Miniature Aerial Vehicles for Traffic Management and Transportation Infrastructure Security

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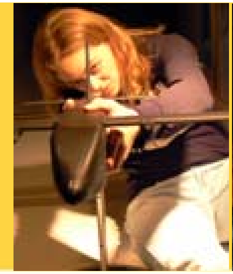
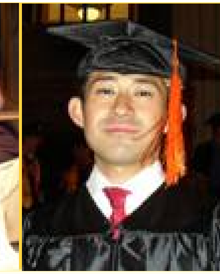
Aerospace Engineering and Mechanics

A department of the Institute of Technology at the University of Minnesota





- Strives for excellence: in education, outreach, and pioneering research.
- Award-winning, internationally-recognized faculty with expertise in three primary areas:
  Aerospace Systems, Fluid Mechanics, and Solid Mechanics.
- 17 faculty
- 300 undergraduates and 85 graduate students
- Institute of Technology has 4,445 undergraduates, 2,450 graduate students, and about 400 faculty across 12 departments.

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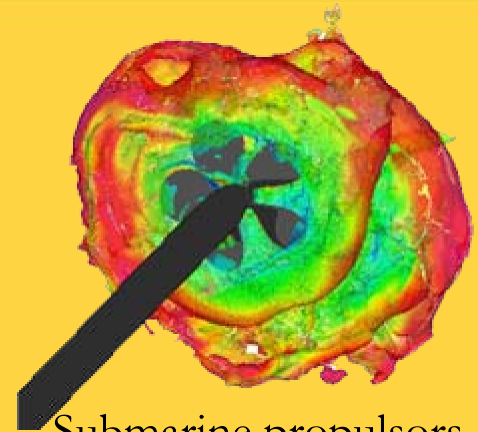
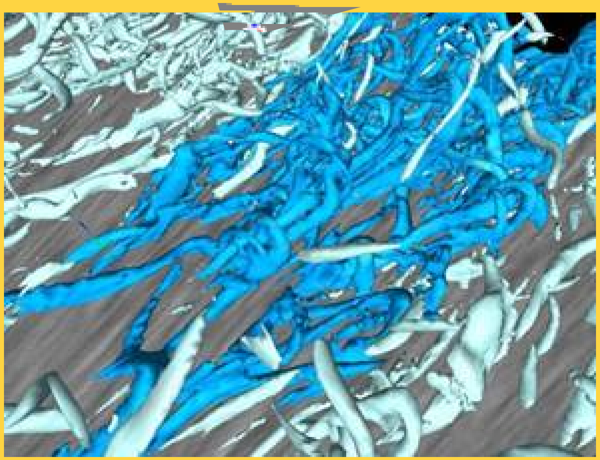
Inlet for Mach 10 Scramjet



Submarine propulsors



Visualizing complex structure in turbulent boundary layers

Water exposed to airflow at Mach 3.0

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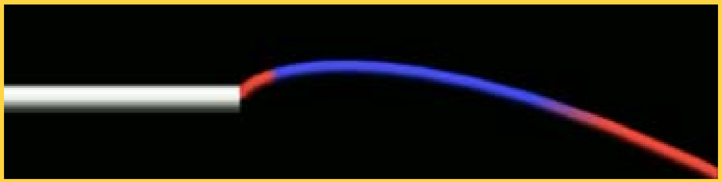
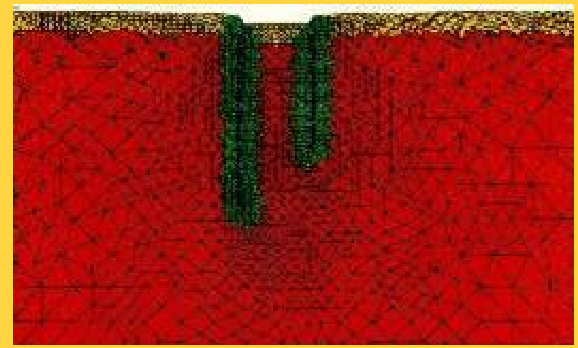
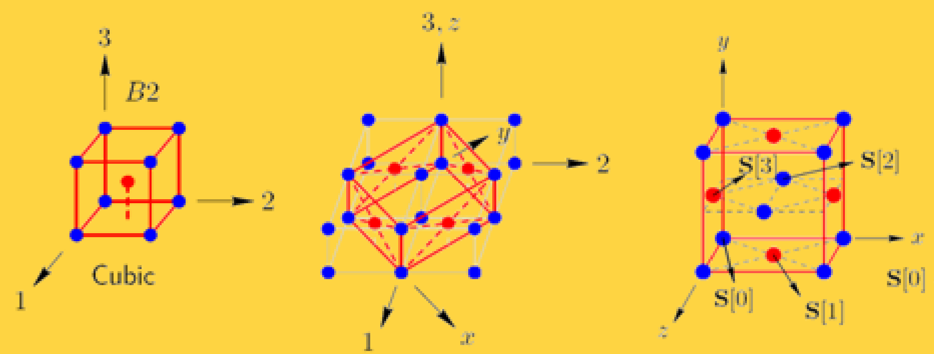


Exploring the Bonded Punch problem



The Quasicontinuum Method

Single Crystal Crack-Tip Plasticity



Martensitic solid-to-solid transformations

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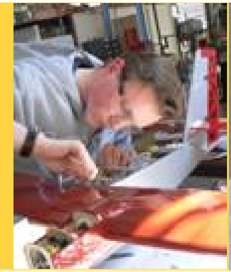
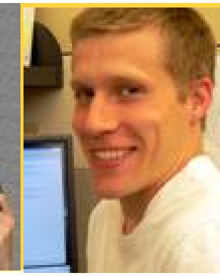
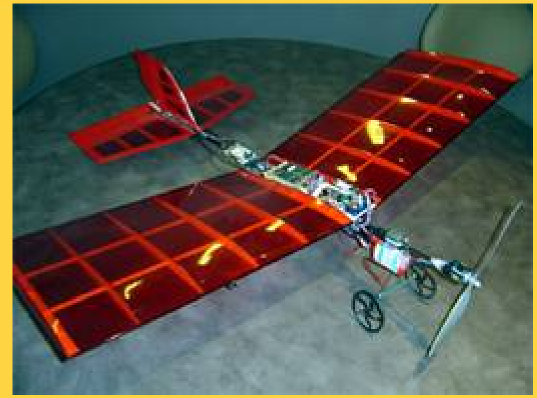
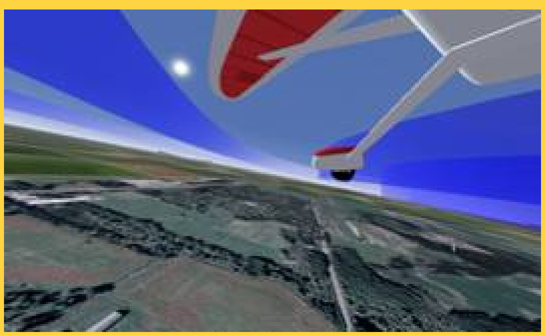




High Integrity Navigation



Advanced UAV flight systems



Synthetic Visual Displays

Supercavitation experimental research

UAV/RPV Research at U of MN

- Project: “Remotely Piloted Aerial Vehicles for Traffic Management and Infrastructure Security Applications”

- Research Sponsors:
  - Intelligent Transportation Systems (ITS) Institute, University of Minnesota.
  - Minnesota Department of Transportation (MnDOT).
  - SRF Consulting.

- Project Objectives:
  - Explore ITS capabilities enabled by Uninhabited Aerial Vehicles (UAV) and Remotely Piloted Vehicles (RPV).
  - Develop “turn-key” sensors and systems which enable their use ITS applications.
    - **“Dual-use Technologies”**: Relevant to homeland security applications.
  - Explore regulatory issues associated with operating them for these ITS applications.

ITS Applications: Classification

- Potential missions for UAV/RPV in ITS applications can be divided into two broad groups:
  - Strategic
    - Operations where the aerial vehicle is expected to traverse or cover a large geographical area.
    - Operation *mostly* in response to pre-planned events.
    - Vehicle must have some level of autonomy.
  - Tactical
    - Operations in and around a small geographical area.
    - Operation can be in response to planned or unplanned events.
    - Tele-operation of the vehicle is possible.
- Our focus is on tactical operations.

Example of Tactical Operations

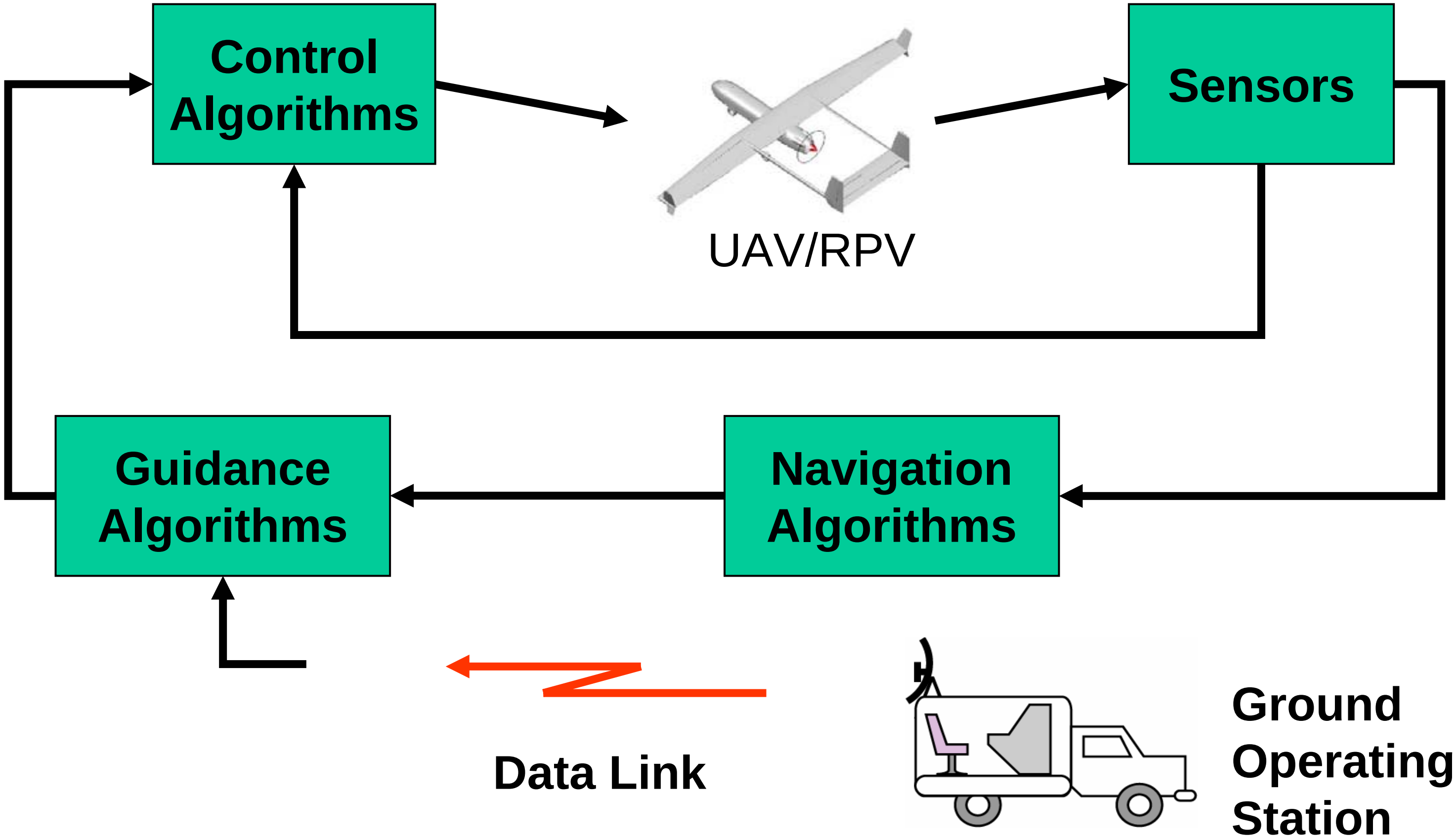
- Recent examples: Hurricane Katrina recovery effort
  - 5 *Silver Fox* UAVs used during hurricane Katrina search rescue operation.
  - Remotely piloted helicopters used for structural inspection
- Planned future uses:
  - Evacuation coordination
  - Nodes for communication & navigation networks
  - Delivery of emergency supplies.
  - Intelligent Transportation Systems (ITS) sensor platforms (e.g. Utah Highway Patrol *Bergen Observer* used for accident scene management)

Silver Fox

Applications, Regulations & Technology

- The use of RPV in support of tactical ITS or law enforcement operations is practical and possible in the current regulatory environment.
- Regulatory issues associated with operation in the National Airspace System make strategic UAV/RPV operations much more challenging.
- Many of the *off-the-shelf* vehicle guidance, navigation and control solutions MAY NOT have the performance required to support these applications:
  - Attitude determination systems.
  - Navigation.

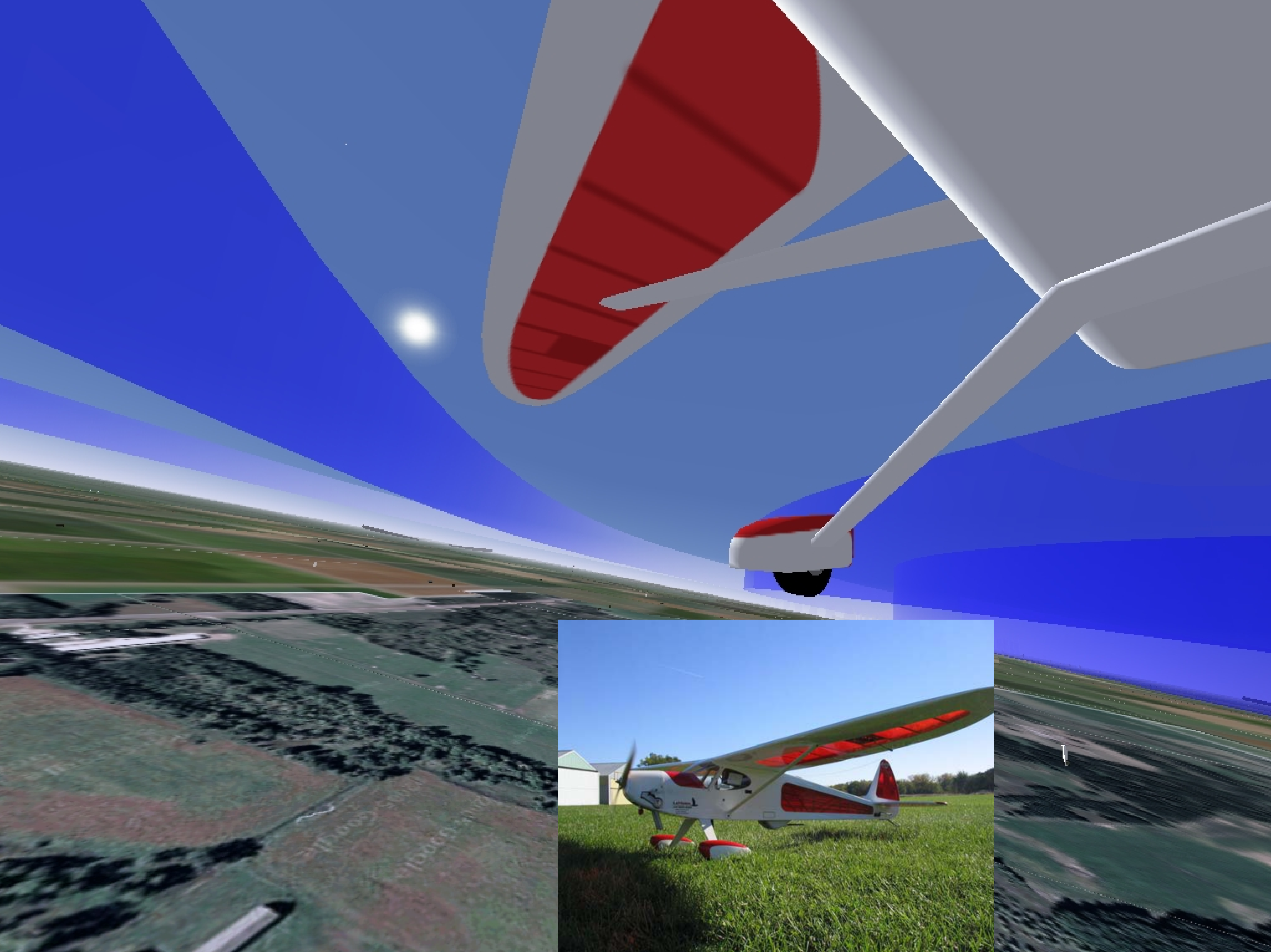
Guidance Navigation & Control

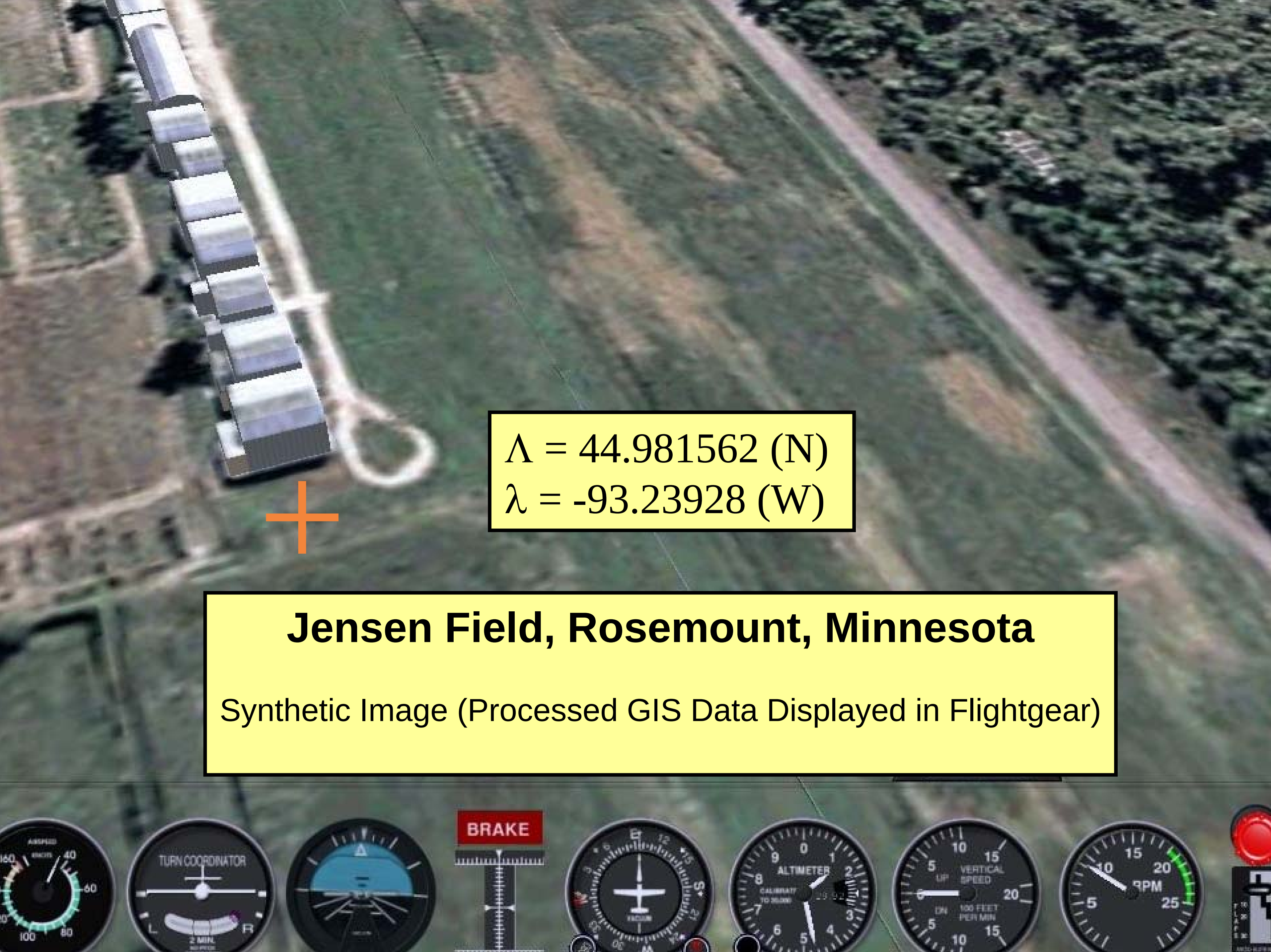


- **Currently, our UAV/RPV work does NOT involve sensor payload design.**

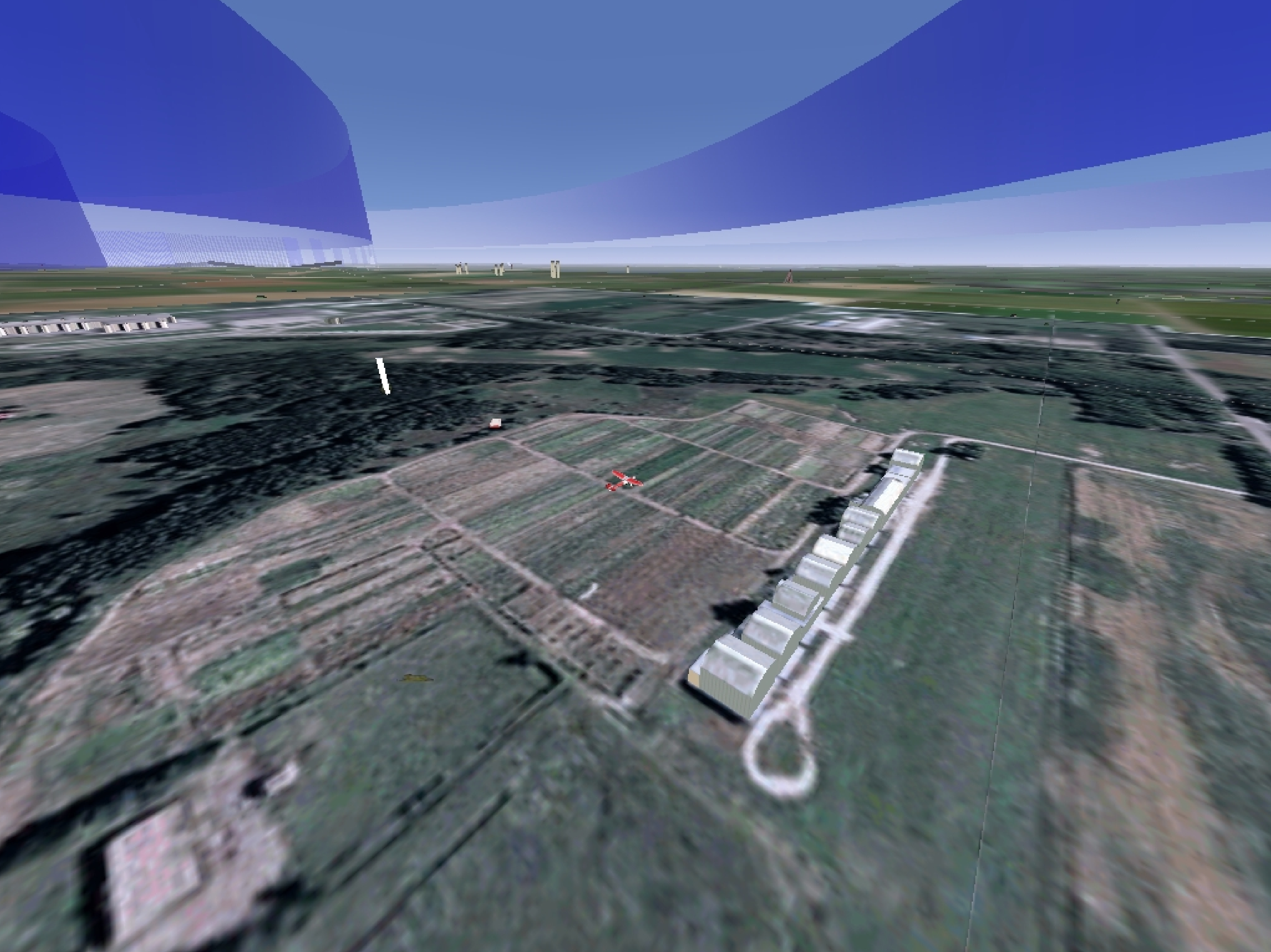
VIDEO

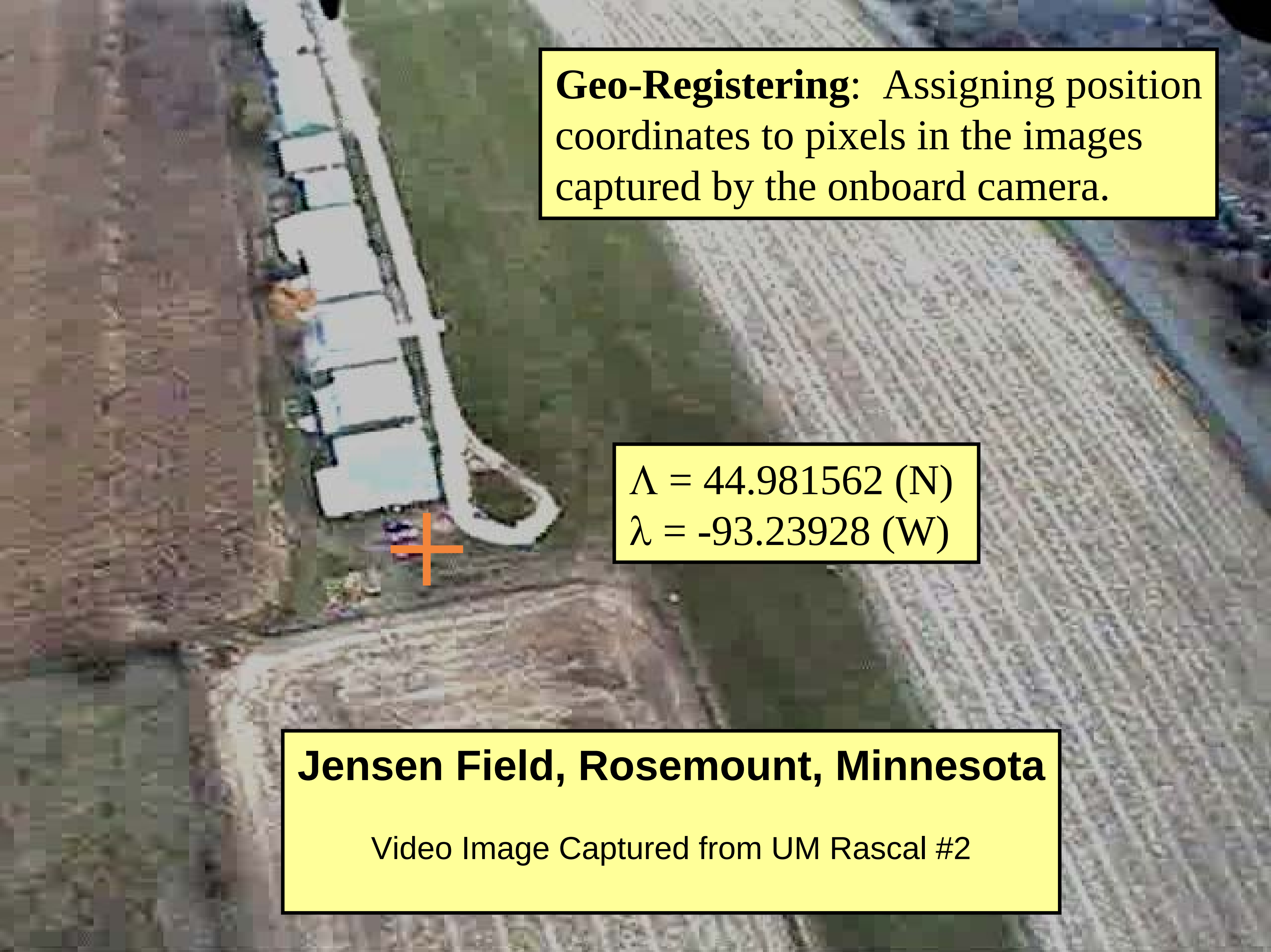
http://www.aem.umn.edu/people/gebre/UAV2/Big/chapt1-divx6.avi





Λ = 44.981562 (N)
λ = -93.23928 (W)
Jensen Field, Rosemount, Minnesota
Synthetic Image (Processed GIS Data Displayed in Flightgear)
BRAKE
TURN COORDINATOR
ALTIMETER
VERTICAL SPEED
RPM





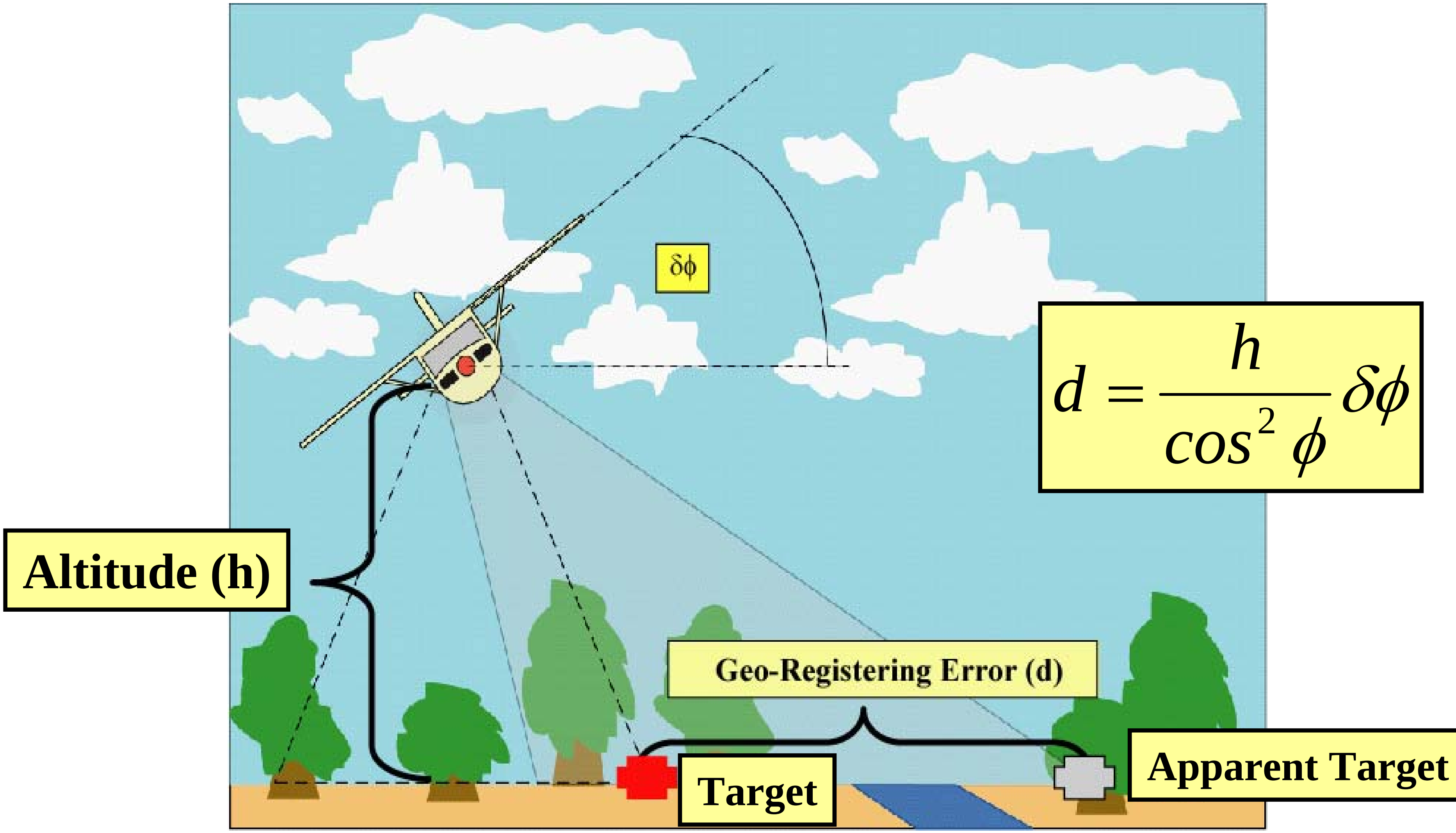
Geo-Registering: Assigning position coordinates to pixels in the images captured by the onboard camera.

Λ = 44.981562 (N)
λ = -93.23928 (W)

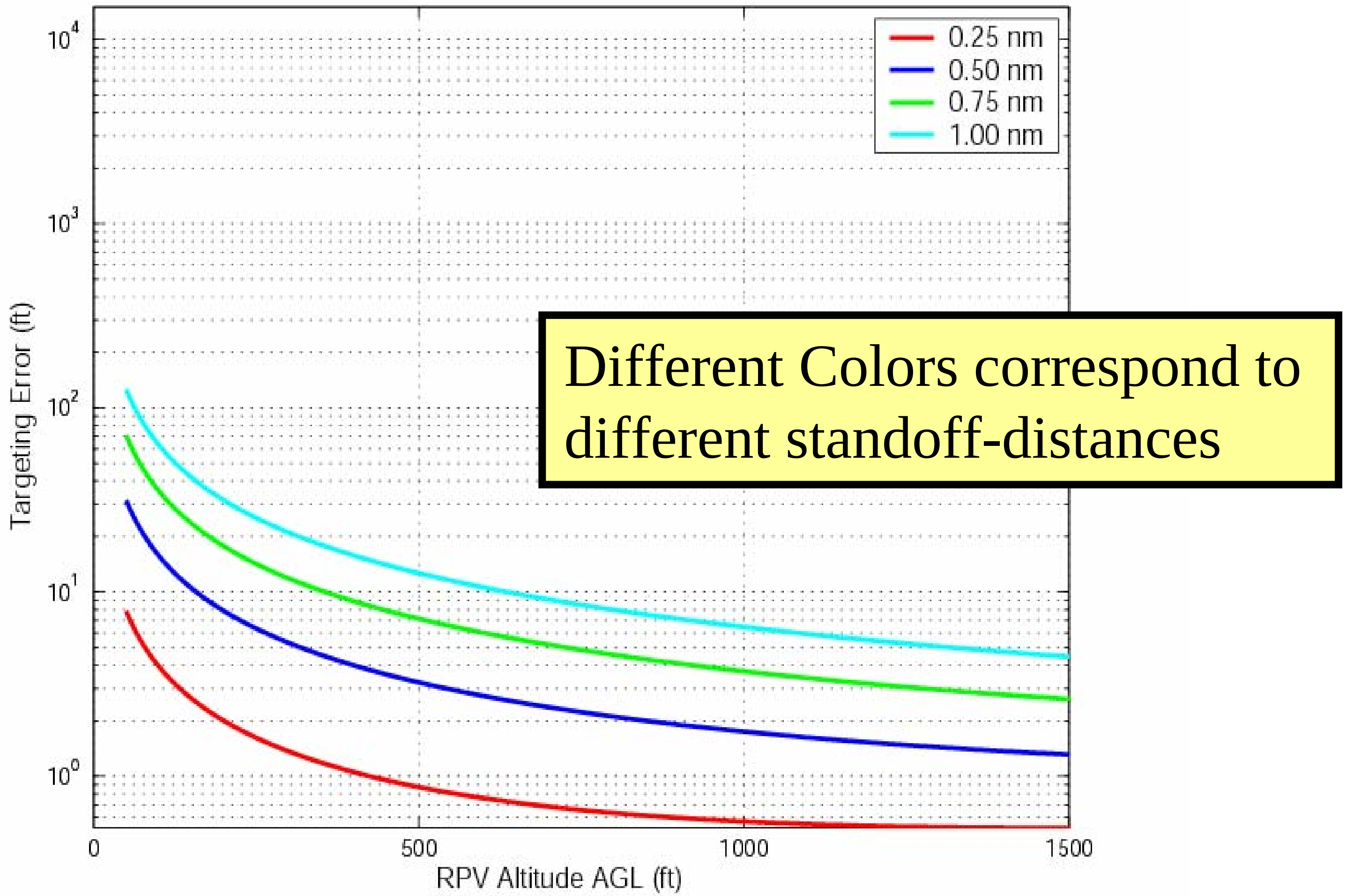
Jensen Field, Rosemount, Minnesota

Video Image Captured from UM Rascal #2

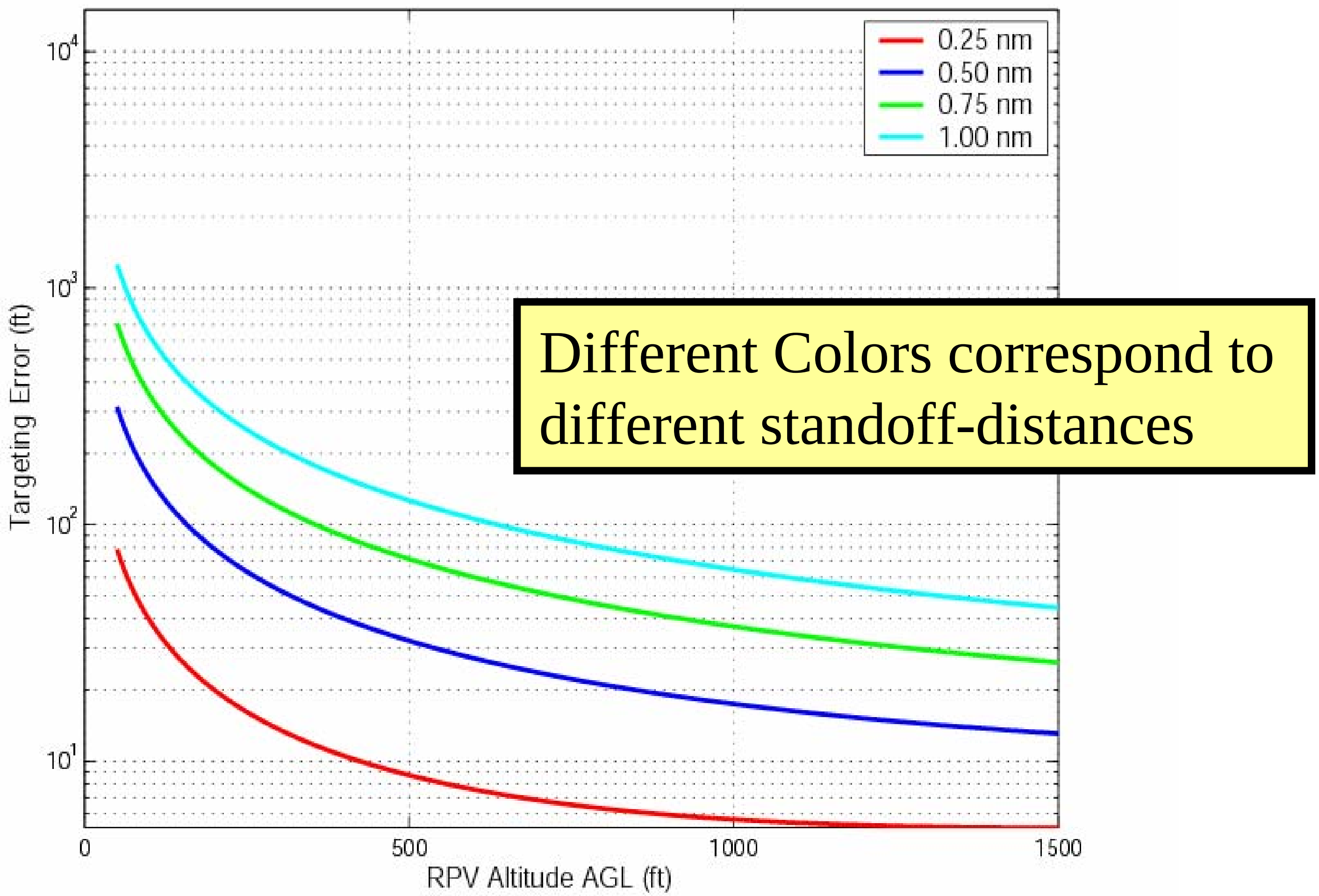
One Dimensional Error Analysis



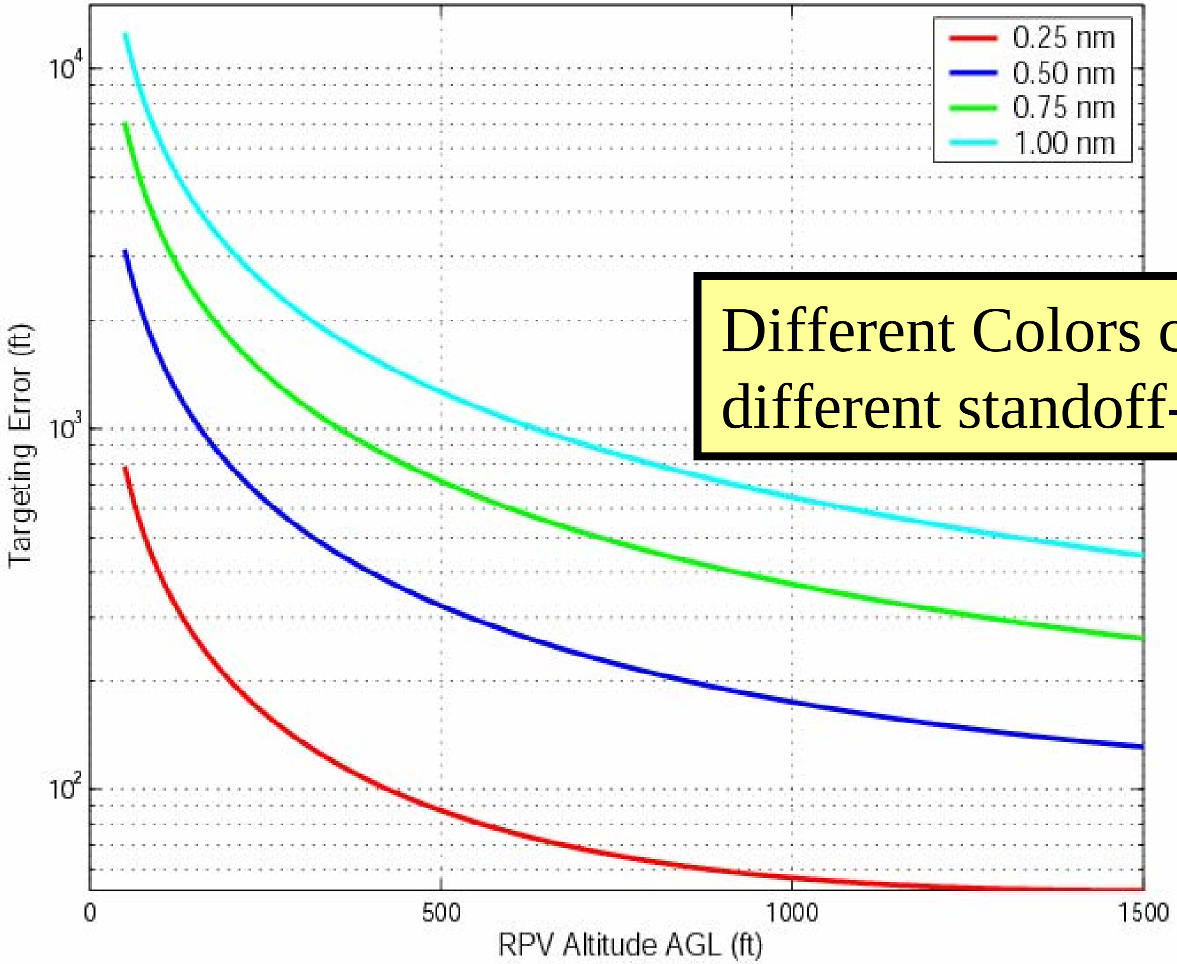
Effect of a 0.01^0 Pointing/Attitude Error



Effect of a 0.1^0 Attitude/Pointing Error



Effect of a 1^0 Attitude/Pointing Error

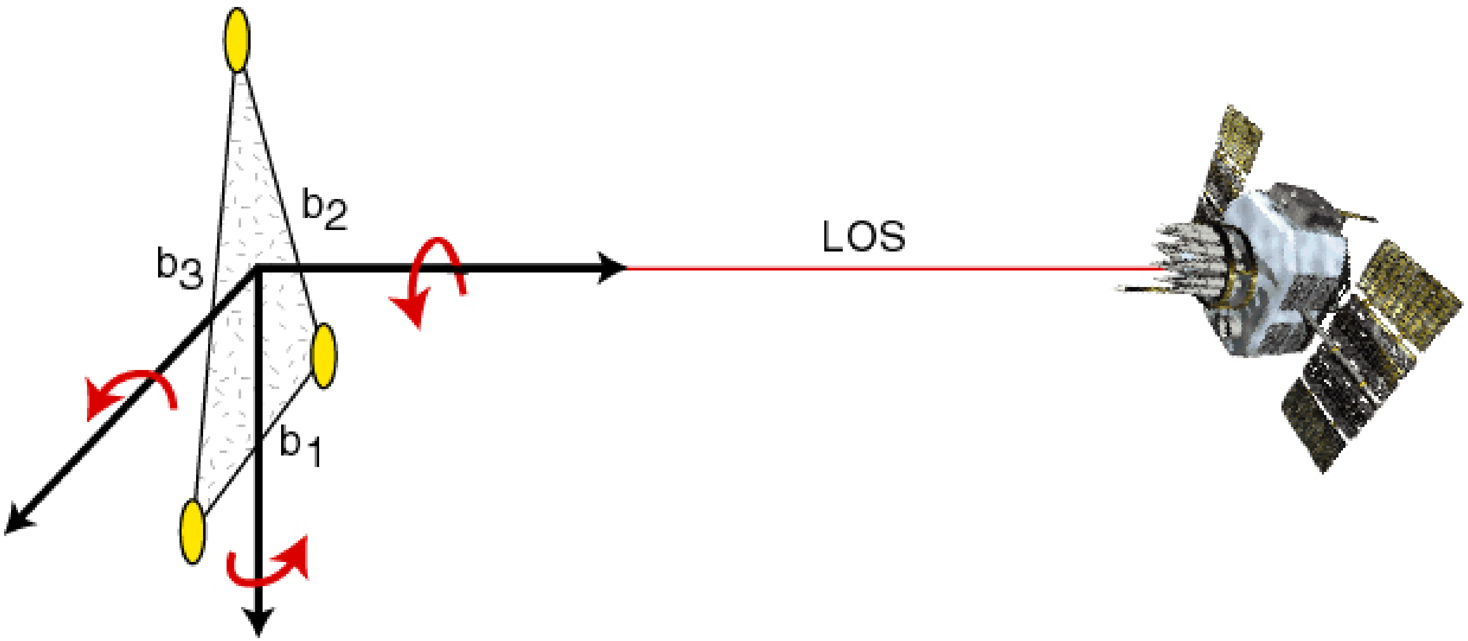


Different Colors correspond to different standoff-distances

Navigation and Attitude Sensors

- Position and Velocity Estimation
  - GPS augmented by the FAA's Wide Area Augmentation System (WAAS).
  - Must ensure that the navigation solution has the integrity required for the application on hand.
- Attitude Estimation
  - 1st Generation: MIDG II GPS/INS from Microbotics Inc.
    - Triad of magnetometers, triad of accelerometers, triad of rate gyros aided by GPS.
    - Cannot achieve required accuracy in all potential maneuvers
  - 2nd Generation: Multi-antenna GPS attitude system
    - Triad of Novatel Superstar II receivers
    - Modified to run off a common oscillator

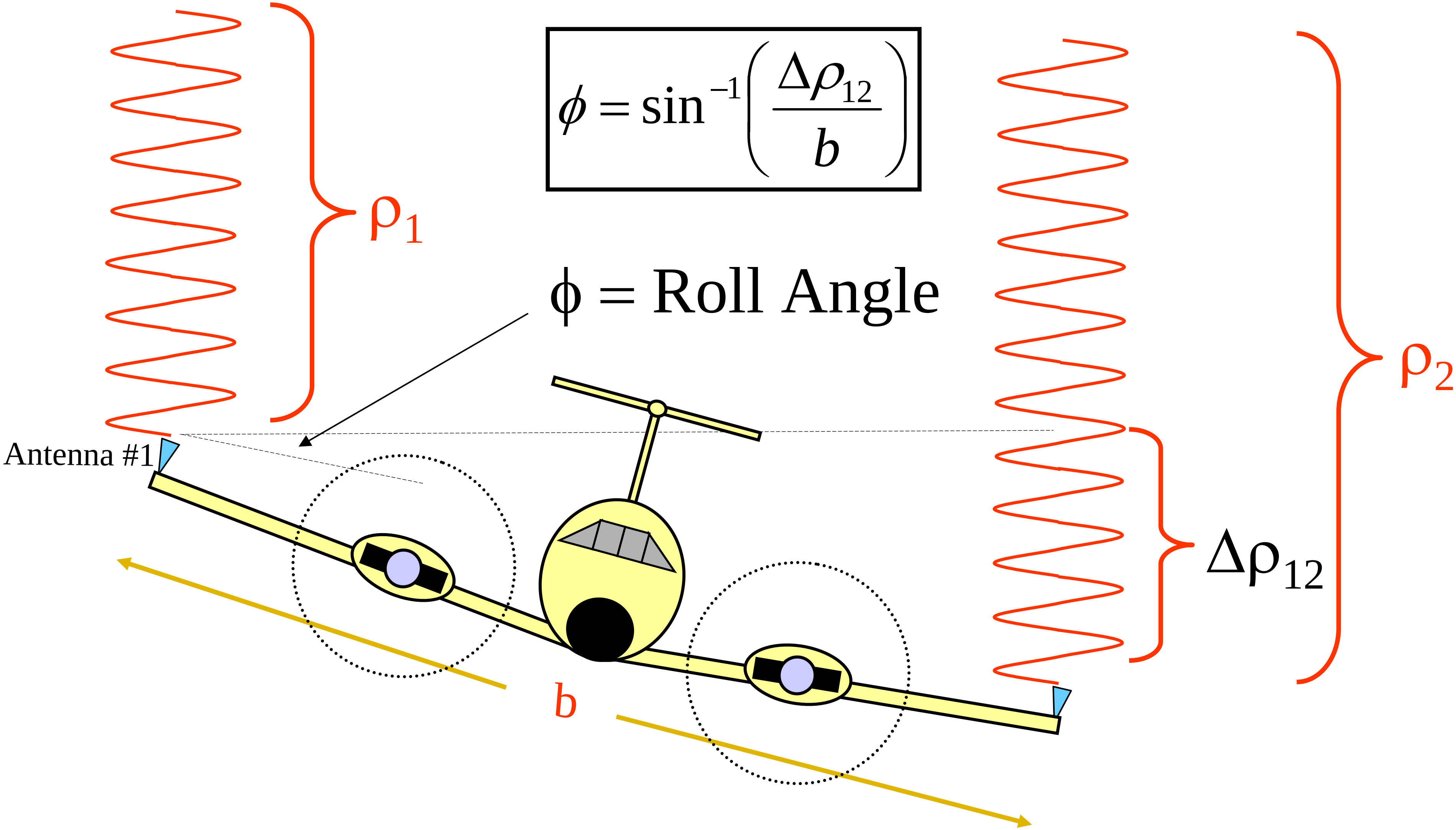
GPS Based Attitude Determination



- A planar array of 3 or more GPS antennas can be arranged so that they define a plane.
- Orientation of the plane can be determined by knowing the difference in range from the antennas to GPS satellites

GPS Attitude Determination

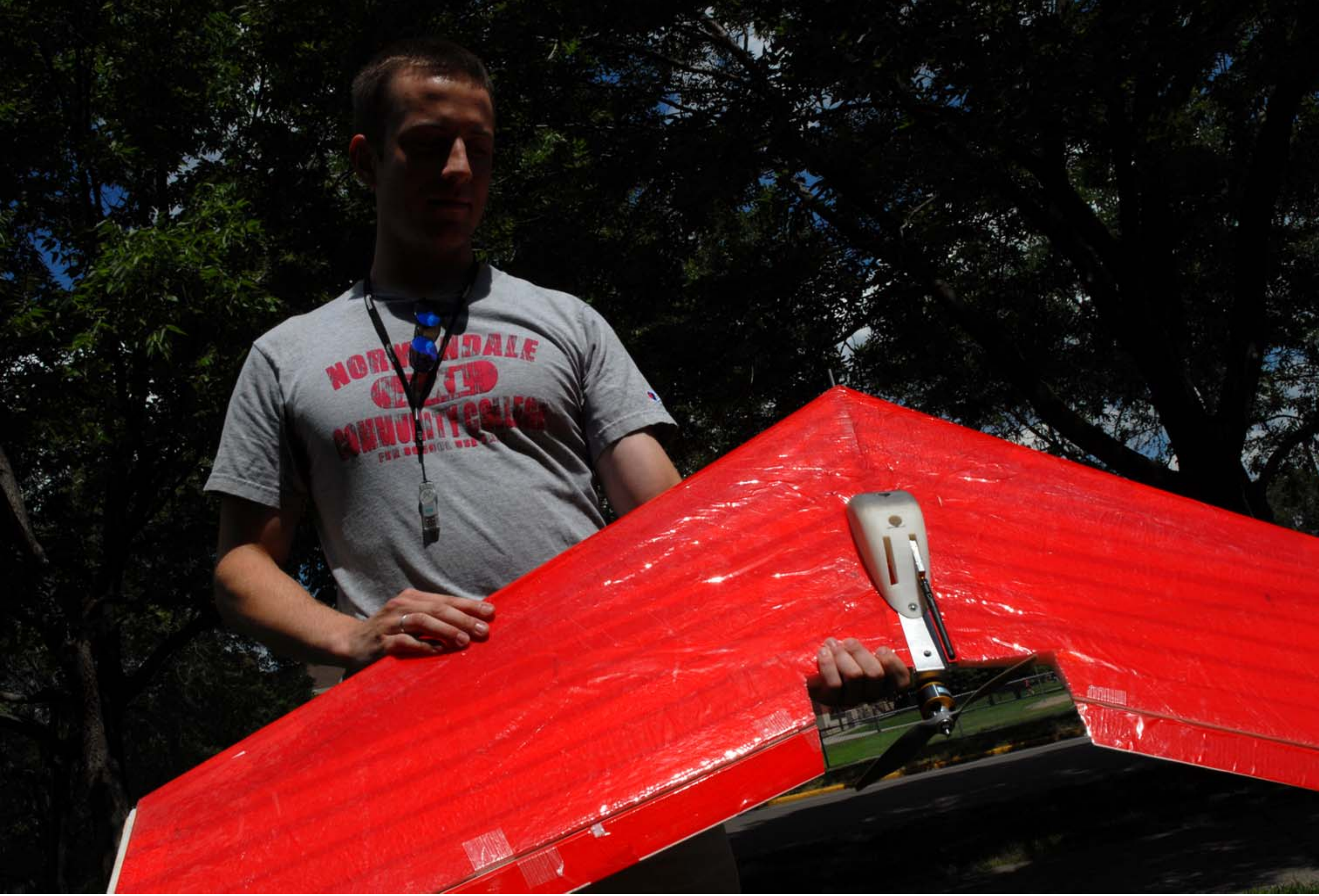
$$\phi = \sin^{-1}\left(\frac{\Delta\rho_{12}}{b}\right)$$

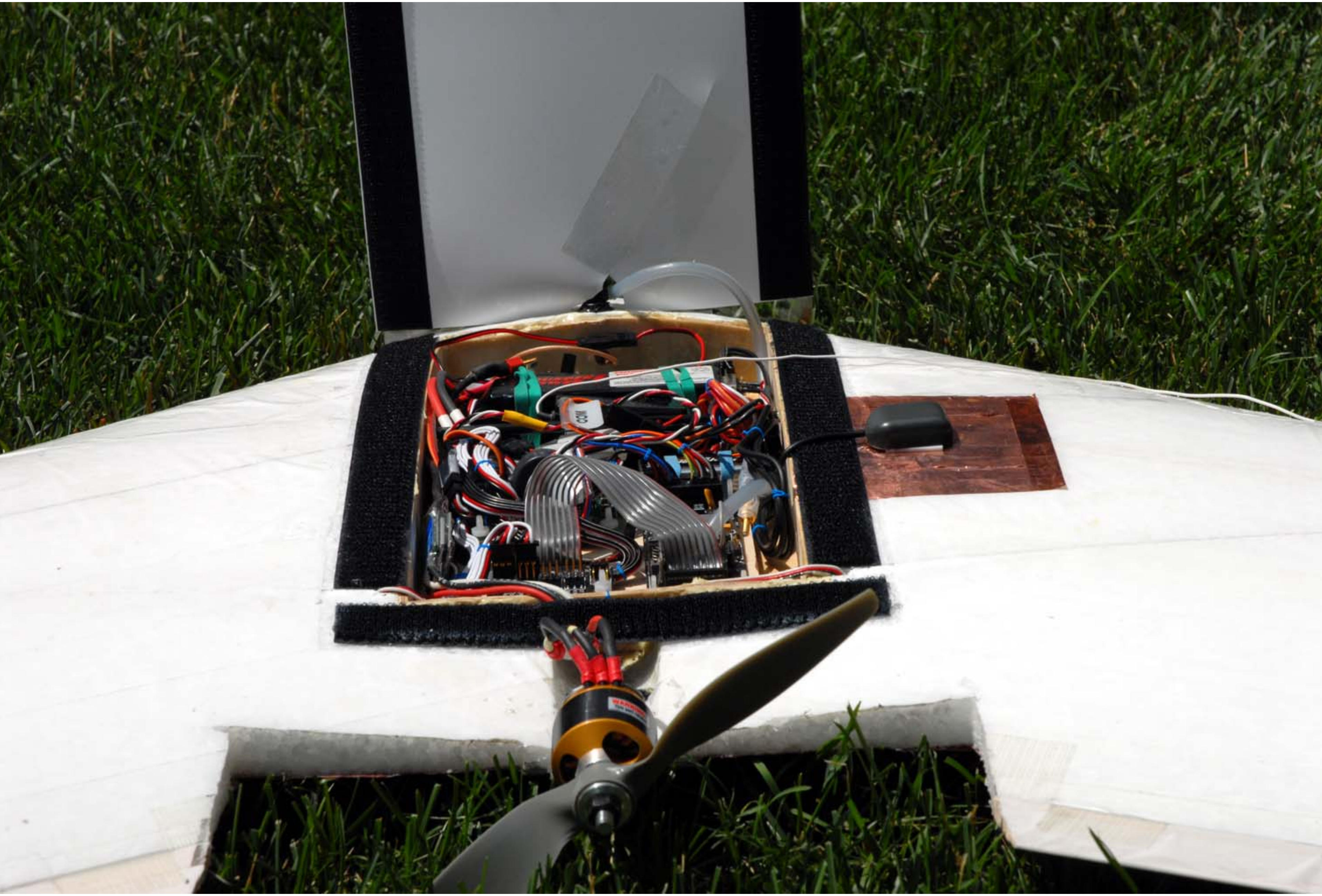


GPS Attitude Determination System

- Carrier Phase Differential GPS Attitude determination system.
- Three antennas in a short baseline configuration
- Three Novatel SuperStar GPS receivers:
  - WAAS capable
  - Differentially corrected position and accurate velocity output
- Receivers have been modified to run off the same oscillator
  - Makes attitude algorithm more robust
  - Makes attitude algorithm more accurate


MINNESOTA
M





Summary and Conclusions

- The use of RPV in support of tactical ITS or law enforcement operations is practical and possible in the current regulatory environment.
- Regulatory issues associated with operation in the National Airspace System make strategic UAV/RPV operations much more challenging.
- Many attitude determination solutions which appear or are advertised to be off-the-shelf may not be quite suitable for UAV/RPV applications

Acknowledgements

- We acknowledge the support of the following organizations:
  - ITS Institute at the University of Minnesota
  - Minnesota Department of Transportation
  - SRF Consulting
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  - Troy Wigton
  - Romeo Ahohe