U.S. ARMY COMBAT CAPABILITIES DEVELOPMENT COMMAND ARMY RESEARCH LABORATORY

ARL Research Efforts

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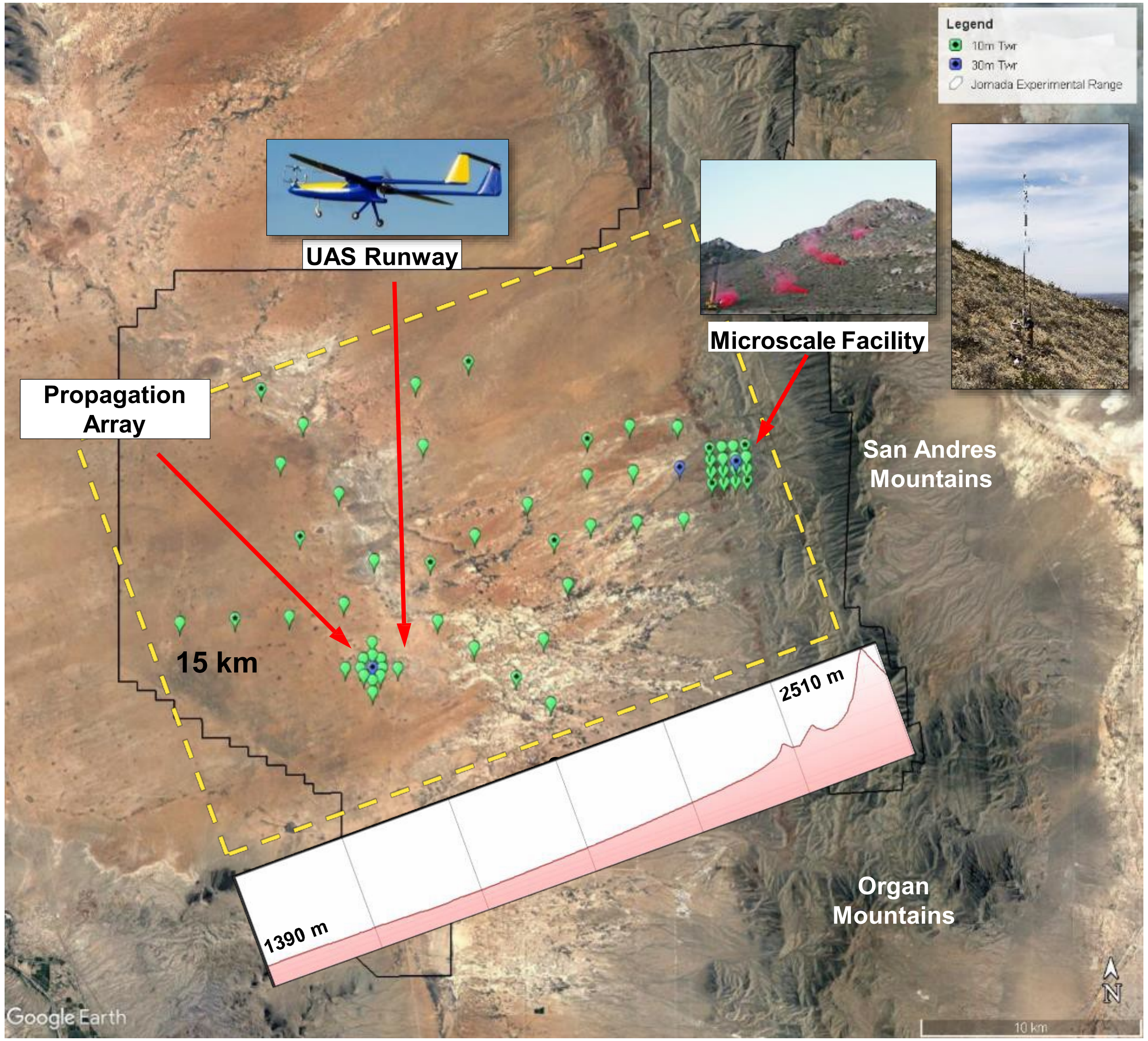
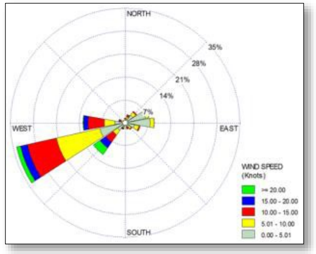
METEOROLOGICAL SENSOR ARRAY (MSA)



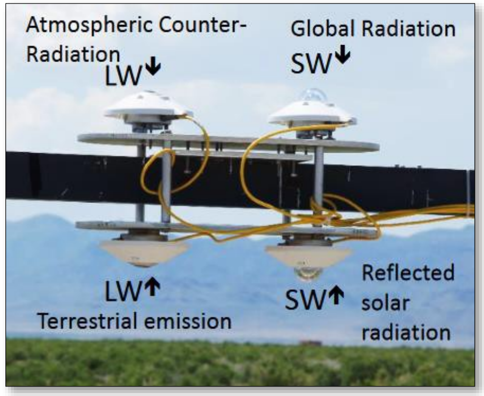


Dominant Wind Direction

Las Cruces, NM

MSA – SURFACE ENERGY BUDGET

Net Radiometer



Dr. Sebastian Hoch, U. Utah

Sonic Anemometer

Gill Instruments

+

LI-COR

LI-COR®

= Sensible (H) & Latent (L_v�) Heat Flux

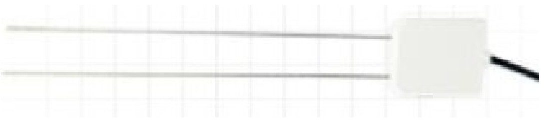
Soil Thermal Property

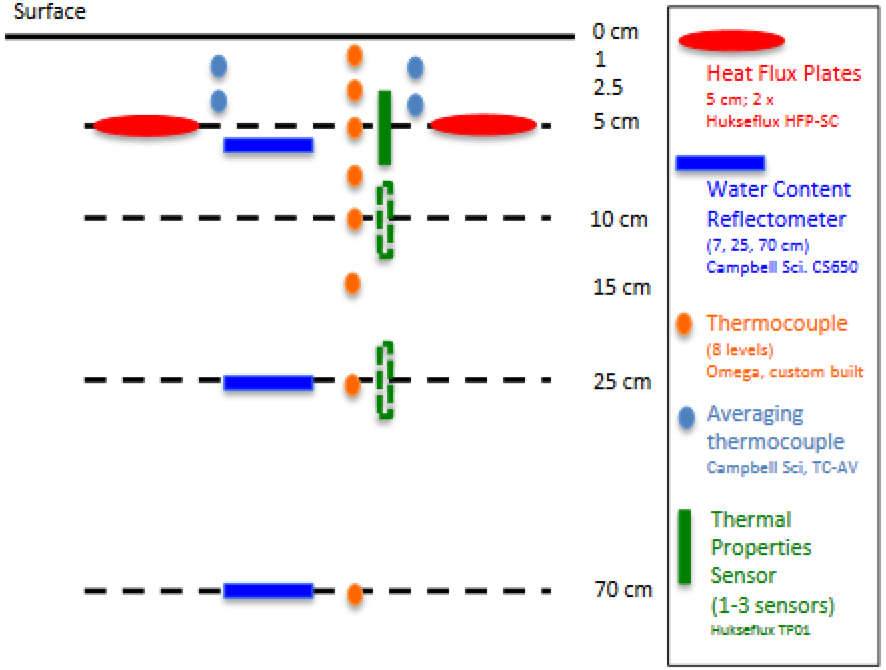
© Hukseflux thermal sensors

Heat Flux Plate

© Hukseflux thermal sensors

Water Content Reflectometer



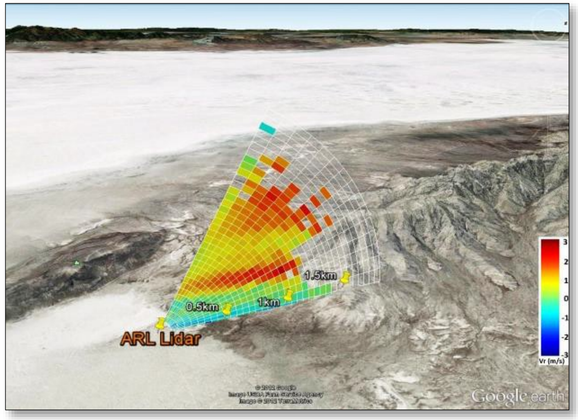


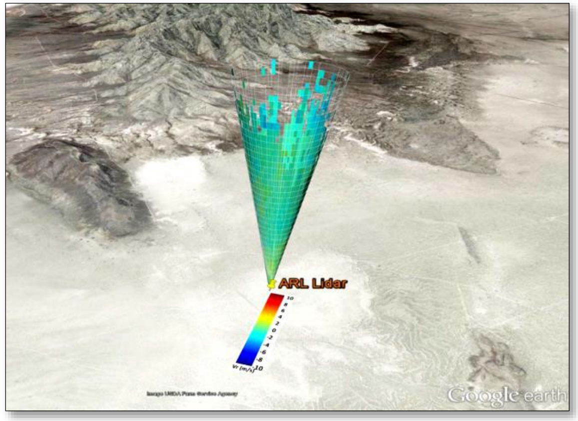
Dr. Sebastian Hoch, U. Utah

MSA – REMOTE SENSING

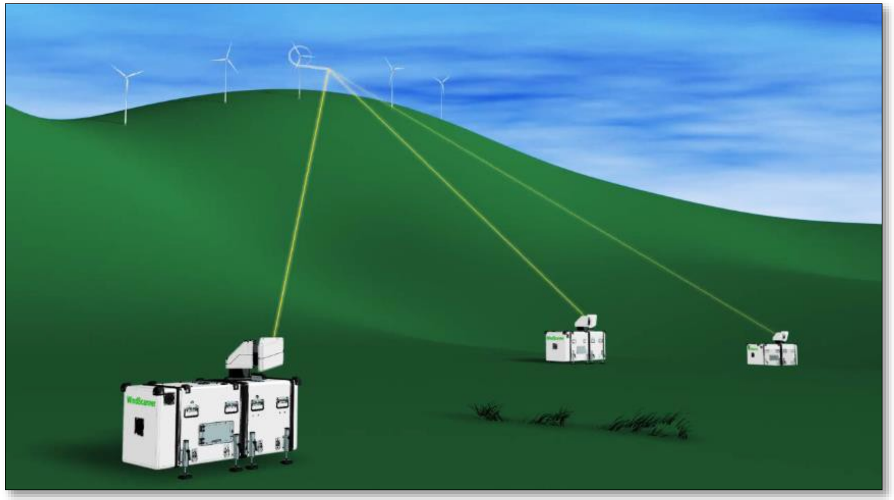
Doppler LiDAR (Light Detection And Ranging):

$$v_r = u \sin\varphi \cos\theta + v \cos\varphi \cos\theta + w \sin\theta$$



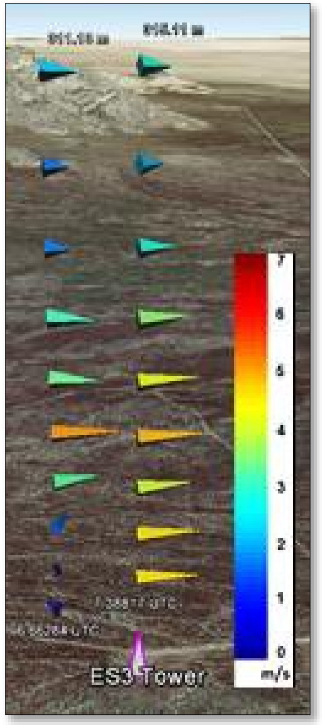


Single LiDAR scans



Dr. Nikola Vasiljevic, Technical U. Denmark

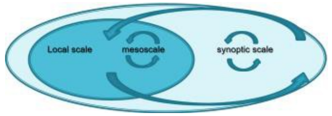
Multiple synchronized LiDARs can measure u, v, w

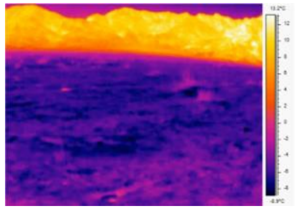


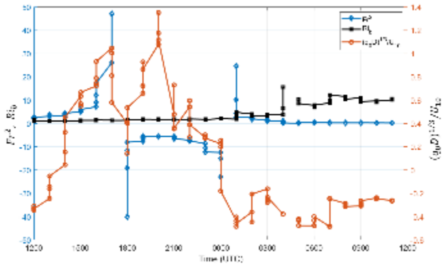
Y. Wang et al 2016 JARS

MSA RESEARCH METHODOLOGY

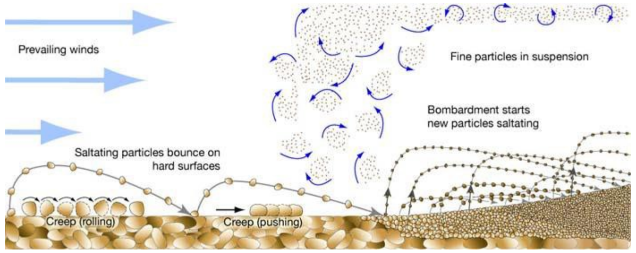
Surface Processes → influences → **Environmental State** → effects → **Army Systems**



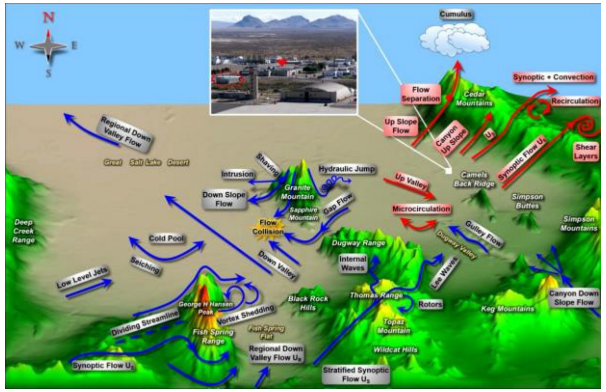




C. Payne et al. 2021 Atmosphere



http://www4.uwsp.edu/geo/faculty/lemke/geomorphology/lectures/11_aeolian.html



J. Fernando et al. 2015 BAMS

UAS ROTOR-WAKE INTERACTIONS

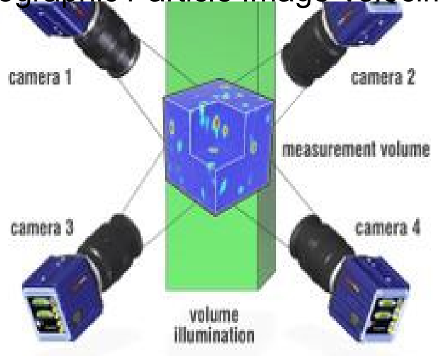
To develop an Intelligent Autonomous System (IAS) for battlefield operations it is necessary for the IAS to rapidly sense, react, and learn from the environment through integrated onboard in-situ sensors which rely on proper integration

Glen Throneberry, Adam Takeshita, Dr. Fangjun Shu, Dr. Abdessattar Abdelkefi, & Dr. Christopher Hocut

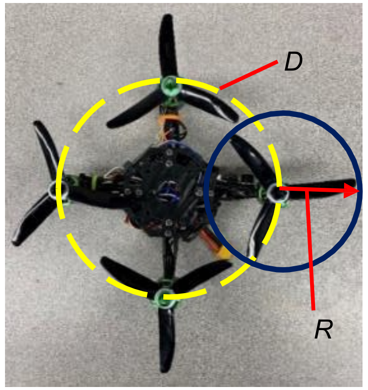
NMSU Mechanical & Aerospace Engineering Wind Tunnel Facility

Flow Visualization

Tomographic Particle Image Velocimetry (PIV)



FORWARD FLIGHT – WAKE PROPAGATION DISTANCE (L/R)

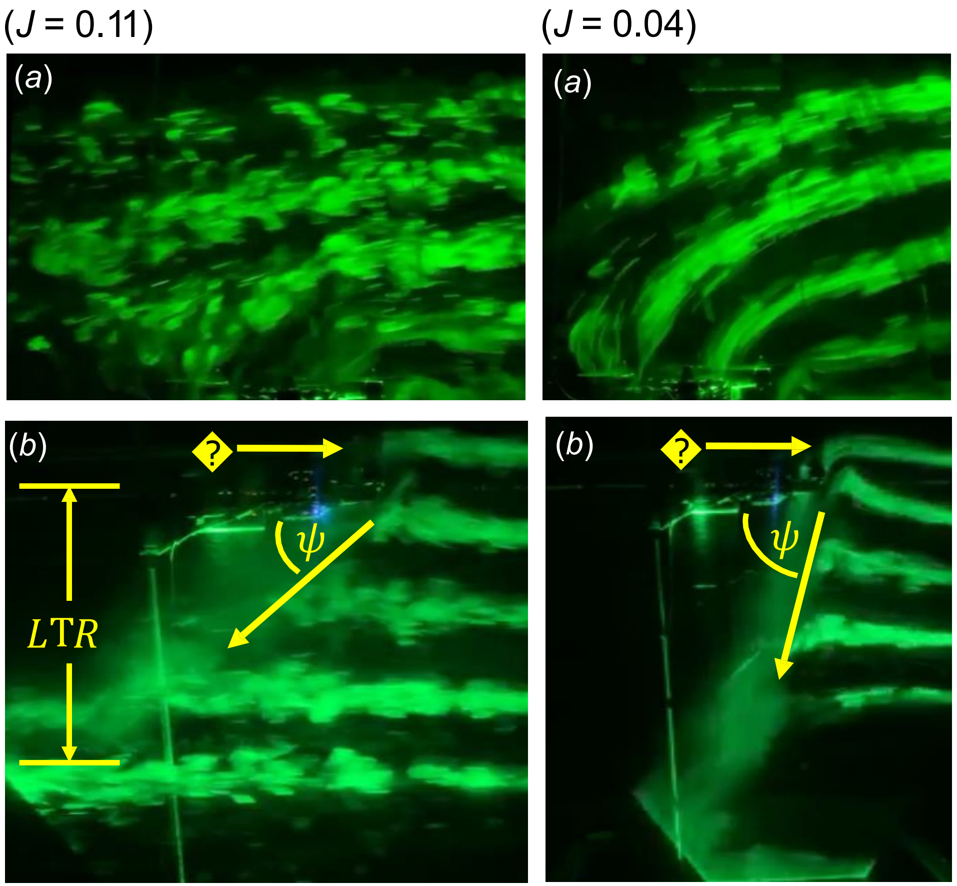


$$\frac{L}{R} \sim \phi\left(\frac{?}{R}, \frac{?}{2\Omega R}\right)$$

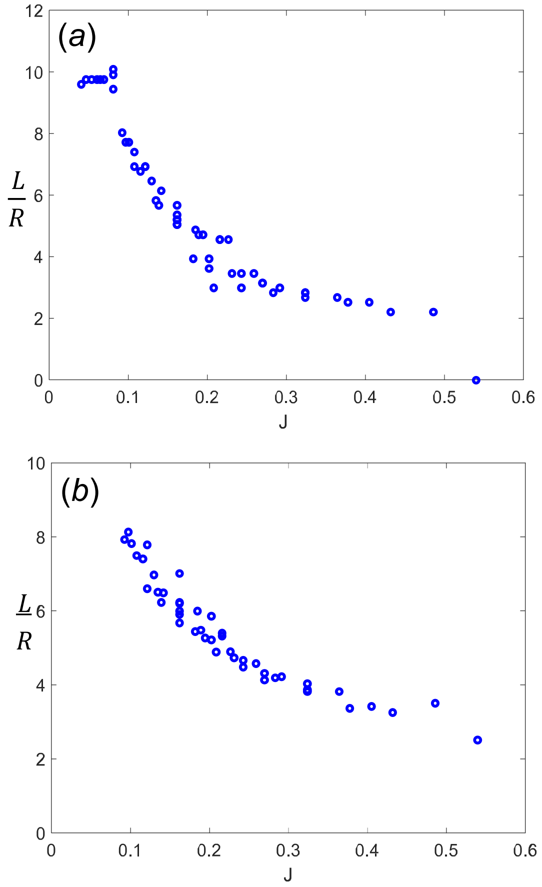
Advance Ratio, J

$$\frac{L}{R} \sim \phi\left(\frac{?}{R}, J\right)$$

Flow Visualization above (a) and below (b) the UAS

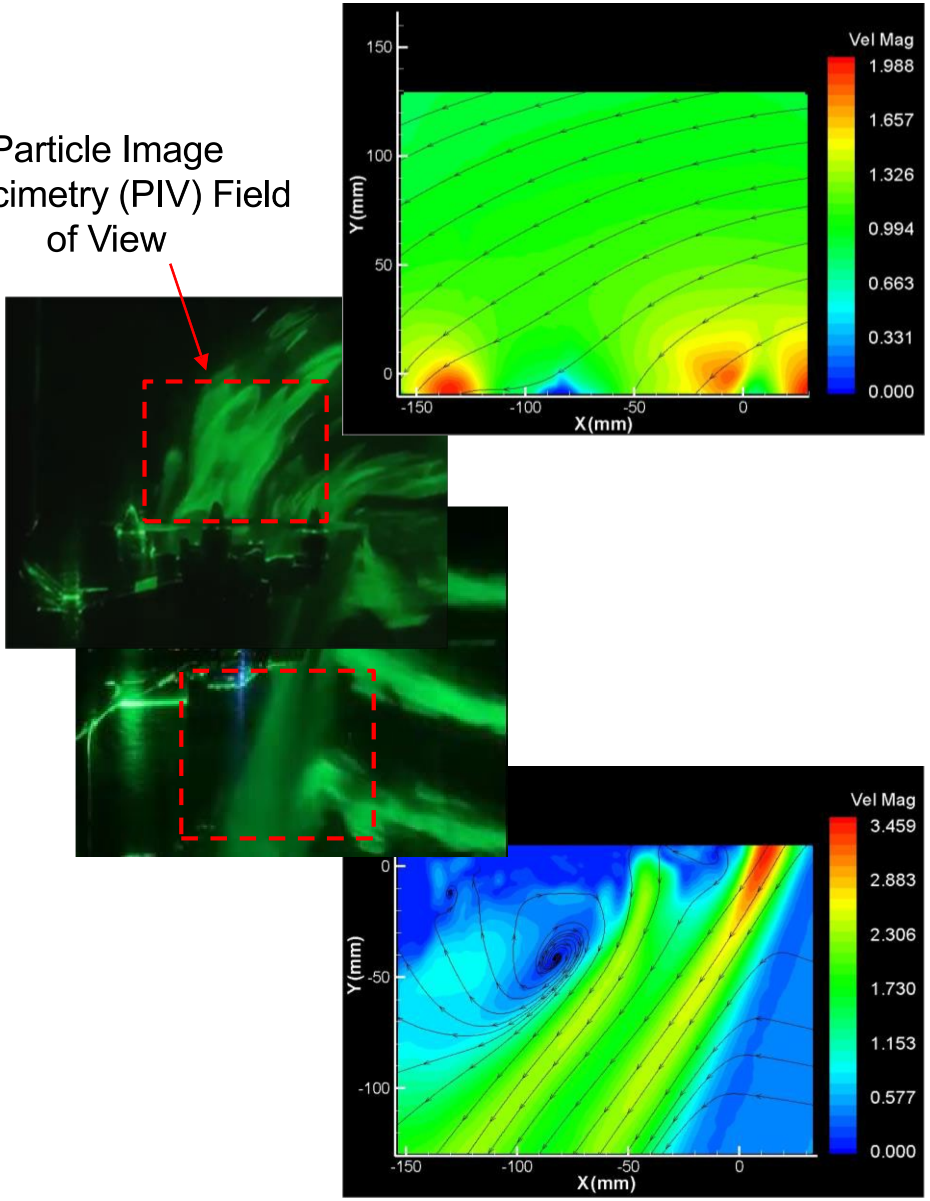


Wake propagation distance (L/R) above (a) and below (b) the UAS

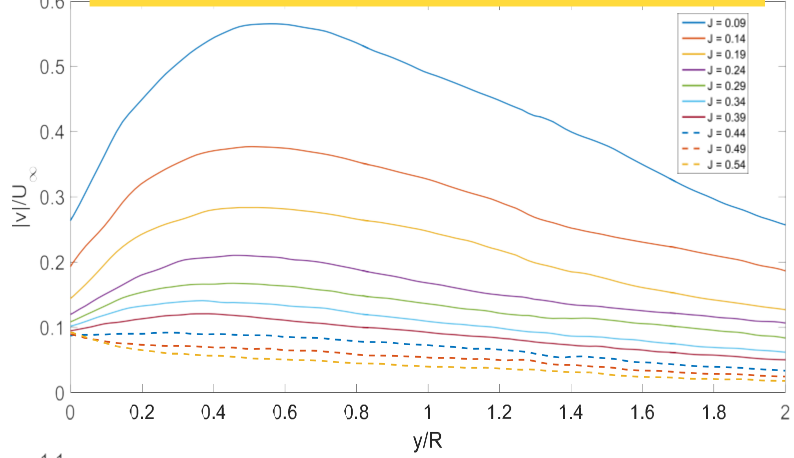


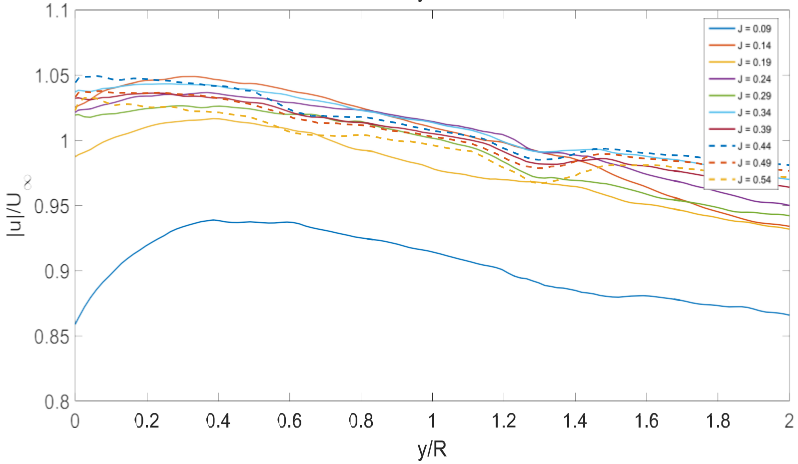
FORWARD FLIGHT – VELOCITY CORRECTION

Particle Image Velocimetry (PIV) Field of View



Horizontal (�) and Vertical (�) velocity at y/R above the UAS

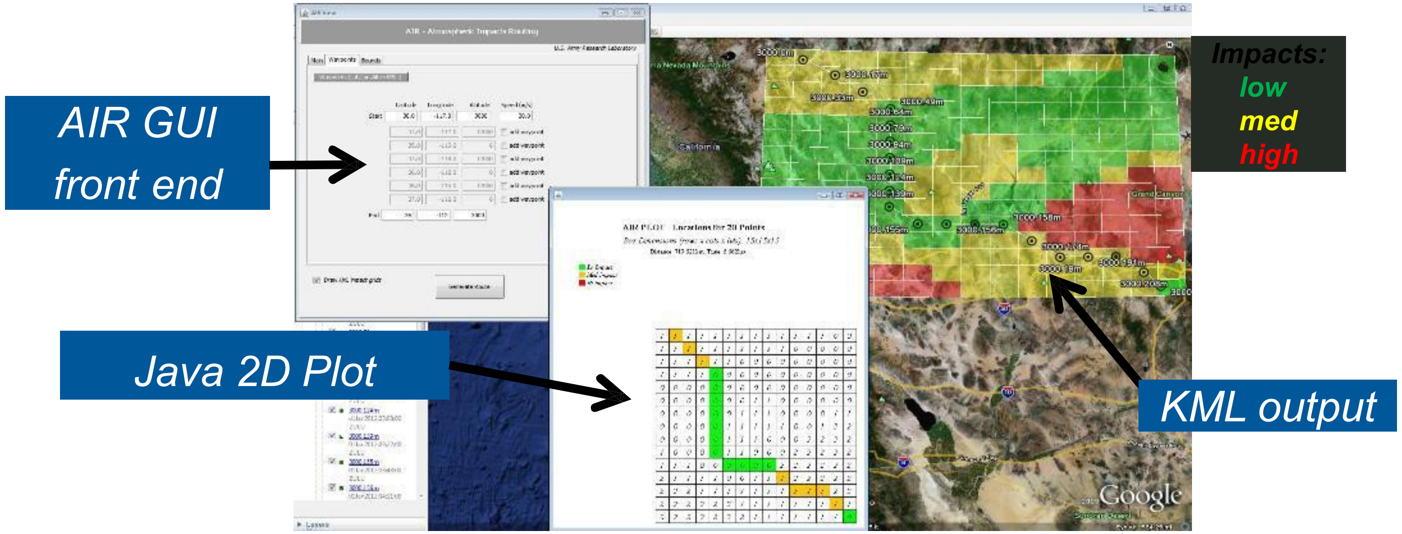




AUTOMATED IMPACTS ROUTING (AIR)

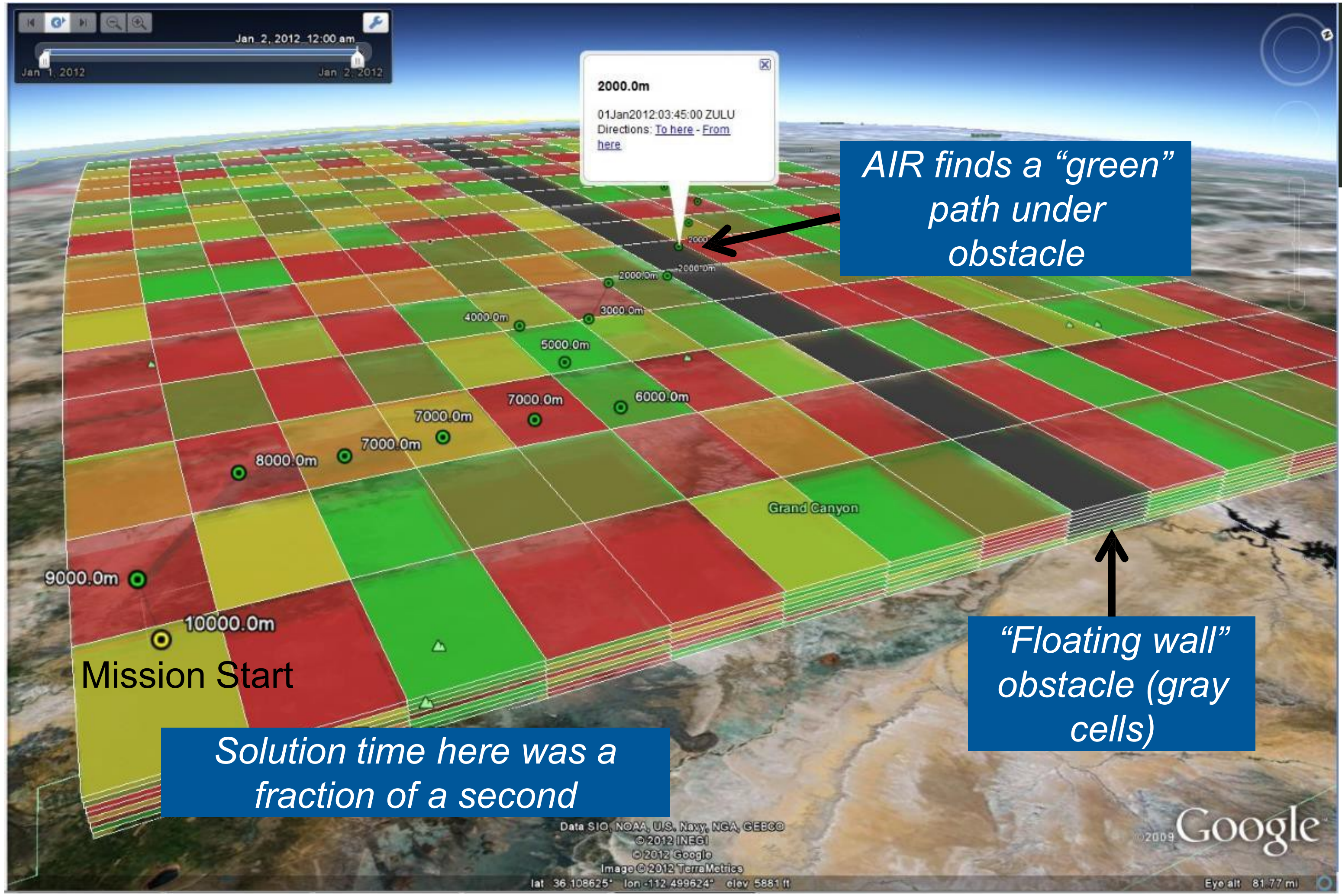
- <u>Automated Impacts Routing</u> (AIR - *a software system*) calculates an optimized air or ground system route based on environmental effects and obstacles along a path.
- *Path optimization employs a modified A* (A-star) search algorithm.*

- AIR web service / desktop application:
  - Written in Java (platform independent)
  - Ingests 3D weather/other "impact" grid(s) – *from MyWIDA, IWEDA, or other…*
  - Allows *3D obstacles to be avoided*
    - E.g., areas of known threat; conflicting friendly activity; *chemical release areas*; or other potential obstacles which may be represented as 3D volumes.
  - *Output* format is Open Geospatial Consortium (OGC) standard Google Earth KML



AIR 4D Output

AIR's fast execution path-finding solutions for complex impact arrays and obstacles



AIR finds a "green" path under obstacle

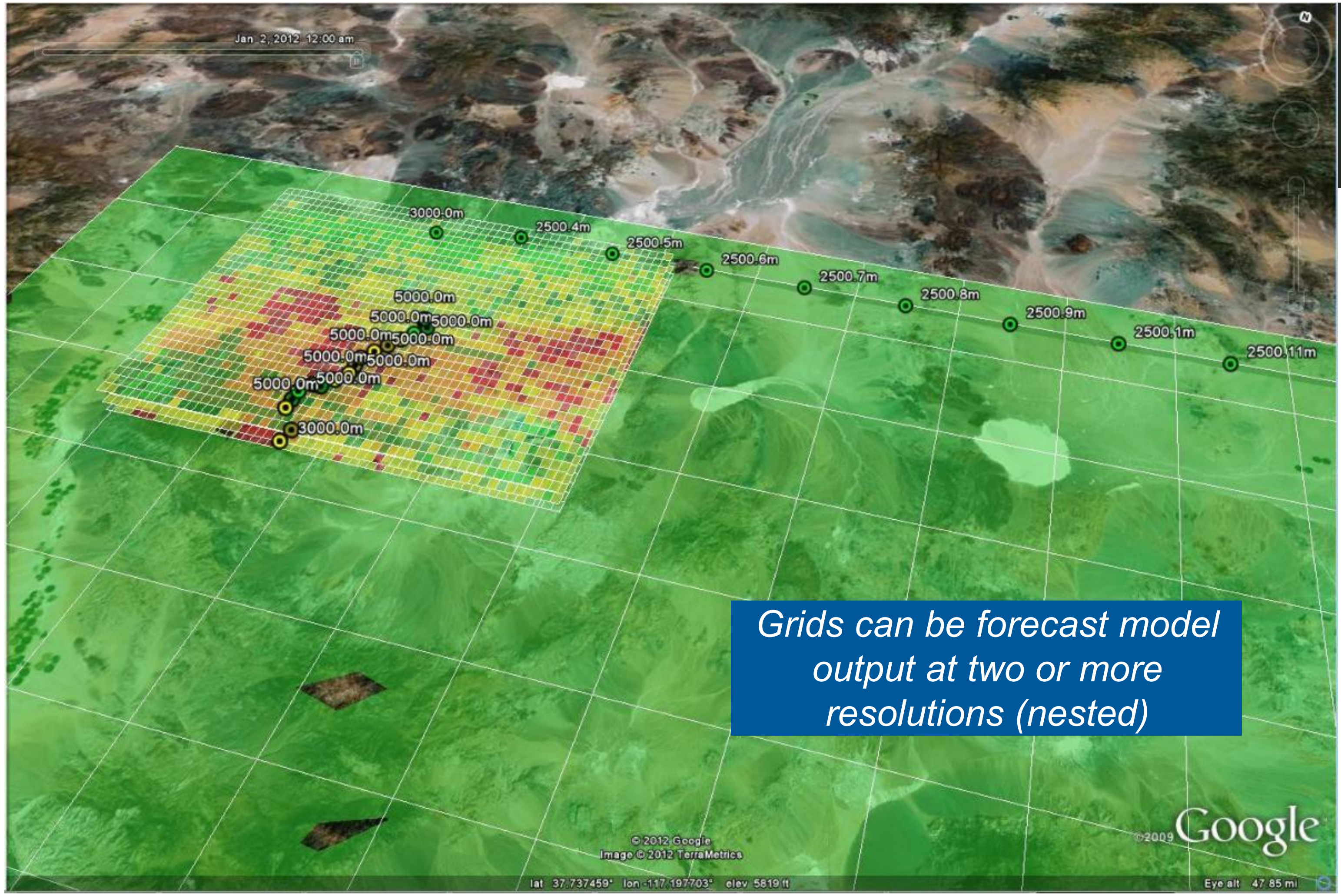
"Floating wall" obstacle (gray cells)

Solution time here was a fraction of a second

Impacts:
low
med
med high
high

AIR Ingest of Multiple Grids

AIR's asynchronous path optimization at multiple spatial and temporal resolutions



Grids can be forecast model output at two or more resolutions (nested)

Impacts:
low
med
med high
high

AIR – Use with UAS/drone

AIR demonstrated AI: Full control of UAS in DoD-funded experiment:

•SBIR (Phase II) – **Environmentally Aware Autonomous UAS** – AIR embedded with UAS flight control systems:

AIR software has been embedded into UAS/drone

- Milestone demonstrations took place:
  - September 2019 (*Wi-Fi data*)
    - Embedded AIR received adverse weather and obstacle data updates from ground station.
    - ***AIR processed data real-time onboard***, sent optimized path to UAS flight controls.
    - Multiple data updates were uploaded during flight.
    - UAS successfully avoided all adverse weather and obstacles.
  - July 2020 (*swarming* virtual test bed – obstacle data sent between drones during flight)
  - October 2020 (*forward-mounted sensor – Intel RealSense R200/435 stereo RGB camera*)
    - *Camera view/details, next slide…*

IN ALL CASES: UAS flew independent of any human control.

UAS/drone can use:
1) Wi-Fi/Networked effects grid.
- and/or -
2) Forward-looking mounted sensor.

(Army.mil stock photo)

AIR – Use with UAS/drone

AIR demonstrated AI: Full control of UAS in DoD-funded experiment (cont.):

- October 2020 Independent Flight (forward-mounted camera view):
  - AIR received object-detection data from forward-mounted sensor.
  - Data processed in real time during flight, UAS updated path and *flew around obstacle(s)*.

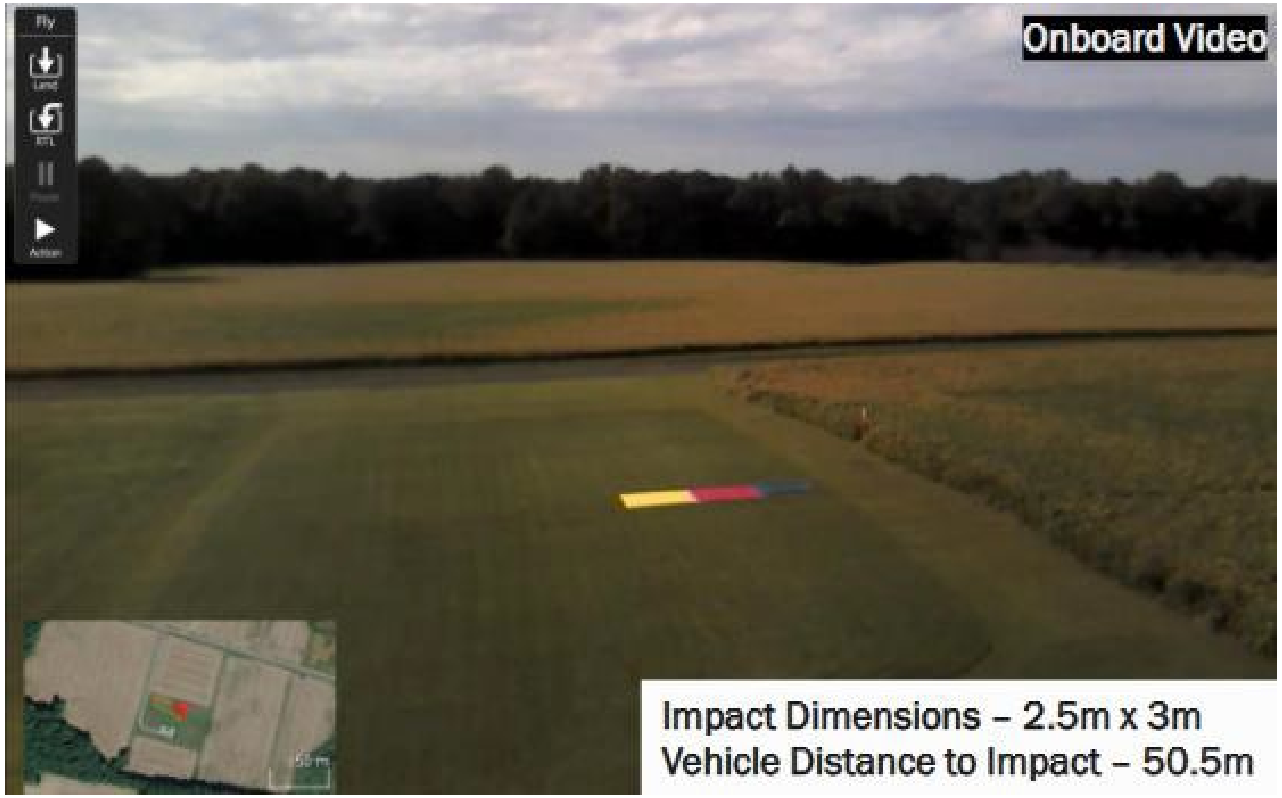


Image courtesy NextGen Federal Systems.

QUESTIONS?