Alternative Obstacle Clearance Criteria for RNP RNAV Instrument Approaches

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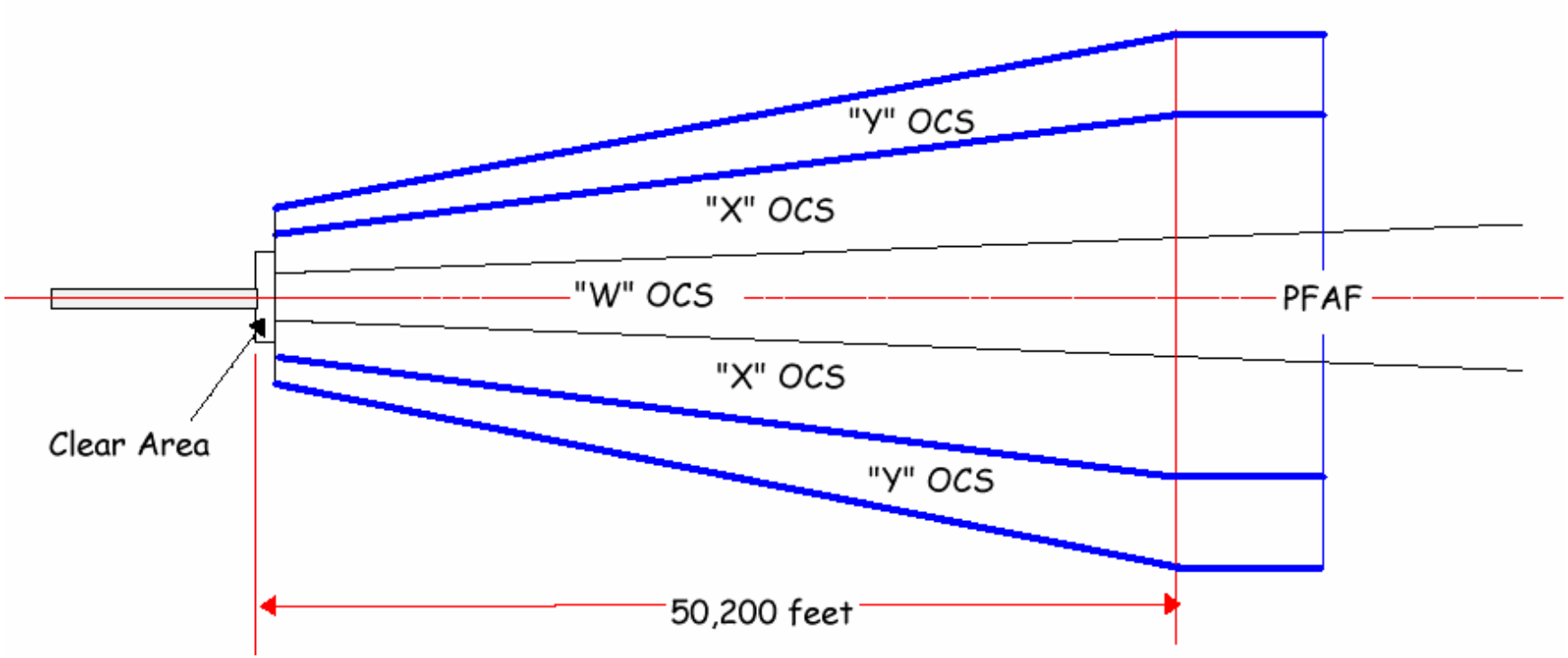
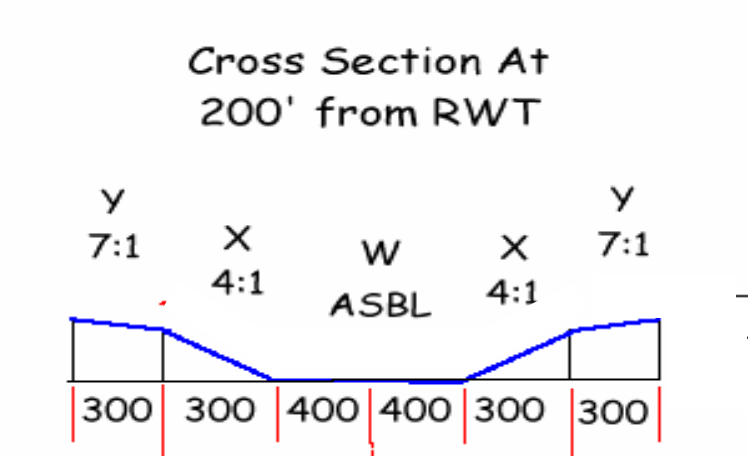
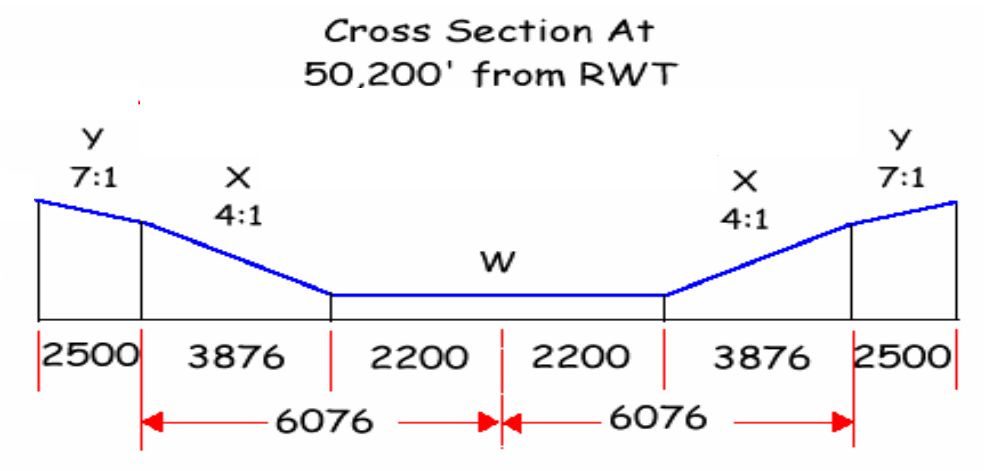
April 2004

Obstacle Clearance Surfaces (OCSs) Instrument Landing System (ILS)



OCSs for ILS





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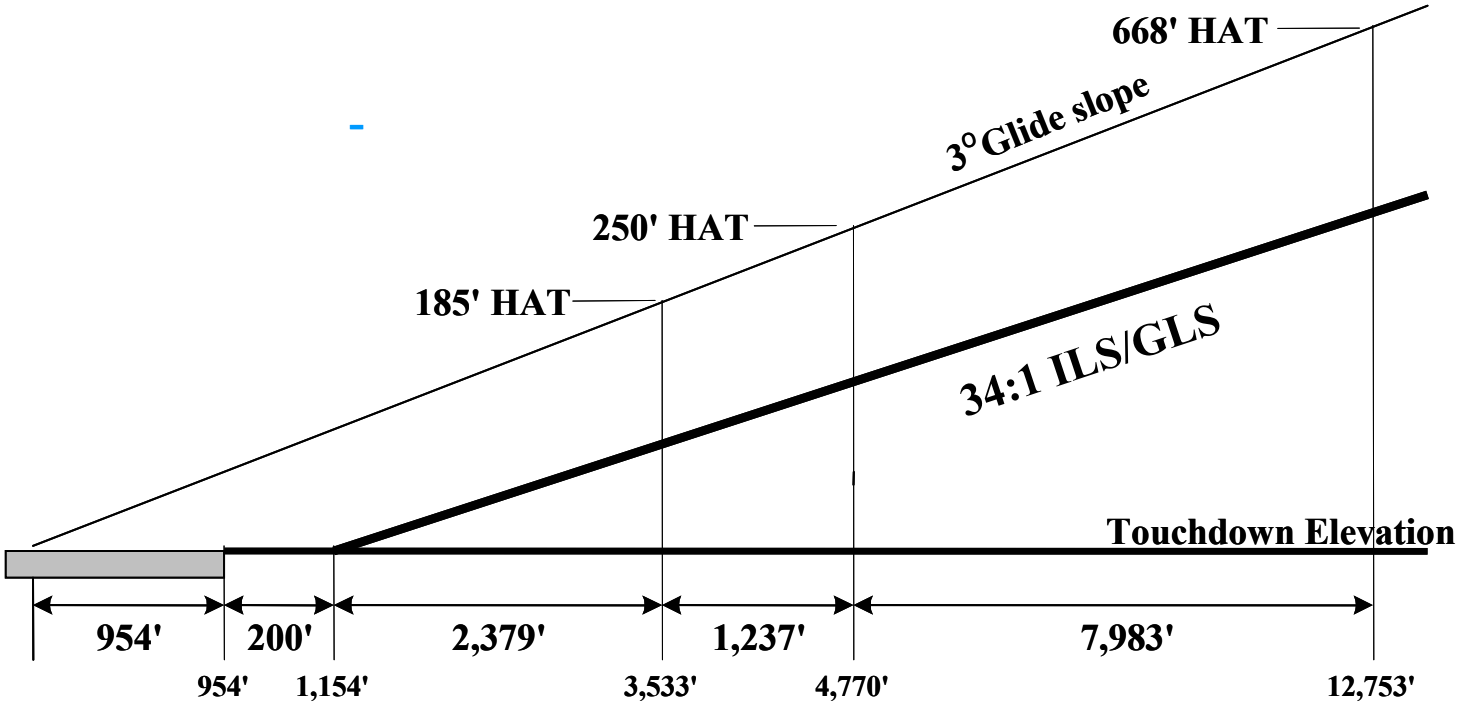
Vertical OCSs



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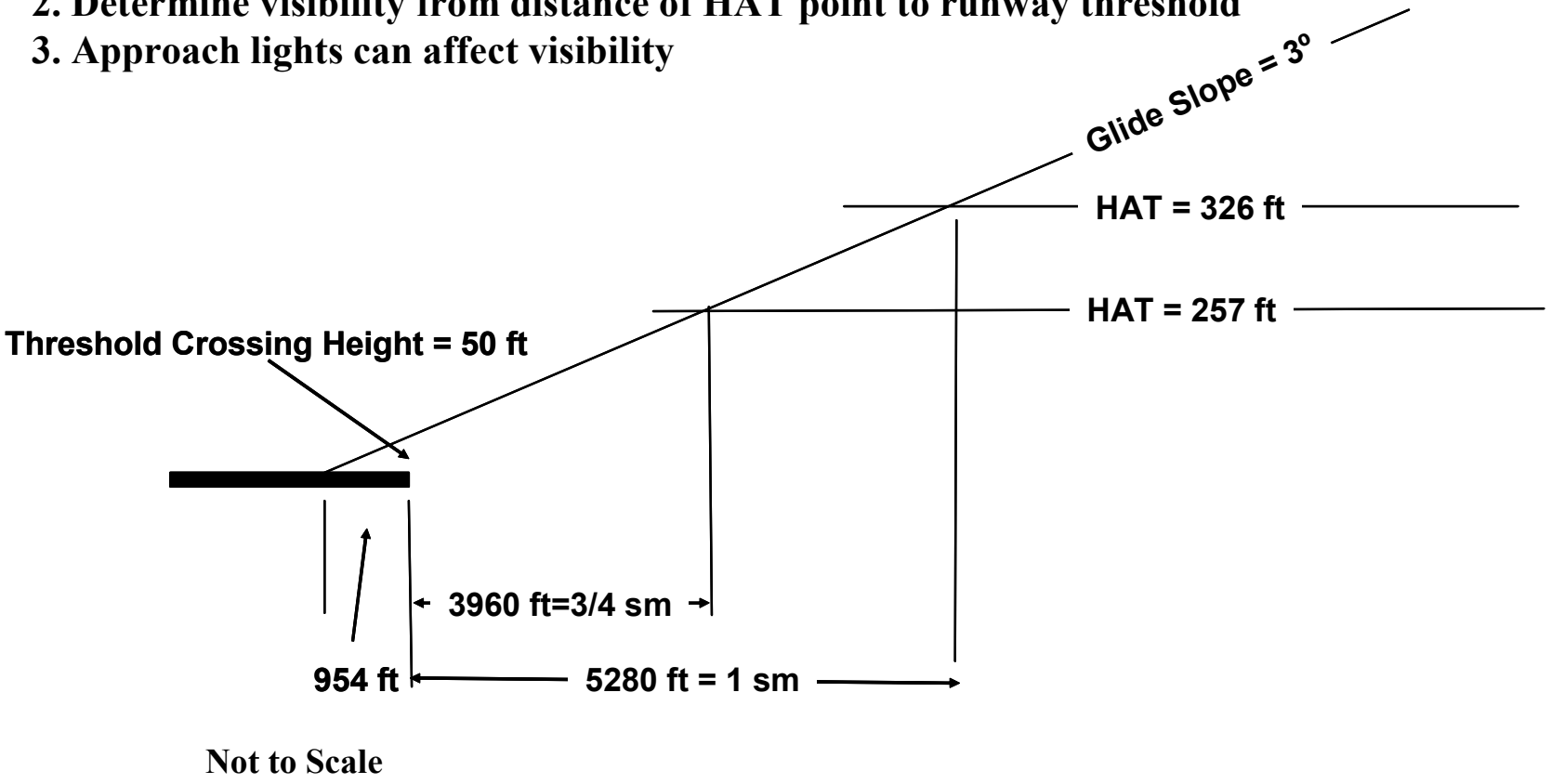
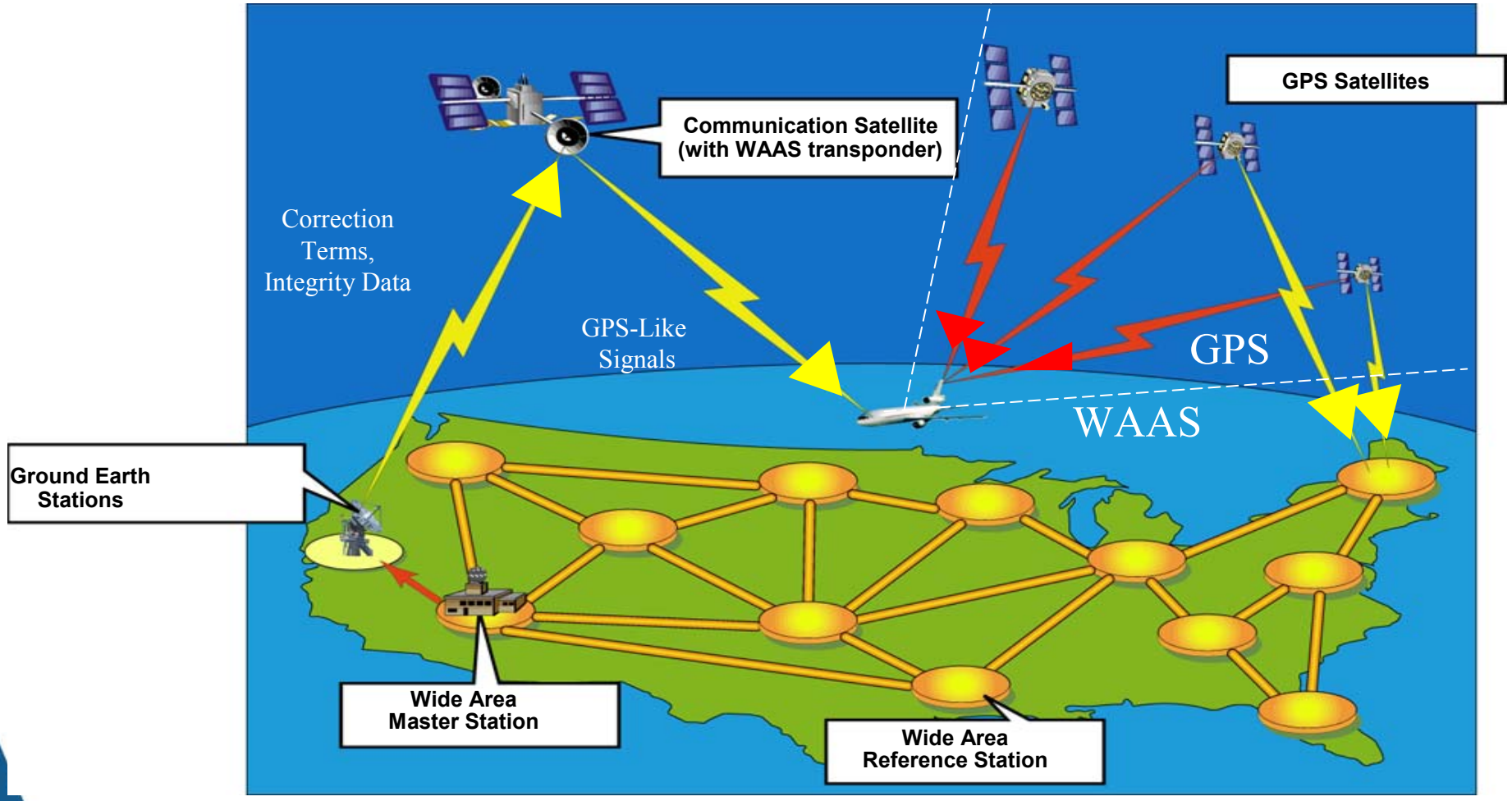
Determining Visibility Minima

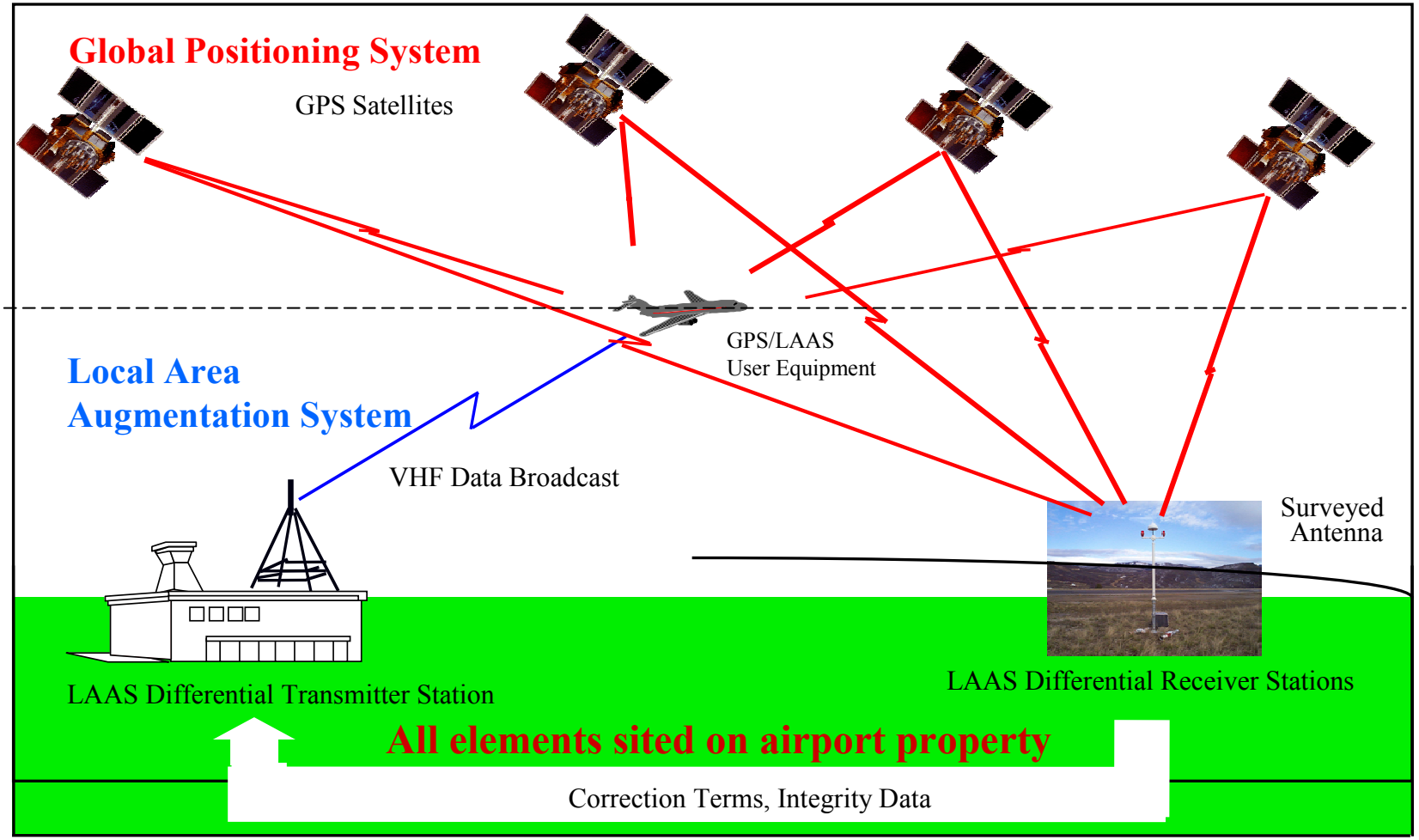
1. Determine Height Above Touchdown (HAT) from OCS
2. Determine visibility from distance of HAT point to runway threshold
3. Approach lights can affect visibility



Wide Area Augmentation System (WAAS)



Local Area Augmentation System (LAAS)

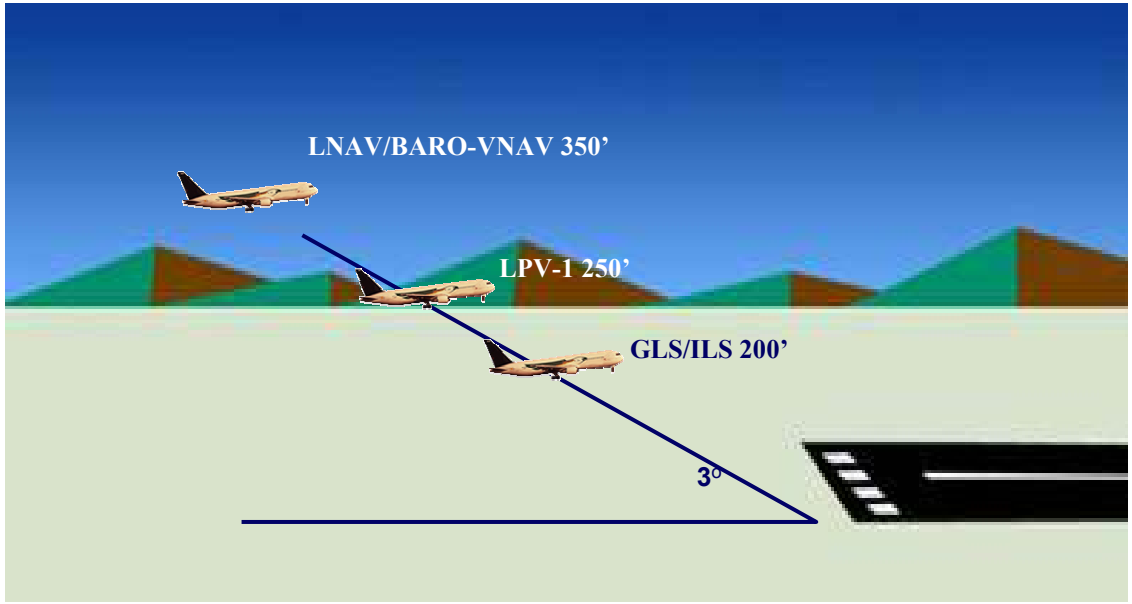


GPS/WAAS/LAAS Approaches
Area Navigation (RNAV) Approaches

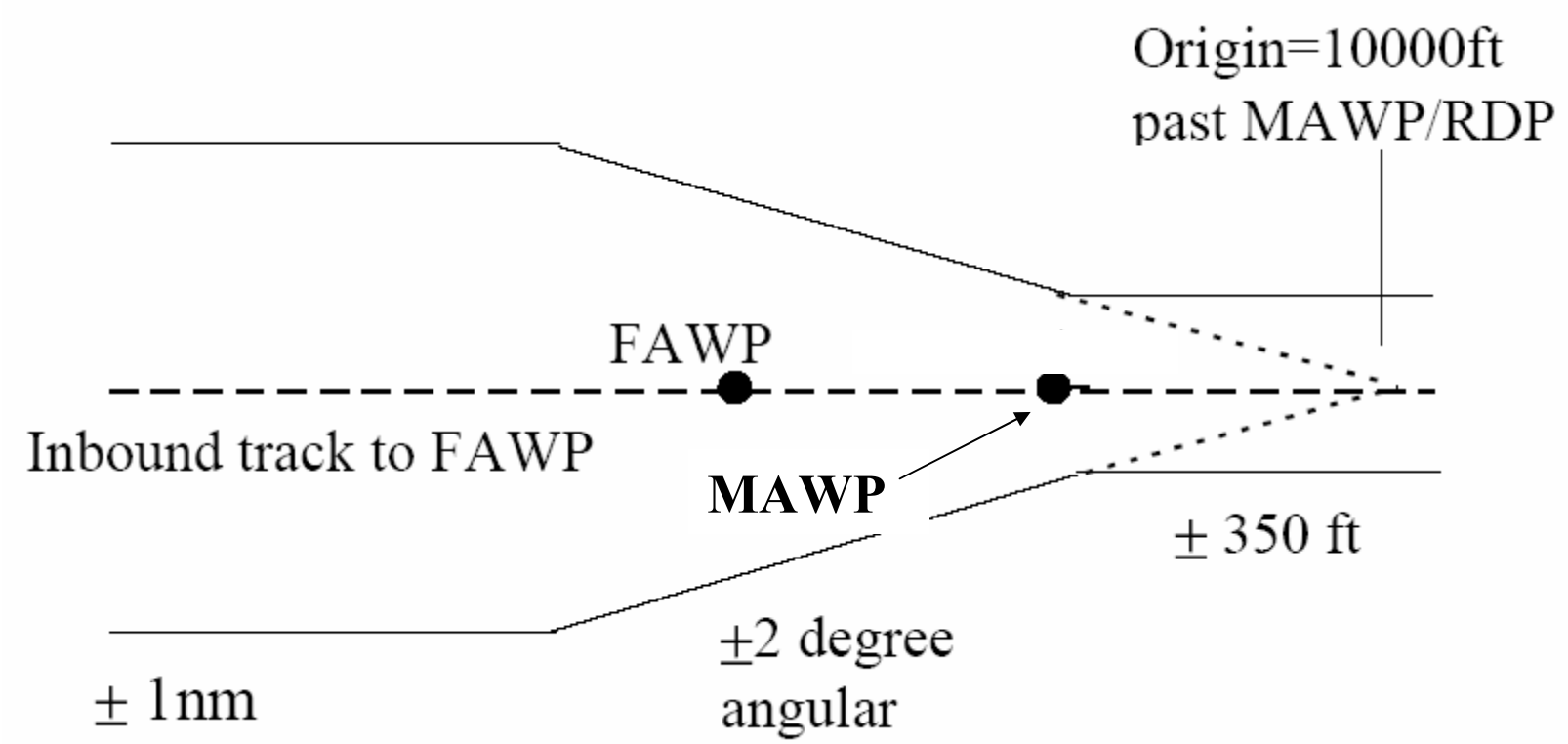
- **WAAS intent has been to provide several levels of service for instrument approaches**
  - **Lateral Navigation (LNAV)**
    - **No vertical guidance (Non-precision Approach)**
  - **Lateral/Vertical Navigation (LNAV-VNAV) and Barometric/Vertical Navigation (BARO-VNAV)**
    - **Comparable performance to NPA lateral guidance and vertical guidance using barometric altimeter**
    - **Requires WAAS or GPS-BARO/VNAV (no DME/DME in USA)**
    - **Best theoretical HAT is 250 ft (rarely attained)**
  - **LPV**
    - **"Near CAT I service"**
    - **Best LPV minima: 250 ft HAT**

GPS/WAAS/LAAS Approaches (Concluded)

- **LAAS (and future WAAS with dual frequency)**
  - **GNSS Landing System (GLS)**
    - **Equivalent of ILS CAT I**
    - **Best GLS/ILS Cat. I minima: 200 ft HAT**



Display Sensitivity of GLS/LPV Approaches



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Reference: DO 229C (WAAS MOPS)

RNAV OCSs

- **Although the navigation error is generally constant throughout the approach for RNAV systems, the increase in display sensitivity results in progressively smaller total errors as the aircraft approaches the runway/NAVAID**
- **Resultant RNAV OCSs are**
  - **GLS: Identical to ILS**
  - **LPV (APV I):**
    - **Horizontal is identical to ILS**
    - **Vertical is more conservative (closer to ground) to account for reduced vertical integrity**

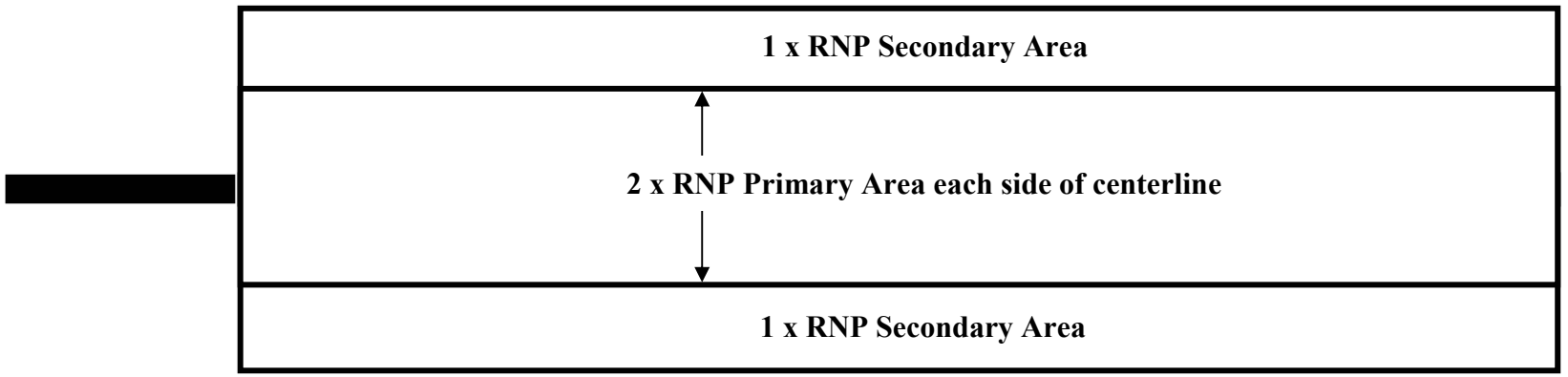
RNP RNAV

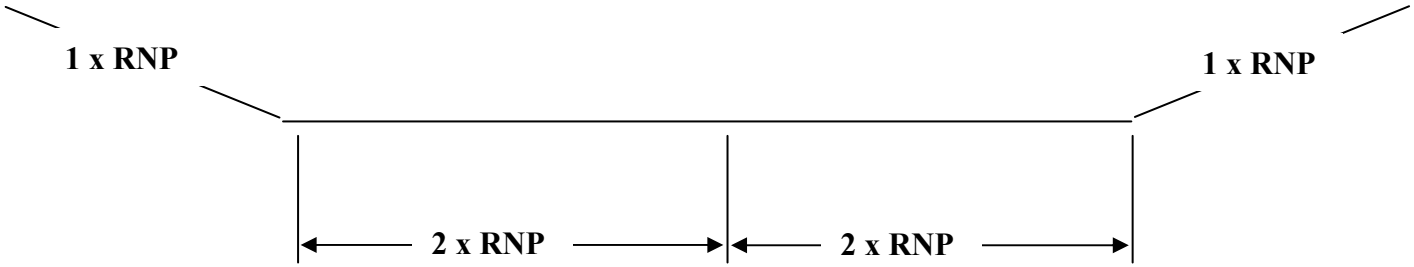
- **RNP RNAV has potential benefits in the oceanic, en route, terminal, and approach domain**
  - **RNP-10 implemented in oceanic airspace**
    - **Reduced route separation**
  - **RNP approaches developed at some airports in Alaska**
    - **Significant airport access benefits attained**
- **Focus of this discussion will be the final approach segment**

RNP RNAV Approaches

- **RNP RNAV assumes constant display sensitivity and constant navigational errors**
  - **Nearly constant total flight errors approaching the runway**
- **Currently use BARO-VNAV vertical profile**
  - **Other profiles are under investigation**
- **RNP-.3 can be flown with GPS, WAAS, or LAAS avionics**
  - **RNP-.3 using DME/DME currently not authorized in USA**
- **RNP RNAV below .3 will require Special Aircraft and Aircrew Authorization Required (SAAAR)**
  - **Additional certification, equipment, and training**

Required Navigation Performance (RNP RNAV)





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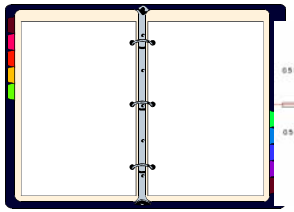
The GPS Approach Minima Estimator (GAME) Model

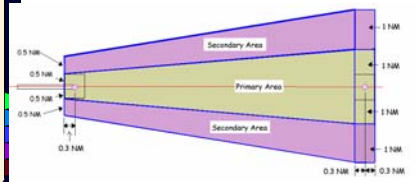
GAME Objectives

- Computer model developed to provide objective estimates of benefits of IAPs
- Digital airport, terrain and obstacle data
- Simplified approach design criteria
  - Straight-in approach with five mile final
    - No intermediate segment
    - Variable glide-slope possible, but only 3 degrees slope presented
  - Missed approach only for GLS/ILS
    - Simplified missed approach

GPS Approach Minima Estimator (GAME) Model

Terrain Data Base





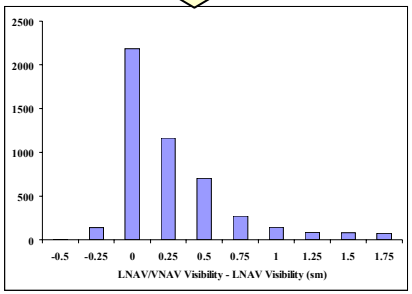
Approach Design Criteria

Obstacle Data Base

Minima Estimation Software

Repeat for Thousands of Runway Ends

Airports Data Base



Generate Statistics

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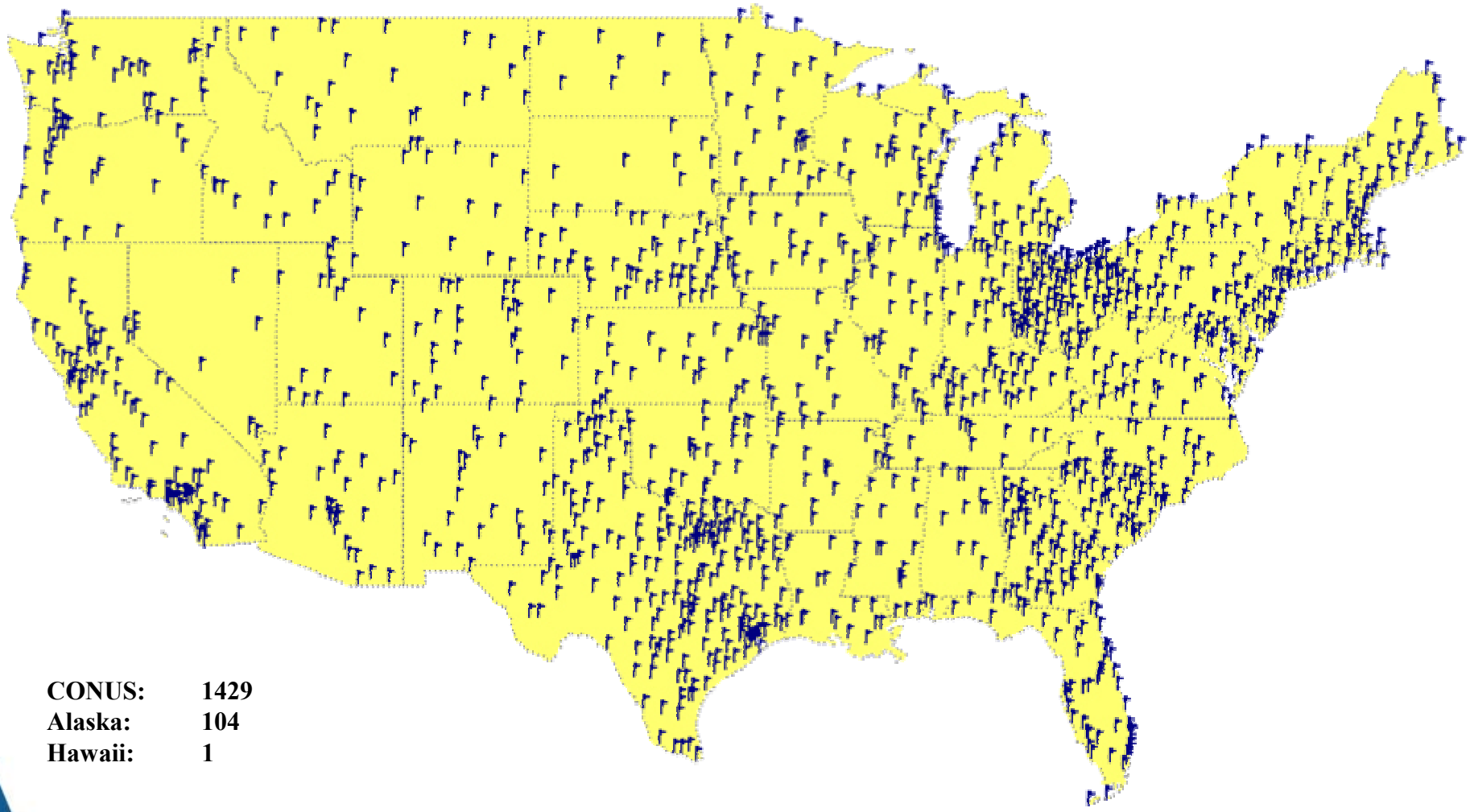
GAME Airports:
1534 airports and 5073 runway ends



CONUS: 1429
Alaska: 104
Hawaii: 1

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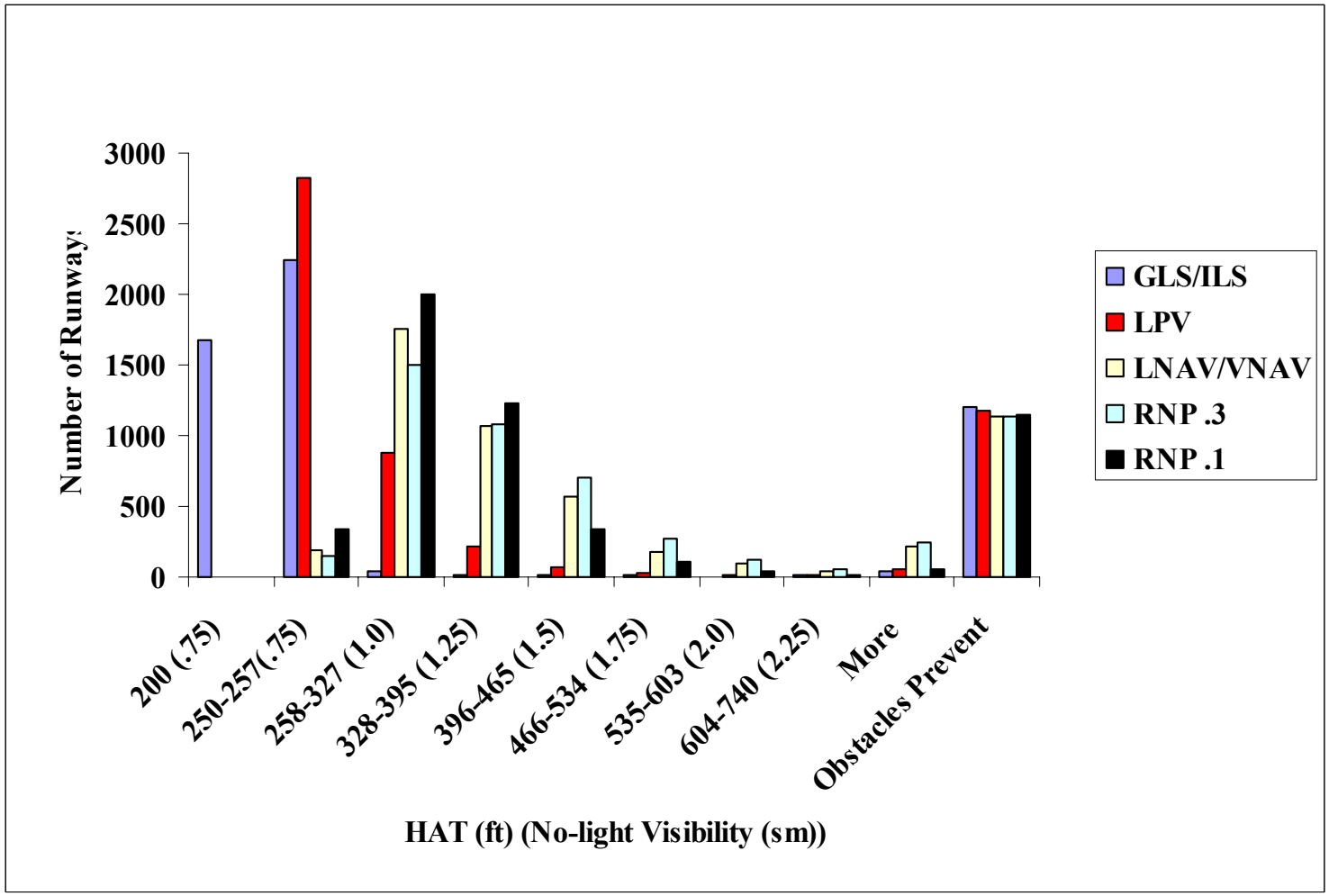
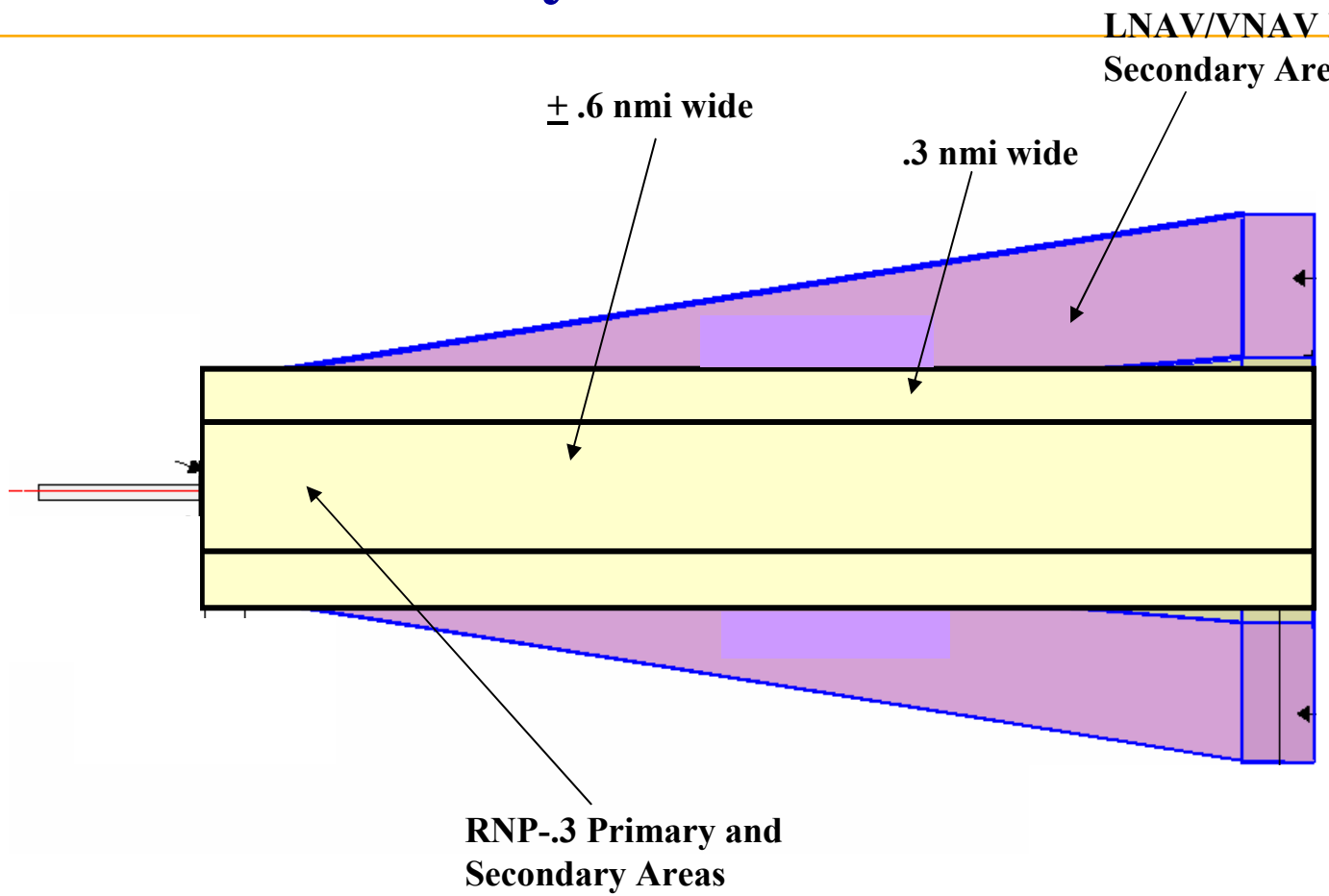
Instrument Approach HATs



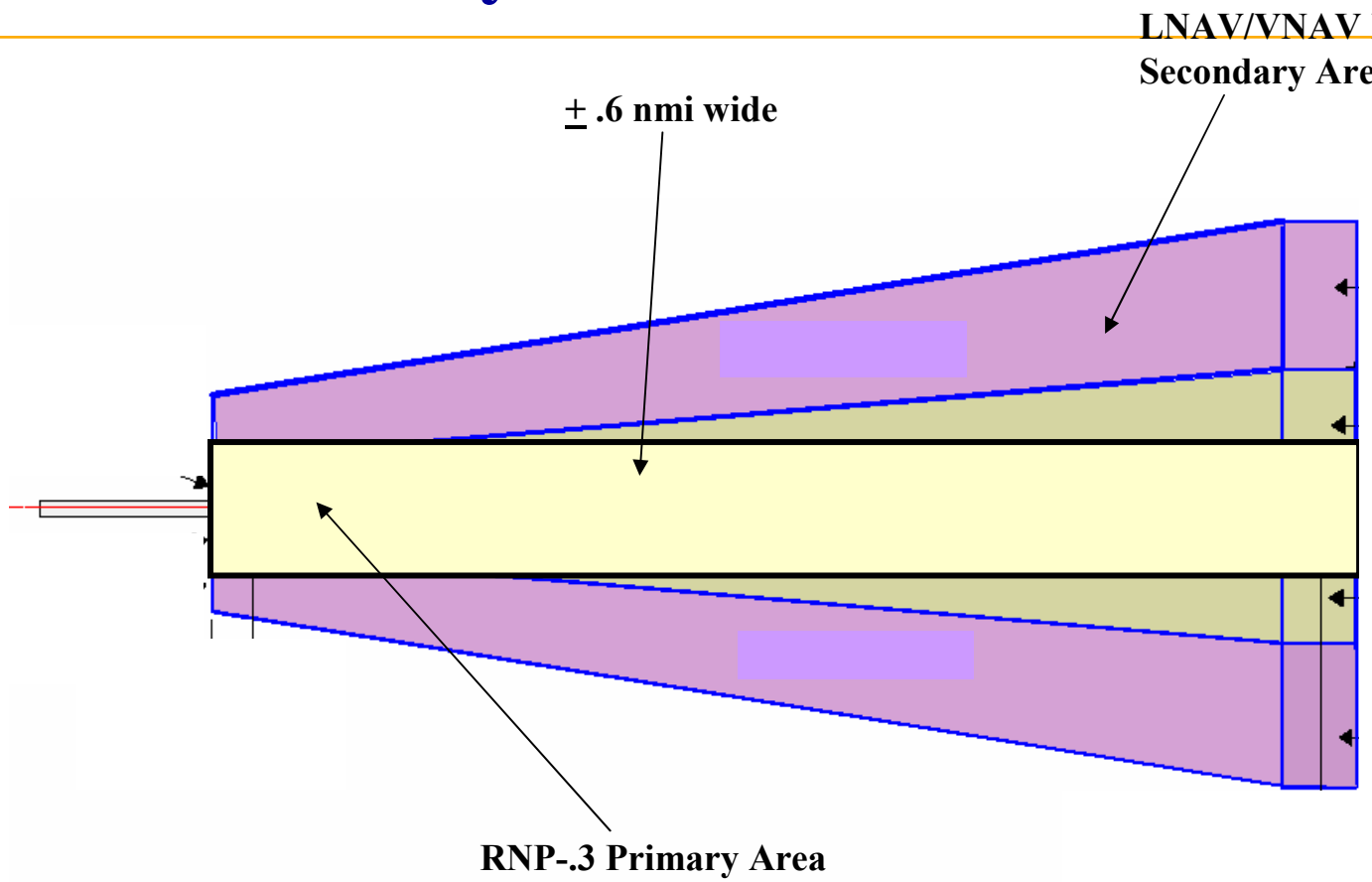
Observations

- ILS, GLS, and LPV dominate the lowest visibility minima
- Even RNP RNAV with SAAAR has increased approach minima at most runways relative to ILS/GLS/LPV
  - Some runways will exhibit improved minima
    - E.g., Runways in Alaska noted previously
  - Despite additional certification, equipment and training requirements
- Why do the RNP RNAV approaches show reduced benefits?
  - Investigate effect of removing secondary areas from OCSs
  - Investigate effect of curved approaches (short finals)
    - 3 nm length of final

RNP-.3 and LNAV/VNAV-BARO/VNAV With Secondary Areas



RNP-.3 and LNAV/VNAV-BARO/VNAV No Secondary Areas



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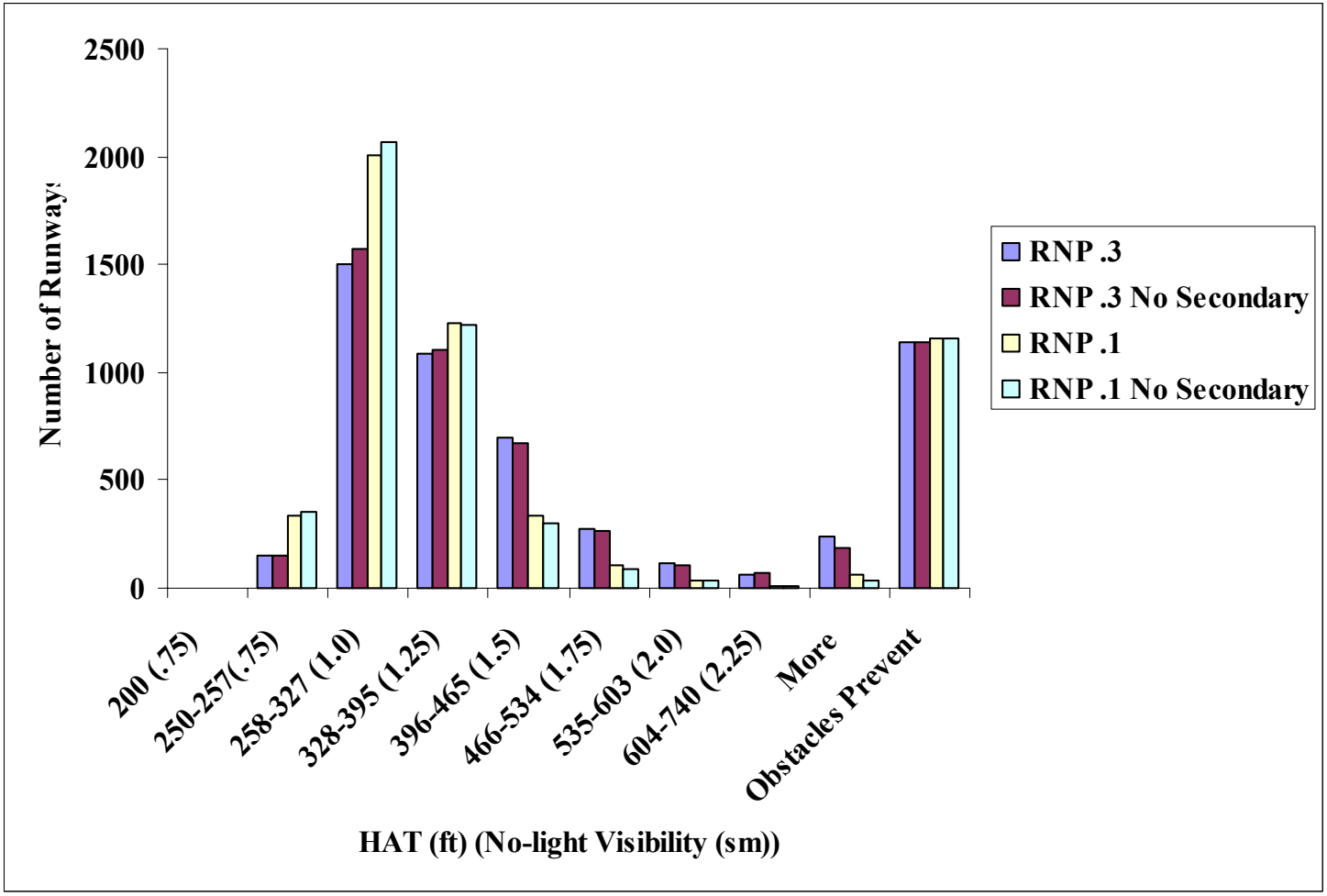
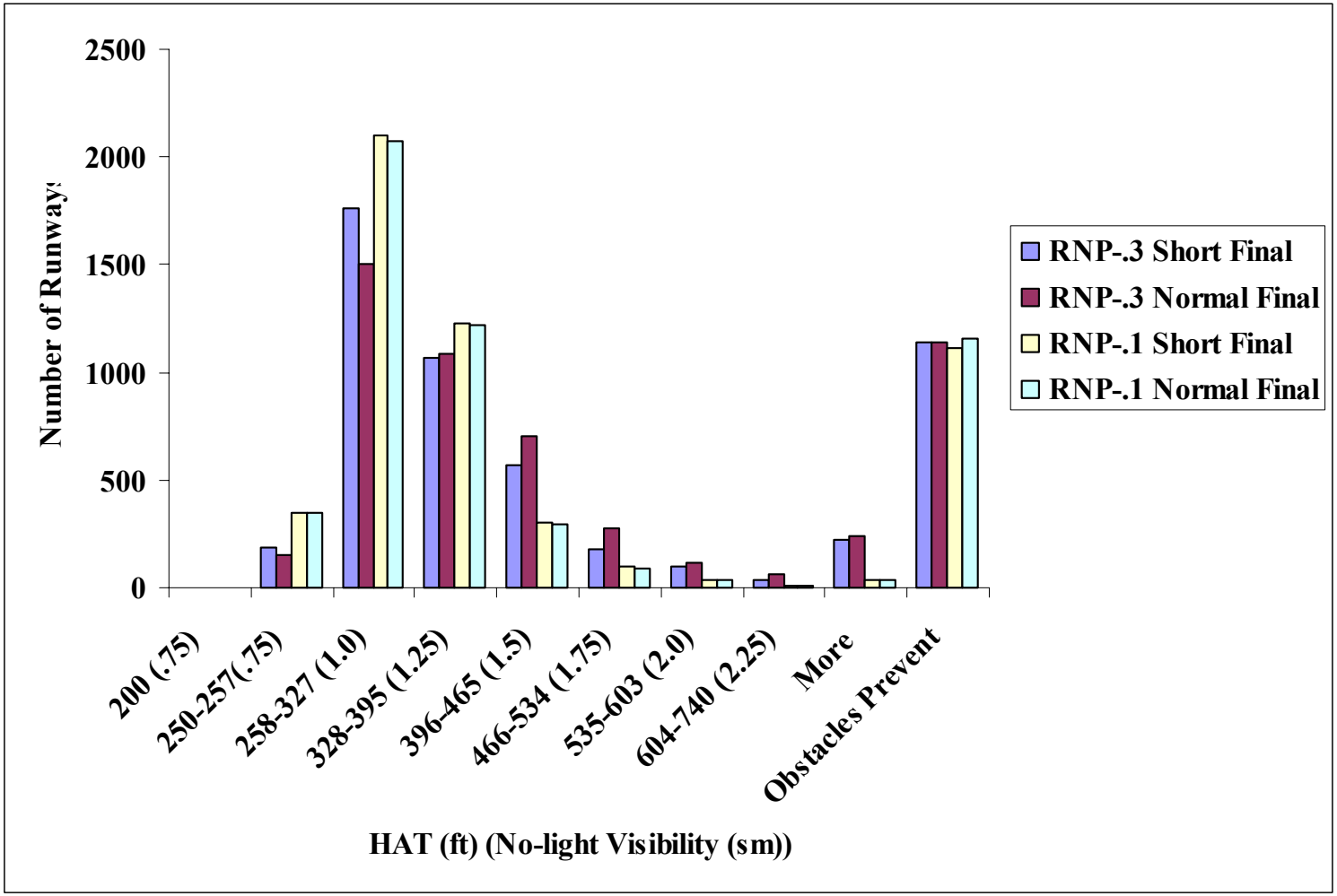
Effect of Secondary Areas



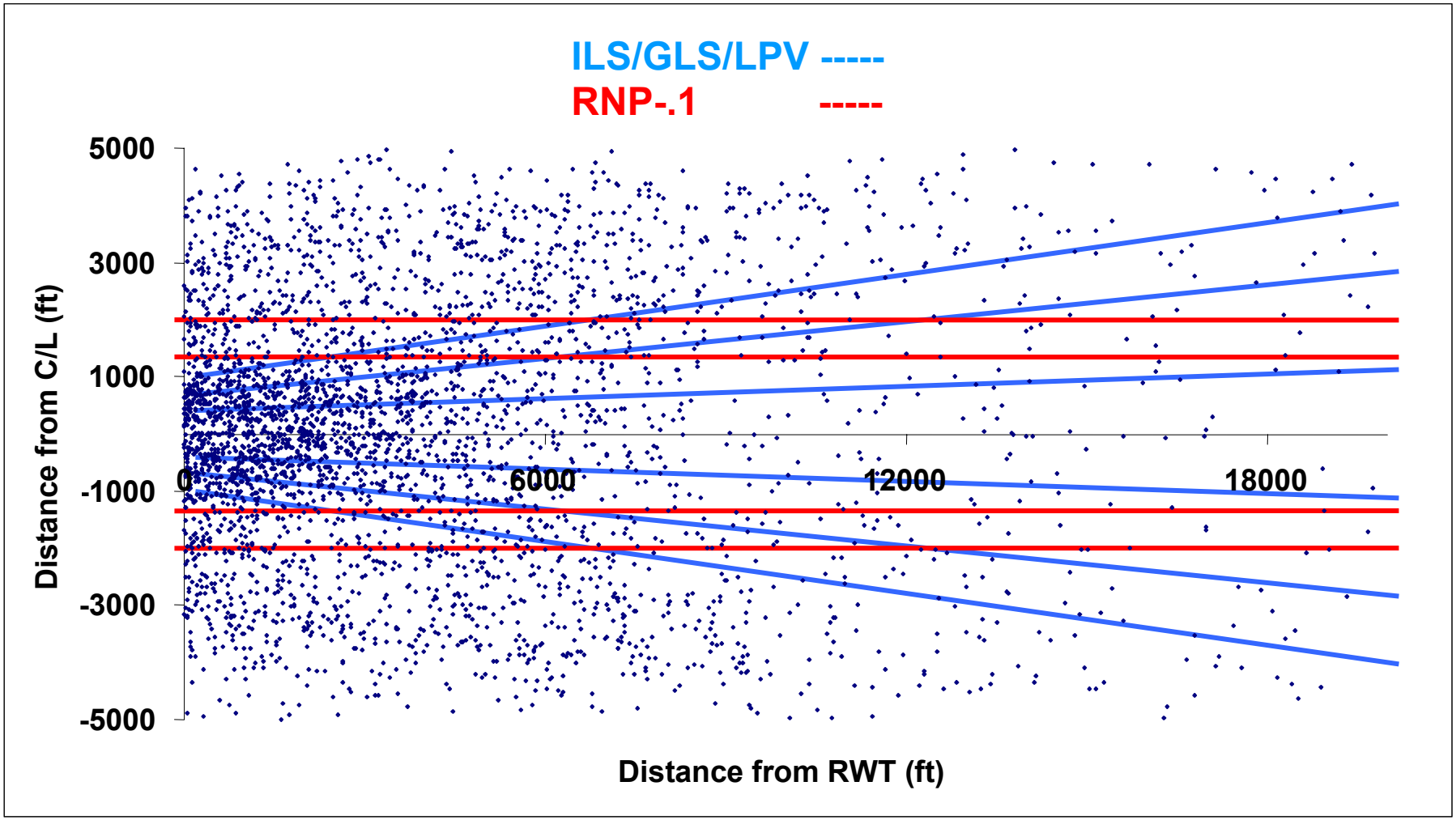
Effect of Short Finals (Curved Approaches)



Observations

- **Removal of secondary areas and use of short finals has some effect at some runways, but RNP RNAV performance is still not comparable to ILS, GLS or LPV**
- **Why?**

Distribution of Controlling Obstacles 5000+ LNAV/VNAV Approaches



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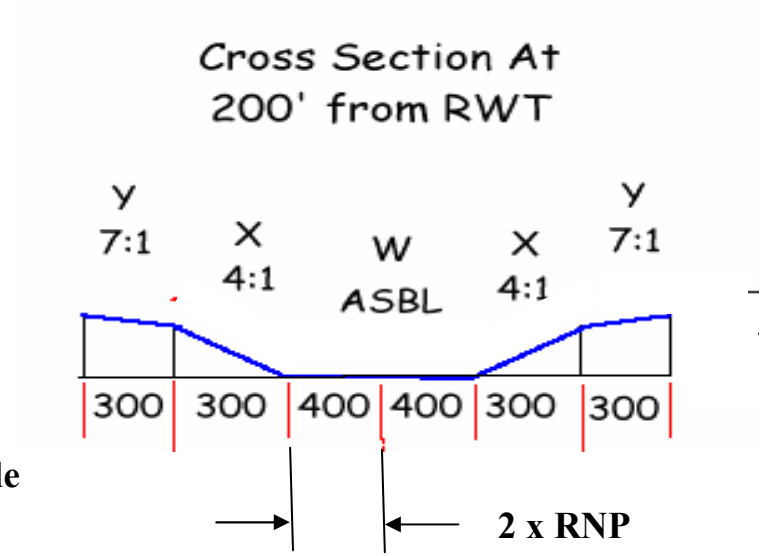
Narrow RNP RNAV OCSs

- **Suppose we narrow the RNP RNAV OCS significantly**
- **Example:**
  - **ILS/GLS/LPV OCS is ± 400 ft wide near the runway threshold**
  - **Let 2 x RNP = 400 ft ➔ RNP = 200 ft/6076 ft/nm = .033 nm**
    - **No secondary areas**



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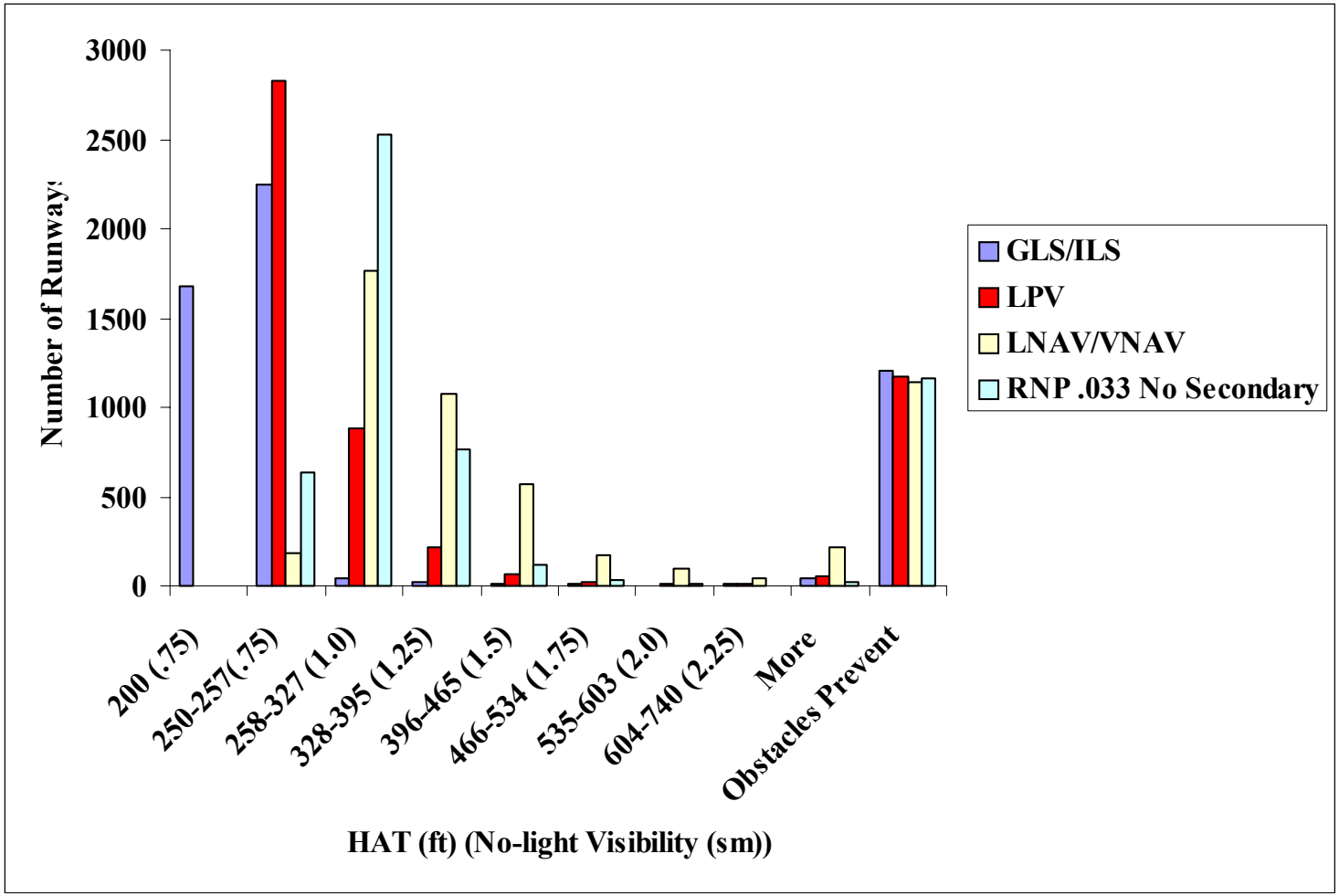
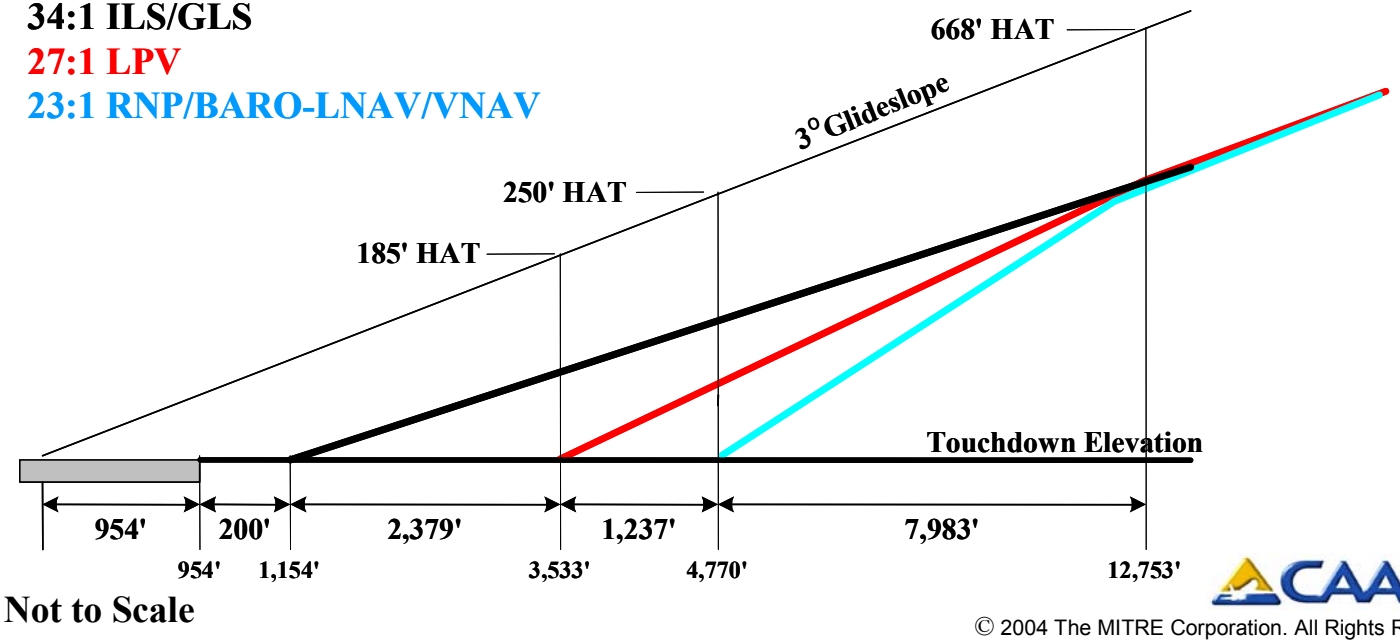
Effect of RNP-.033

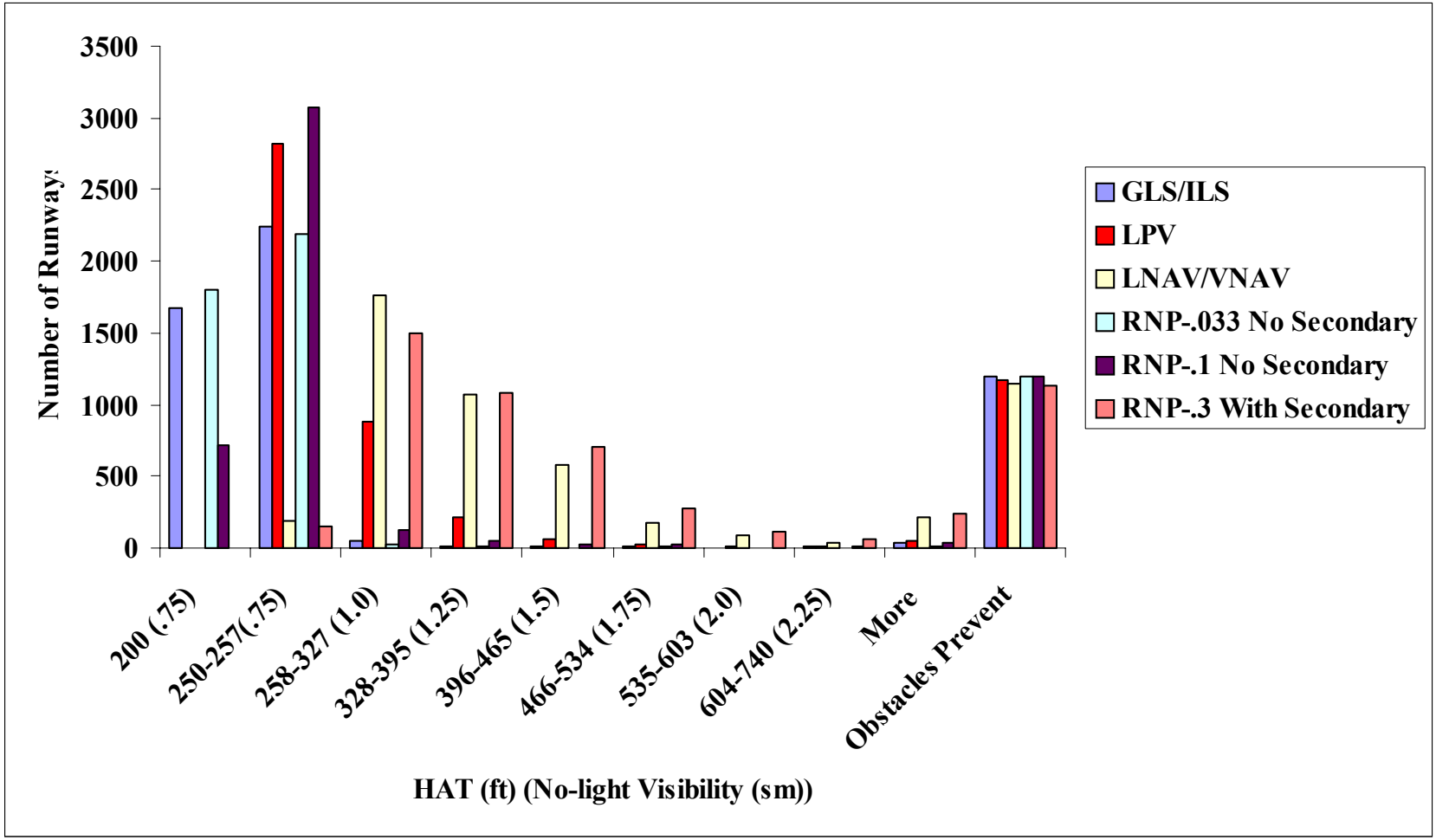


Observations

- Even with significantly reduced RNP values, the RNP minima are still not comparable to ILS. GLS, or LPV
- "Culprit" must be the vertical OCS
- As an example, suppose we use the GLS vertical OCS



Effect of GLS Vertical OCS on RNP RNAV



Note: Normally RNP is restricted to 250 ft HAT minimum. For GLS vertical, a minimum of 200 ft HAT is assumed.

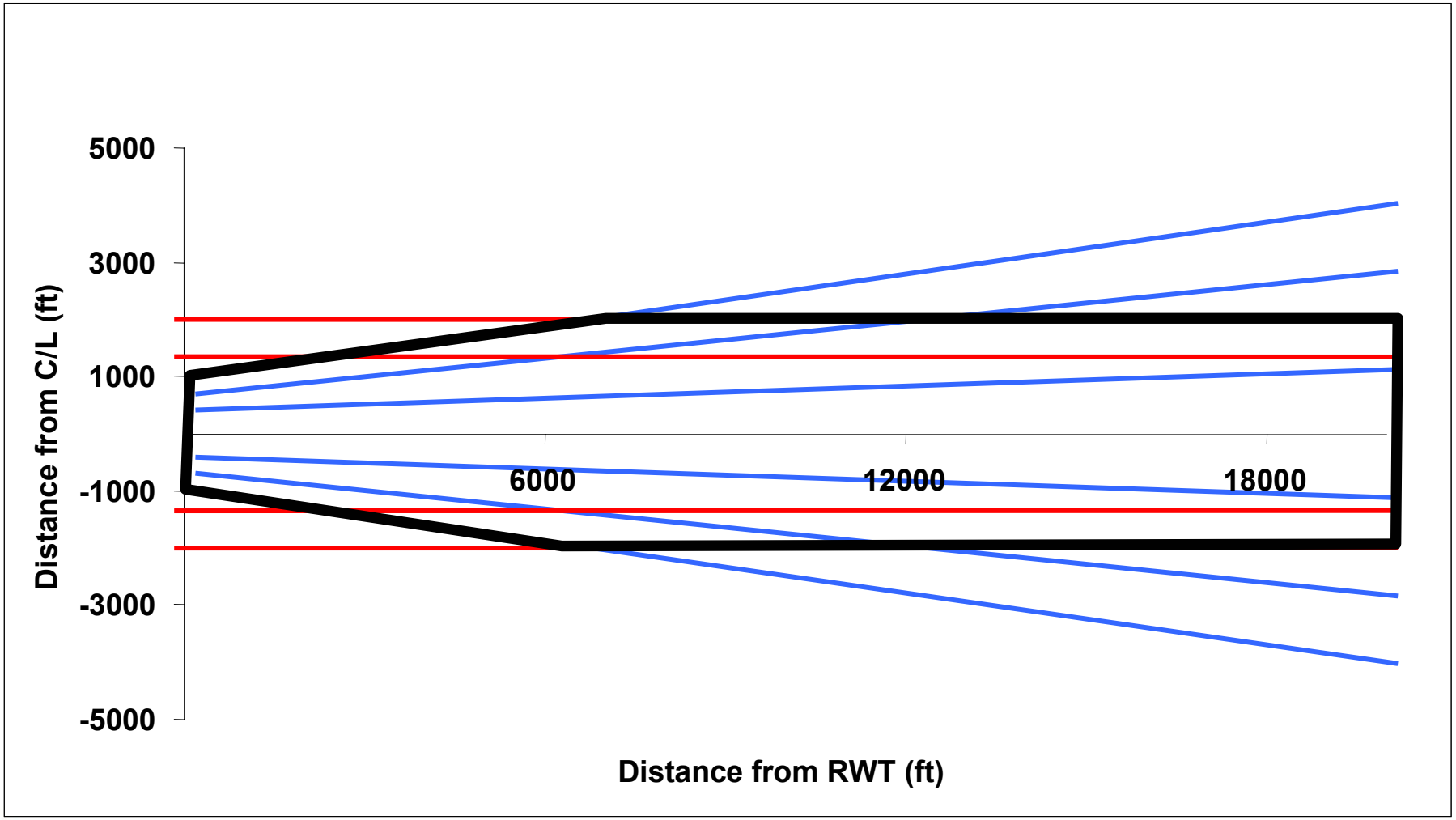
Observations

- The use of the improved vertical OCS produced lower minima for RNP RNAV approaches
  - ILS/GLS OCS only proposed as an example
- Complexity of certification for small RNP values (such as RNP-.033) is unknown
  - RNP-.1 will still require SAAAR
    - Increased certification, equipment, and training costs
- RNP RNAV and SAAAR will certainly be beneficial at some airports, but it is clear that there will be no substantial benefit over ILS, GLS or even LPV at most airports
- Is there a less costly/easier way to attain good minima at most airports?

Hybrid Approaches

- It may be possible to combine RNP, GLS, and/or LPV into a single hybrid approach, where RNP RNAV criteria are used far from the runway, and the aircraft transitions to a GLS or LPV approach near to the runway
  - Possible application using ILS also
- Such approaches should avoid the extra certification, equipment, and training of SAAAR
- What would the benefits be of such approaches?

RNP-.1 and ILS/GLS/LPV Hybrid Horizontal Depiction



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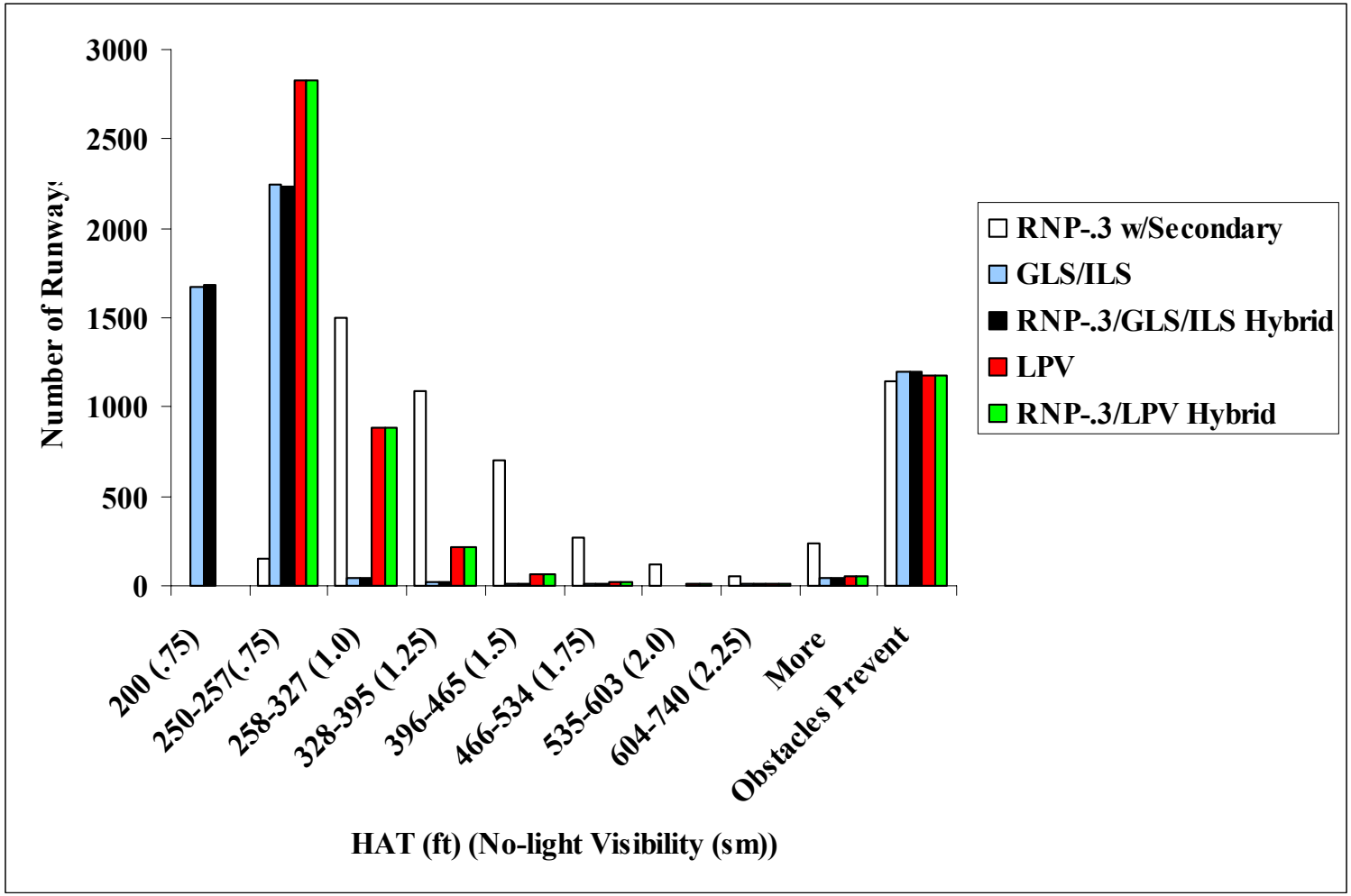
Hybrid RNP/GLS and RNP/LPV Approaches

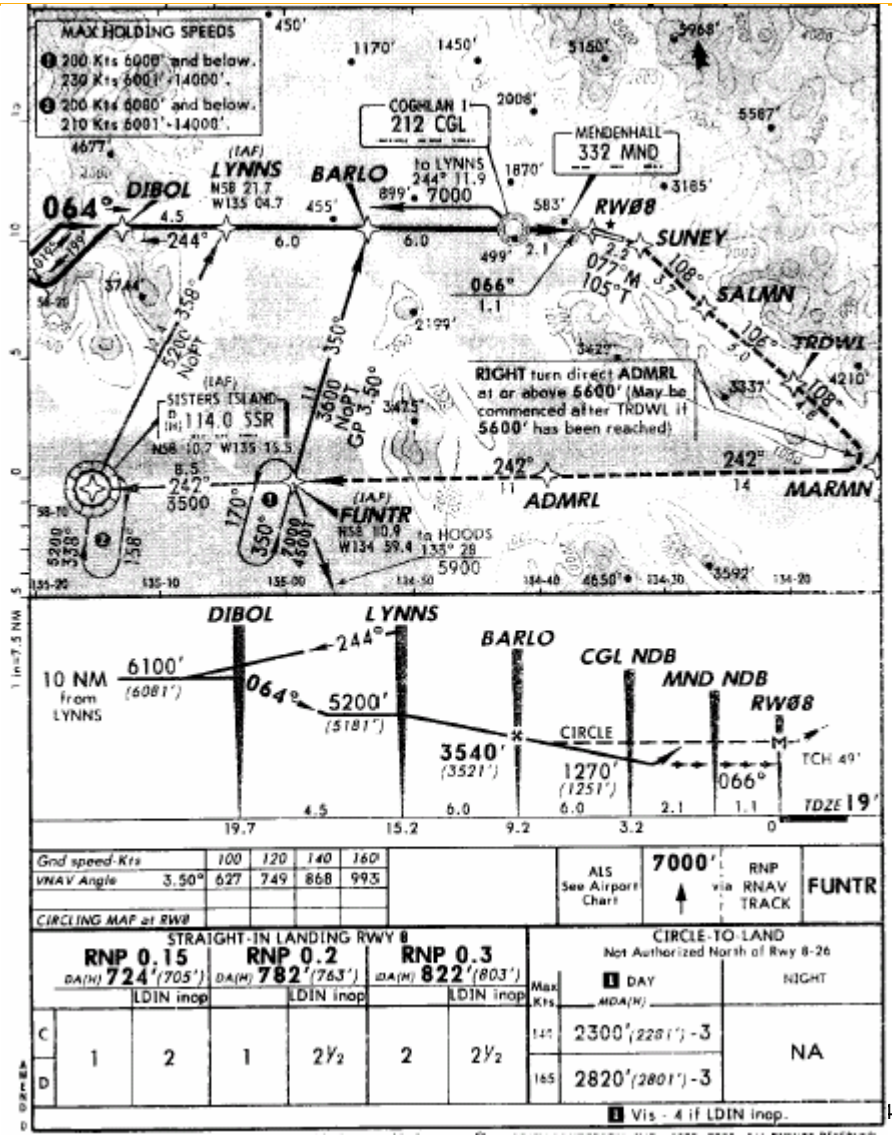


Observations

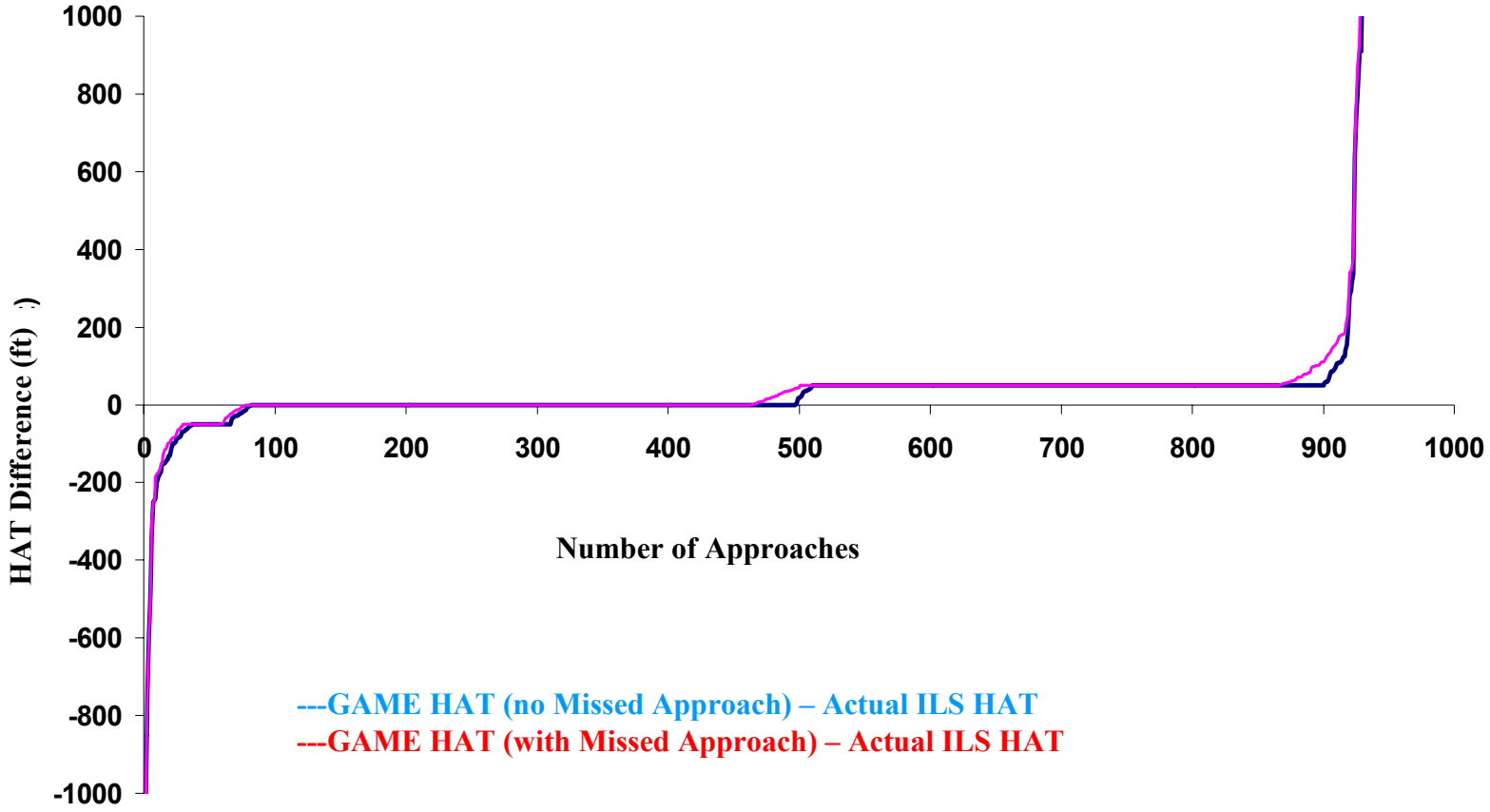
- **Application of current RNP RNAV approach criteria will result in higher minima at most airports in comparison to ILS, LAAS or WAAS-based approaches**
  - **Some airports will benefit, but most will have *higher* minima**
- **Improvement of the vertical profile of RNP RNAV offers significant benefit with respect to approach minima**
  - **GLS vertical OCS investigated in this paper**
- **Hybrid RNP RNAV and LAAS/WAAS approaches appear to have excellent capability to achieve the benefits of RNP and low approach minima while avoiding the costs of SAAAR**
  - **RNP to GLS and LPV investigated in this paper**

Backup Slides

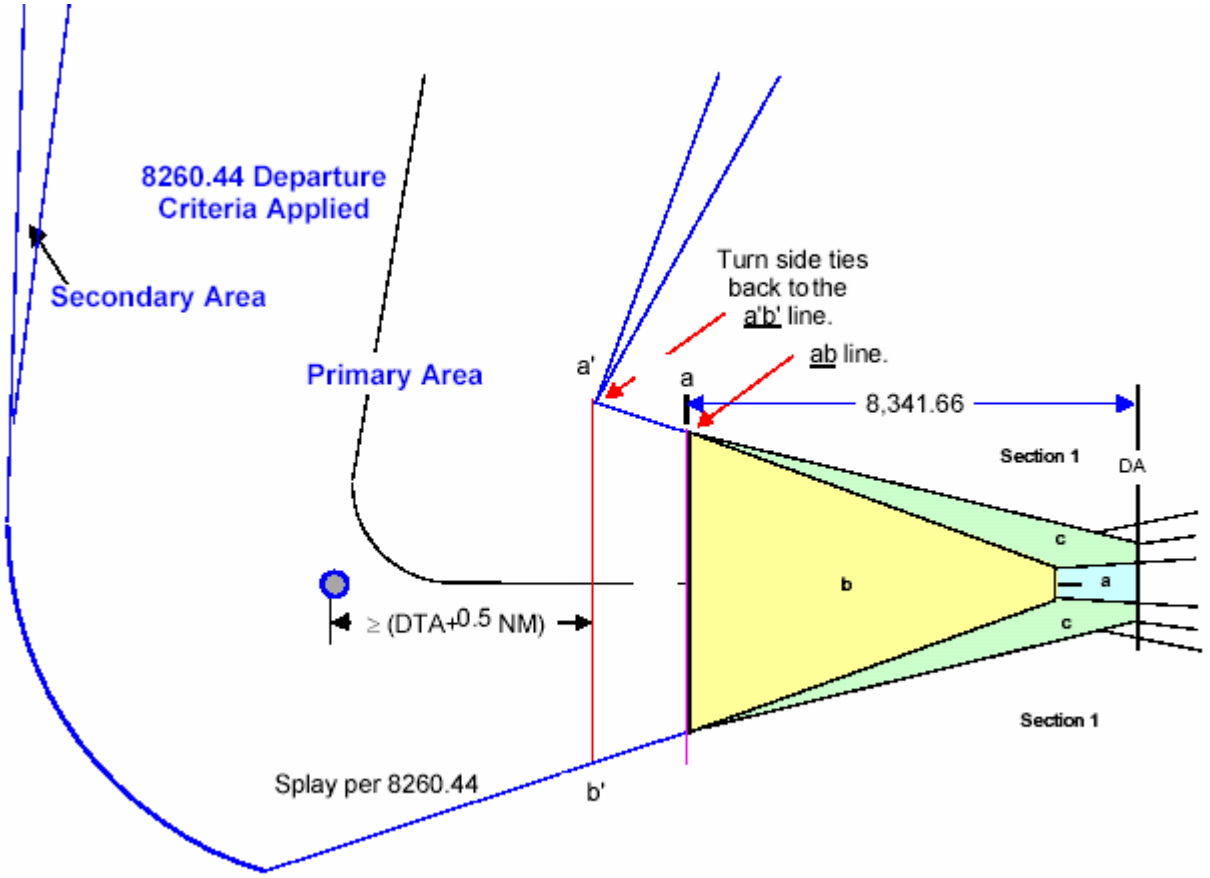
Instrument Approaches to Juneau, Alaska, USA



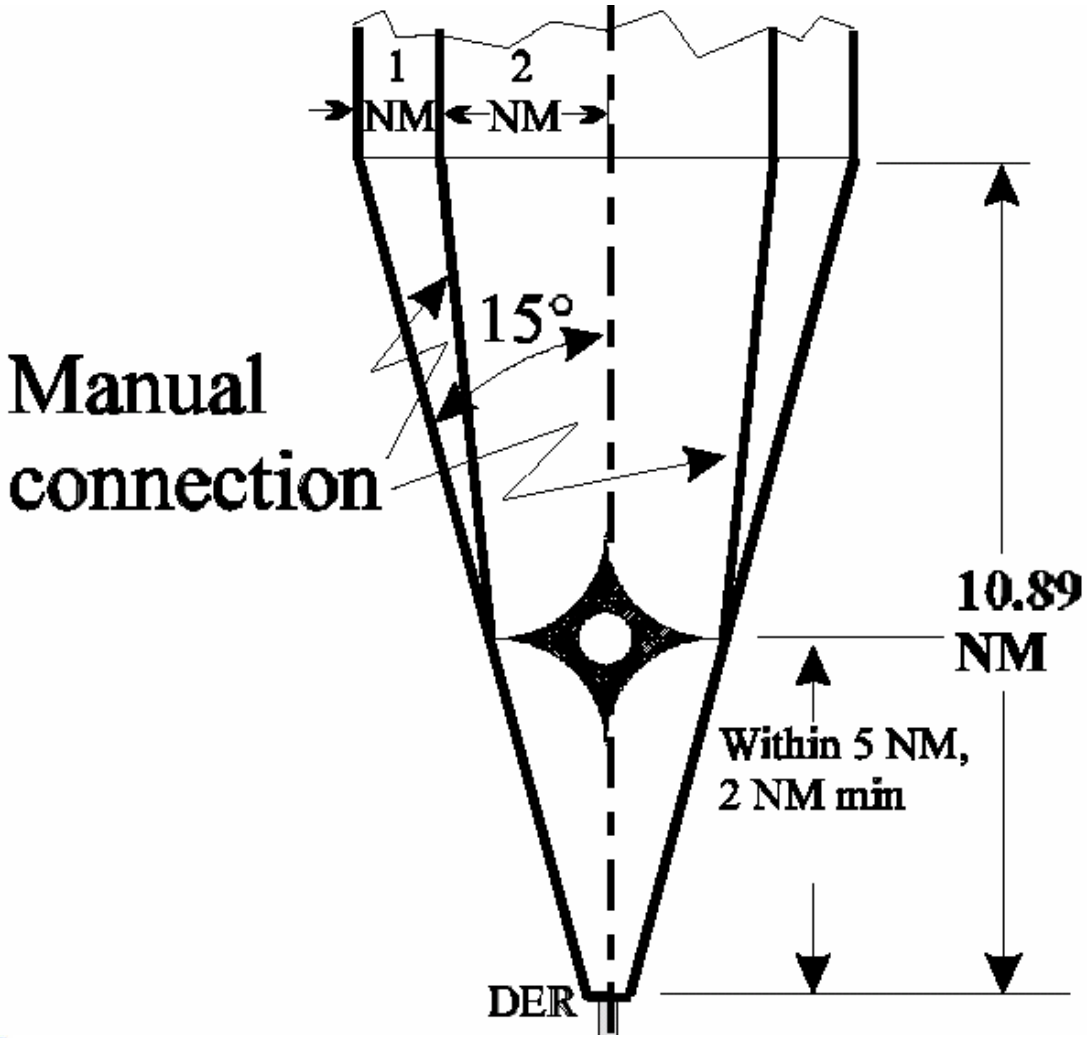
Effect of the Missed Approach GAME Validation



GLS/LPV Missed Approach Splay
FAA Order 8260.50



GLS/LPV Missed Approach Splay
FAA Order 8260.44A



RNP Missed Approach Splay
FAA Order 8260.51