Advanced RAIM



Blanch, J., Walter, T., Enge, P., Lee, Y., Pervan, B., Rippl, M., Spletter, A., Kropp, V., "Baseline Advanced RAIM User Algorithm and Possible Improvements," IEEE Transactions on Aerospace and Electronic Systems, Volume 51, No. 1, January 2015.



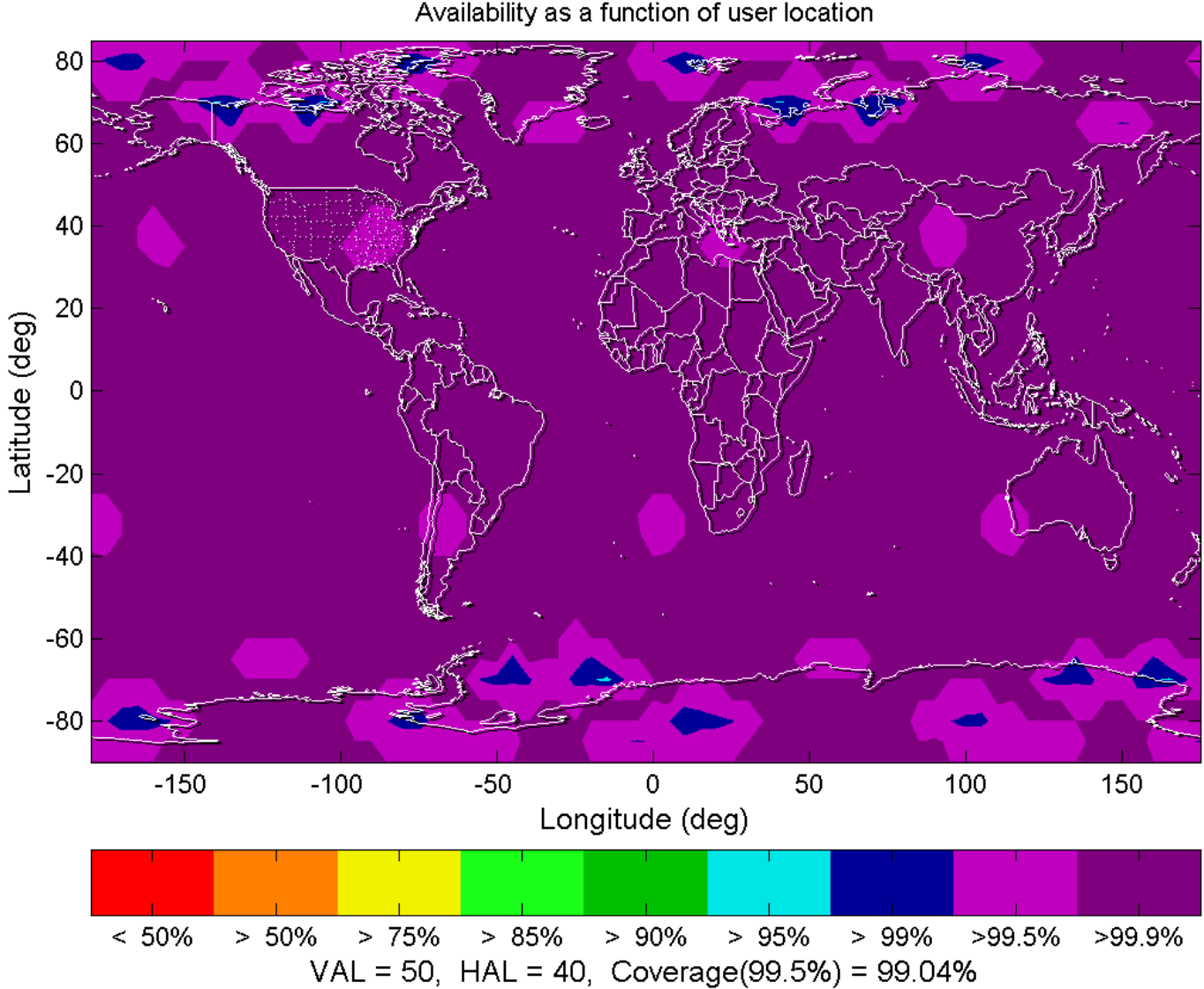
MAAST Description

- Stanford has a freely available tool to simulate SBAS and ARAIM performance
 - Matlab® Availability Analysis Simulation Toolset (MAAST)
 - <https://gps.stanford.edu/resources/tools/maast>
 - Satellites used and their locations provided by almanac files
 - Can change which constellations are used and their layout
 - Specify user grid, timeframe, and time steps
 - e.g. global grid, 10 sidereal days, and 600 second steps
 - Specify ISM parameters
 - P_{sat} , P_{const} , URA , URE , b_{nom}
 - Output corresponding protection levels, accuracy, and EMT
 - Produces maps of availability and corresponding coverage



L1/L5 VPL Availability Map

24 GPS +
 24 GAL
 $P_{\text{const}} 10^{-4}$
 $P_{\text{sat}} 10^{-5}$
 URA = 1 m
 Bias = .75 m





L5-Only HPL Availability Map

24 GPS +

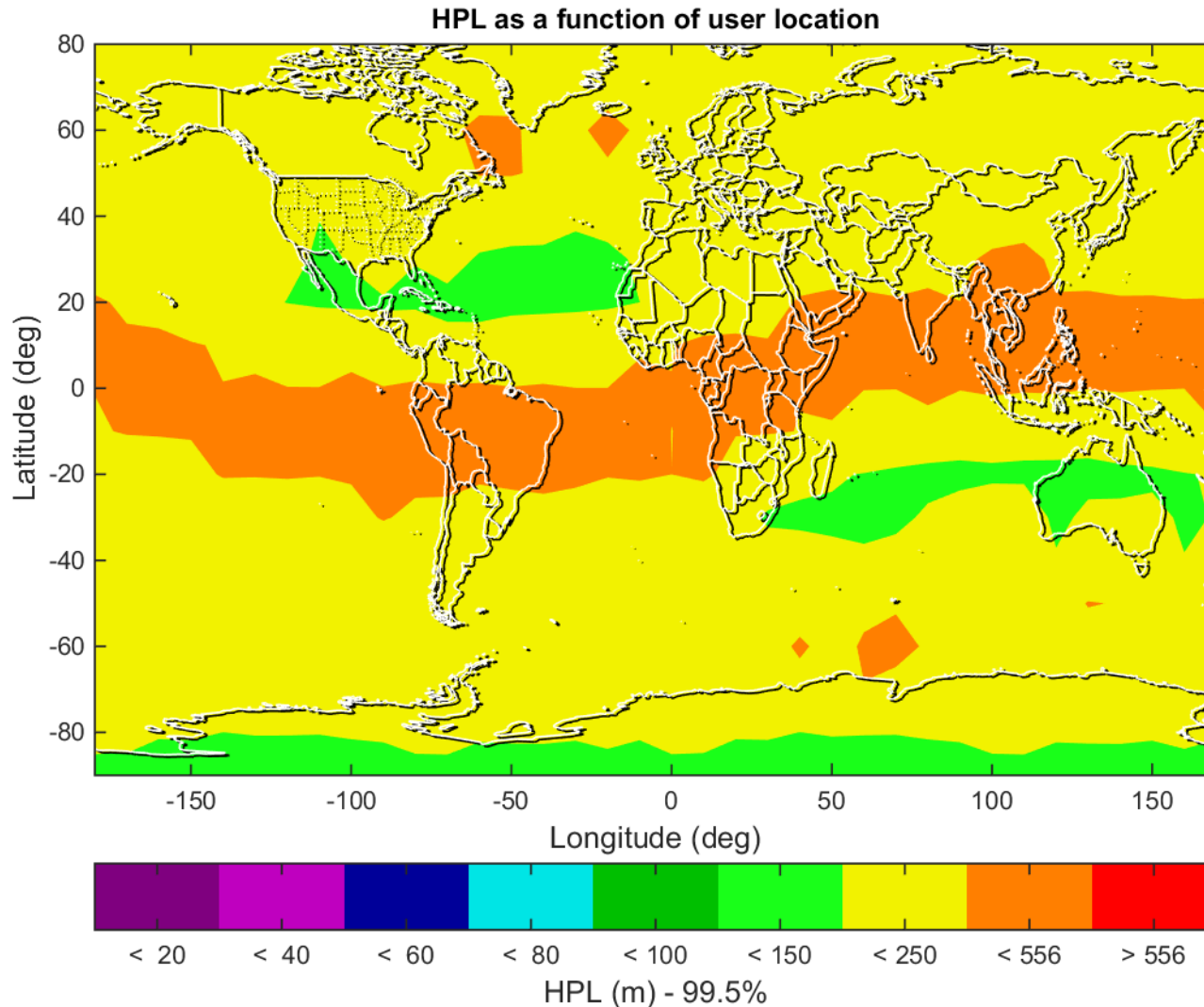
24 GAL

$P_{\text{const}} 10^{-5}$

$P_{\text{sat}} 10^{-5}$

URA = 2.5 m

Bias = .75 m





Availability Drivers: Two constellation example

GPS 24 + Galileo 27

Satellite fault rate



Constellation fault rate

Nominal error



		P_{SAT}				
		1.E-07	1.E-06	1.E-05	1.E-04	1.E-03
URA	1	100.00	100.00	100.00	100.00	100.00
	1.25	100.00	100.00	100.00	100.00	99.78
	1.5	92.77	92.96	92.96	92.77	87.53
	1.75	28.88	28.88	28.88	28.88	26.45
	2	1.14	1.14	1.14	1.14	0.83
URA	1	95.96	95.96	95.96	93.67	91.39
	1.25	90.59	90.59	90.59	84.40	81.71
	1.5	68.06	68.06	68.06	59.05	40.88
	1.75	16.98	16.86	16.86	8.37	
	2	1.02	0.57	0.57		
URA	1	95.81	95.81	95.76	93.67	91.39
	1.25	90.59	90.59	90.59	84.40	78.09
	1.5	68.06	68.06	68.06	58.99	40.88
	1.75	16.86	16.74	16.67	8.30	
	2	.57	0.51	0.32		

$P_{const} < 10^{-8}$

$P_{const} = 10^{-6}$

$P_{const} = 10^{-4}$



P_{sat} = Prob. of satellite fault

$b_{nom} = 0.75$ m



H-ARAIM Availability

L1-L5

Constellation/ P_{const}	GPS 10^{-4} Gal 10^{-4}	GPS 10^{-8} Gal 10^{-4}	GPS 10^{-8} Gal 10^{-8}
GPS 23 - Gal 23	RNP 0.1	RNP 0.1	HAL < 40 m
GPS 24 - Gal 24	HAL < 40 m	HAL < 40 m	HAL < 40 m
GPS 27 - Gal 27	HAL < 40 m	HAL < 40 m	HAL < 40 m

Reversionary: L5 Only

Constellation/ P_{const}	GPS 10^{-4} Gal 10^{-4}	GPS 10^{-8} Gal 10^{-4}	GPS 10^{-8} Gal 10^{-8}
GPS 23 - Gal 23	RNP 0.3	RNP 0.3	RNP 0.1
GPS 24 - Gal 24	RNP 0.3	RNP 0.3	RNP 0.1
GPS 27 - Gal 27	RNP 0.3	RNP 0.3	RNP 0.1

Level of service criterion used: 90% coverage of 99.5%-availability quantile (Ref. Milestone II report)



V-ARAIM Availability

Expected V-ARAIM (Offline)

With Airborne Constellation Cross-check: $P_{\text{sat}} = 10^{-5}$, $P_{\text{const}} = 10^{-4}$					
Constellation/URA	.5 m	.75 m	1 m	1.5 m	2 m
Depleted (GPS 23 - GAL 23)	LPV-250	LPV-250			
Baseline (GPS 24 - GAL 24)	LPV-200	LPV-200	LPV-200	LPV-250	
Optimistic (GPS 27 - GAL 27)	LPV-200	LPV-200	LPV-200	LPV-250	LPV-250

Expected V-ARAIM (Online)

Without Airborne Constellation Cross-check: $P_{\text{sat}} = 10^{-5}$, $P_{\text{const}} = 10^{-8}$					
Constellation/URA	.5 m	.75 m	1 m	1.5 m	2 m
Depleted (GPS 23 - GAL 23)	LPV-200	LPV-200	LPV-200	LPV-250	LPV-250
Baseline (GPS 24 - GAL 24)	LPV-200	LPV-200	LPV-200	LPV-200	LPV-250
Optimistic (GPS 27 - GAL 27)	LPV-200	LPV-200	LPV-200	LPV-200	LPV-250

Level of service criterion used: 90% coverage of 99.5%-availability quantile (Ref. Milestone II report)