Vertically-guided Instrument Approaches Using the Wide Area Augmentation System (WAAS)

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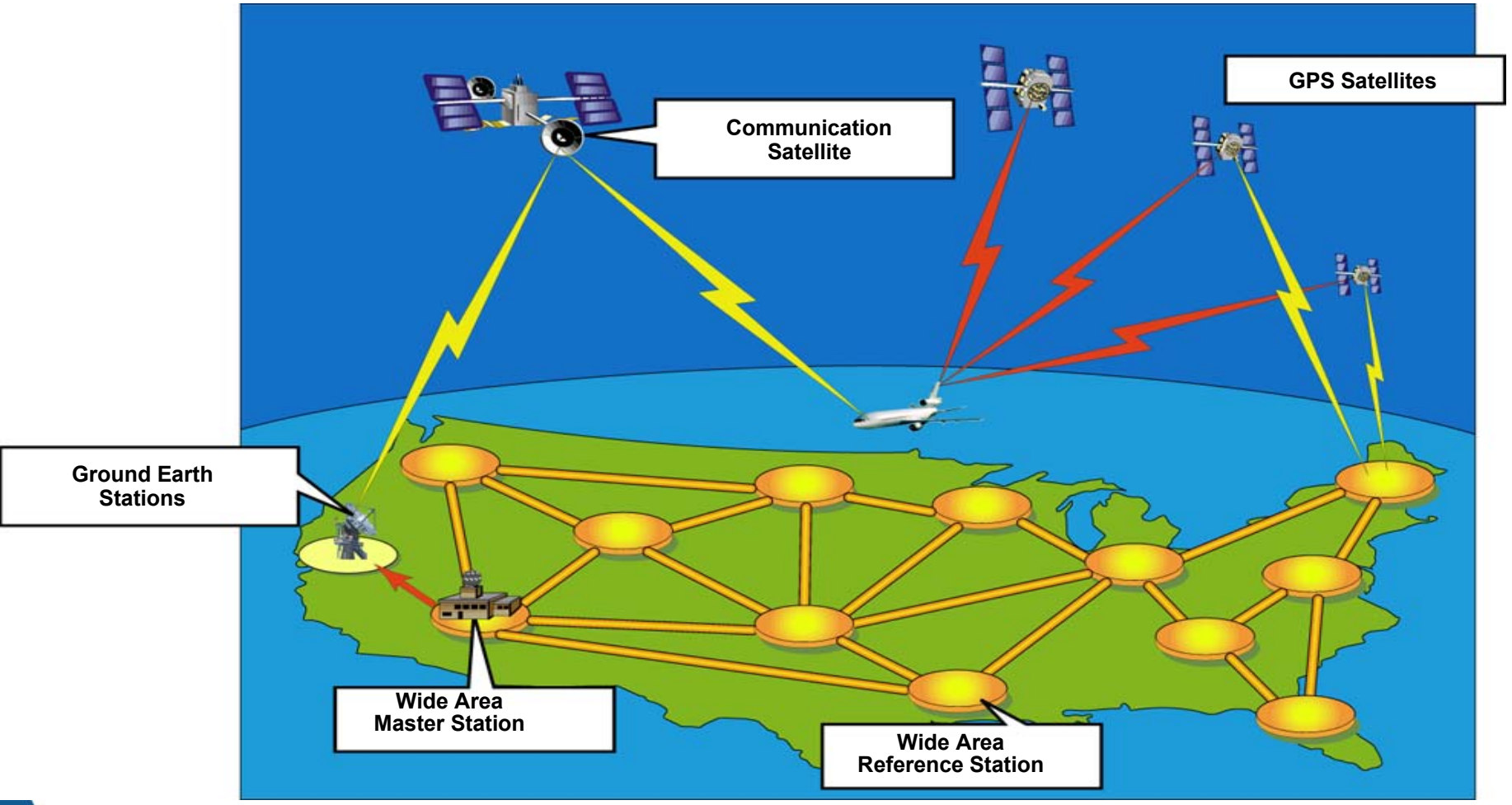
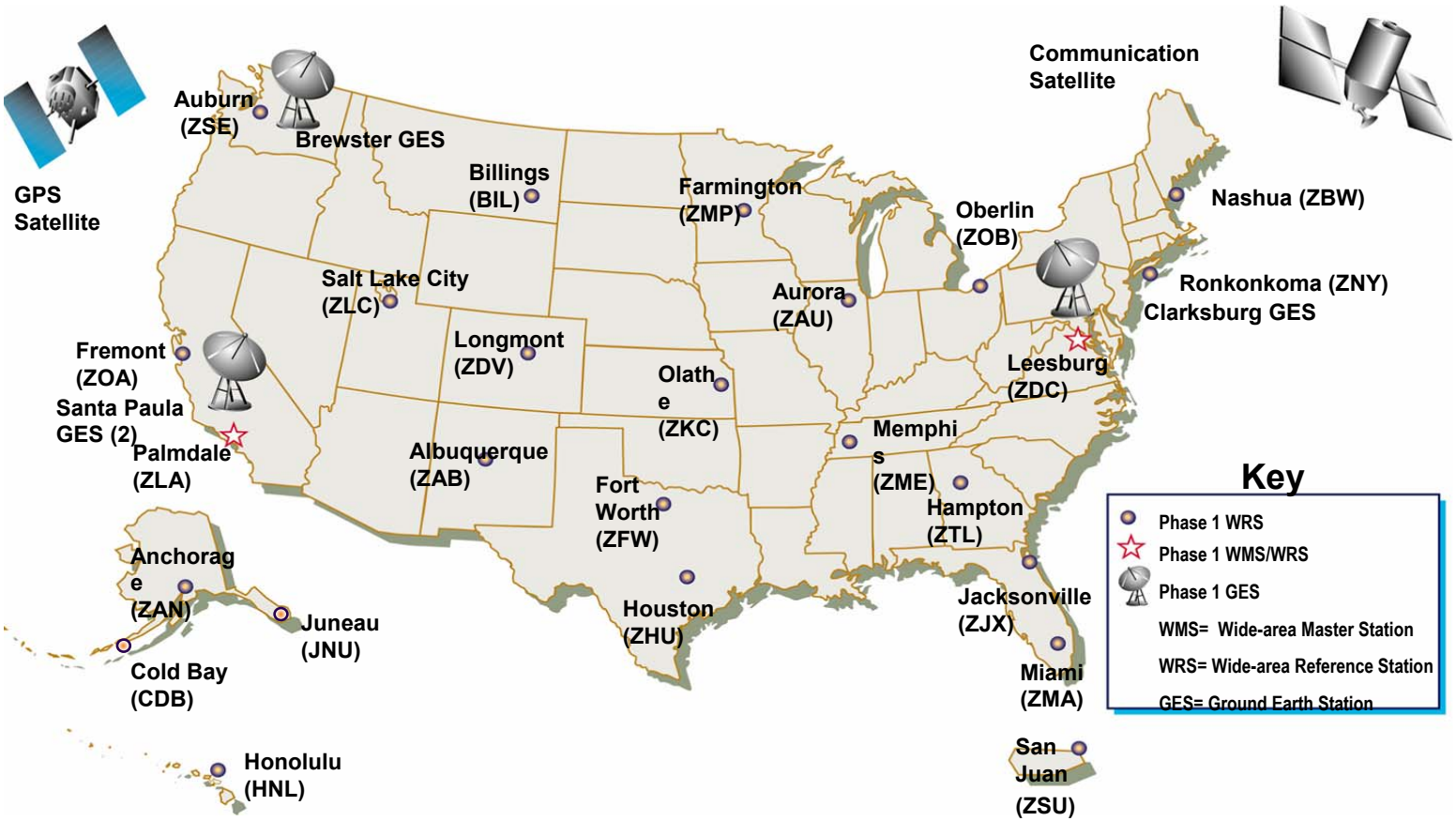
Wide Area Augmentation System (WAAS)



Wide Area Augmentation System

Initial Equipment Locations



WAAS Benefits

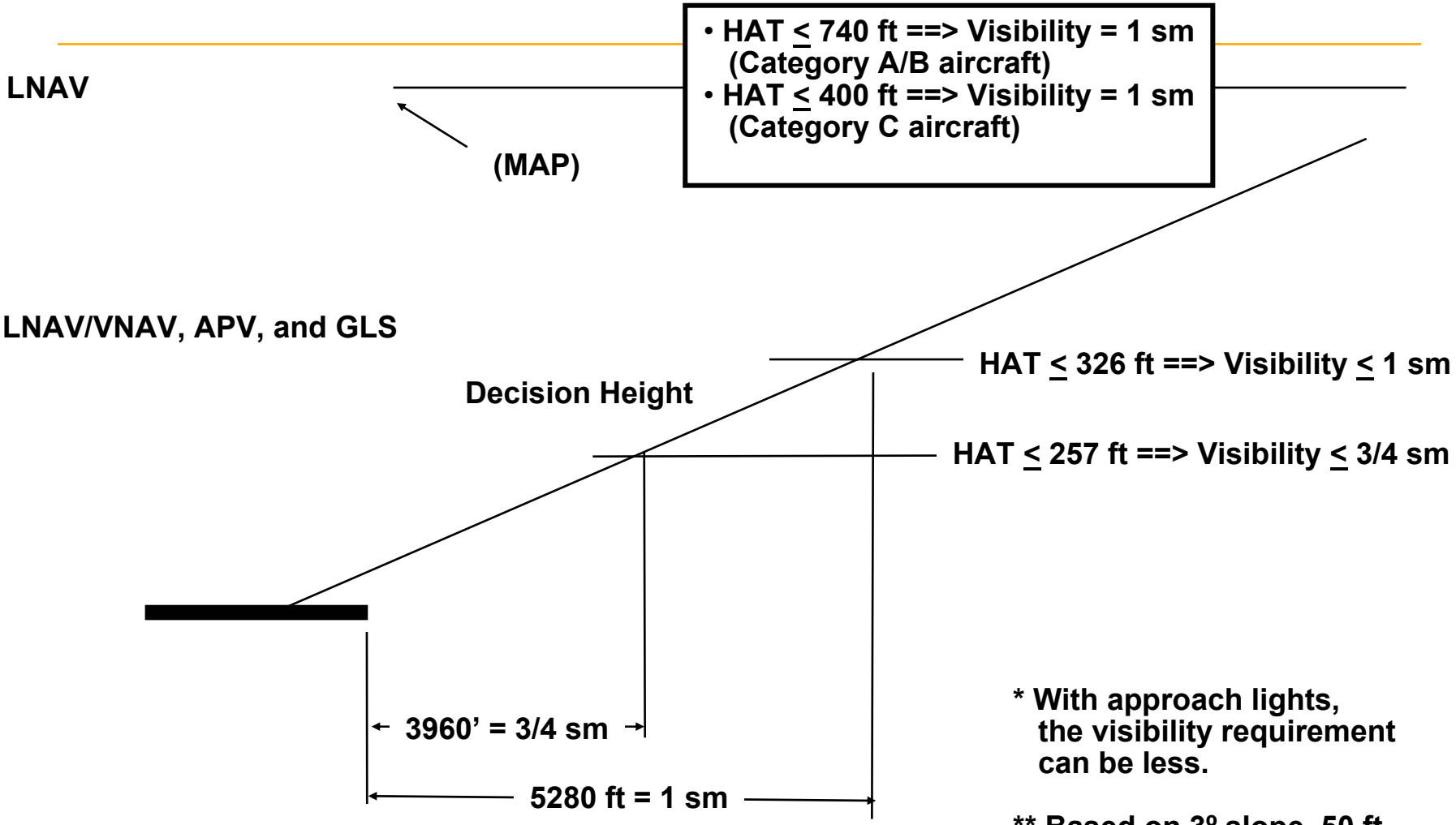
- **WAAS will provide increased accuracy and availability for navigation throughout CONUS (and much of Alaska), and provide advanced navigation procedures, such as departures and curved approaches**
- **A significant safety benefit will be the provision of vertically-guided approaches to nearly all runways**
  - **USA has 5000 airports with at least one runway 3000 ft long**
- **Initial plans were to provide vertical guidance to Category I approach minima**
  - **200 ft Height Above Touchdown (HAT)**
  - **Integrity re-evaluation in 1999 indicated this goal was overly optimistic for single-frequency WAAS**

Instrument Approaches

- **GNSS Landing System (GLS)**
  - **Equivalent to ILS Category I approach with lowest HAT of 200 ft and lowest visibility of ½ statute mile**
  - **Generally not considered possible with high availability for single-frequency WAAS**
- **LNAV/VNAV – BARO/VNAV**
  - **Originally designed for FMS-equipped aircraft with sophisticated barometric altimetry system**
  - **Flyable with DME/DME Inertial, GPS or WAAS**
- **LNAV**
  - **Nonprecision approach flyable with DME/DME Inertial, GPS or WAAS**

Visibility Values

- HAT ≤ 740 ft ==> Visibility = 1 sm (Category A/B aircraft)
- HAT ≤ 400 ft ==> Visibility = 1 sm (Category C aircraft)



* With approach lights, the visibility requirement can be less.

** Based on 3º slope, 50 ft crossing height

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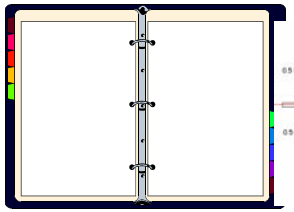
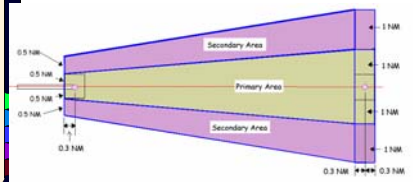
GPS Approach Minima Estimator (GAME) Model

Terrain Data Base





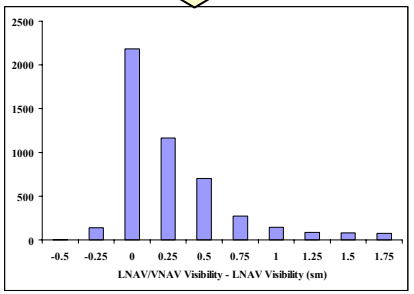
Approach Design Criteria

Obstacle Data Base

Minima Estimation Software

Repeat for Thousands of Runway Ends

Airports Data Base



Generate Statistics

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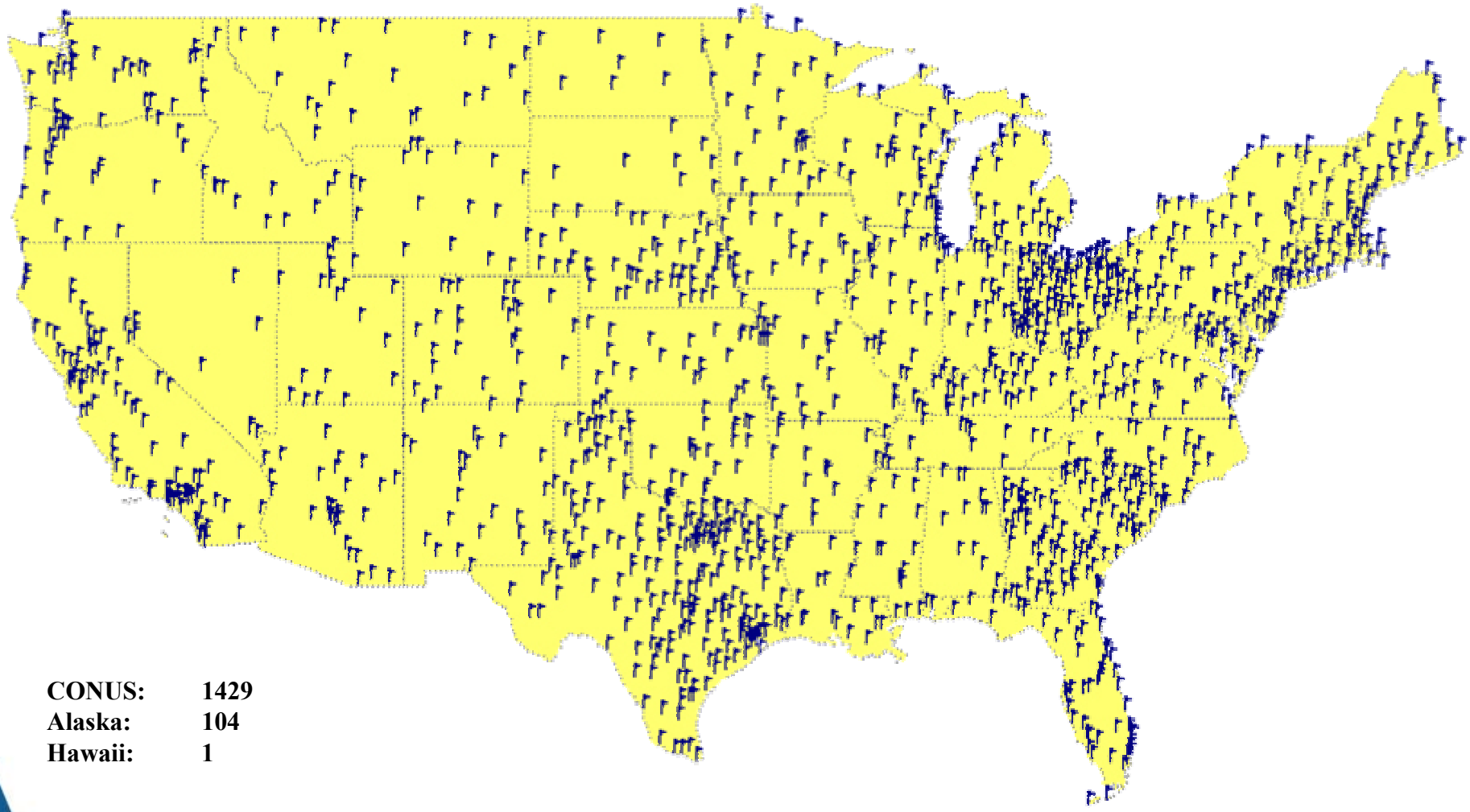
GAME Airports:
1534 airports and 5073 runway ends



CONUS: 1429
Alaska: 104
Hawaii: 1

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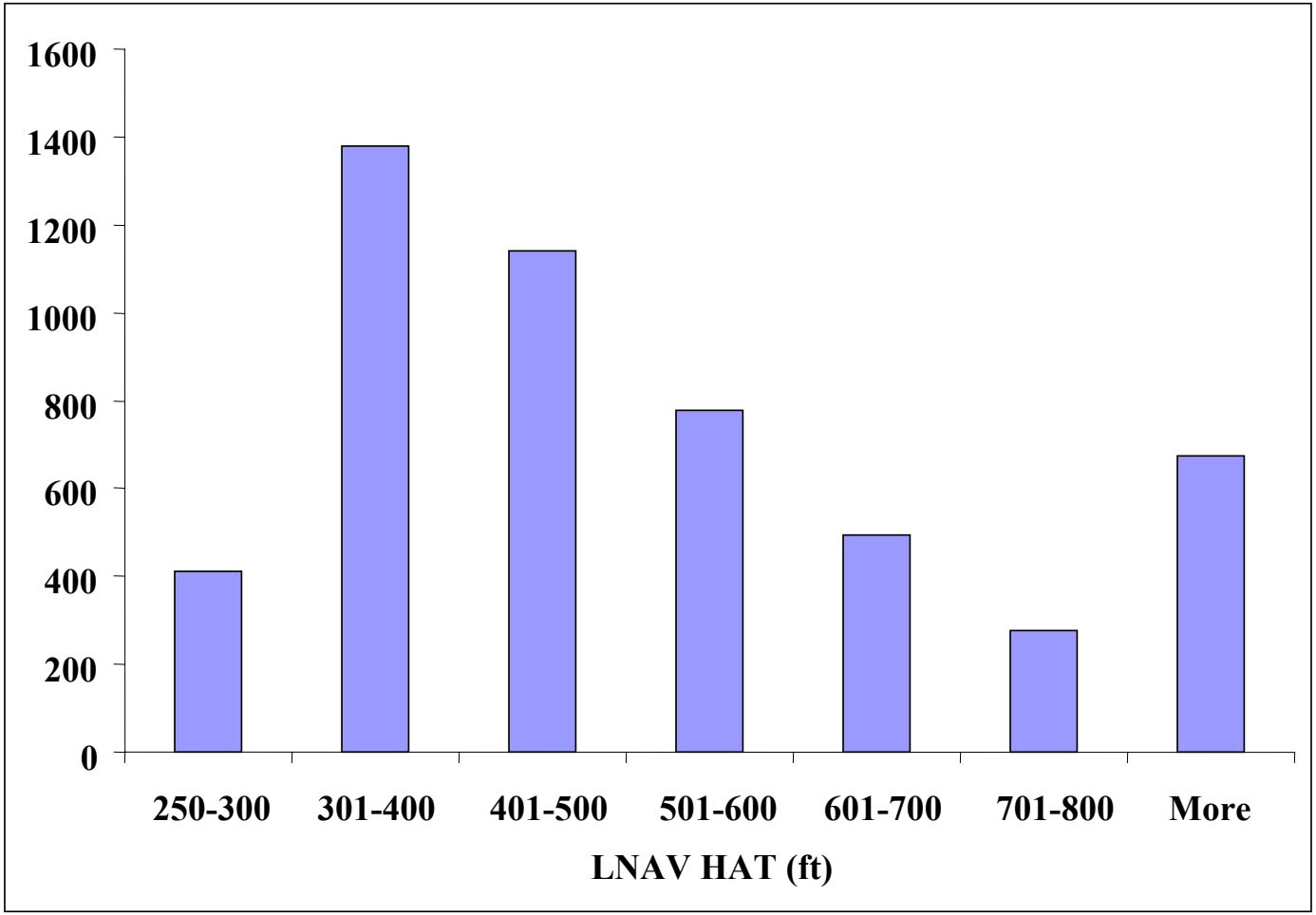
Estimated HAT for LNAV Approaches (Existing Capability without WAAS)



5147 runway ends at 1534 airports

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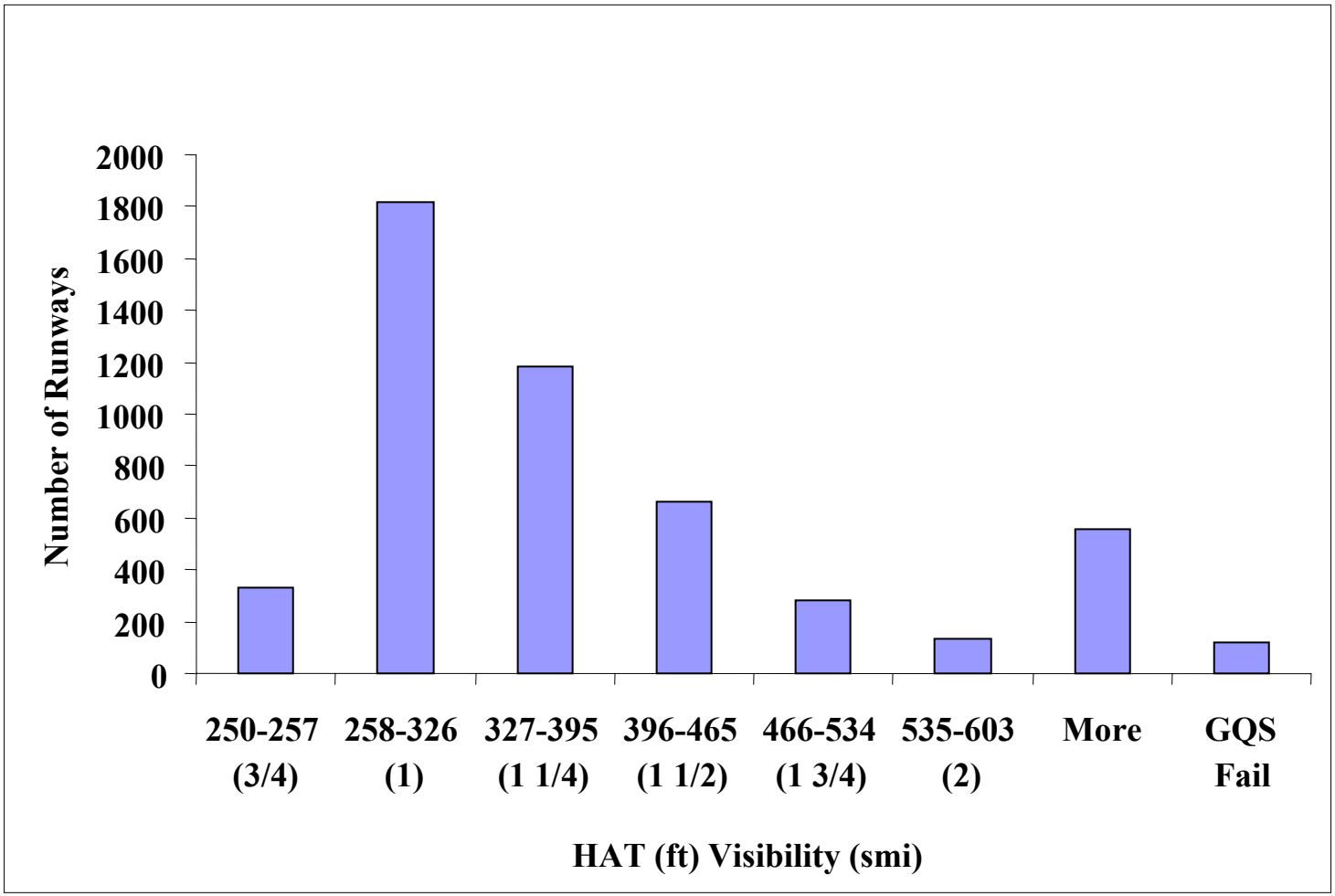
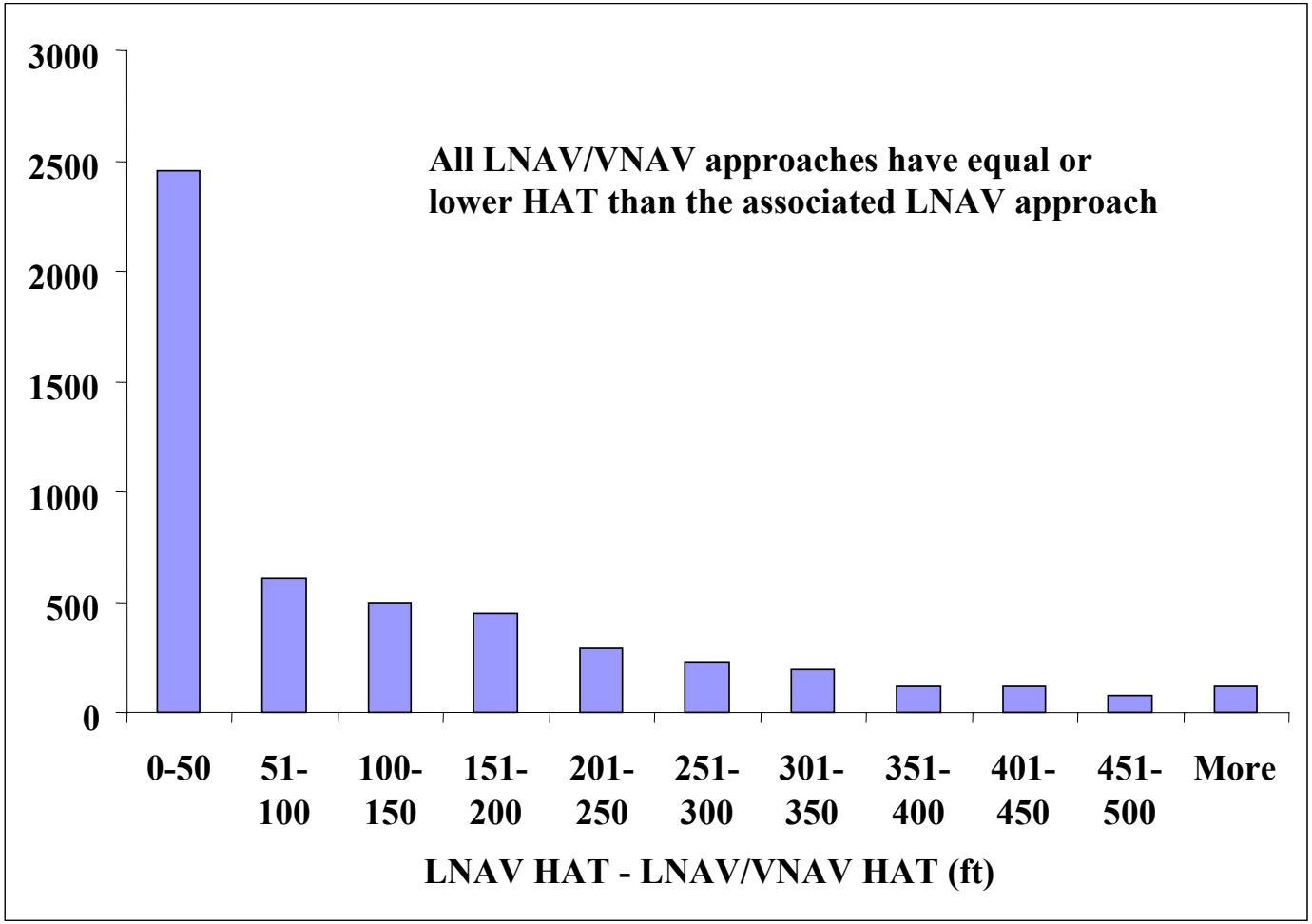
Estimated LNAV/VNAV HAT



Estimated Improvement in HAT with LNAV/VNAV(Available at WAAS Phase I)



5147 runway ends at 1534 airports

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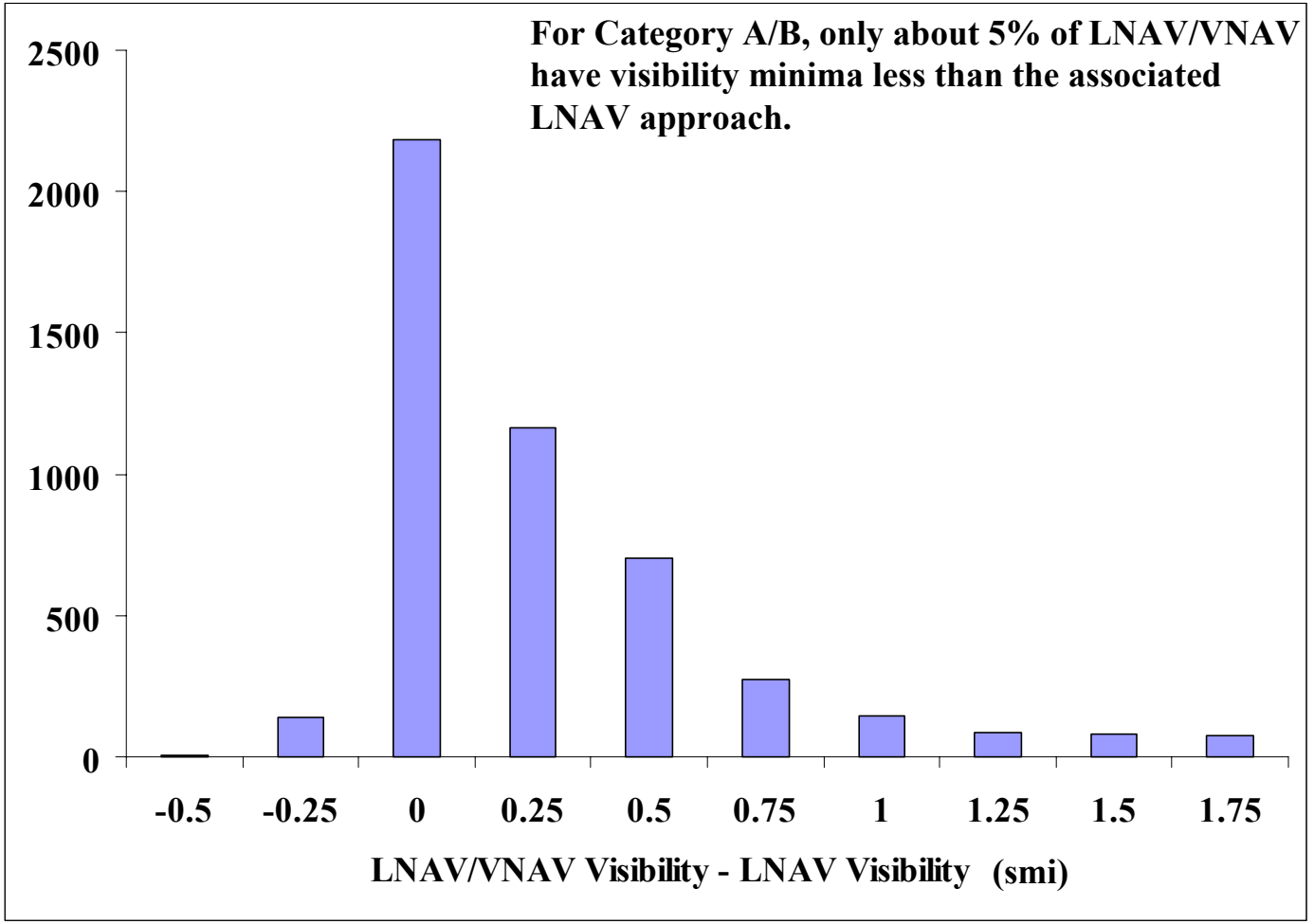
Estimated Visibility Benefit for LNAV/VNAV vs. LNAV (Cat A/B Aircraft)



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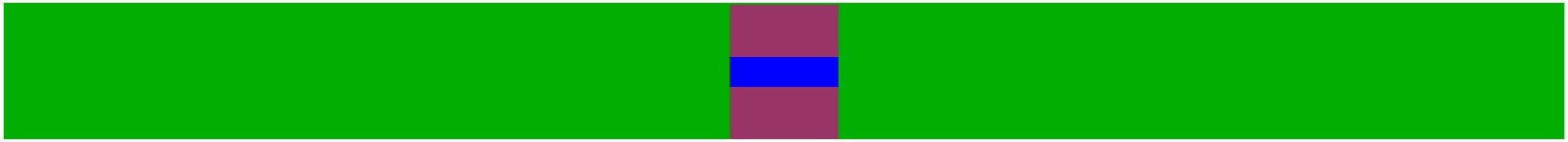
New Approaches

- **To improve near-term instrument approach benefits of WAAS, the FAA investigated instrument approach criteria that used the horizontal and vertical integrity available from WAAS**

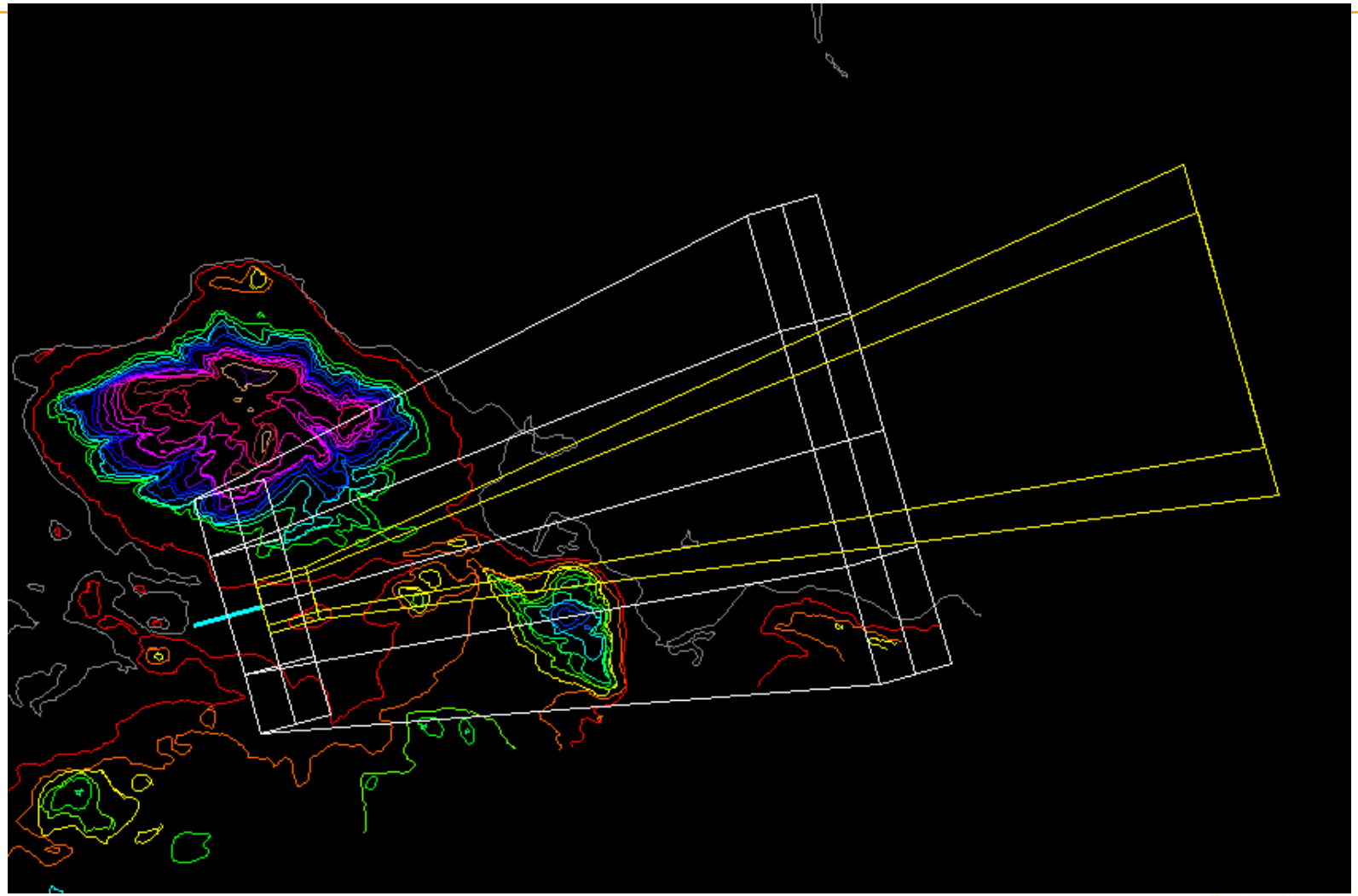


LNAV/VNAV - RNP .3 (556 m horizontal by 50 m vertical)

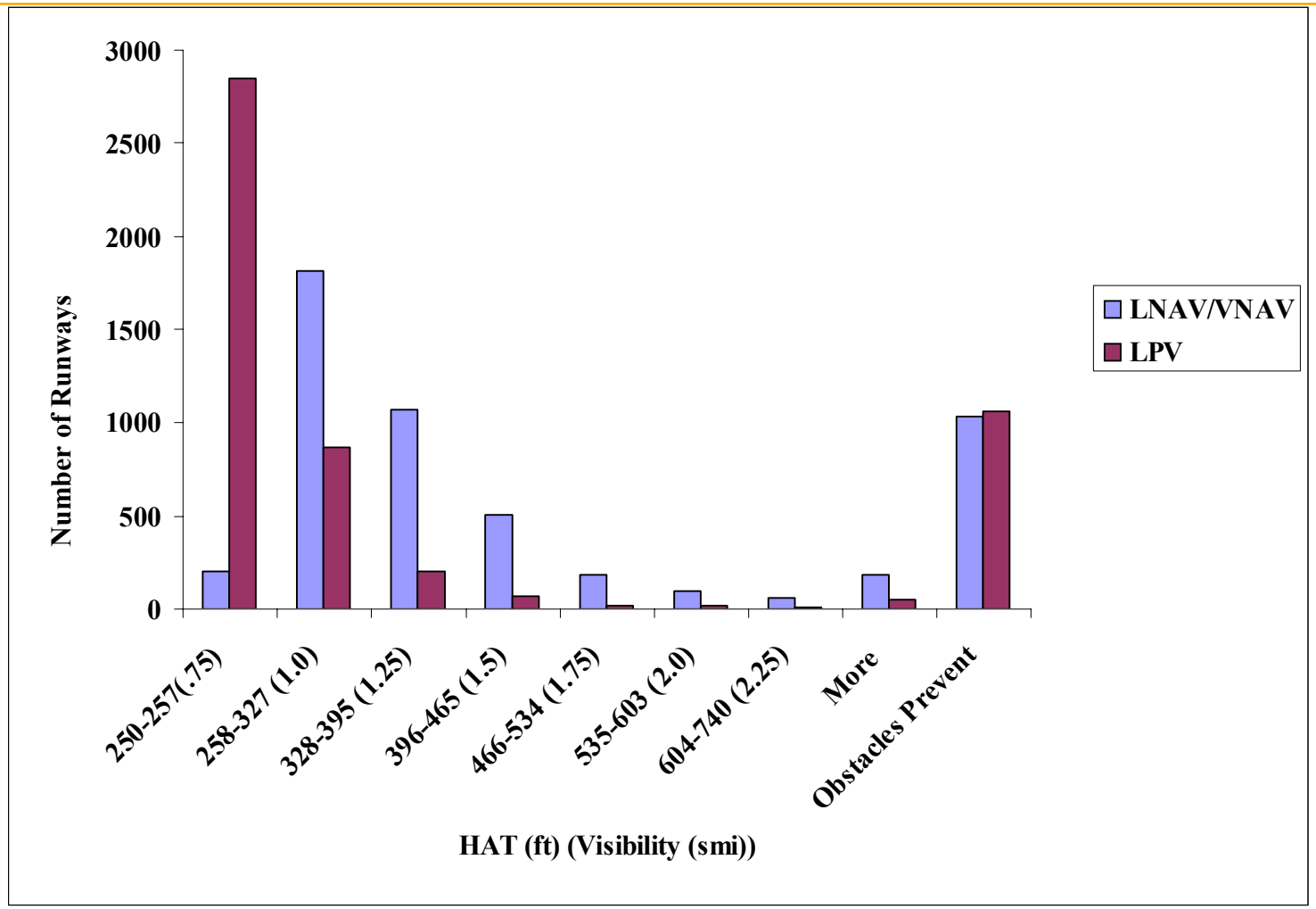
LPV (40 m horizontal by 50 m vertical)

GLS (40 m horizontal by 12 m vertical)

Comparison of LNAV/VNAV with LPV Primary & Secondary Obstacle Surfaces



Comparison of LNAV/VNAV with LPV

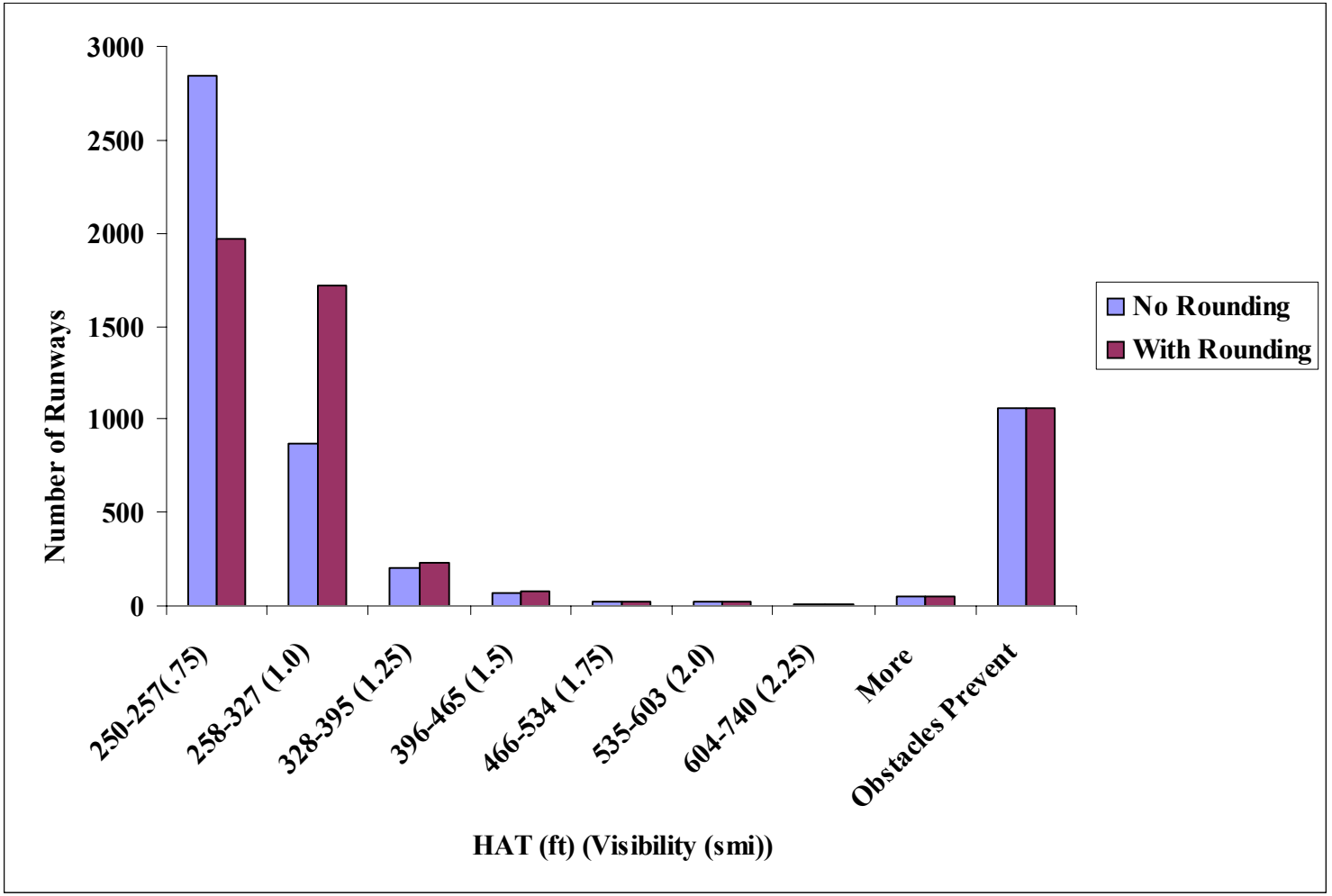


5142 runway ends at 1534 airports

LPV

- **Significant increase in capability for no additional investment in WAAS ground facilities**
- **The FAA has decided to implement LPV**
  - **First approaches are to be implemented this year**
- **LPV criteria will be incorporated into ICAO Satellite-Based Augmentation System (SBAS) standards and recommended practices as Approach with Vertical Guidance I (APV-I)**

Rounding of HATs



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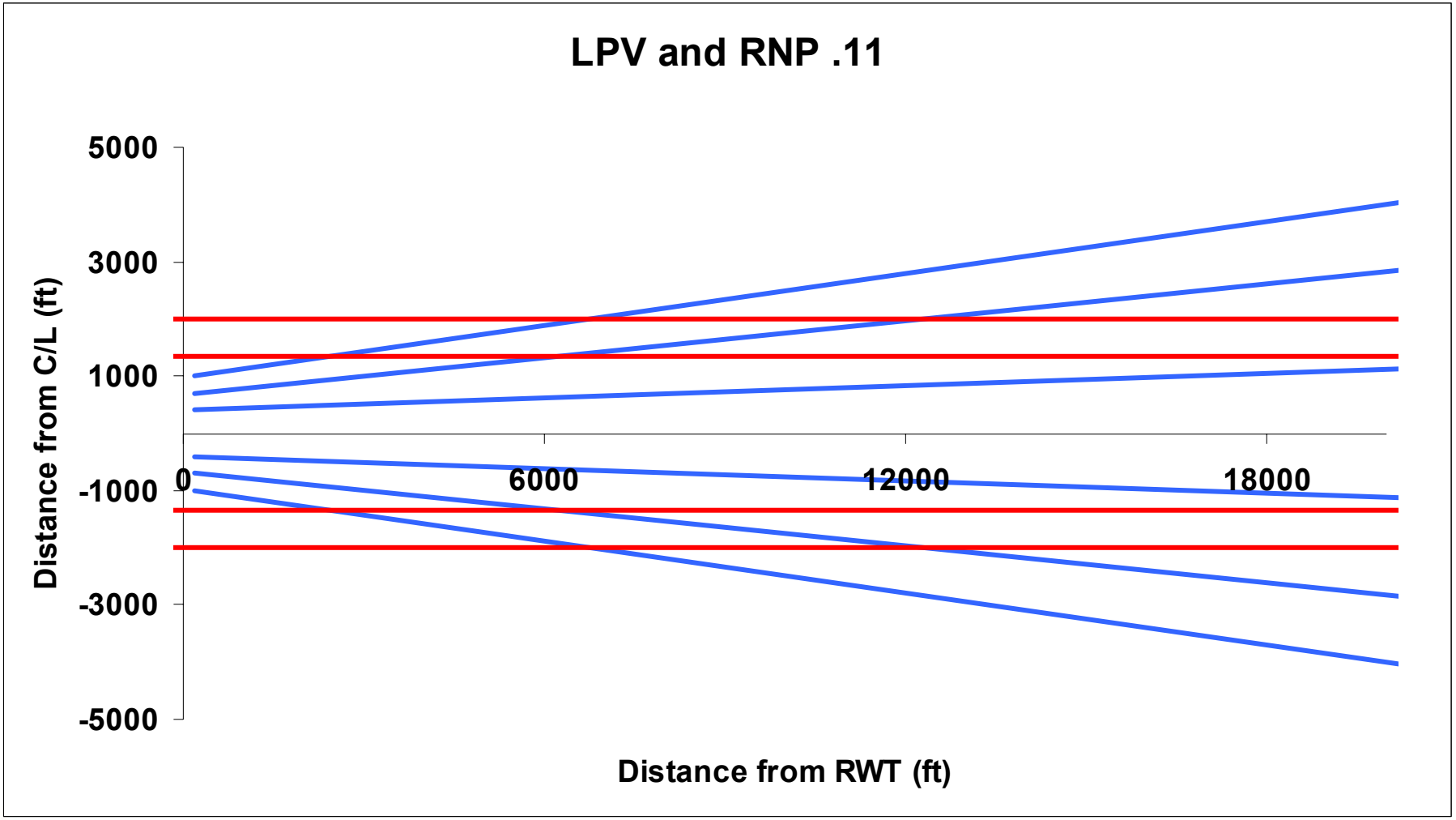
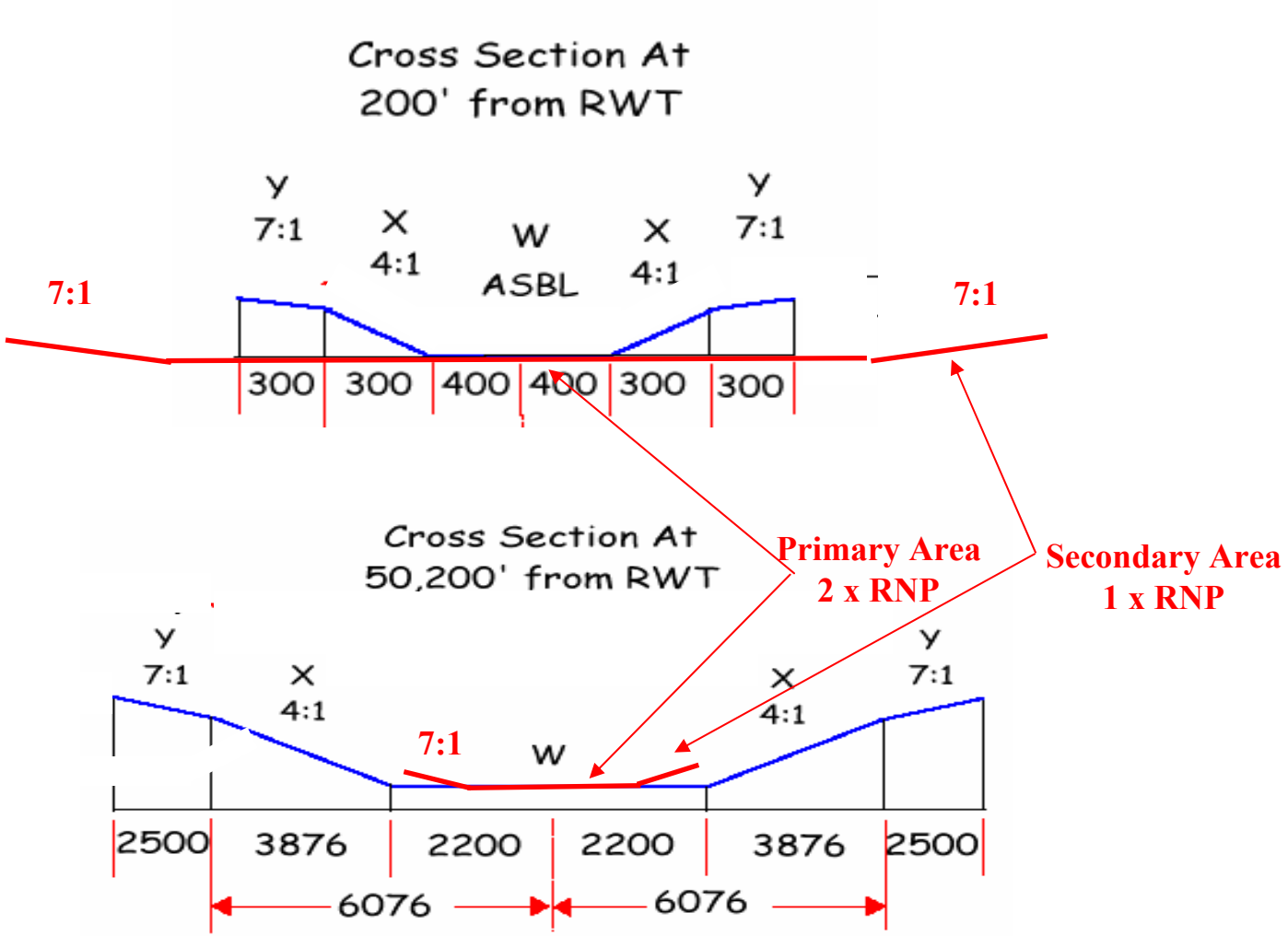
Required Navigation Performance (RNP) Instrument Approach Procedures

- Enhancement to navigation specifying accuracy and containment areas
- For instrument approaches, containment area is generally 2 x RNP value (in nautical miles)
- Provides for rectangular versus trapezoidal obstacle clearance areas
  - BARO-VNAV vertical obstruction areas
- Generally flyable
  - By GPS or WAAS equipped aircraft for RNP .3 or higher
  - By FMS equipped aircraft for all RNP values
    - GPS and inertial often required for RNP $\leq$ .3
    - Specific certification required

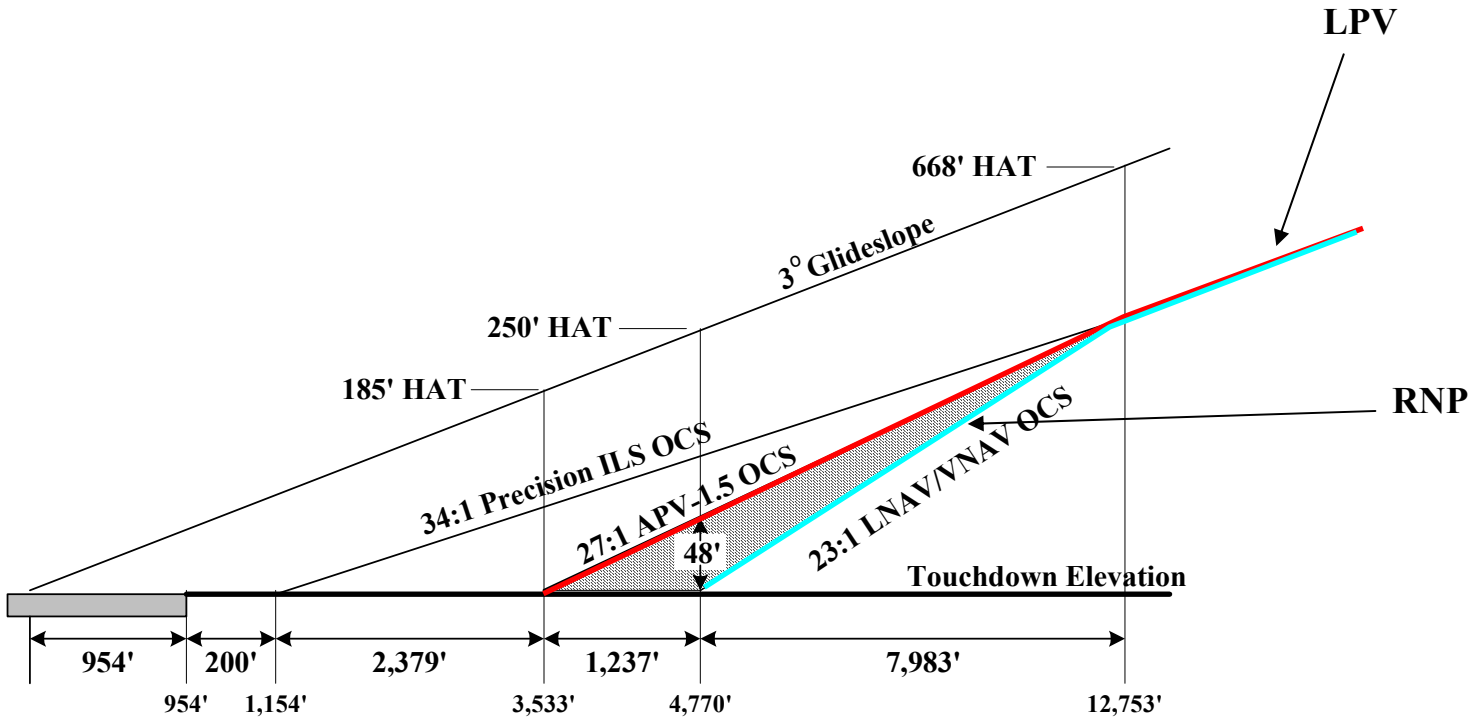
RNP .11 and LPV Horizontal Depiction



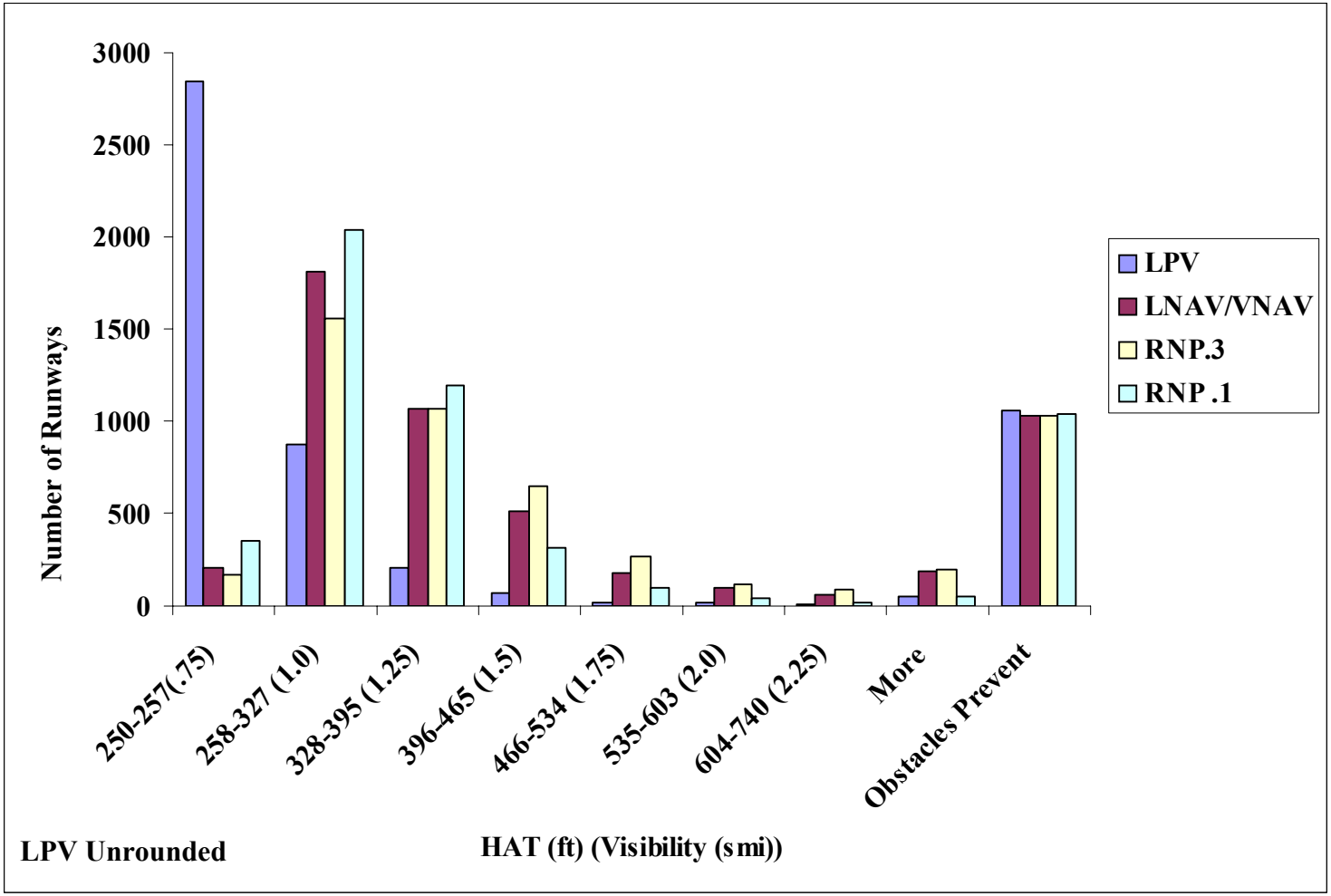
RNP .11 and LPV Draft Criteria
Vertical Depiction from End of Runway



Obstacle Clearance Surfaces
Side View



RNP Approaches Versus LPV and LNAV VNAV



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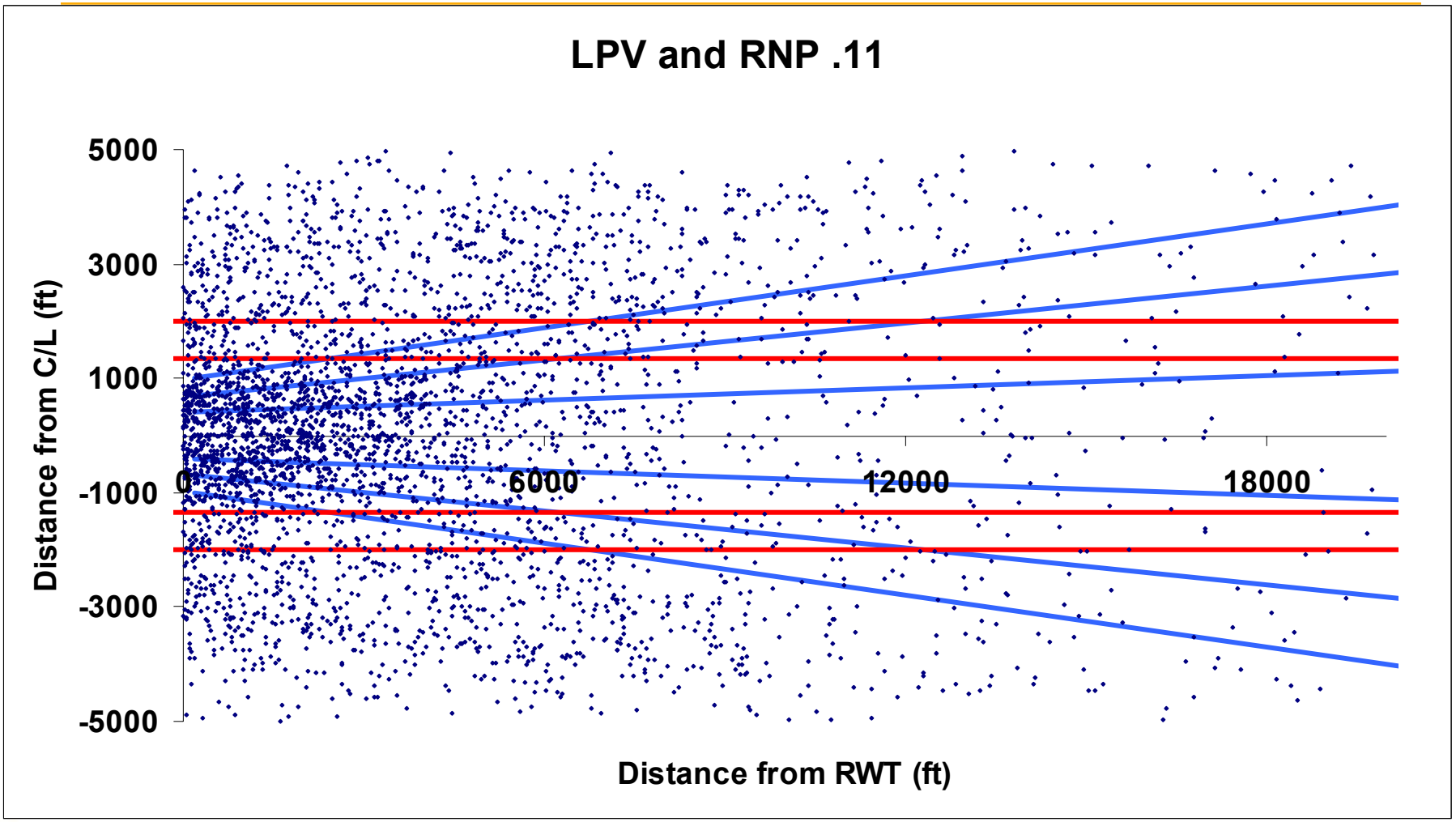
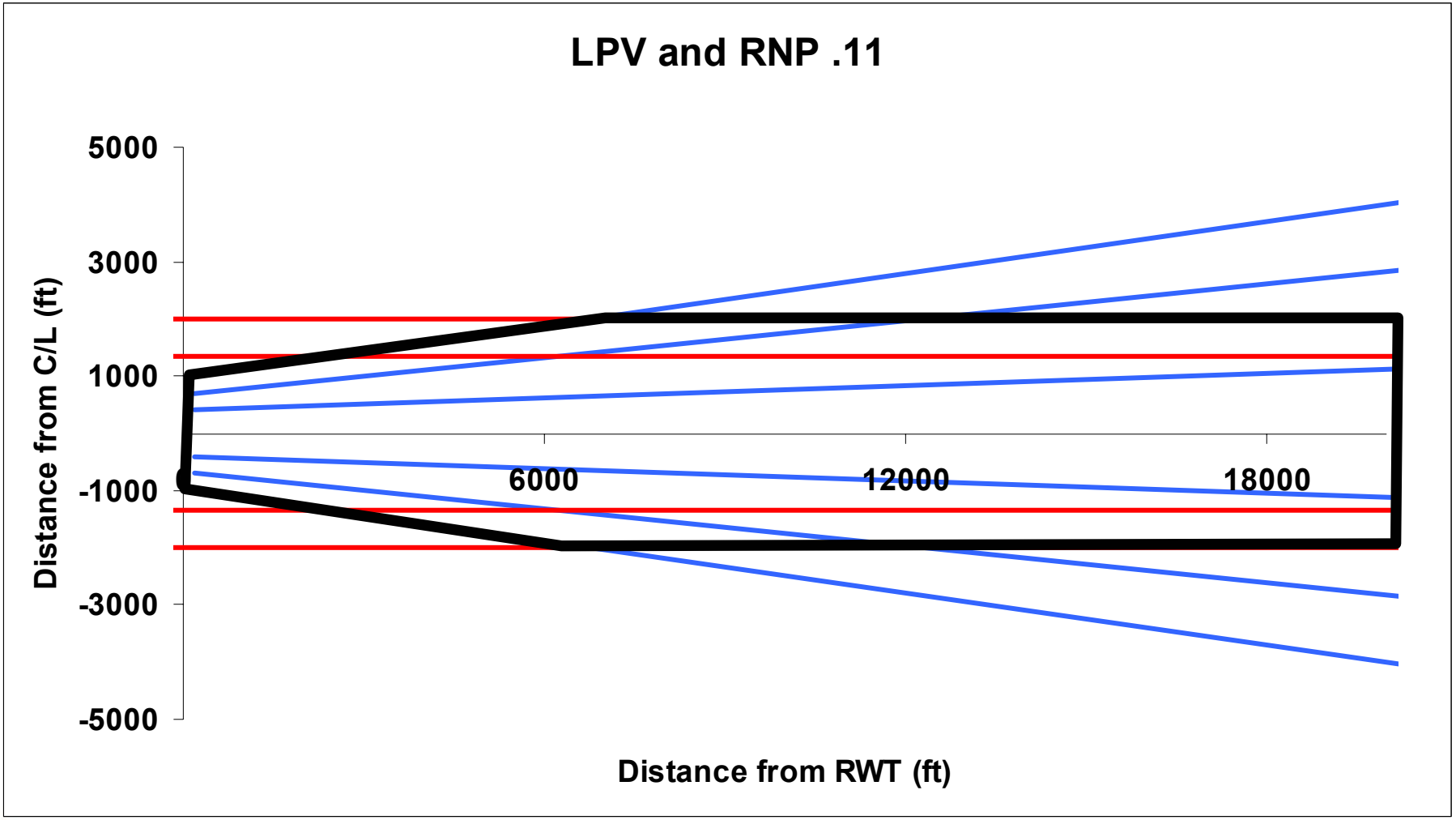
RNP .11 and LPV Draft Criteria Depiction with Controlling Obstacles



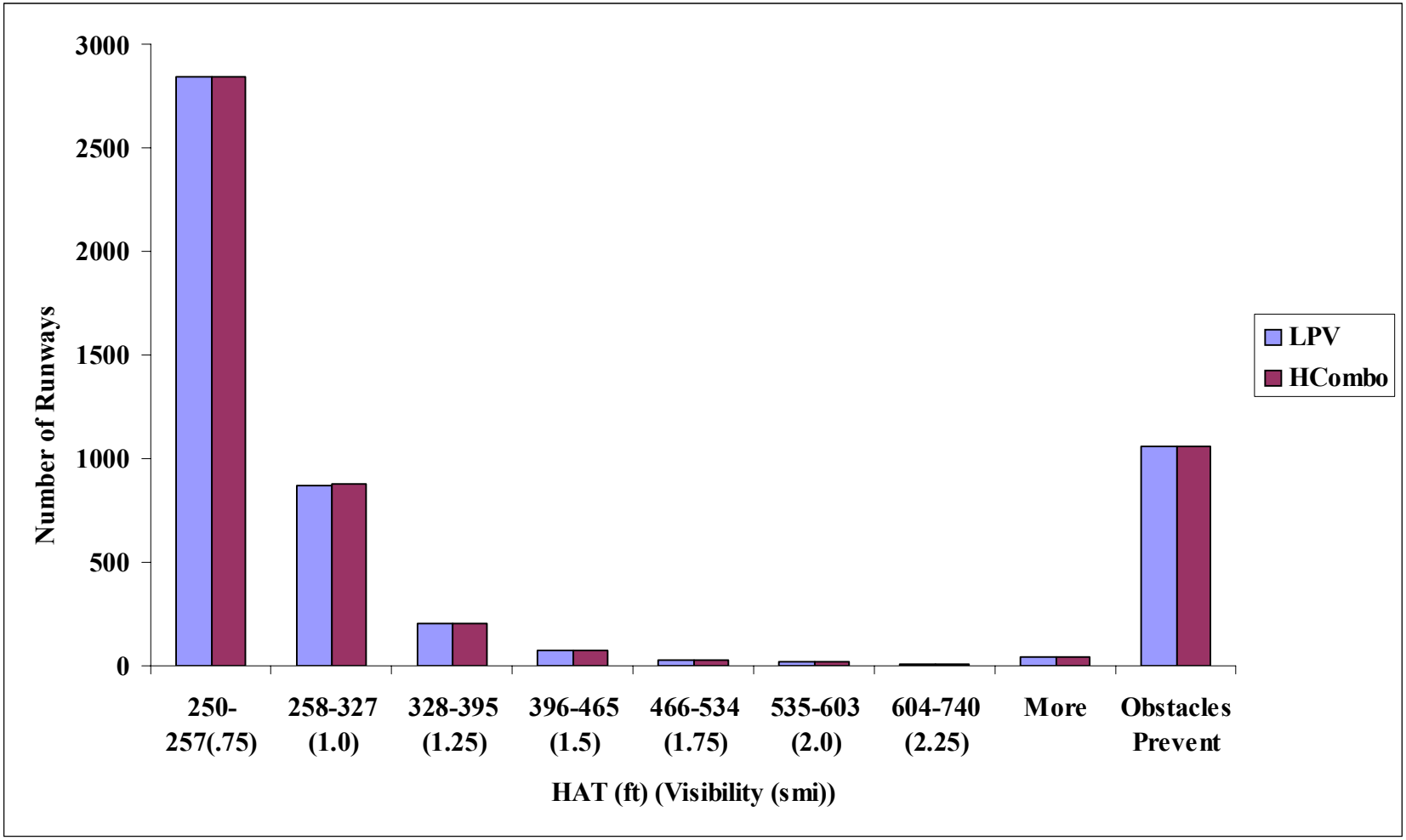
Improving Vertically Guided Approaches

- **Horizontal Improvement**
  - **LPV obstacle clearance standards are very ‘wide’ far from the runway, but narrow close to the runway**
  - **RNP are wider near the runway, but narrow far from the runway**
  - **Developed combination approach that uses RNP when far from the runway, and transitioning to LPV as the aircraft approaches the runway**

RNP .11 and LPV Horizontal Depiction



RNP/LPV Horizontal Combination (Unrounded)



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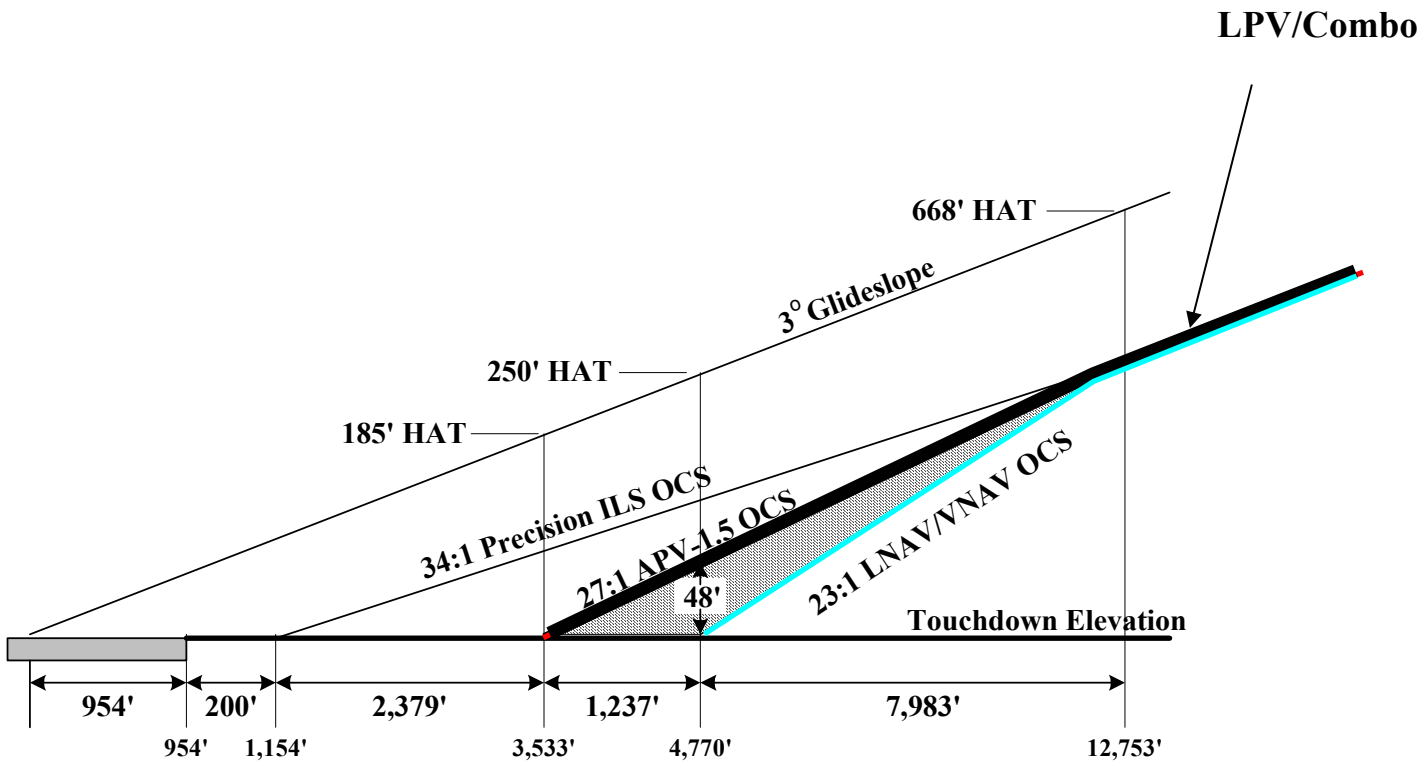
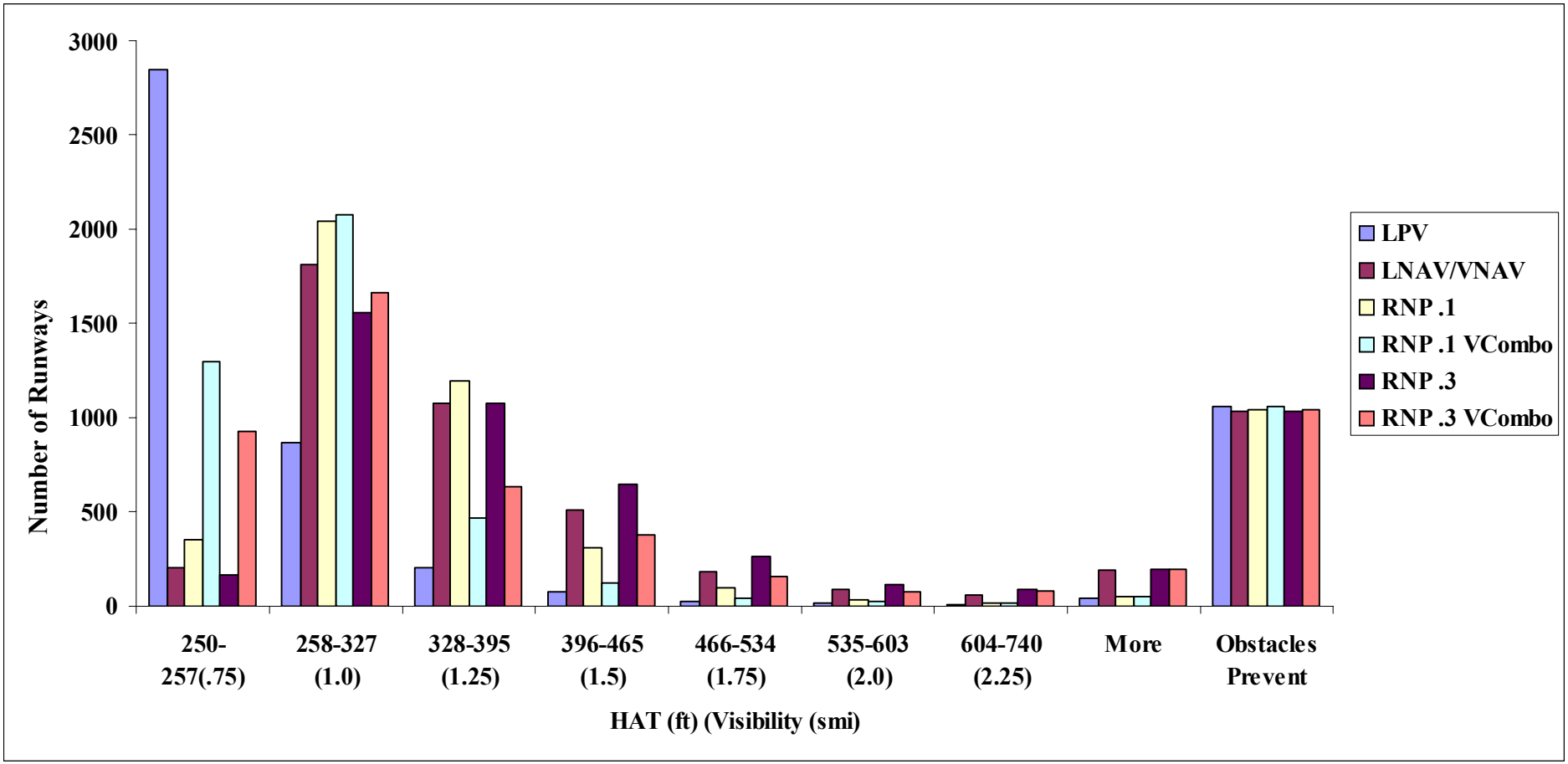
Improving Vertically Guided Approaches

- **Vertical Improvement**
  - **RNP approaches use BARO-VNAV vertical obstacle clearance profiles**
    - **The BARO-VNAV profile has the same vertical integrity limit as the LPV profile, but is temperature compensated and seemingly more conservative**
  - **Developed combination approach that uses RNP horizontal obstacle clearance profiles with LPV vertical profile**

Vertical Obstruction Surfaces



RNP/LPV Vertical Combination (Unrounded)



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Observations

- **LPV will provide a significant increase in capability for WAAS-equipped aircraft with little cost to the FAA WAAS program**
- **RNP provides reasonable instrument approach capability for non-WAAS equipped aircraft**
  - **Minima are not as low as LPV**
- **Some improvement may be possible for RNP with improved criteria**
  - **Overall with improved vertical criteria for RNP**
  - **Airport specific for improved horizontal criteria**