



Improving Collision Avoidance Systems



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Topics

- **Ground Collision Avoidance Development**
 - Platform Agnostic Architecture
 - Enhanced Precision Elements
- **Digital Terrain**
 - Requirements for Aviation
 - Influences of Product Features
 - Enhanced Terrain Handling

Auto CA Timeline

- 1985 – 97 **AFTI/F-16 Development**
- 1998 **AFTI GCAS Program**
- 2000 – 01 **GCAS Demos**
- 2003 **SecDef Mishap Reduction Memo & ACAS Testing**
- **2009 ACAT/FRRP**
- **2008 – 11 F-22 NASA ACAT Development**
- **2011 ACAT/SUAV**
- 2011 – 14 **F-16 Integration & Fielding**
- 20?? **F-22 & 35 Integration**





F-16
2010 Risk Reduction Project
2014 Production Fielding



Small UAV
2012 Migration to Smart-Phone

RECENT WORK

What is Different about this Work?

Understanding

- **Requirements**

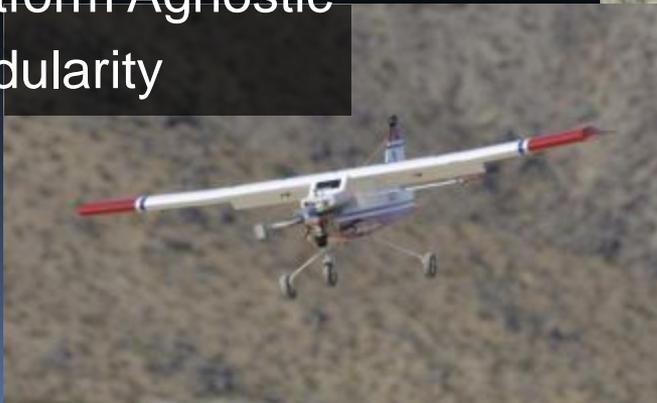
What is most Important

1. **Do No Harm**
2. **Do Not Interfere**
3. **Prevent Collisions**

- **Functionality**

- Sensor Agnostic
- Platform Agnostic
- Modularity

Mountainous SDO
100' Buffer
125' Min
0.2 sec.



Precision

- Digital Terrain
- Terrain Handling
- Aircraft Performance Modeling

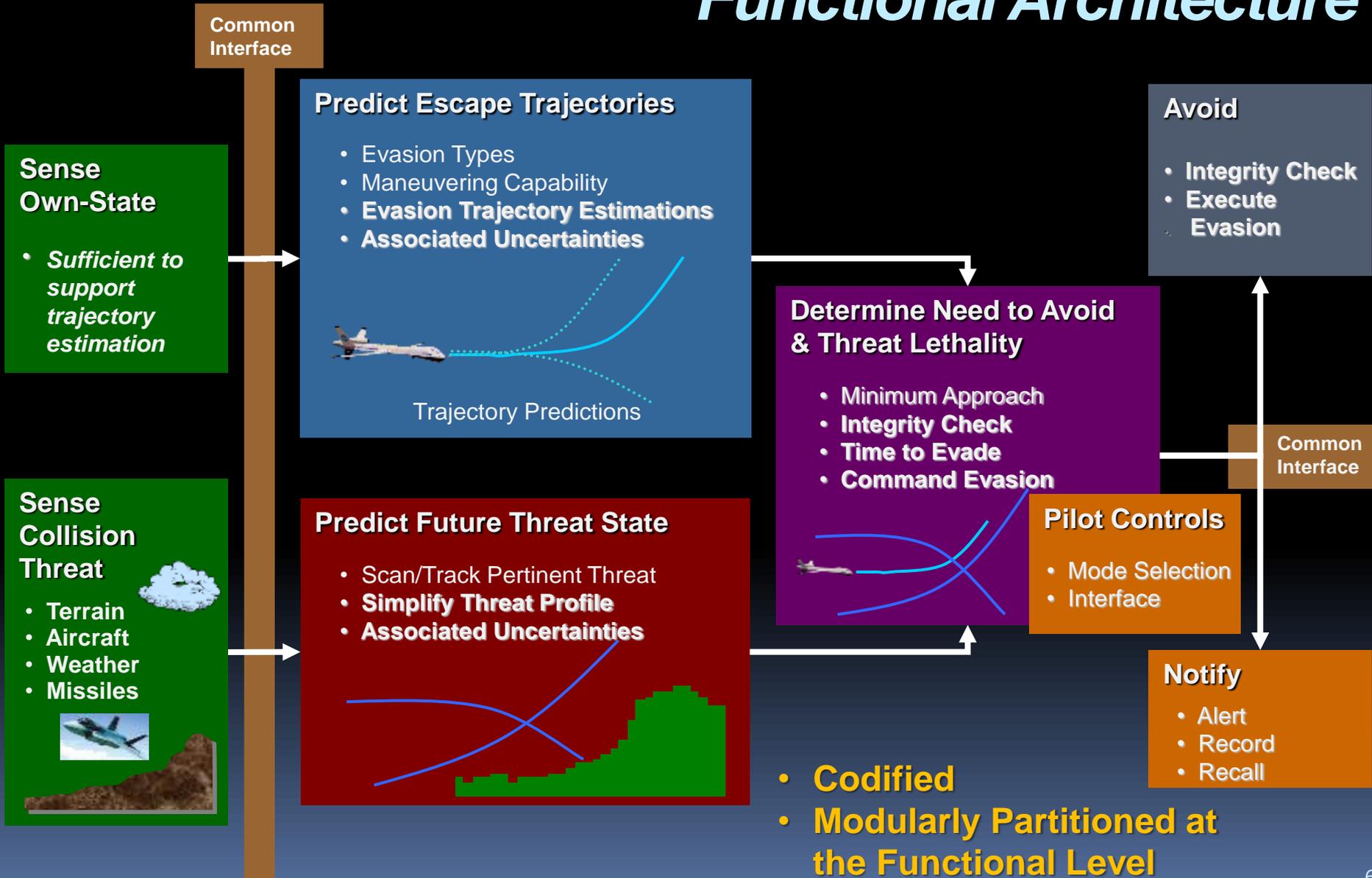
Mountainous SDO
0 Buffer
87' Min
0.2 sec.



- Pilot Interface



ACAT Common Functional Architecture



Flight Test Results

■ F-16 Flight Test Evaluation

- 103 Flights Conducted
- 141 Total Flight Hours
- 1670 Recoveries

□ Conclusions

- Excellent Mishap Prevention
- Nuisance Free Operation

■ Small-UAV Test Evaluation

- Added Many Features for Low Performance Aircraft
- Implemented Algorithm on Smart Phone
- 21 Flights
- 208 Recoveries

Mountainous SDO
100' Buffer
125' Min
0.2 sec.

□ Conclusion

Overall

Mountainous SDO
0 Buffer
87' Min
0.2 sec.

Smooth Terrain
0 Buffer
100' AGL
LOW Protection

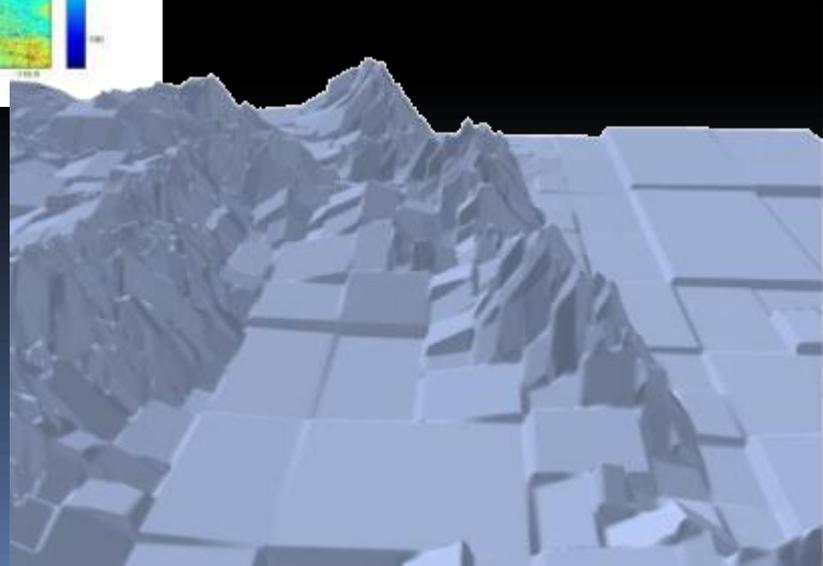
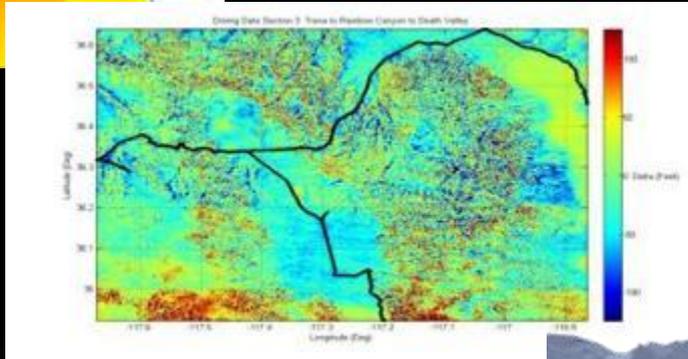
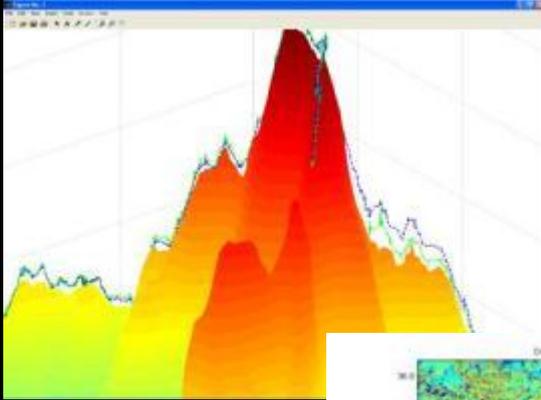
Extreme Terrain
0 Buffer
170' Min
LOW Protection



A Level of Precision has been Achieved that May Allow a Walk-On Smart Device to Provide a Capability Better than Today's EGPWS & TAWS

Digital Terrain

Requirements, Products & Techniques



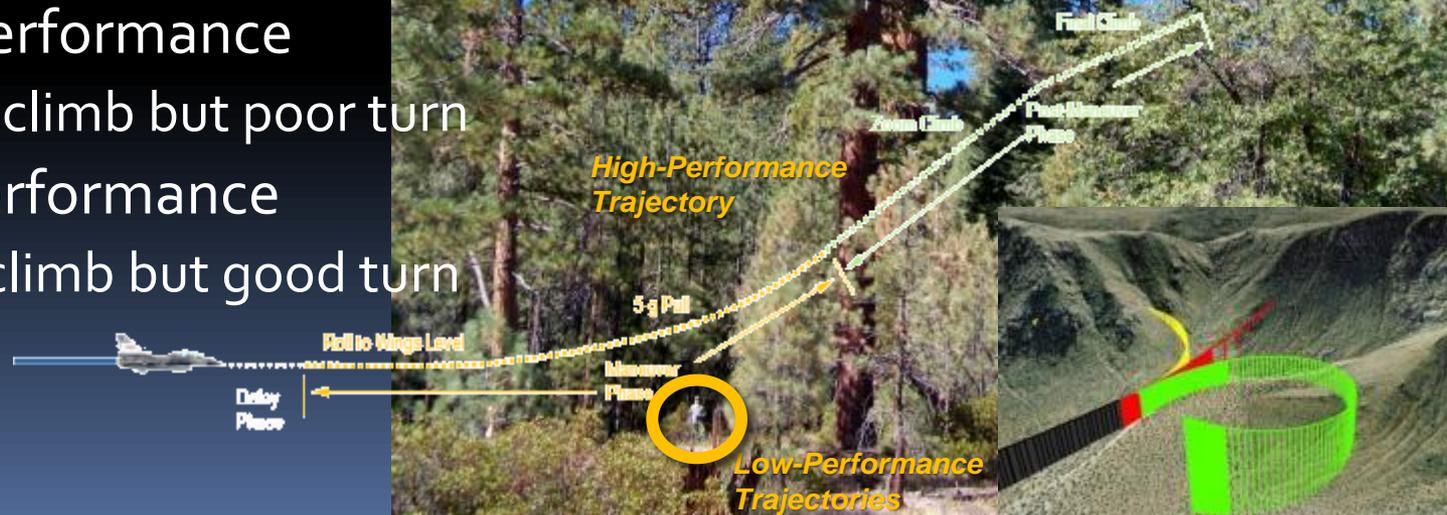
Requirements for Aviation

- **Bare-Earth vs First Return**

- Most Products are Bare-Earth
- Aviation needs First Return

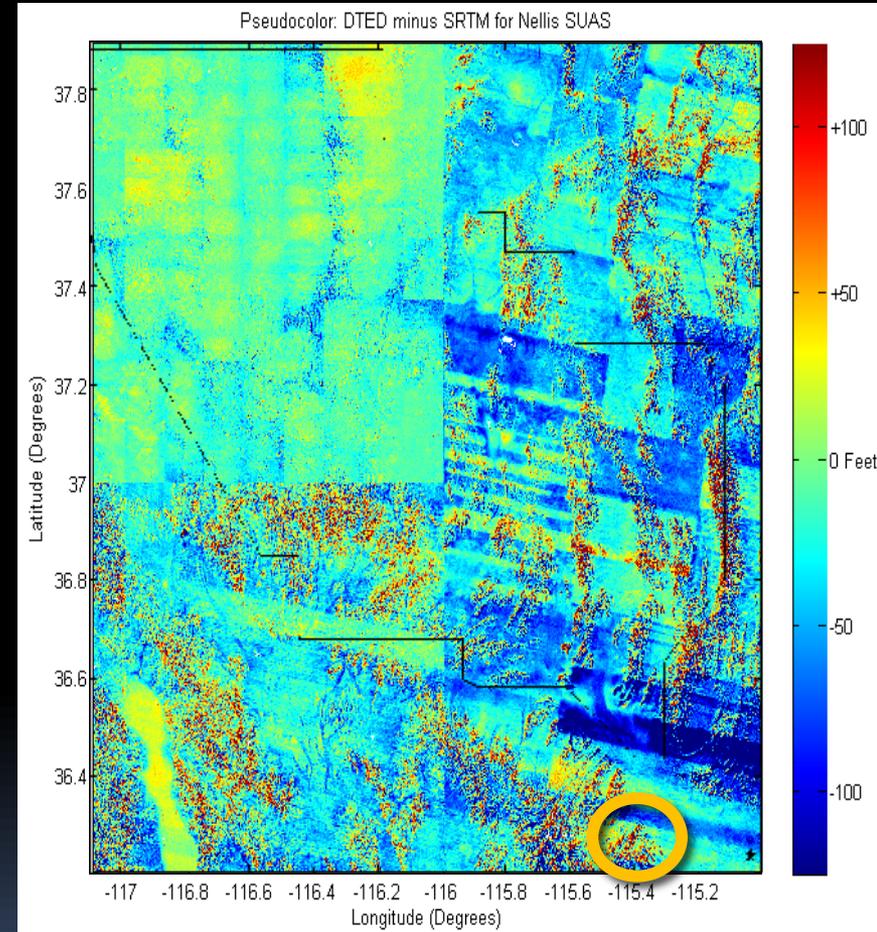
- **Required Level of Fidelity Varies**

- Horizontal vs Vertical = Mountainous flying vs Smooth
- Commercial
 - Only close to terrain near runway
- High-Performance
 - Good climb but poor turn
- Low-Performance
 - Poor climb but good turn



Digital Terrain Artifacts & Evaluation Techniques

- **New Products Available**
 - Shuttle Radar Topography Mission (**SRTM**)
 - Others
 - Different Products Give Different Elevations for Same Location

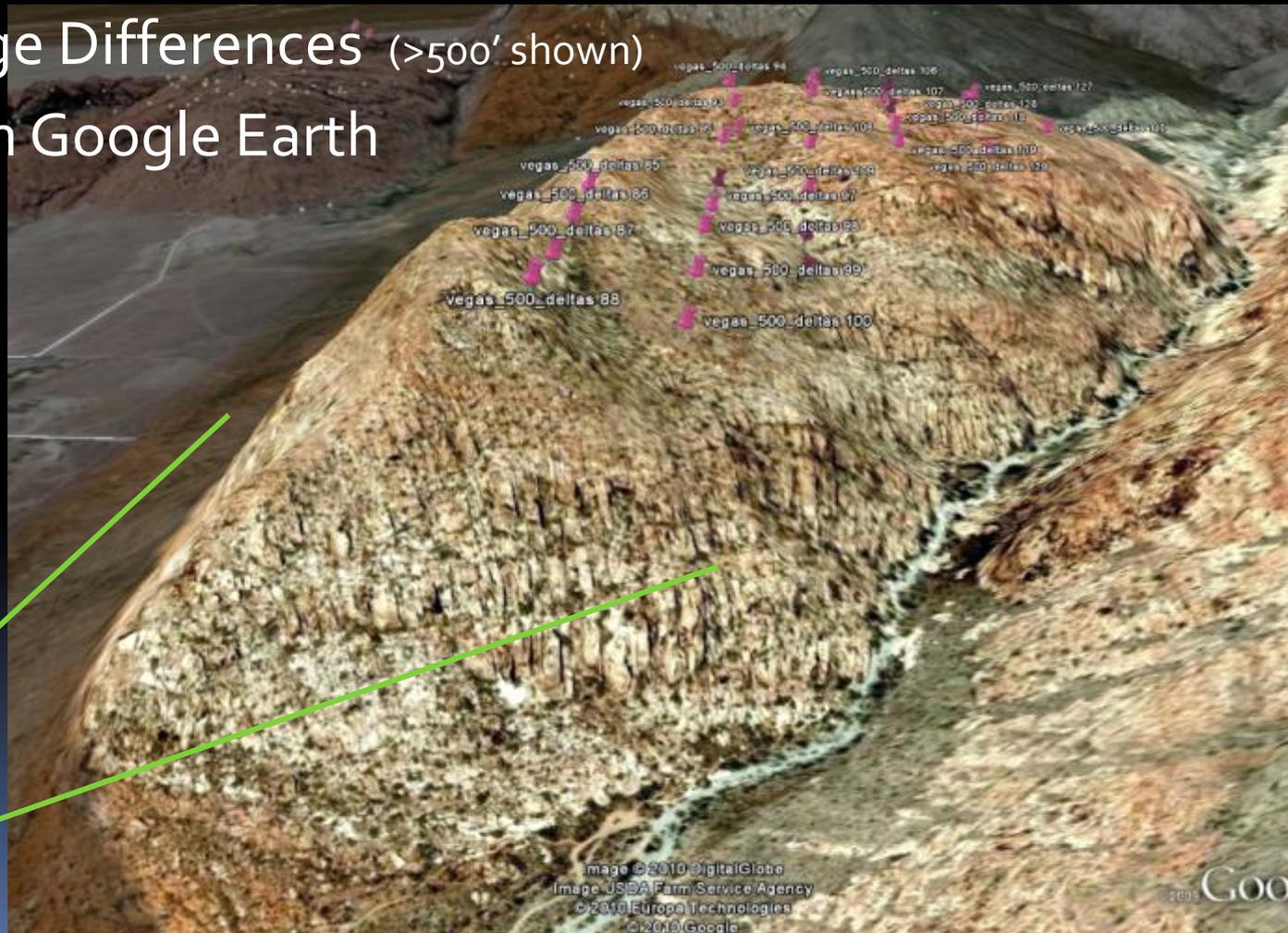
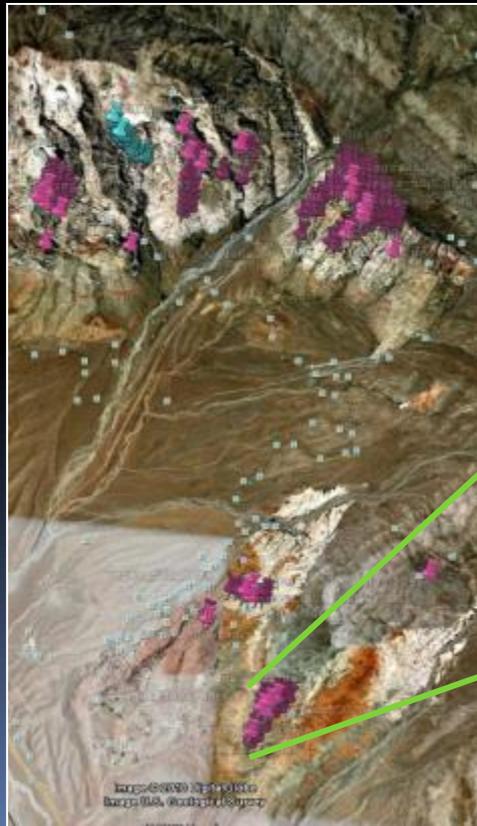


Both Products Can't be Right if they have Different Elevations

DTED Survey

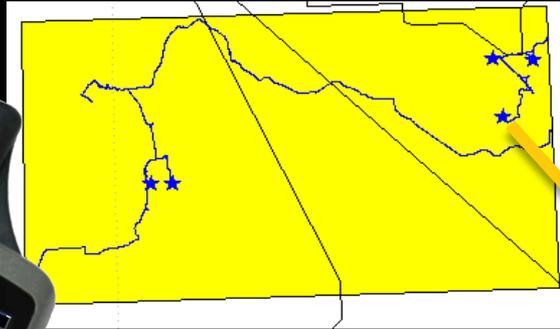
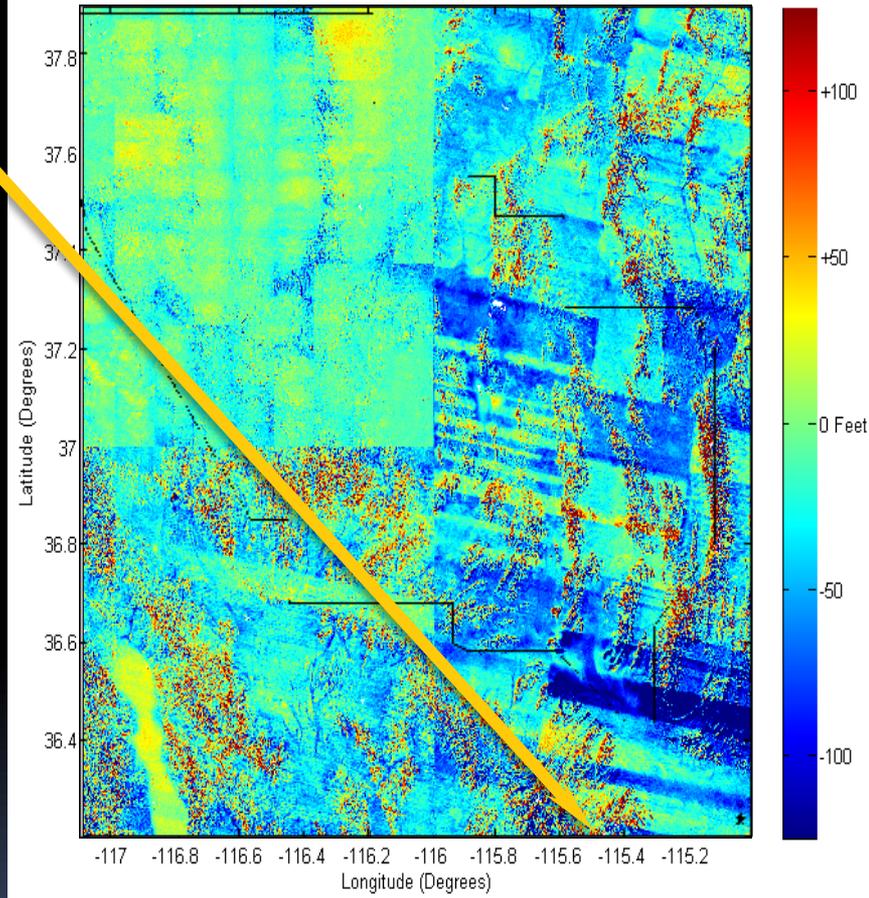
- Identify Points of Interest

- Flag Large Differences (>500' shown)
- Review in Google Earth



DTED Survey

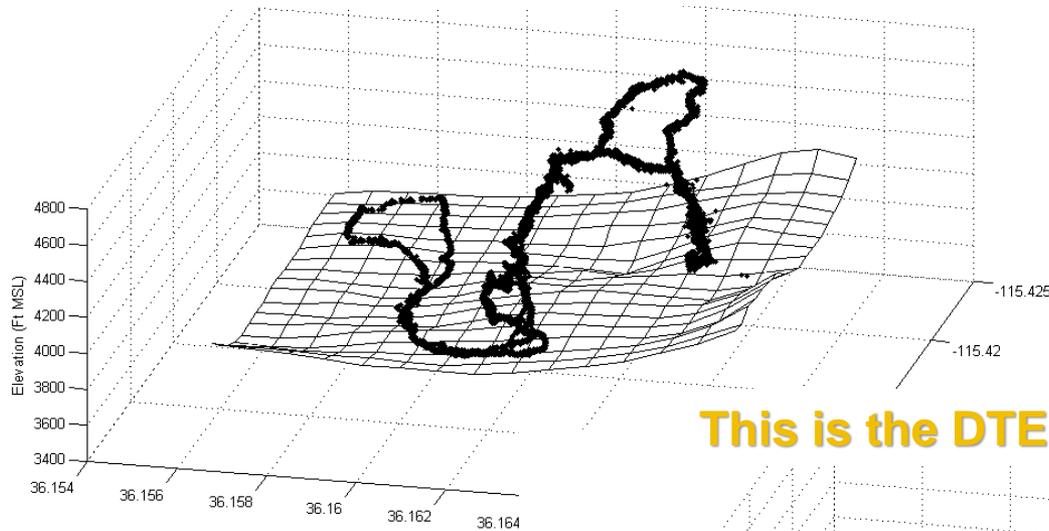
Pseudocolor. DTED minus SRTM for Nellis SUAS



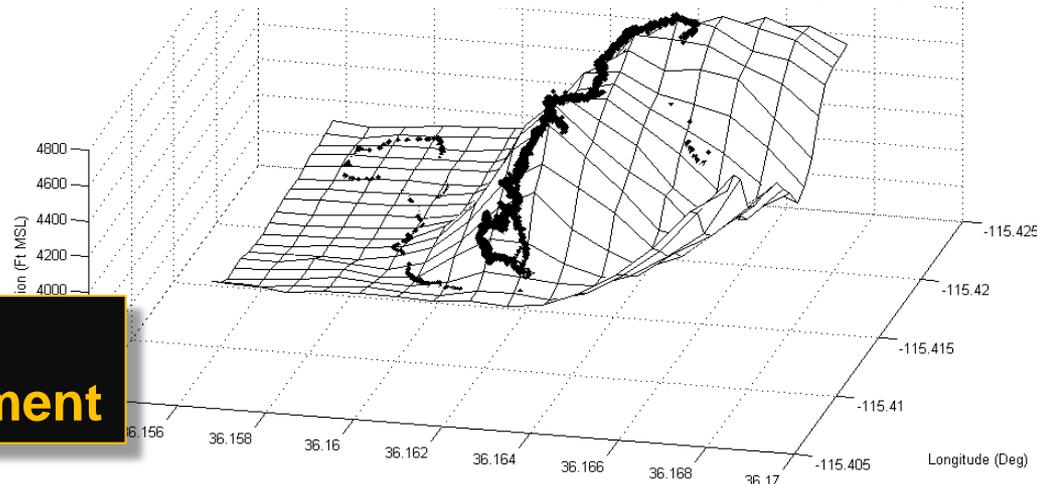
DTED Requirements

CANNOT be overcome with creative design

This is the DTED you are flying today



This is the DTED you will be flying



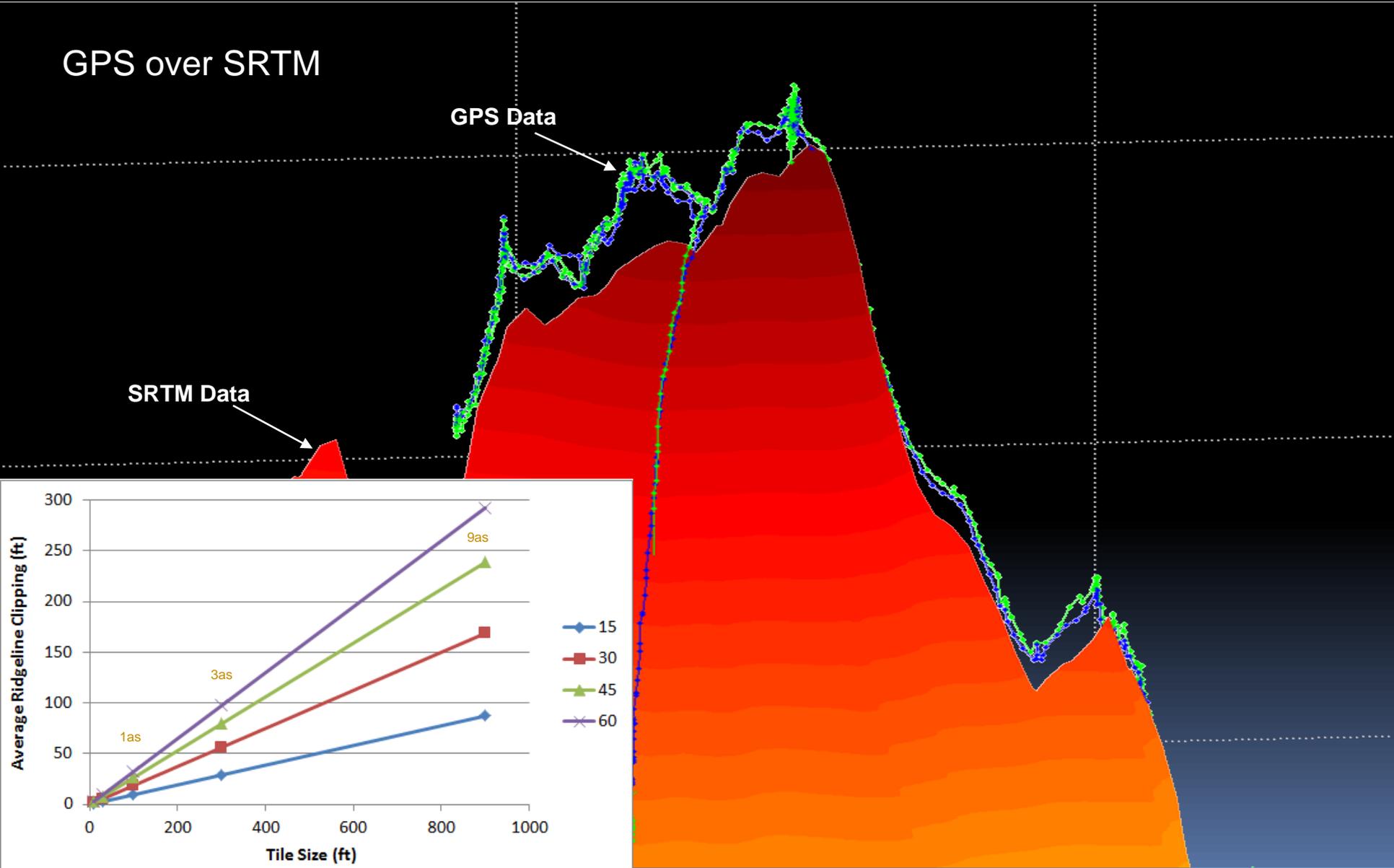
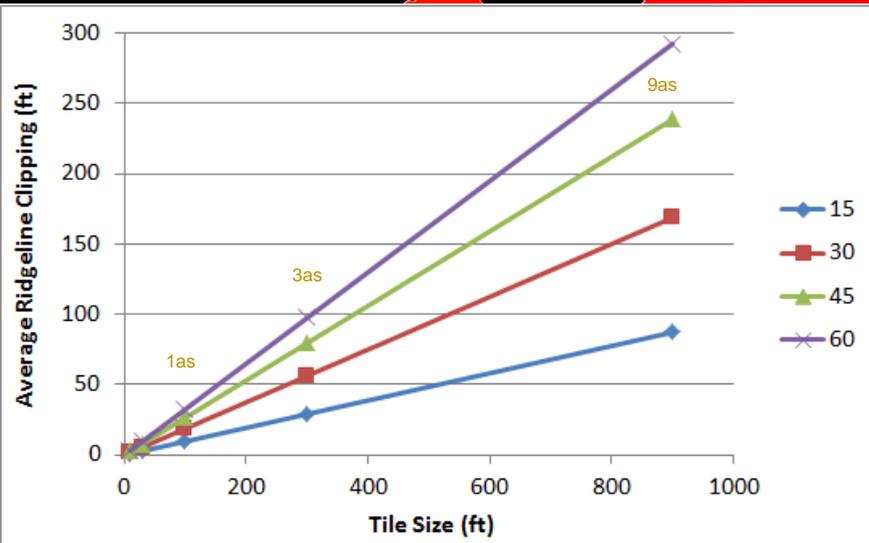
**DTED Management
Is an Ongoing Requirement**

Graphic of Ridgeline Effect

GPS over SRTM

GPS Data

SRTM Data



SRTM Background Scatter

- **SRTM DTED Error**
 - Edwards west range has particularly noisy SRTM data
 - 30' DTED uncertainty used in strafing mode

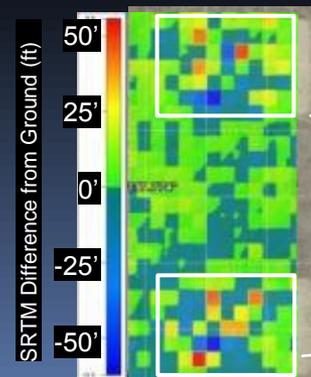
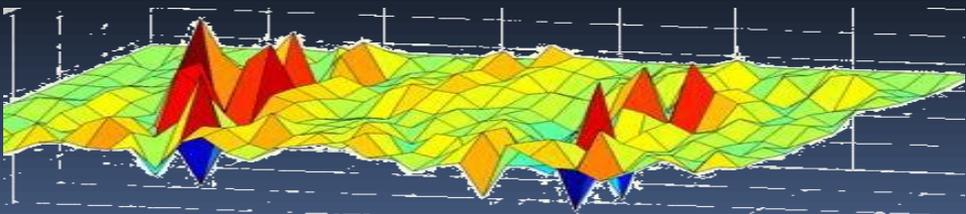
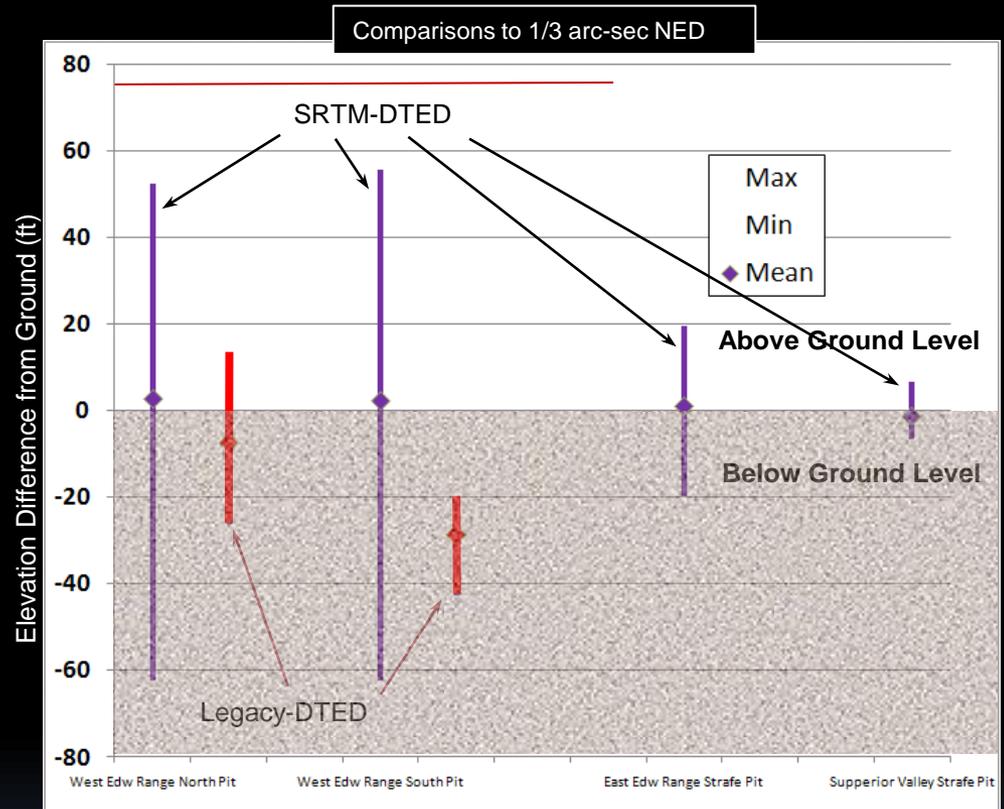
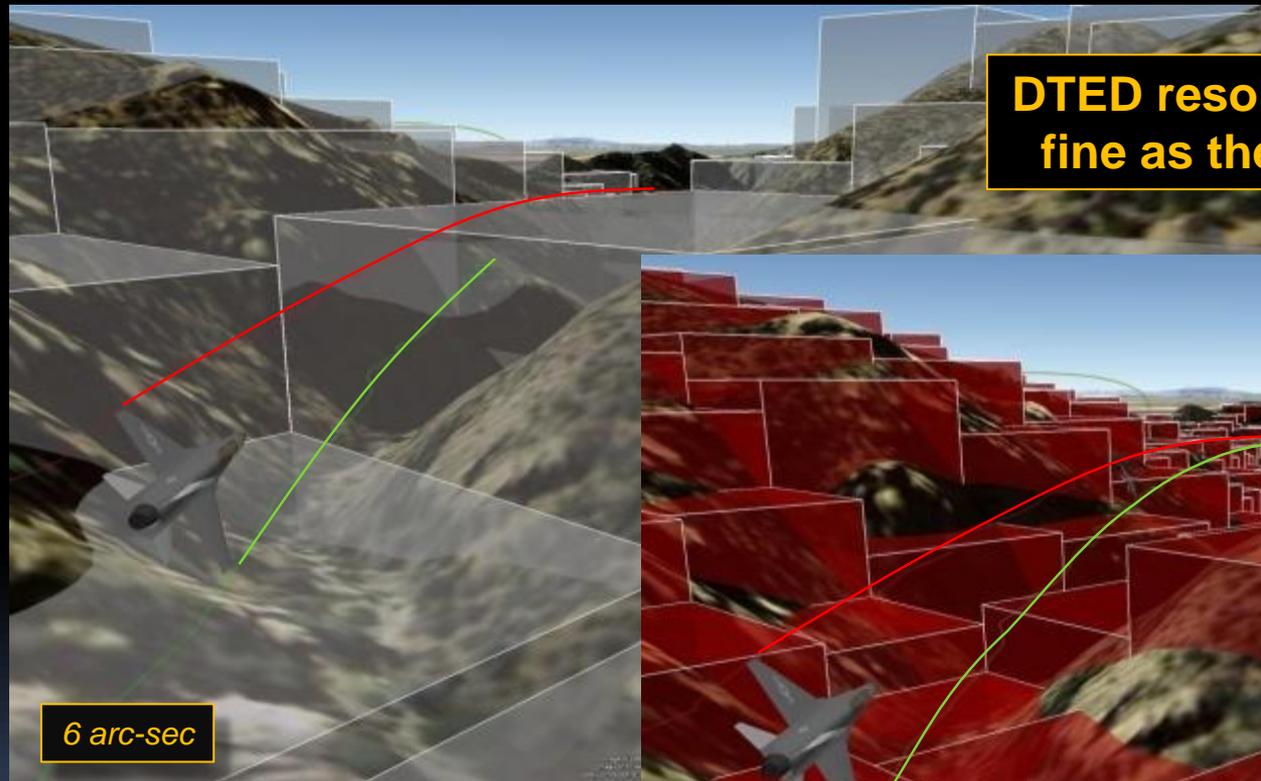
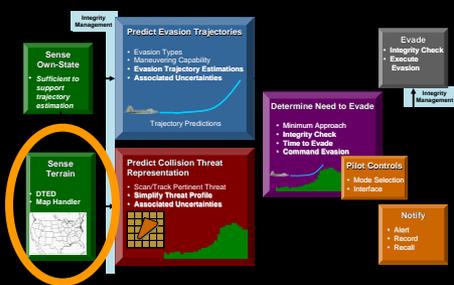


Illustration of high freq. noise in SRTM data over Edwards west range strafing pits

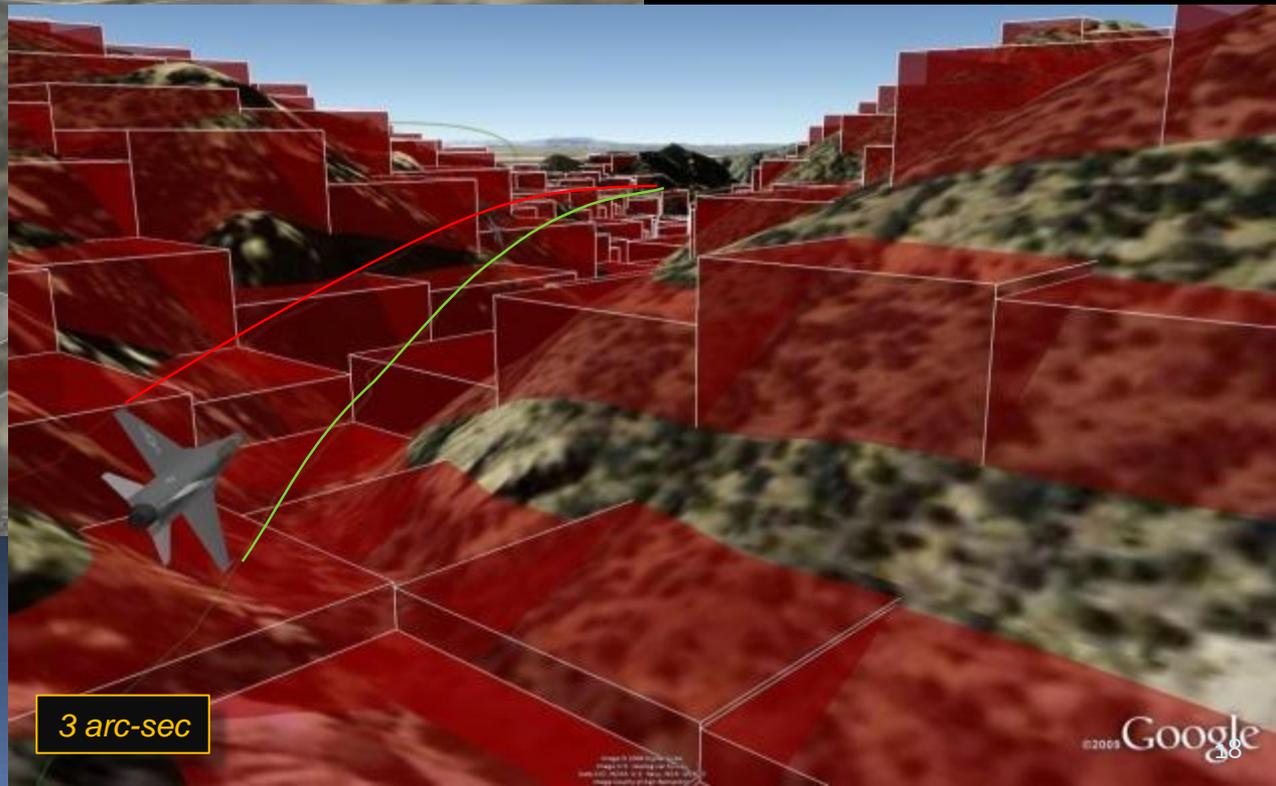
	North Pit	South Pit
Mean	2.86459 ft	2.402481 ft
StdDev	19.3191 ft	20.64314 ft
Min	-62.3352 ft	-62.3352 ft
Max	52.4928 ft	55.7736 ft

FRRP F-16

DTED Resolution Findings

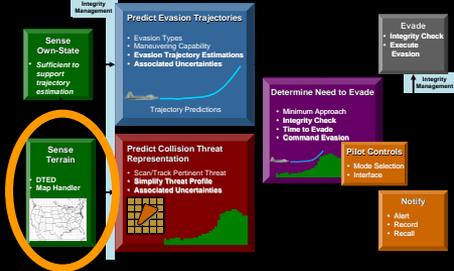


DTED resolution must be at least as fine as the altitude of the mission



Binary-Tree Tip-Tilt

(Patent Pending)



Original DTED

- **Tight control of errors induced by compression**
 - Easily Adjusts to Mission Requirements
 - Geographic Control of Errors
 - Re-Rasters at any Resolution
- **Rapid Decompression**



Compressed Terrain

- **Map Size**
 - Original DTED = 2.76 Gbytes
 - Binary-Tree Tip-Tilt = 328 Kbytes
 - 8415 : 1 Compression Ratio**
- **Current F-22 Plan**
 - 1000' Flight Globally
 - Landing at 1500 Bases
 - Upgrade Computers to allow Global Storage
- <200M for Entire Globe**

The logo for iCAS-GA features the text "iCAS-GA" in a bold, red, italicized font. It is positioned within a dark grey rectangular box. This box is part of a larger graphic consisting of a blue circle with a horizontal line passing through its center, extending to the left and right edges of the frame.

iCAS-GA



***WHAT IS NEXT?
IMPROVED COLLISION AVOIDANCE
SYSTEM***

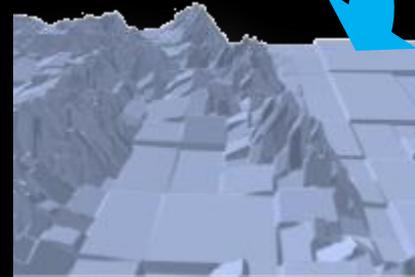
iCAS

- >300 Gb of Global Terrain Data

- To 180 Mb File

- Processed through a 108k algorithm

- Issuing 2 bits to direct a pilot when and where to avoid



iCAS is:





DISCUSSION

