

Issues using Radar Altimeters for a Real-Time Integrity Monitor for SVS

Jacob Campbell

Advisor: Maarten Uijt de Haag, Ph D.

Presented at:

JUP Quarterly Review

Atlantic City

October 26, 2000



Overview

- **Background**
- **TAWS vs. SVS**
- **Terrain Database Integrity**
- **Integrity Algorithms**
- **Future Work**



Background

- **Terrain Awareness Warning Systems (advisory only) have been mandated by the FAA**
- **Significant R&D investment is being made to reduce CFIT**
 - » **NASA's Aviation Safety Program**
 - » **FAA's SafeFlight21 Program**
 - » **NIMA's Ron Brown Airfield Initiative**
- **Shuttle Radar Topography Mission**
- **Previous work at OU on integrity monitor**
- **De-classification of the Department of Defense (DoD) digital terrain elevation data (DTED) level I**



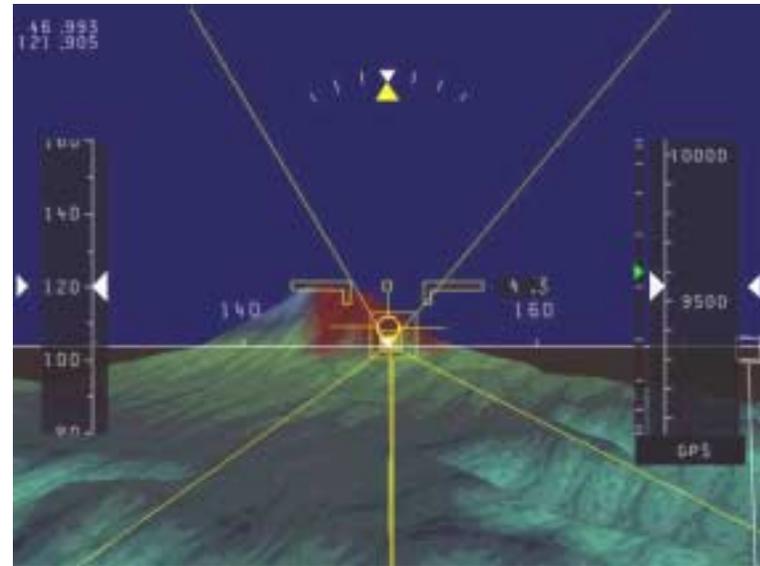
Terrain Awareness Warning System (TAWS)

- **Generally provides a Plan display**
(note: Universal has a perspective display)
- **Data Sources**
 - » Terrain Database (also can include obstacles)
 - » GPS for positioning
 - » **Radar Altimeter (GPWS)**
 - » Other Sensors
- **Advisory System**



Synthetic Vision System (SVS)

- Provides perspective view of terrain
- Data Sources
 - » Terrain Database
 - » GPS
 - » INS (for attitude)
 - » Radar Altimeter (used for integrity monitoring)
- Flight Critical System



Database Certification

- **Two Parts**
 - » **Certify Database is Correct upon Creation**
 - **Cross check different sources?**
 - **Measurement Verification?**
 - » **Certify Data Read has not been corrupted or terrain changed**



Integrity Algorithms

- Background
- TAWS vs. SVS
- Terrain Database Integrity
- **Integrity Algorithms**
- Radar Altimeters
- Future Work



Database Profile and Synthesized Profile

- Database Profile generated by obtaining terrain height below aircraft from terrain database
- Synthesized Profile generated by
 $\text{GPS Height} - \text{Radar Altimeter Height}$

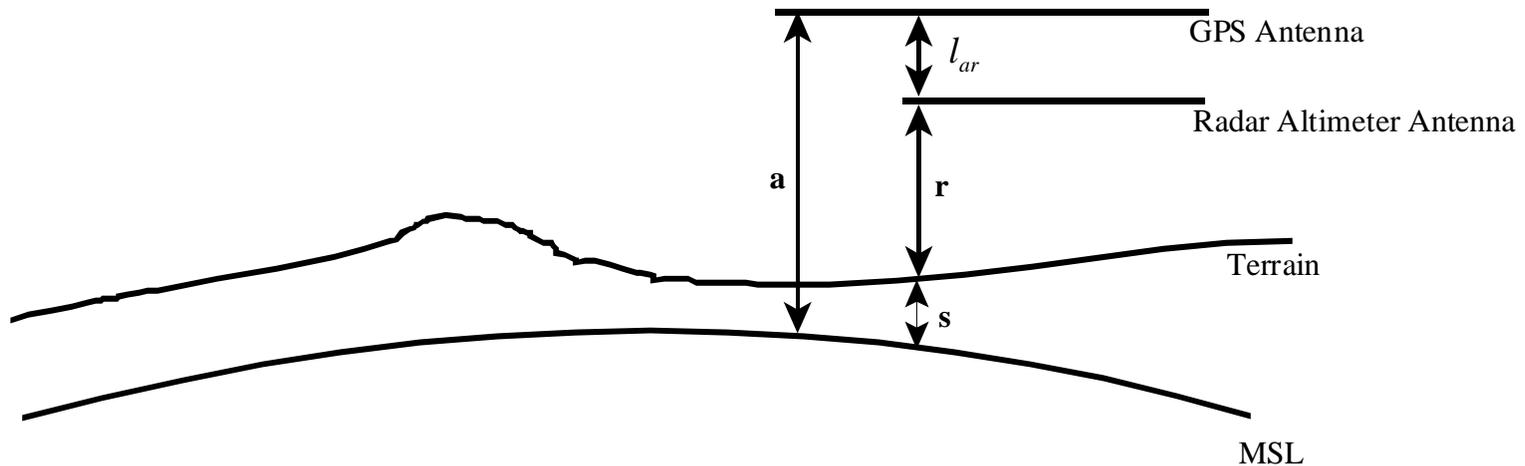


Map Profile:

$$d_i = d(e_i, n_i) + b_d + n_{di}$$

Sensed (Synthesized) Profile:

$$s_i = a_i - r_i - l_{ar} + b_s + n_{si}$$



Absolute Disparity:

$$p_i = s_i - d_i$$

Successive Disparity:

$$p'_i = p_i - p_{i-1}$$



Current DTED Terrain Avoidance

- **Test Statistic:**

- » **Scaled Mean Square Difference (MSD) of Absolute and Successive Difference**

- T was found to be a chi-square distribution, with $n = \text{degrees of freedom}$

$$T = \frac{n}{\sigma^2} MSD_{ad}(n) = \frac{1}{\sigma^2} \sum_{i=1}^n P_i^2$$



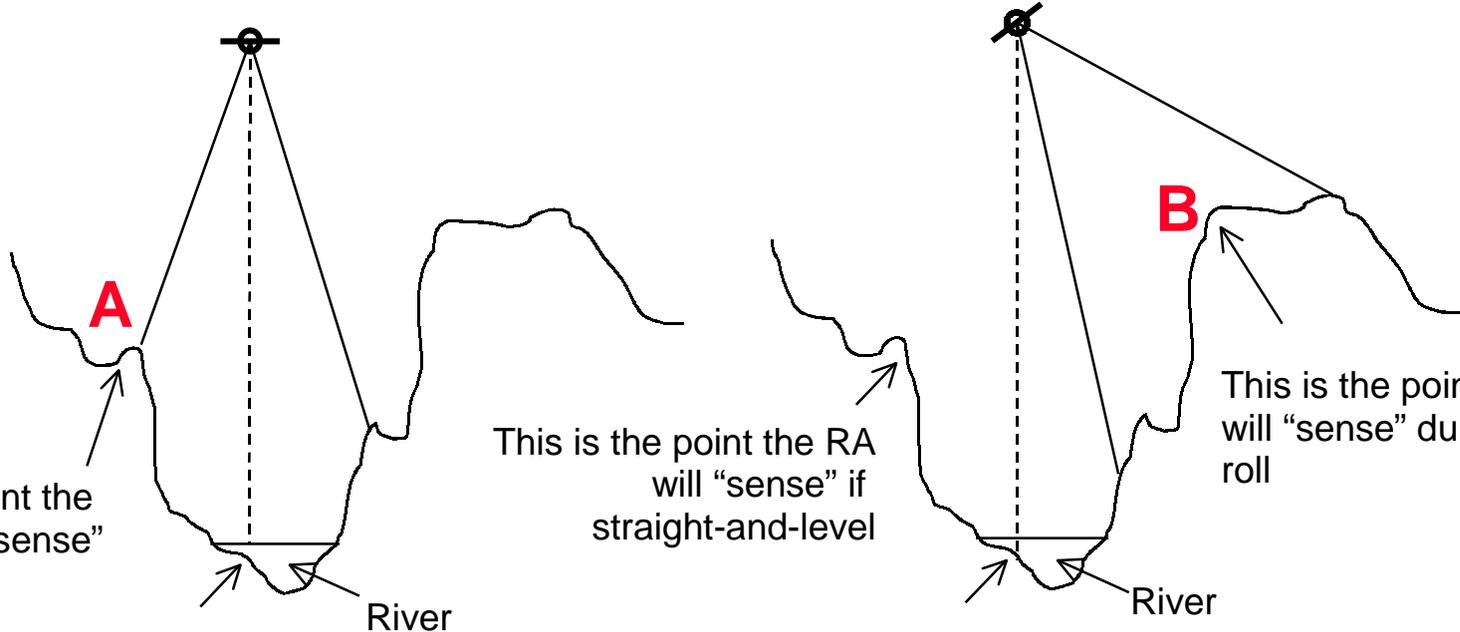
Problem!

Integrity Threshold Exceeded

- **Why?**
 - **GPS Accurate**
 - sub-meter LAAS data used
 - sub-meter post processed Ashtech data used
 - **Database DTED Level 1**
 - **Radar Altimeter**



Radar Altimeter



This is the point the RA will “sense”

This is the point we’ve been using from the DTED to compute the AD

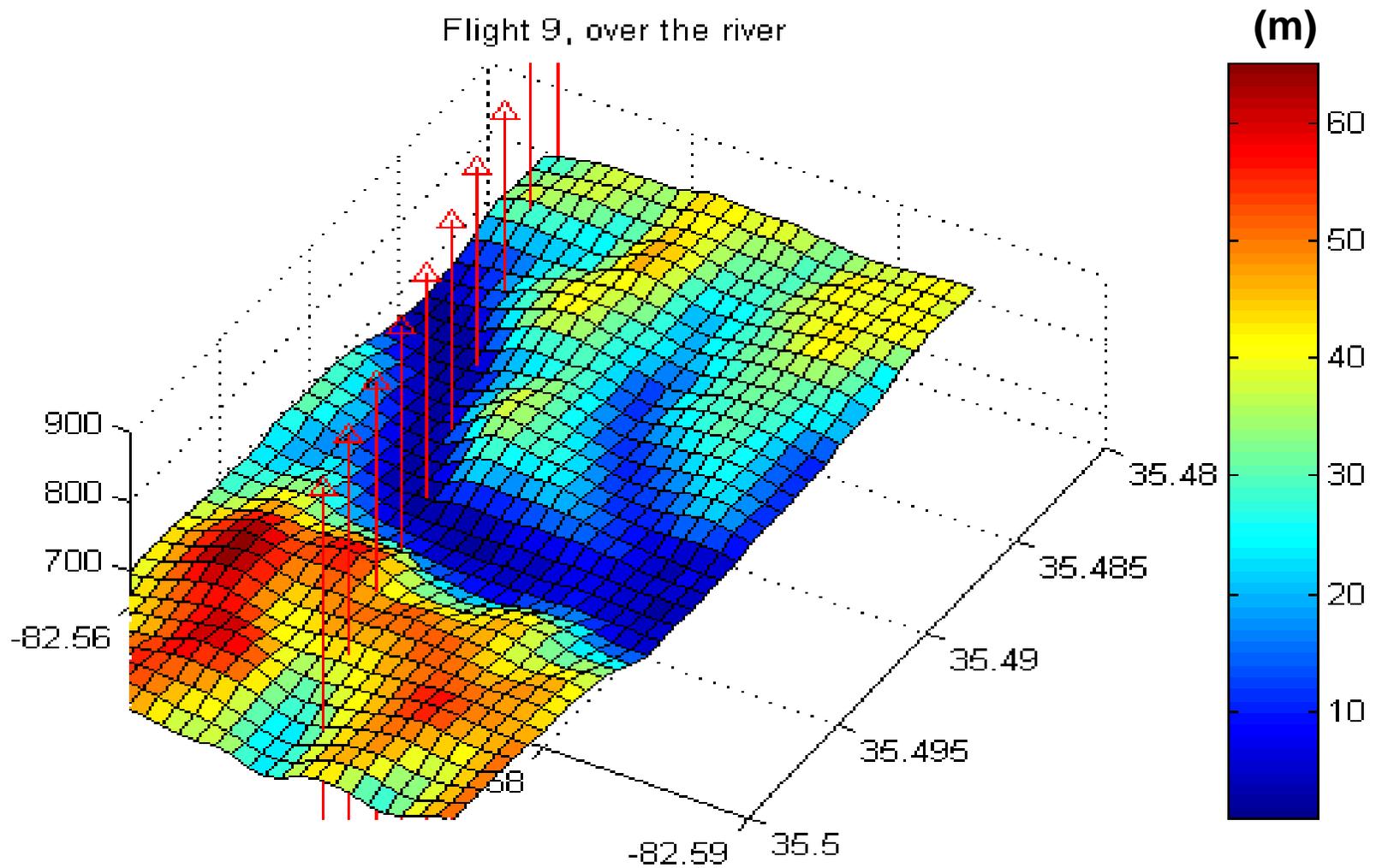
This is the point the RA will “sense” if straight-and-level

This is the point we’ve been using from the DTED to compute the AD

This is the point the RA will “sense” during this roll

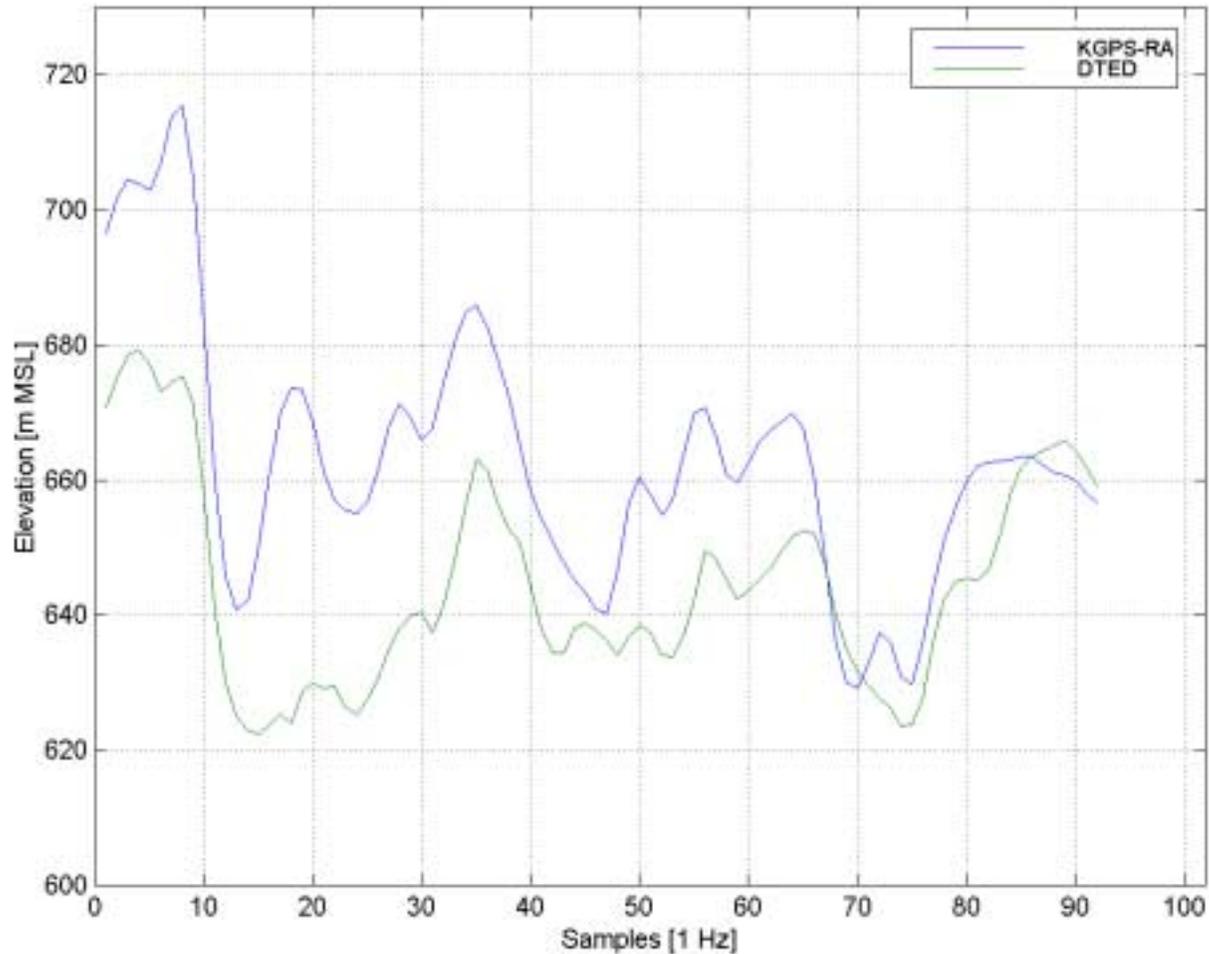


Flight 9, over the river

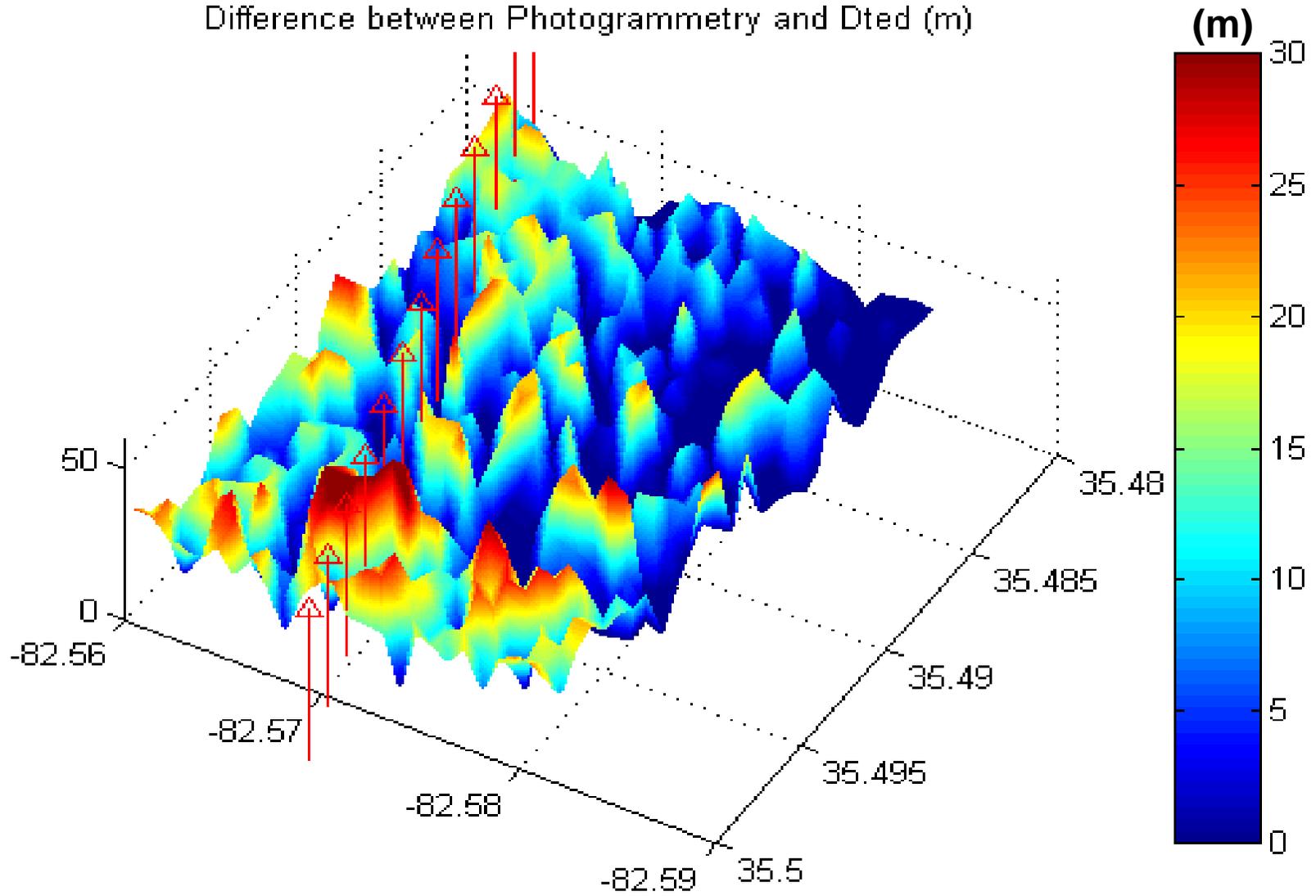


Test Results - 1

Database Profile to Runway 16 using DTED

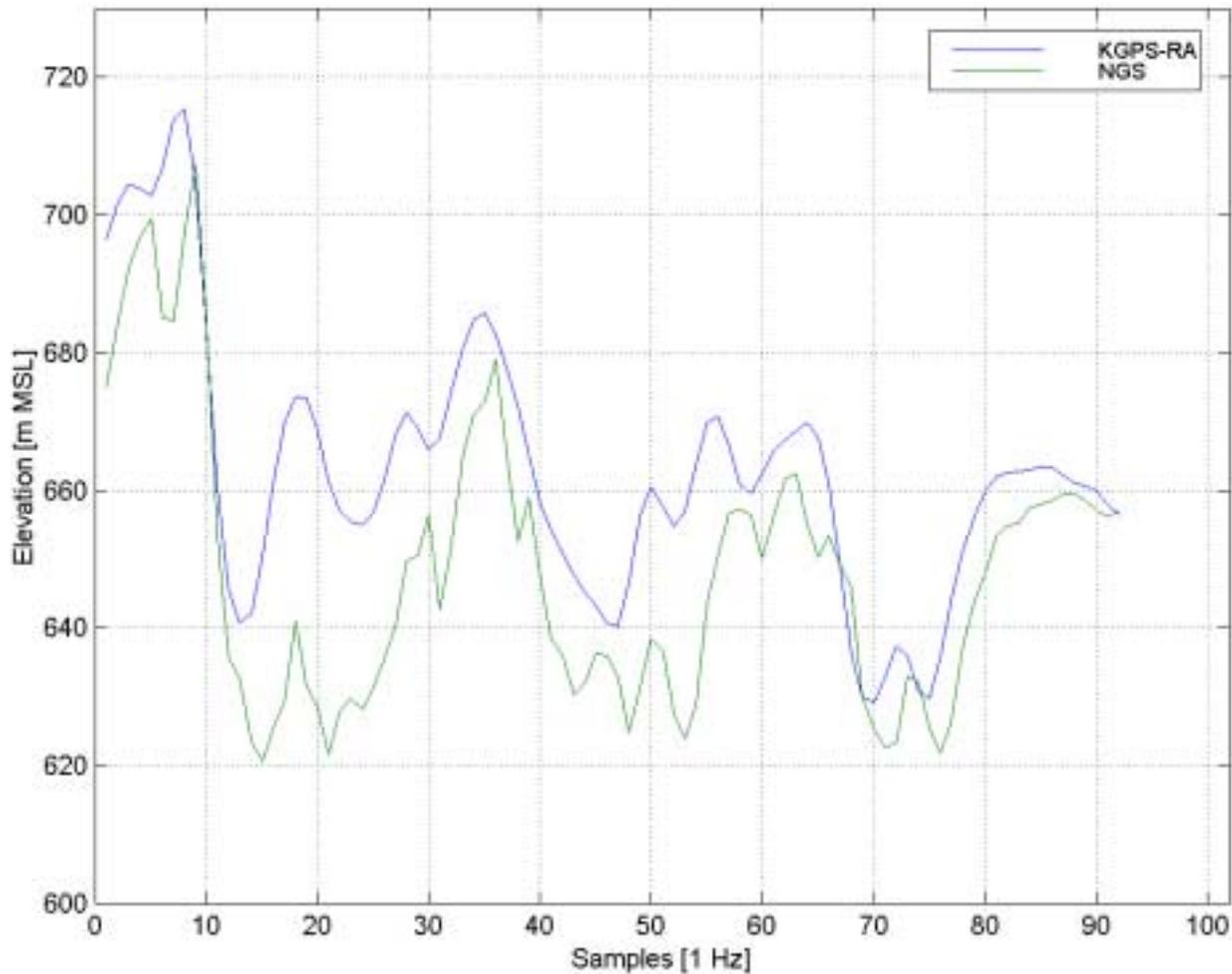


Difference between Photogrammetry and Dted (m)



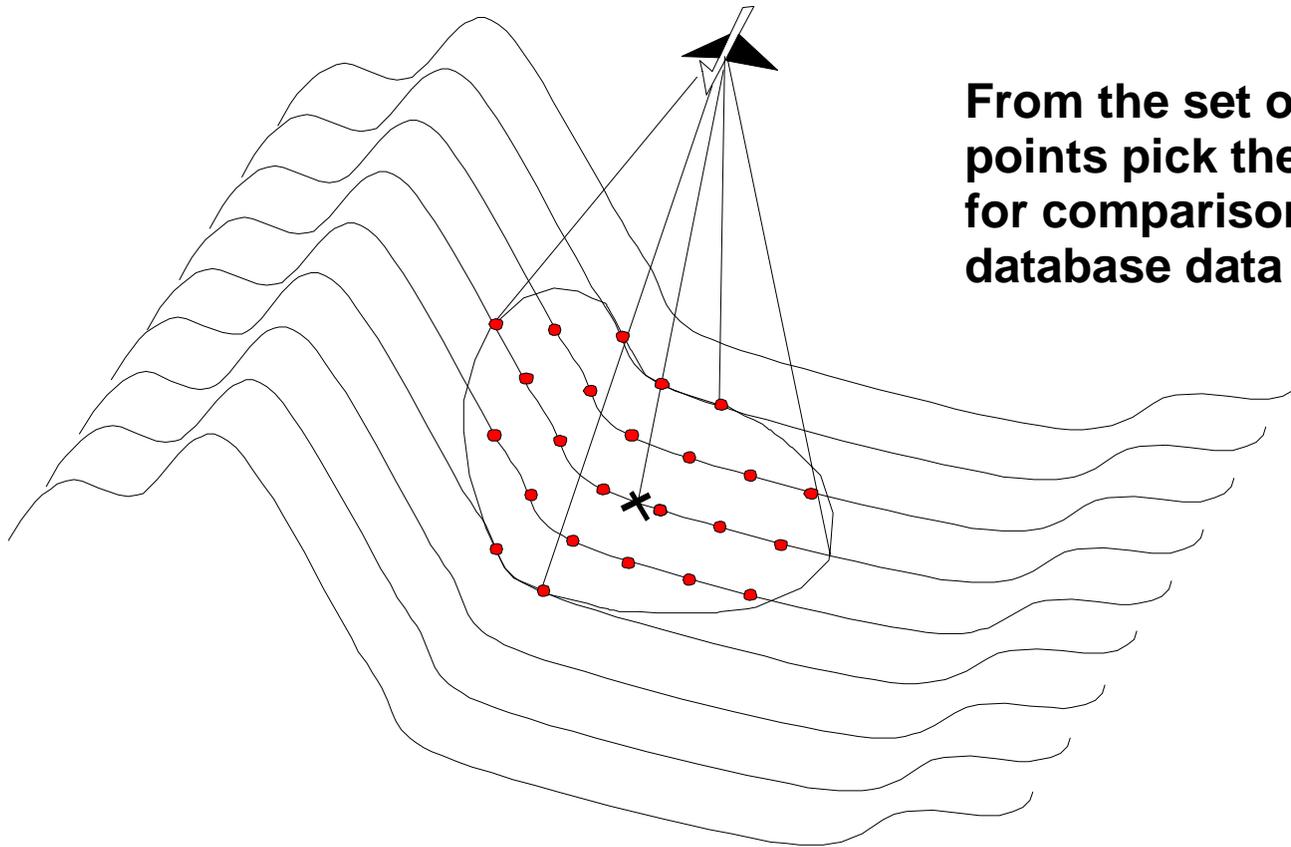
Test Results – 2

Database Profile to Runway 16 using NGS Data



Radar Altimeter Characterization

"Spot" Algorithm

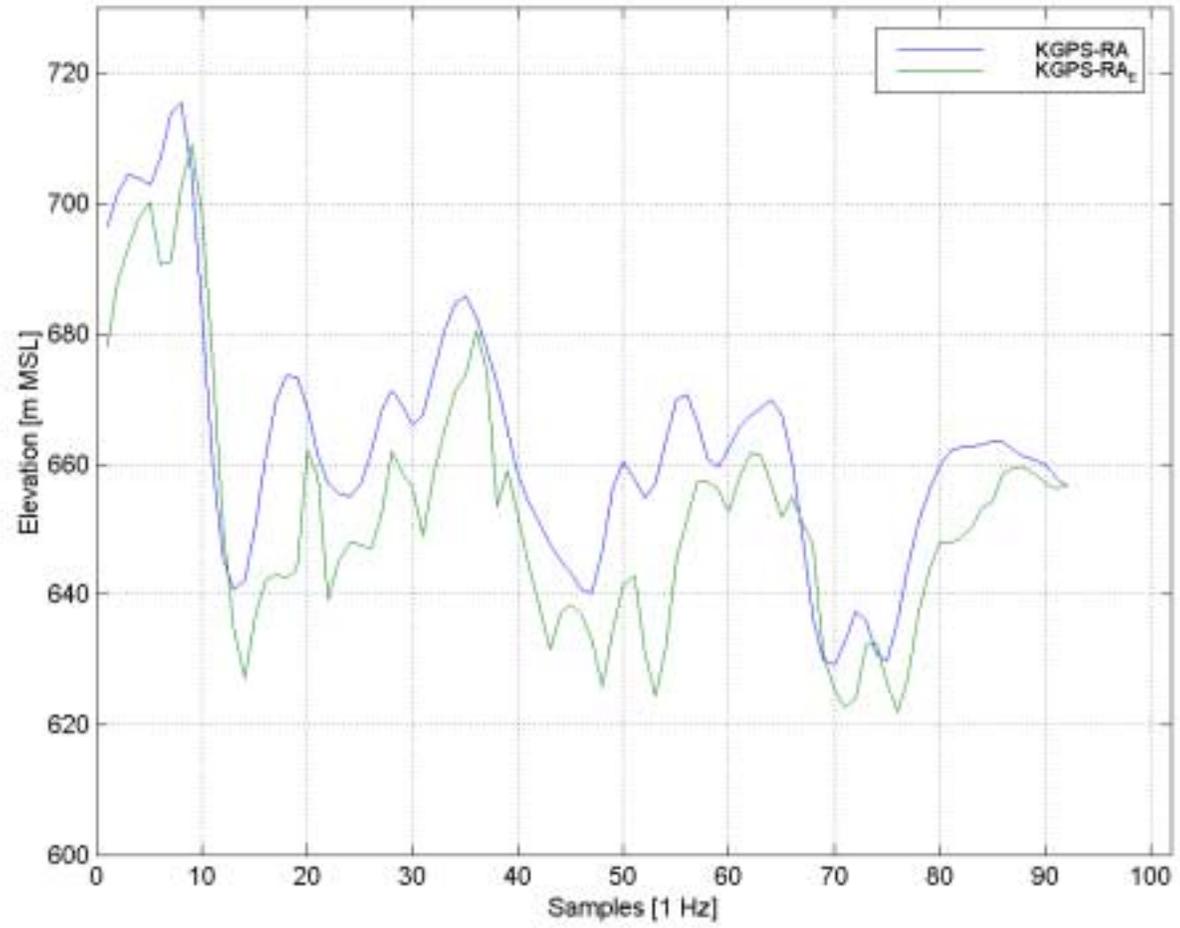


From the set of candidate points pick the closest one for comparison with the database data



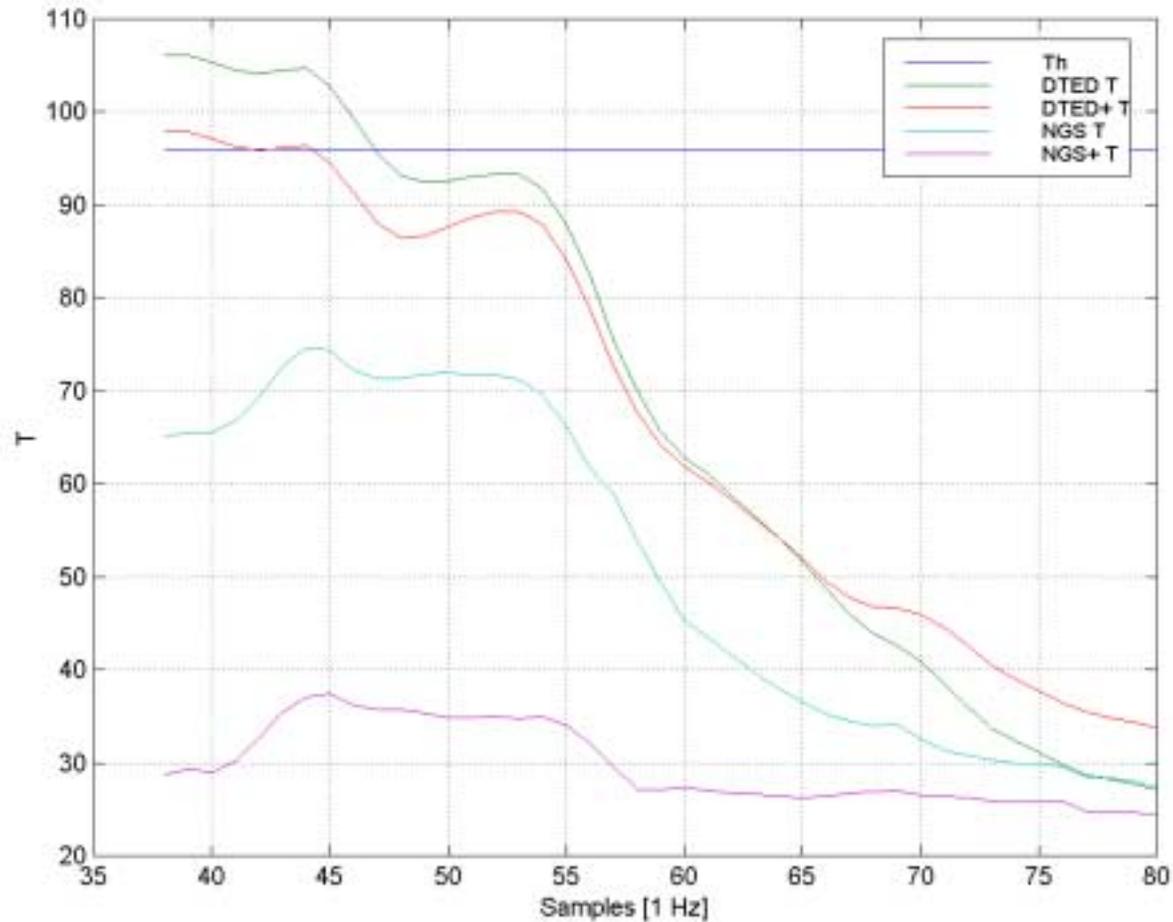
Radar Altimeter Characterization

Database Profile to Rwy 16 using the NGS data and the "Spot" Algorithm



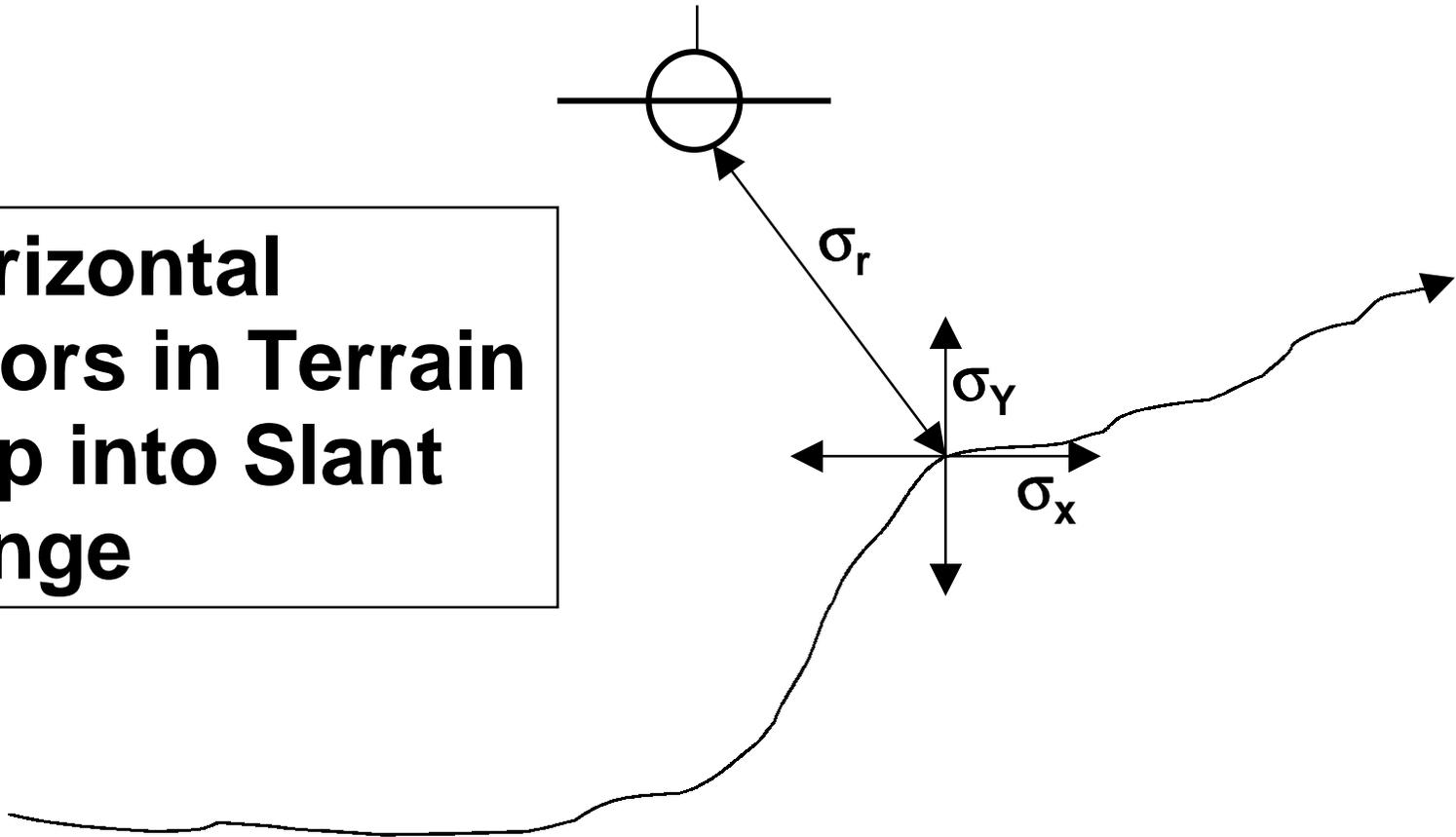
Radar Altimeter Characterization

T Statistic for Approach to Runway 16



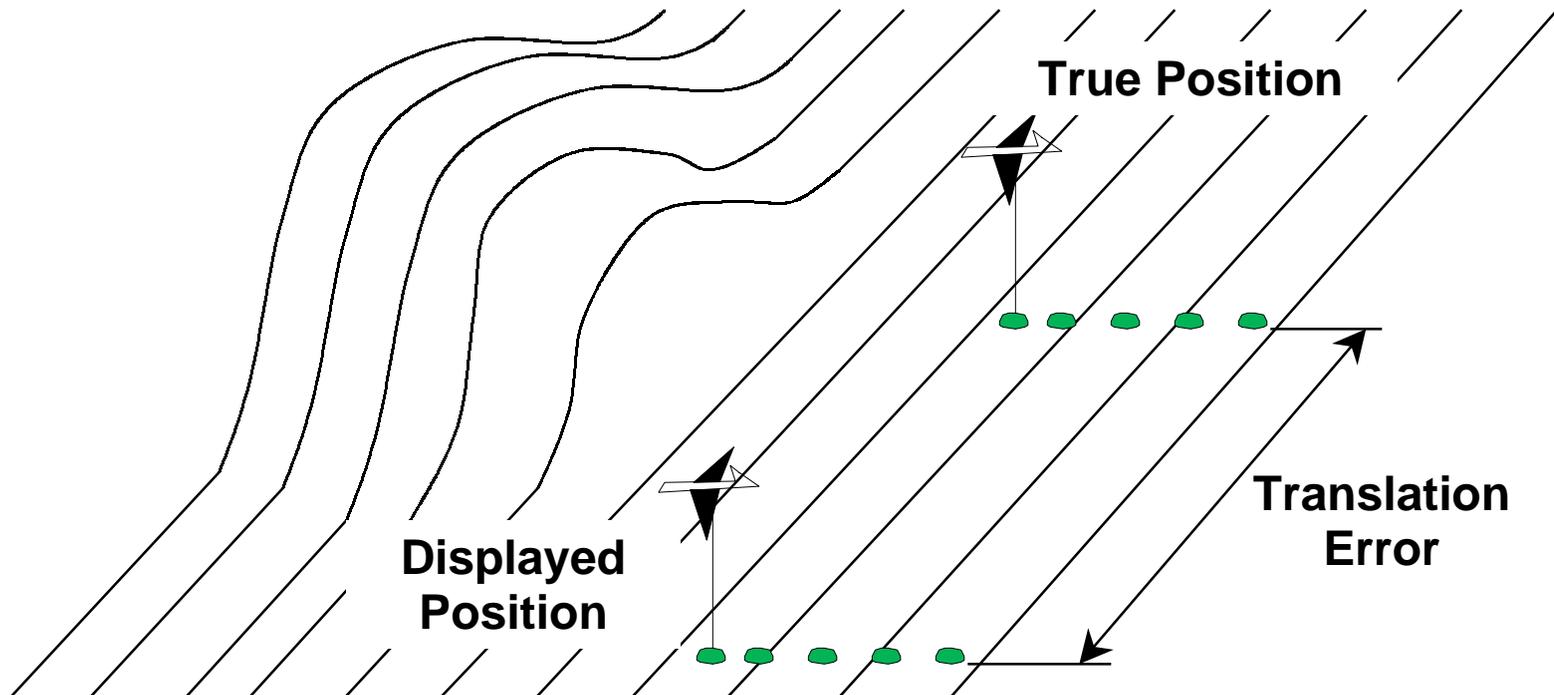
Slant Range Statistics

**Horizontal
Errors in Terrain
Map into Slant
Range**



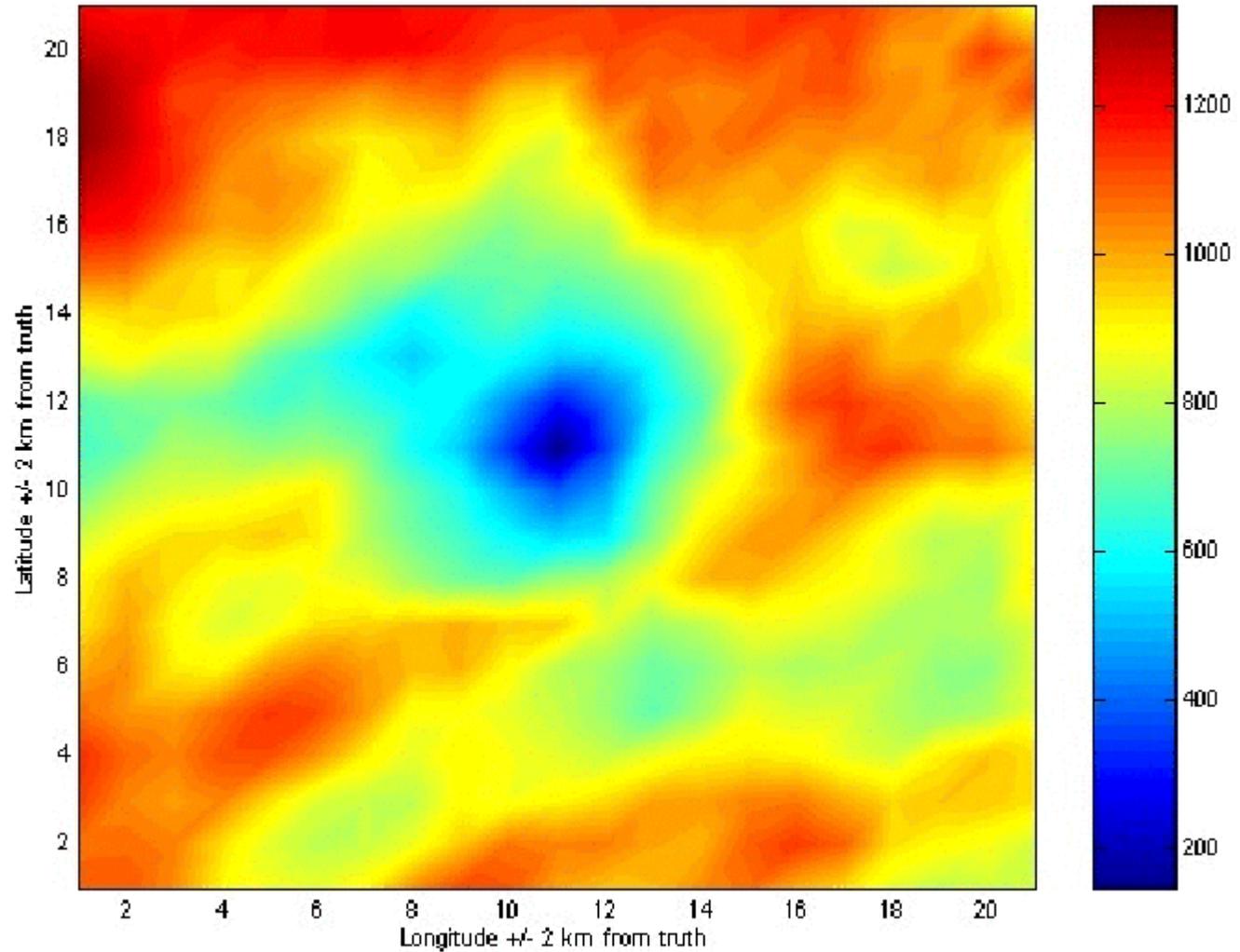
But Does All This Give Integrity?

- Some Data Base Errors Could Slip Past

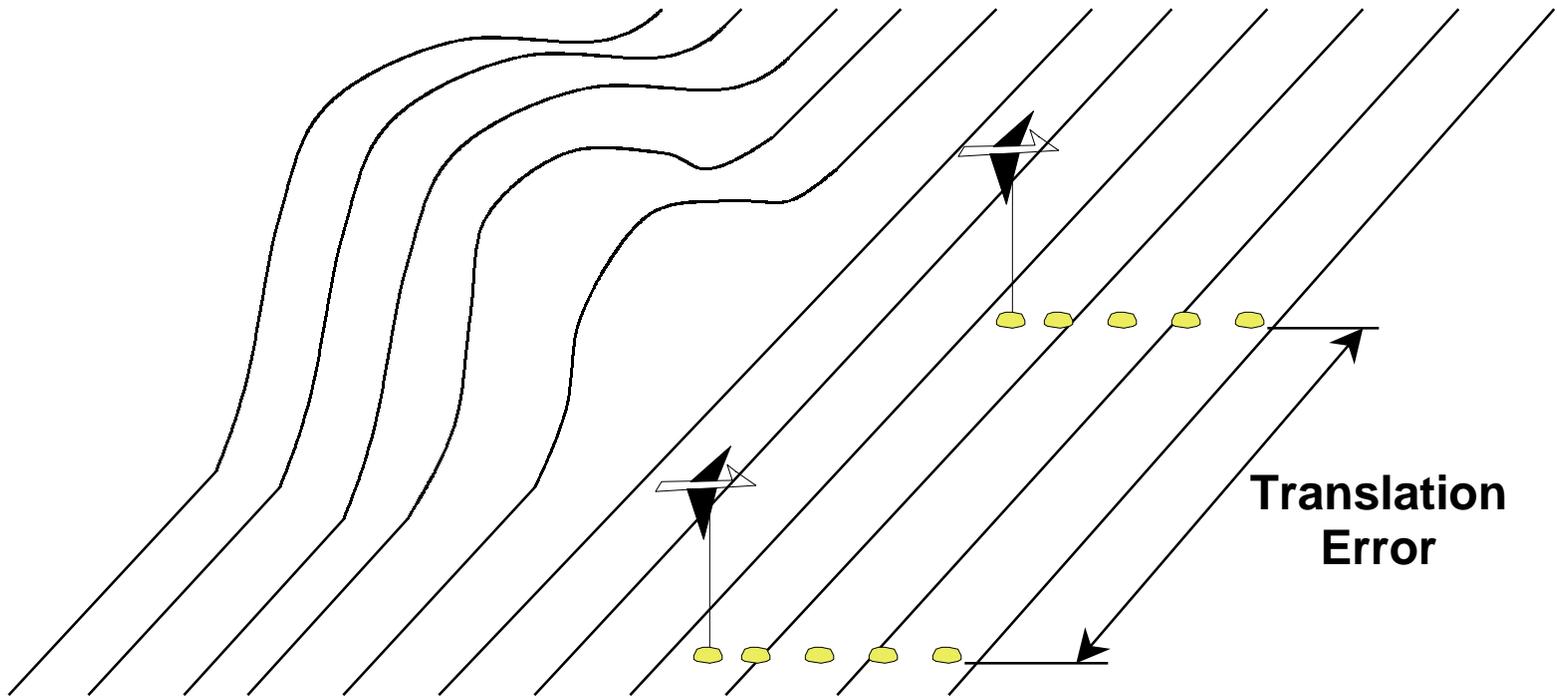


T Statistic (Absolute Disparity) for Entire Search Area

T statistic for n = 500



Integrity Monitoring

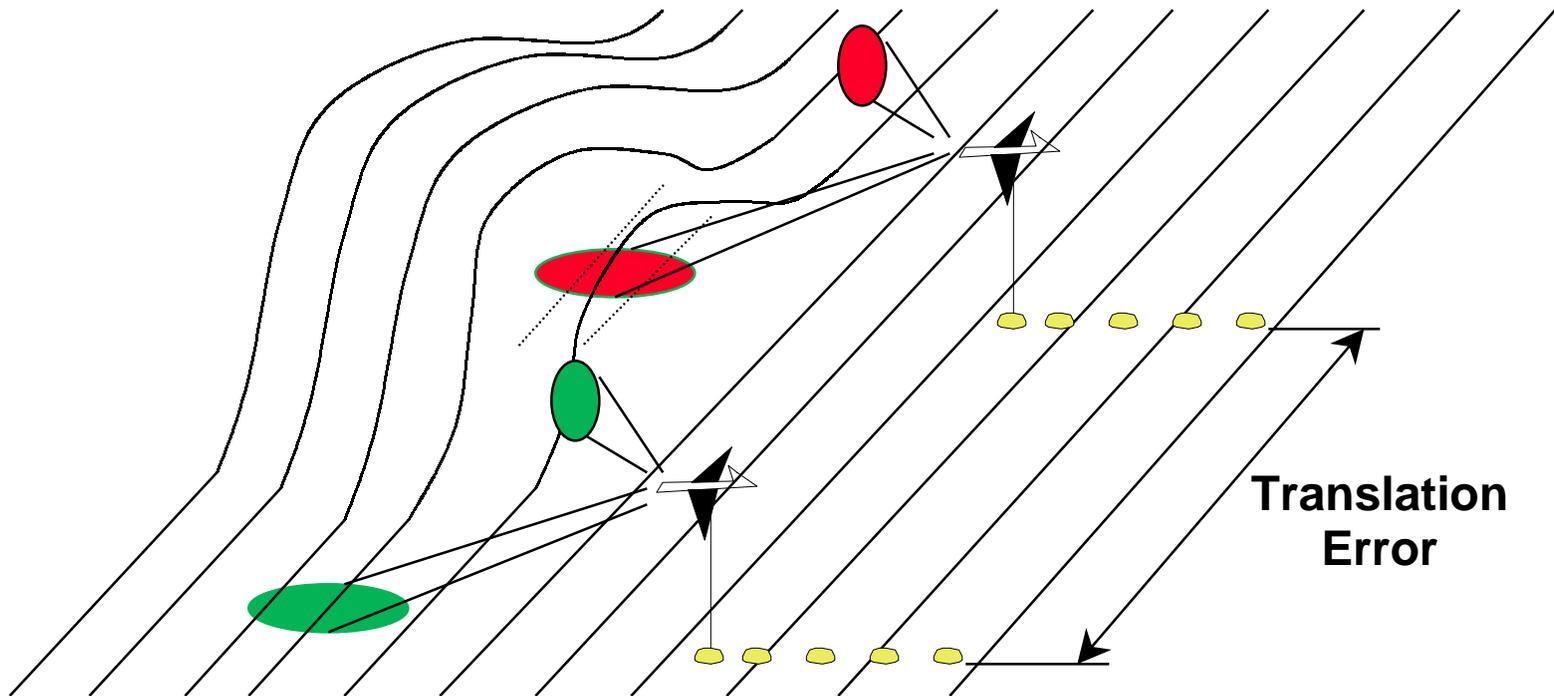


Forward Looking Sensors

- **Purpose**
 - **Search For Significant Terrain Features**
 - Hill Tops
 - **Search For Man Made Objects**
 - Requires Obstacle Database
 - Cell Phone Towers
 - High Tension Power Line Towers



Integrity Monitoring with Forward Looking Radar



Future Work

- **Continued Study of Terrain Test Statistics**
- **Better Model of Radar Altimeter Through use of the Laser Altimeter Data**
- **Research in the Area of Forward Looking Sensors**



