Problem Statement - ADS-B MASPS

Position Integrity and Accuracy

- **Navigation Integrity and Accuracy Metrics Needed for Required Surveillance Performance (RSP) Definition**
  - Accuracy Needed for Conflict Detection & Alerting Analysis
  - Integrity Needed for Separation Assurance Procedures
  - For most NAV systems, Accuracy and Integrity are Independent Metrics:
    - Accuracy reflects nominal, unfailed performance
    - Integrity reflects rare normal / undetected anomaly performance

- **Required NAV Integrity Level in current MASPs is probably too High (For most ADS-B Applications):**
  - Current MASPS Integrity Probability Specified at 1x10^-7 / hr (Reflects Augmented GPS Spec. for Signal-in-Space Integrity)
  - Current RNP NAV equipment only designed for 1x10^-5 / hr Integrity (RNP MASPS: DO-236, DO-236A)

Proposed Revisions to ADS-B MASPS

- **Each Position Report Needs Separate Accuracy (NAC) and Integrity (NIC) metrics:**
  - Navigation Accuracy Category - Based on **Estimated Position Uncertainty** (95% Uncertainty Bound)
  - Navigation Integrity Category - Based on **Position Containment Radius** such that the probability of exceeding this bound without alerting is less than 1x10^-5/ hr or operation.

- **Integrity Level Needed by Participants is Application Dependent:**
  - Non-Essential Apps (Minor Hazard Level) - No Integrity Required
  - Essential Apps (Major Hazard Level) - 1x10^-5 Integrity Level Required
  - Critical Apps (Severe Major Hazard) - 1x10^-7 Integrity Level Required

  (**None** of Current Applications in Development are Anticipated to Require More than 1x10^-5 Integrity Level for NAV and ADS-B)

Proposed Navigation Accuracy (NAC) Categories

NACp	Horizontal Error (95%)	Vertical Error (95%)	Comment
0	> 10 nm	Baro Alt	Accuracy Unknown
1	<10 nm	Baro Alt	RNP-10 Accuracy
2	<4 nm	Baro Alt	RNP-4 Accuracy
3	<2 nm	Baro Alt	RNP-2 Accuracy
4	<1 nm	Baro Alt	RNP-1 Accuracy
5	<0.3 nm	Baro Alt	RNP-0.3 Accuracy
6	< 0.1 nm	Baro Alt	RNP-0.1 Accuracy
7	< 0.05 nm	Baro Alt	e.g. GPS
8	< 30 m	Baro Alt	e.g. GPS (No SA)
9	< 10 m	< 15 m	e.g. WAAS
10	< 3 m	< 4 m	e.g. LAAS

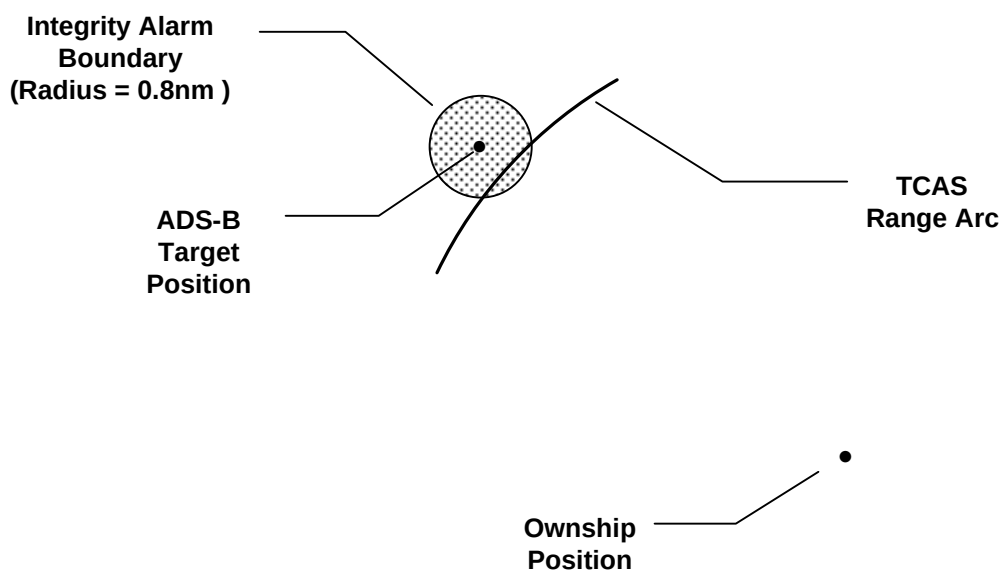
Proposed Navigation Integrity (NIC) Categories

(Horizontal Position States)

NIC	Horizontal Containment	Integrity Level	Comment
0	Unknown	-	No Integrity
1	<20 nm	1X10**(-5)	RNP-10
2	< 8 nm	1X10**(-5)	RNP-4
3	< 4 nm	1X10**(-5)	RNP-2
4	< 2 nm	1X10**(-5)	RNP-1 Integrity
5	<0.6 nm	1X10**(-5)	RNP-0.3 Integrity
6	<0.2 nm	1X10**(-5)	RNP-0.1 Integrity
7	<0.1 nm	1X10**(-5)	e.g. RAIM - GPS
8	<75 m	1X10**(-5)	Future system
9	< 25 m	1X10**(-5)	e.g. WAAS HPL
10	< 7.5 m	1X10**(-5)	e.g. LAAS HPL
11	future expansion	1x10**(-7)	
12	future expansion	1x10**(-7)	

Multi-sensor Integrity Monitoring Example

- **Target AC ADS-B broadcast Data :**
  (NIC = 0, NAC = 5 (< 0.3 nm position uncertainty, e.g. Dual DME)
- **Ownship AC TCAS & ADS-B equipped:**
  (NIC = 7, NAC = 7 (e.g. RAIM based GPS NAV with SA off)
- **TCAS Provides Independent Integrity Monitoring: (NIC=4)**



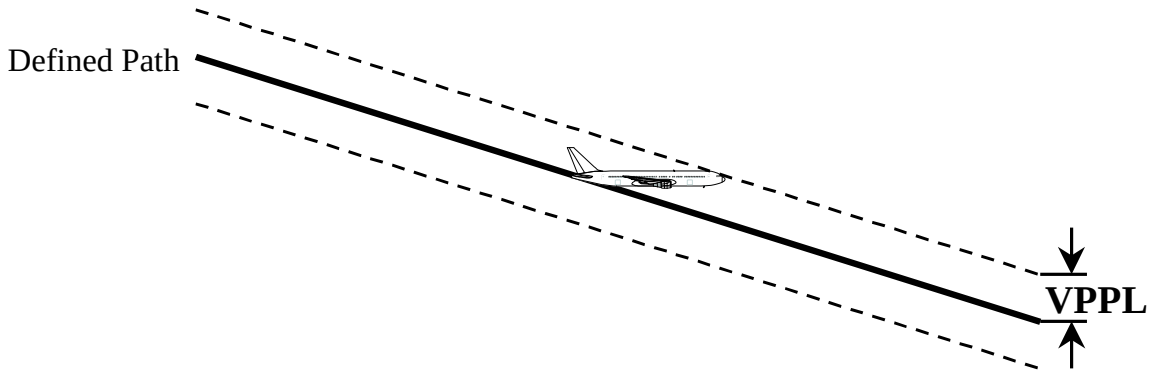
RNP RNAV System Outputs

- Horizontal Plane Outputs (LNAV, RNAV)
  - 95% Radial Accuracy Bound: Estimated Position Uncertainty (EPU)
  - Containment Integrity (TSE) 2xRNP for 1x10**-5 Integrity Level
  - NAV Sensor Integrity Bound Position Containment Radius (Rc)

- Vertical Outputs (VNAV)
  - 95% Height Accuracy Bound ASE - Generic, VFOM - GPS only
  - Vertical Containment Bound Vertical Path Performance Limit (VPPL)
  - Altimetry Sensor Integrity Vertical Protection Limit (VPL) - GPS only

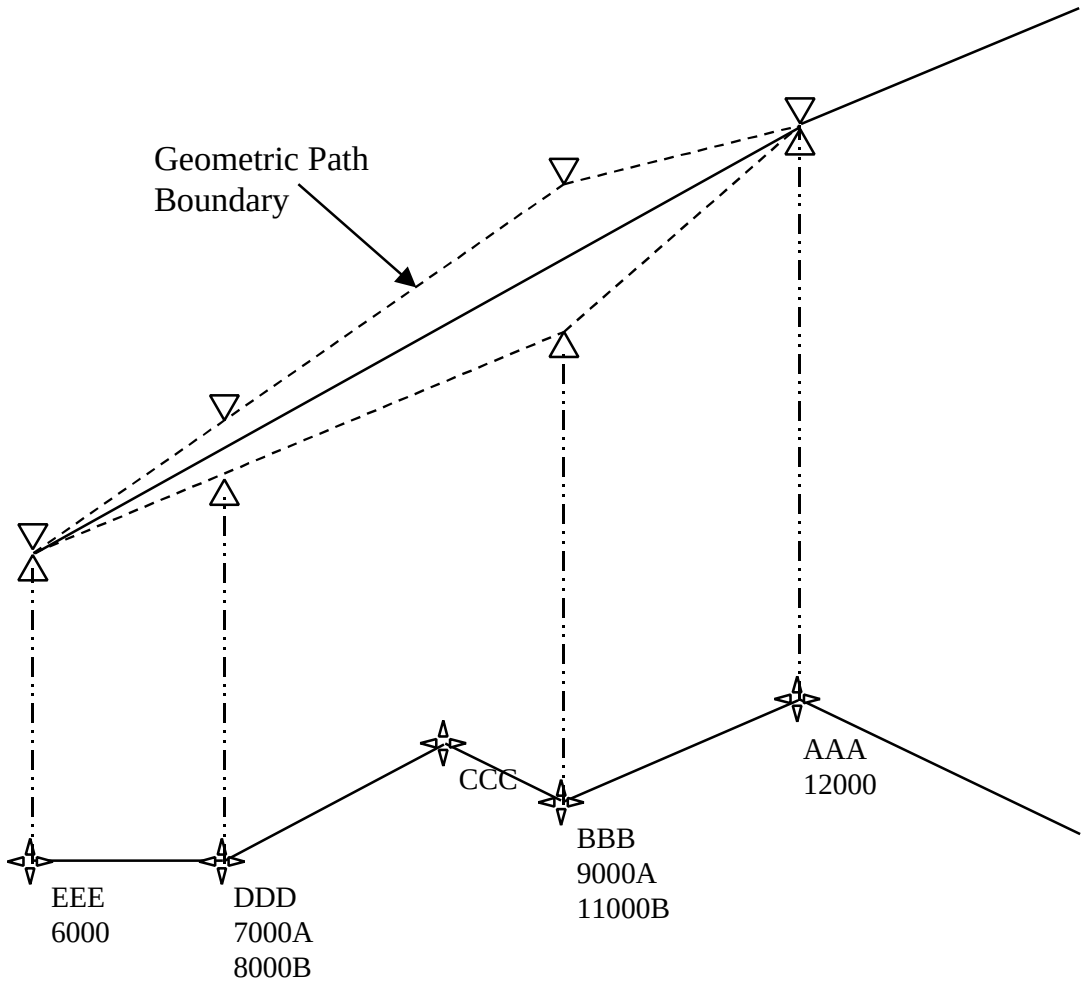
- Proposed ADS-B Broadcast of RNP System outputs
  - NAC based on EPU/HFOM Baro / VFOM
  - NIC based on Rc / HPL Baro / VPL ?
  - RNP Capability for Class A2,A3 Altitude Restrictions in TCP indicator (& Altitude Window Restrictions)

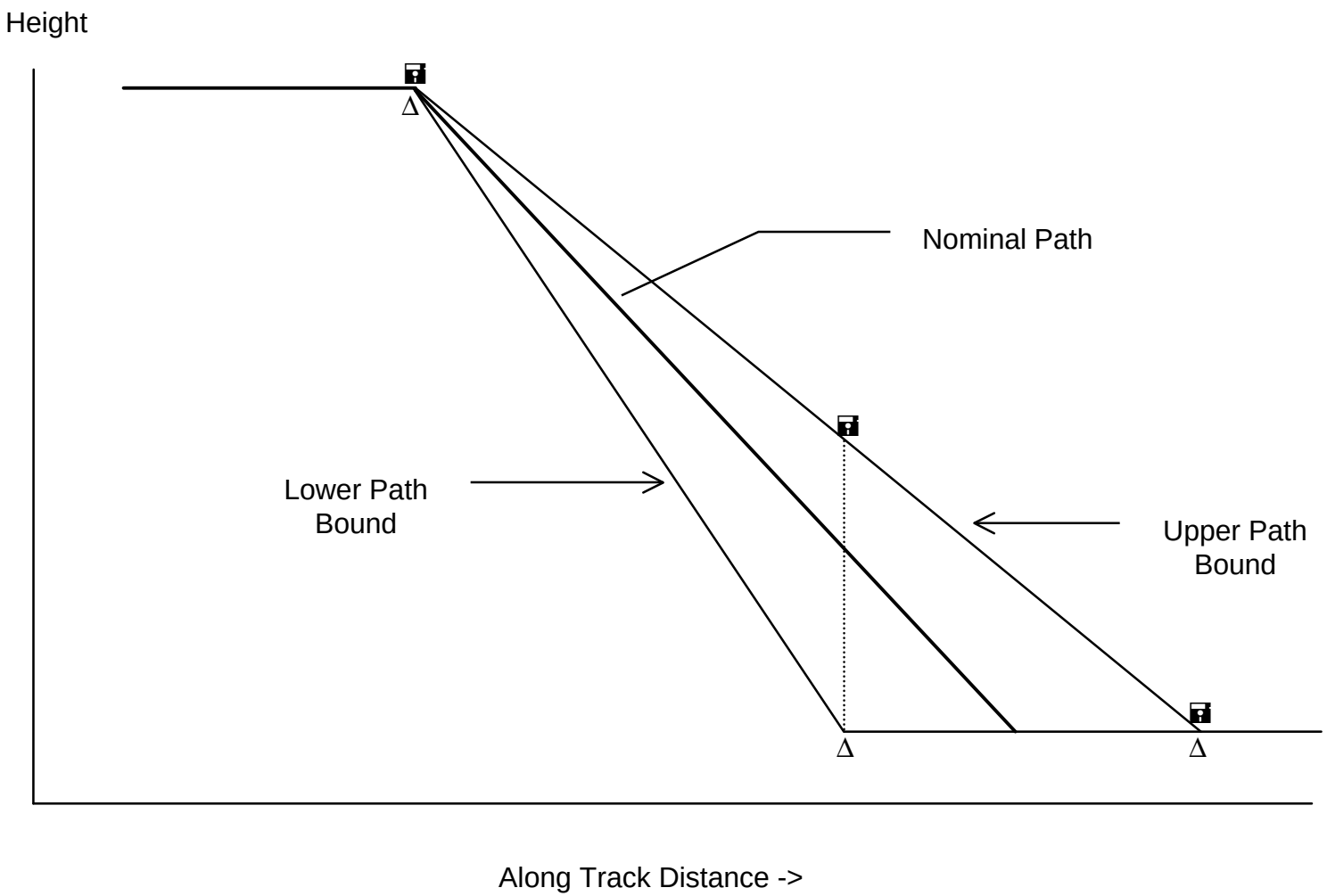
Vertical Path Performance Limit (VPPL)



- VPPL represents a 99.7% limit (containment integrity) for system vertical error (altimetry error, vertical FTE, vertical path def'n error, horizontal coupling error)
- Equivalent to RNP containment integrity (2xRNP), except containment probability is 99.7%, not .99999
- VPPL limits for VNAV are prespecified, e.g. approx. 200 feet between 5000 ft and 29,000 ft altitudes (MSL)

Descent Path Example with Window Constraints



- Example shows two “Window Constraints” and two “AT” Constraints

Descent Example with Descent Slope Bounds