System-Wide Safety

NASA/FAA/AGILITY PRIME WEATHER TECHNICAL INTERCHANGE MEETING

SWS Project Relevant Research

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System-Wide Safety

Project overview

NASA

Tech Challenge 2 - In-Time Safety Management for Emerging Operations

(2018-19) Initial architecture and information req'ts

- UTM-like ecosystem; ASIAS/SWIM-like info sharing
- Ref: NASA TM-2020-220440

(2020-2021) Phase 1

- Architecture and SFCs tailored to domain risks
- Build collaborations on key topics

(2021-2022) Phase 2

- Services with infrastructure for urban ops
- Broader in-time risk assessment span

(2023-2024) Phase 3

- With and by partners
- Urban sUAS <u>and</u> AAM/UAM domains

<u>RDT&E Spirals</u>
Updating, Refining
Extending, Validating,
Transferring, …

"…requirements and standards needed to monitor, assess, and mitigate risks to future safety."

ASIAS - Aviation Safety Information Analysis and Sharing; SWIM – System Wide Information Management; SFCs – Services, Functions, and Capabilities

TC-2 weather-related research activities

System-Wide Safety

1. COTS Leverage – TruWeather service integration and eval (Ersin Ancel)
2. Partner work – MIT/LL Wind service development (James Jones)
3. In-house work –
   - Test System Setup and Integration (Cuong (Patrick) Quach)
   - Wind modeling service for LaRC's Certain test range (Andrew Turner)
   - Wx observation stations and network (OS&N) (Evan Dill)
   - Application to IASMS Services, Functions, and Capabilities (SFCs)

     (Ersin Ancel, Portia Banerjee, and Mateo Corbetta)

Other – "WSDM" (SBIR Phase 2) (A3.03-4970) (ResilienX) (NASA POC: R. Mogford)

Weather Sensor and Data Monitoring Service

(ASTM activity to define standards for Wx Service Providers – Very relevant; but not actively participating)

Partner work – MIT/LL wind service

Utilizes information from NWS and NOAA
Can take in additional observations if available
May function as request-reply or pub-sub service

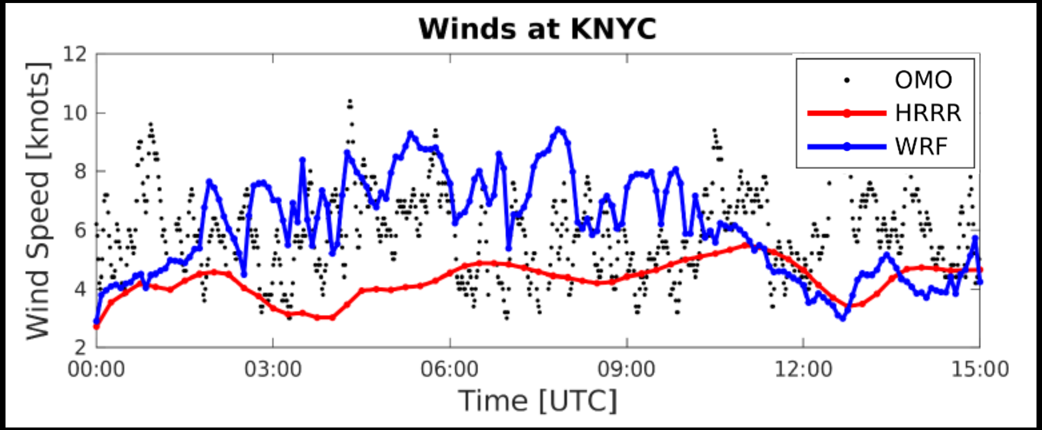
Forecasts:

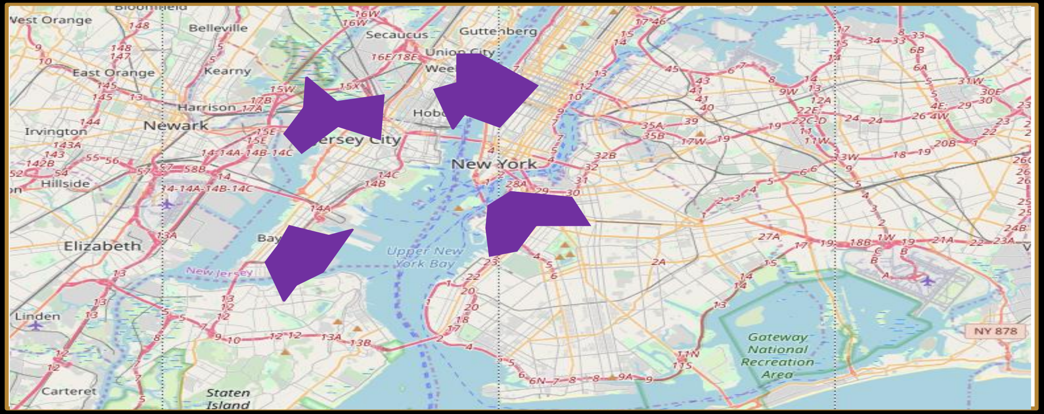
- 100m 2D spatial resolution up to 5000 ft AGL based on Weather Research and Forecasting model (WRF)
- 15-min intervals out to 24 hrs (goal: 5 min)

4 example case days being used for current DFW-area sims (4/20/20, 5/3/21, 7/1/21, 8/10/21)

Developing methods for automatically generating wind hazard areas; to support flight planning and in-flight risk awareness and mitigation/avoidance

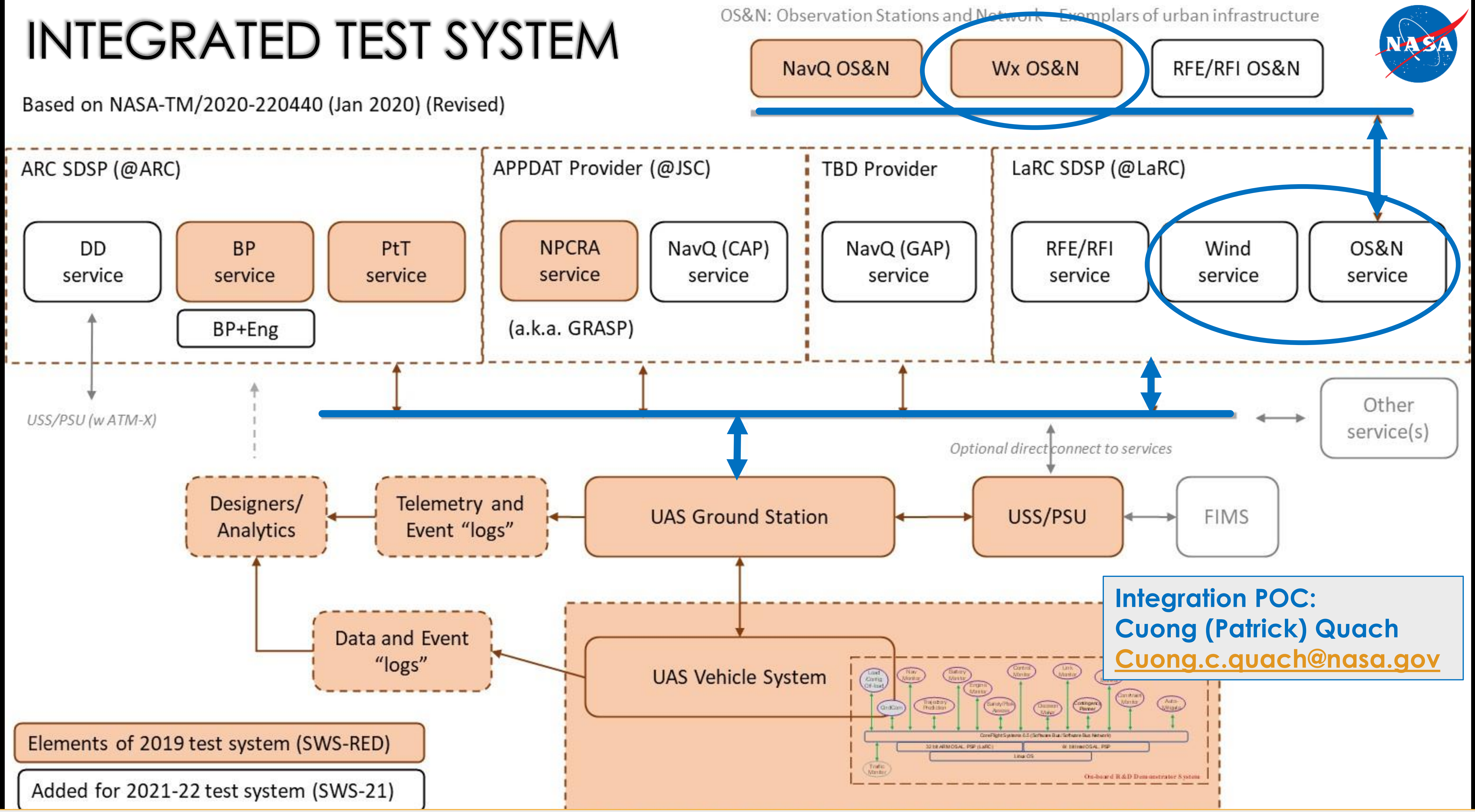
POC: james.jones@ll.mit.edu





INTEGRATED TEST SYSTEM

Based on NASA-TM/2020-220440 (Jan 2020) (Revised)



Integration POC:
Cuong (Patrick) Quach
Cuong.c.quach@nasa.gov

In-house – Wind modeling service

Static Models

Why not create a CFD model?

Simulation time and resources

Simulation via QUIC-URB and WIndNinja

CURRENT WORK

Variable Models

Machine Learning and AI

Neural Network

Large Sensor Network

FUTURE WORK

POC: andrew.t.turner@nasa.gov

Wind simulation software

WindNinja computes spatially varying wind fields for wildland fire and other applications; requires a DEM/DSM for the area; can be run in three modes. https://www.firelab.org/project/windninja

Outputs are ASCII Raster grids of wind speed and direction, a GIS shapefile (for plotting wind vectors in GIS programs), and a .kmz file (for viewing in Google Earth)

QUIC-URB is a wind modelling tool that calculates 3D wind fields for flow around arrays of buildings or other modeled obstructions. https://www.lanl.gov/projects/quic/quicurb.shtml

Several output files enable visualizations or other uses of the calculated flow fields.

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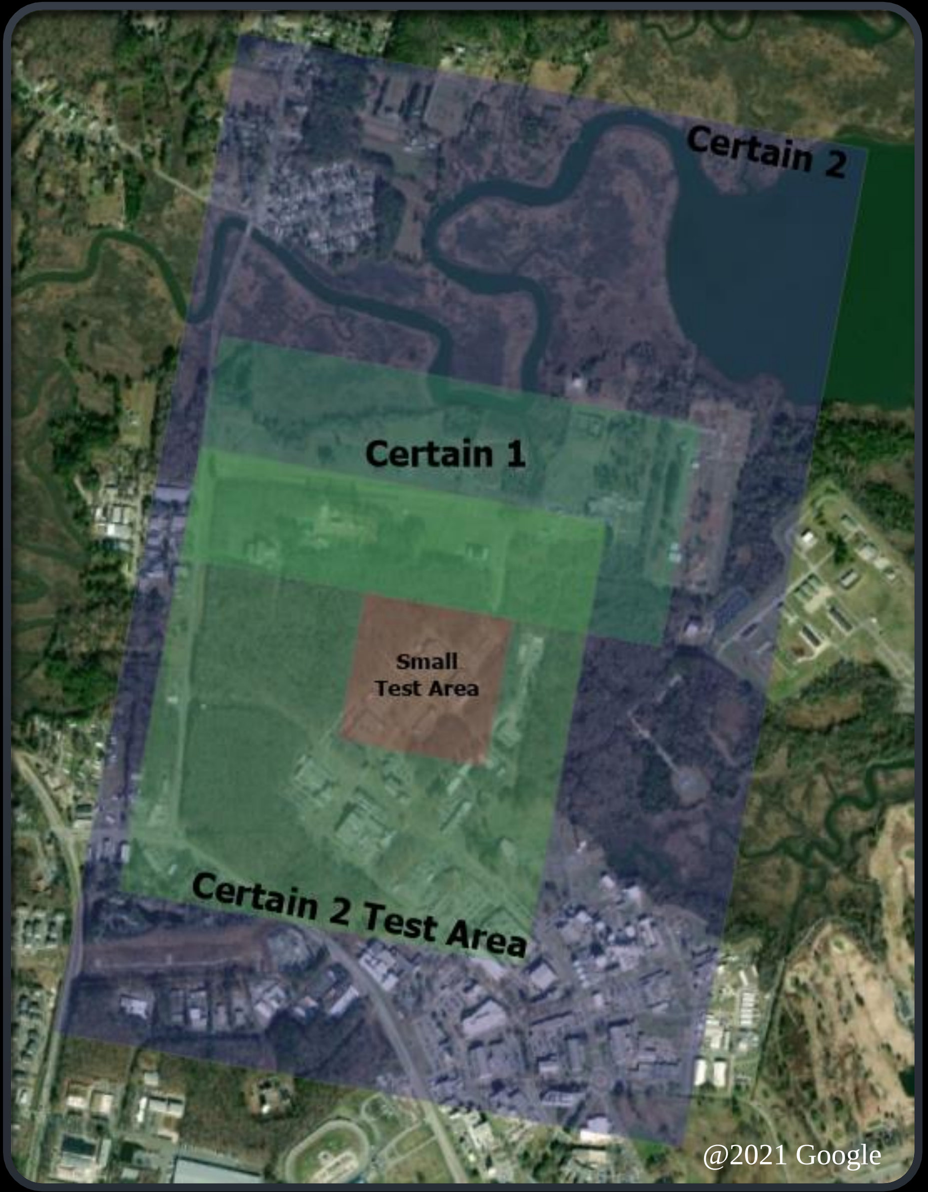
Bounding boxes

FOR WIND MODELS CREATED TO DATE WITHIN THE CERTAIN TEST RANGES AT LARC



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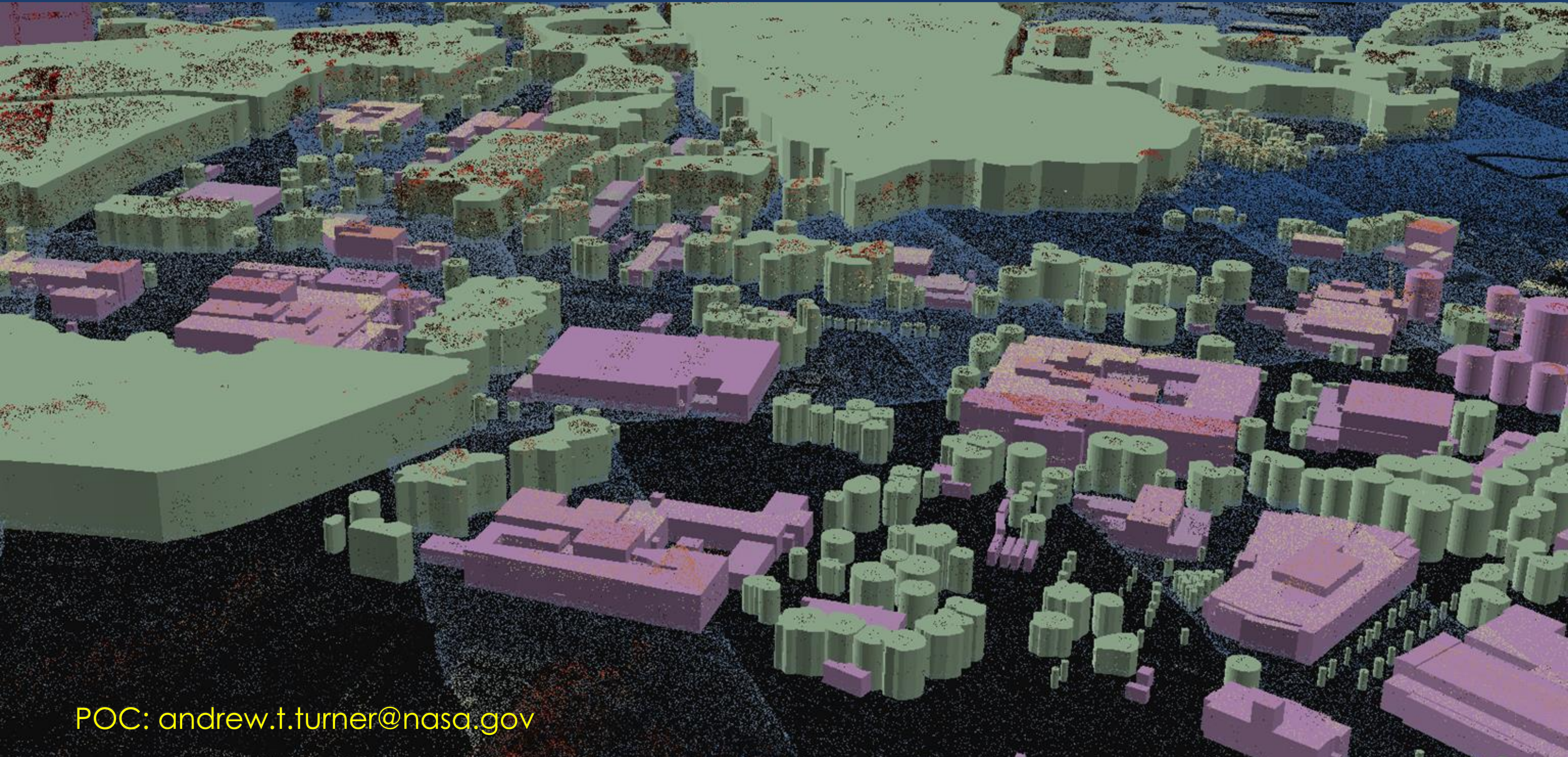
LaRC Model: Shapefile and Lidar Overlay



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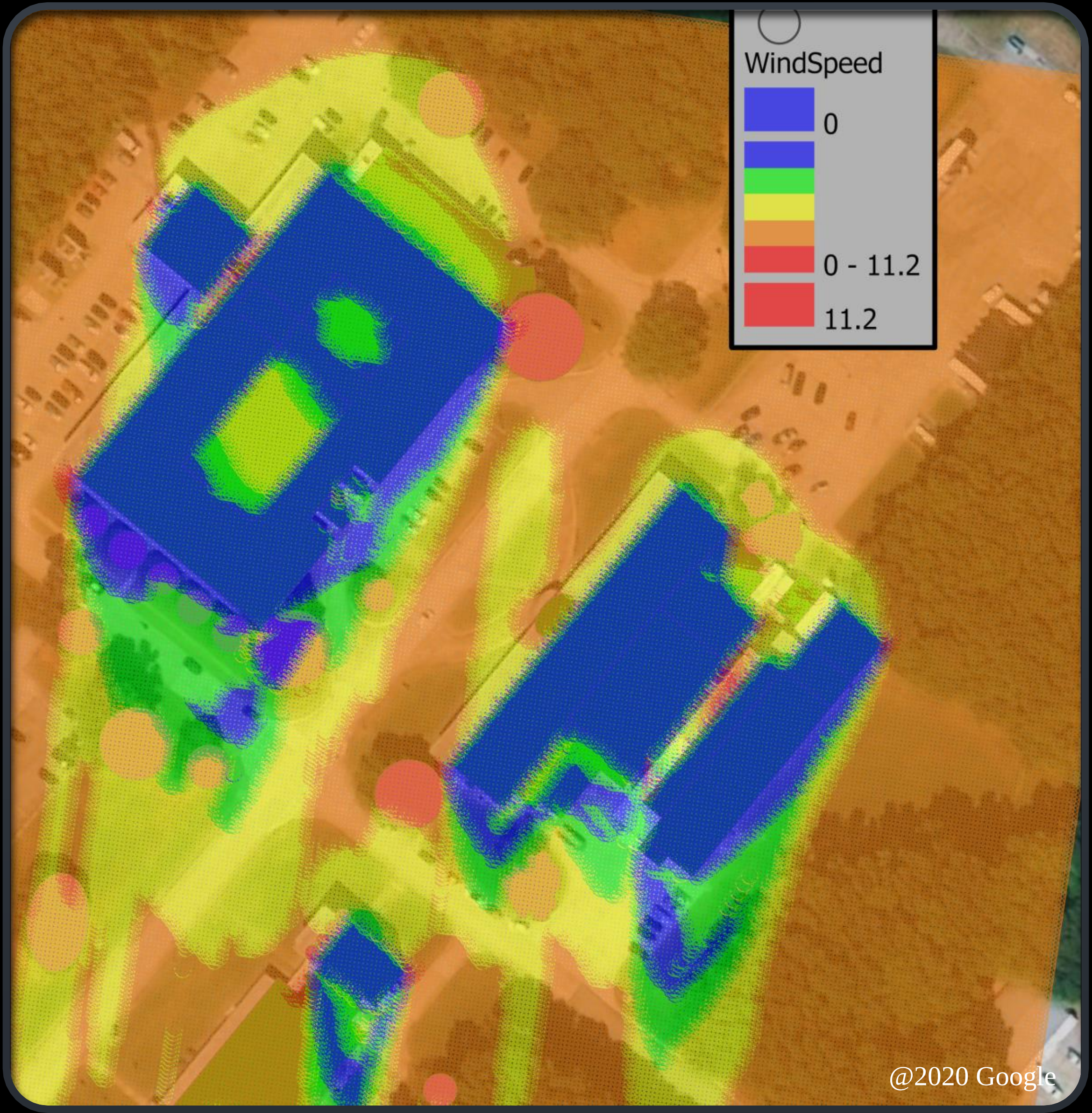
Example 2D Z-slice from QUIC-URB



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Wx observing stations and network at LaRC

The network is on-line but evolving – individual stations may be off-line when being upgraded and then coming back online; the current state changes weekly. The data contains the following Wx info and is updated at least every 5 sec: Wind Speed/Direction, Rainfall, Air Temp, Humidity, Local Air Pressure (Ceiling and Visibility planned for at least one location)

Data can be accessed via: https://cepic.ndc.nasa.gov/LOGS/Meteor/

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Wx observing stations and network at LaRC

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MEASUREMENT LIST

Min, Avg, Max Wind Speed (m/s)
Min, Avg, Max Wind Direction (deg)
Air Temp (C)
Relative Humidity (%)
Air Pressure (hPA)
Rain Accumulation (mm)
Rain Duration (secs)
Rain Intensity (mm/hr)
Hail Accumulation ()
Hail Duration (sec)
Hail Intensity (hits/cm^2)

Cloud ceiling (m) (planned)
Horizontal visibility (m) (planned)

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Effect of wind on UAV flight trajectory deviation

POCs: Portia Banerjee, Matteo Corbetta, and George Gorospe

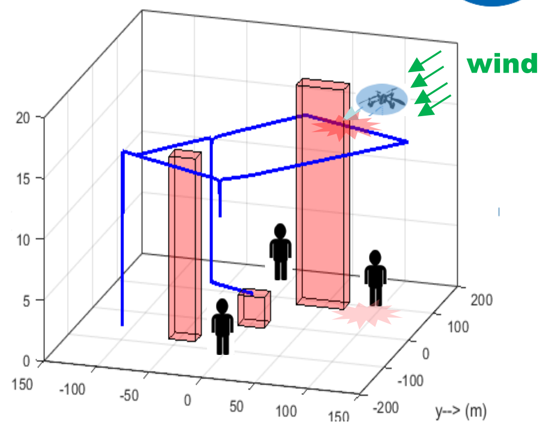
Computing the Probability of Obstacle Collision due to wind:

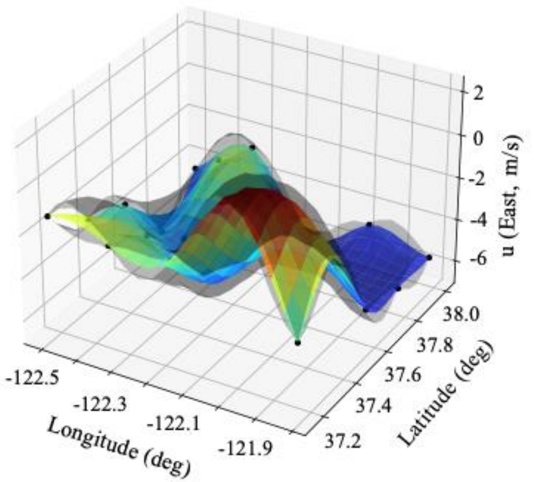
Wind data
- Online weather service for average wind speed and direction every 1km every 1 hr.
- Local wind gust data from ground anemometers close to UAV flight region.

Wind models
- Steady state wind with **Gaussian Process Regression (GPR)**.
- Wind turbulences based on **Von Karman model**

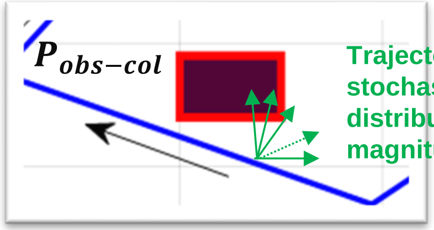
6 degrees-of-freedom **UAV trajectory simulator** with aerodynamic drag capturing wind effect.

Probability of Obstacle Collision based on predicted trajectory with wind distributions.

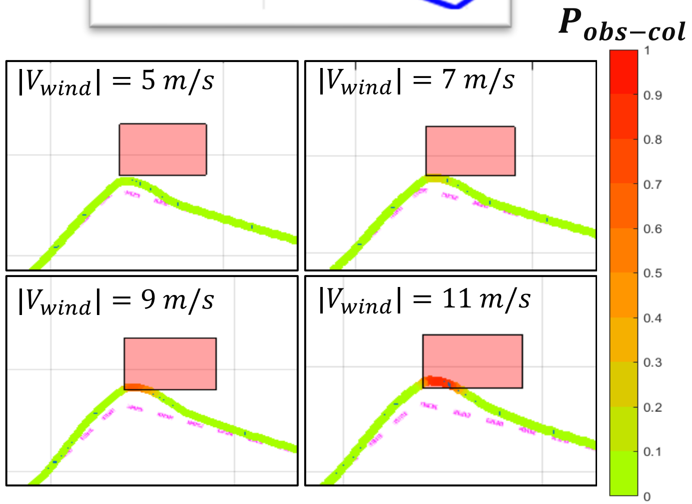




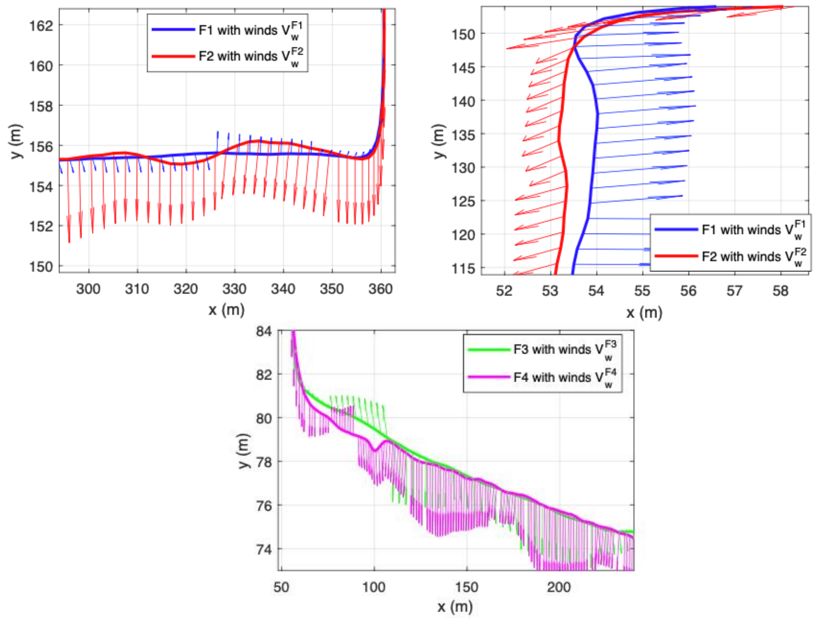
GPR is implemented to interpolate the sparse grid of available steady-state wind data points and obtain the wind field along the horizontal u (West-East) and vertical v (South-North) directions, with corresponding 1 sigma-band (gray surface).



Trajectory deviation is stochastic dependent on distribution of wind magnitude and direction.



Simulation: High wind magnitude (keeping direction fixed) causes increased trajectory deviation at the turns → increasing probability of obstacle collision.



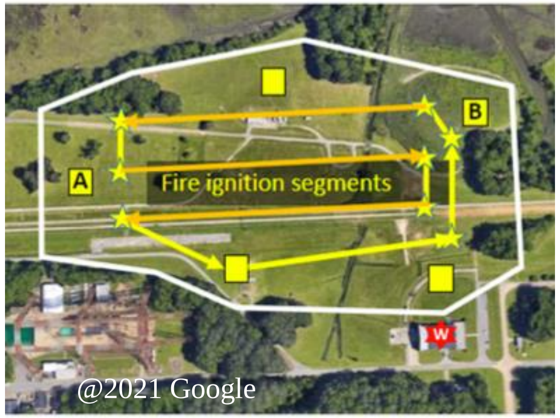
Experiments: Higher deviations and oscillations observed for UAV flights on windy days (arrows indicate the instantaneous wind magnitude and direction measured by ground sensor 2 along the trajectory.)

"Probability of Obstacle Collision for UAVs in Presence of Wind," Banerjee, Corbetta, Jarvis, Smalling, and Turner, AIAA Aviation Forum, 2022.

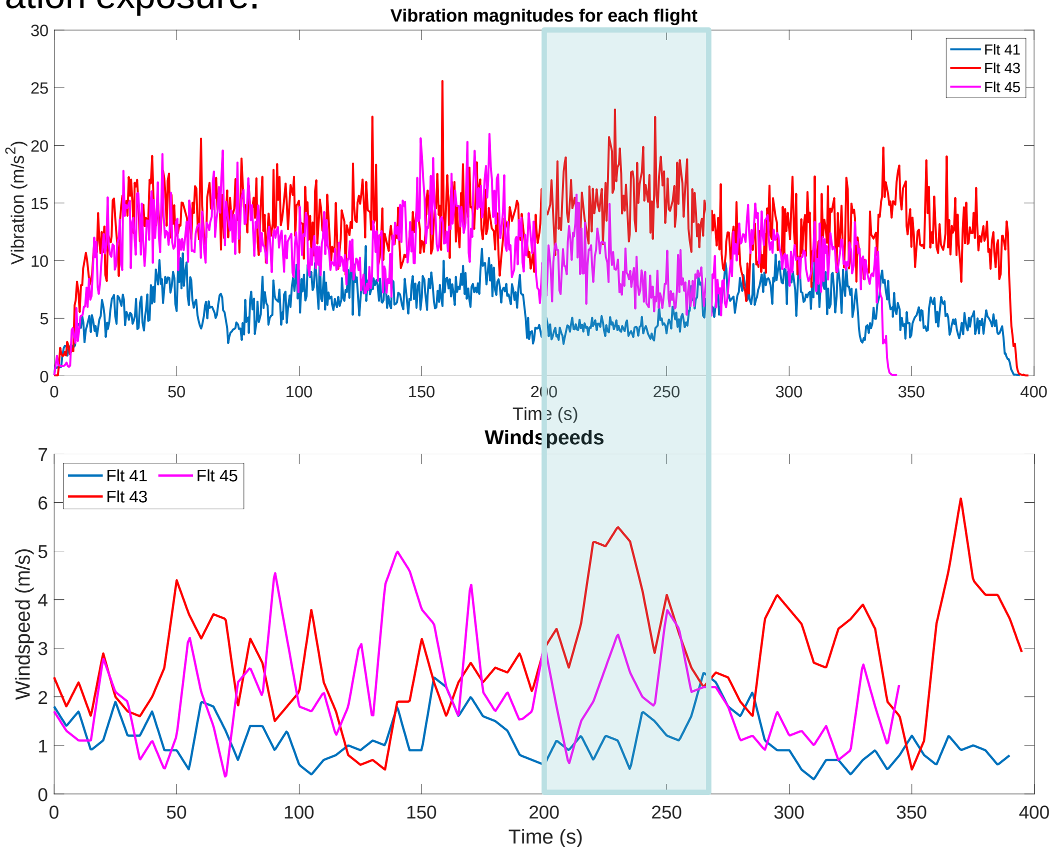
Effect of wind on UAV vibrations

POCs: Portia Banerjee, Matteo Corbetta, and George Gorospe

- High vibrations can induce faults in the safety-critical components of the UAV including the on-board sensors used for guidance and control, such as the inertial measurement unit (IMU) and/or GPS sensors or incorrect attitude sensing and therefore uncertain state estimation causing the multirotor to drift from its desired position or eventually lead to loss-of-control.
- Within SWS, we are investigating effect of wind on vibrations recorded by on-board vibration sensors and IMU accelerometers from UAV flight experiments.
- To aid this study, we are developing a vibration testbed (single-axis shake table) for IMUs in lab at NASA Ames to compare measurements from pristine IMU vs IMU post vibration exposure.

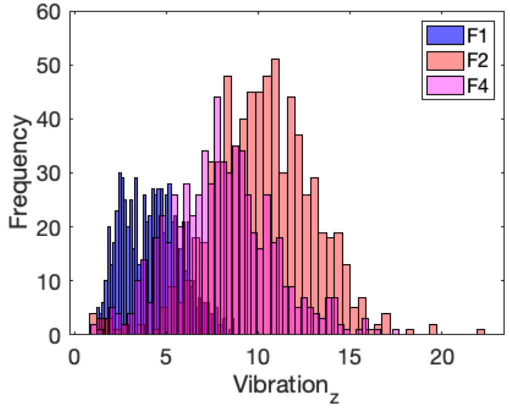


UAV flight experiments conducted at NASA Langley Research Center (Red star marks the location of the ground wind sensor close to the flight region).
Flt 41 (F1), Flt 43 (F2) and Flt 45 (F4) are three flight paths corresponding to the same trajectory flown on different days with different wind conditions. Overall, corresponding windspeed magnitudes were in this order:
F4> F2> F1



Higher vibration is recorded by UAV on-board sensors on days with high wind magnitude.

Vibration levels depicted as histograms.



Vibration testbed for IMUs

Single-axis shake table for short and long duration IMU testing.

Effect of wind when estimating Pc

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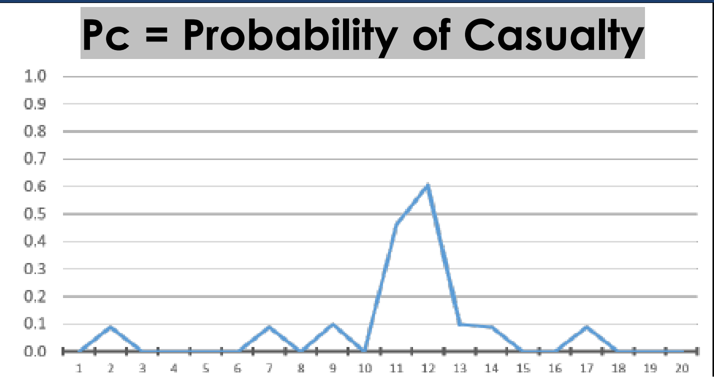
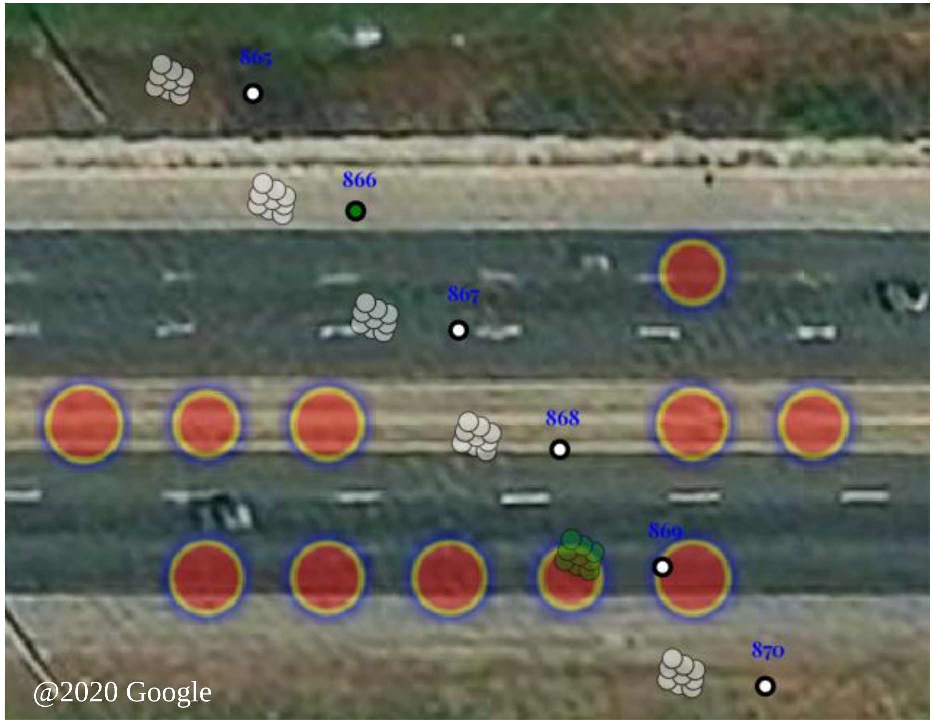




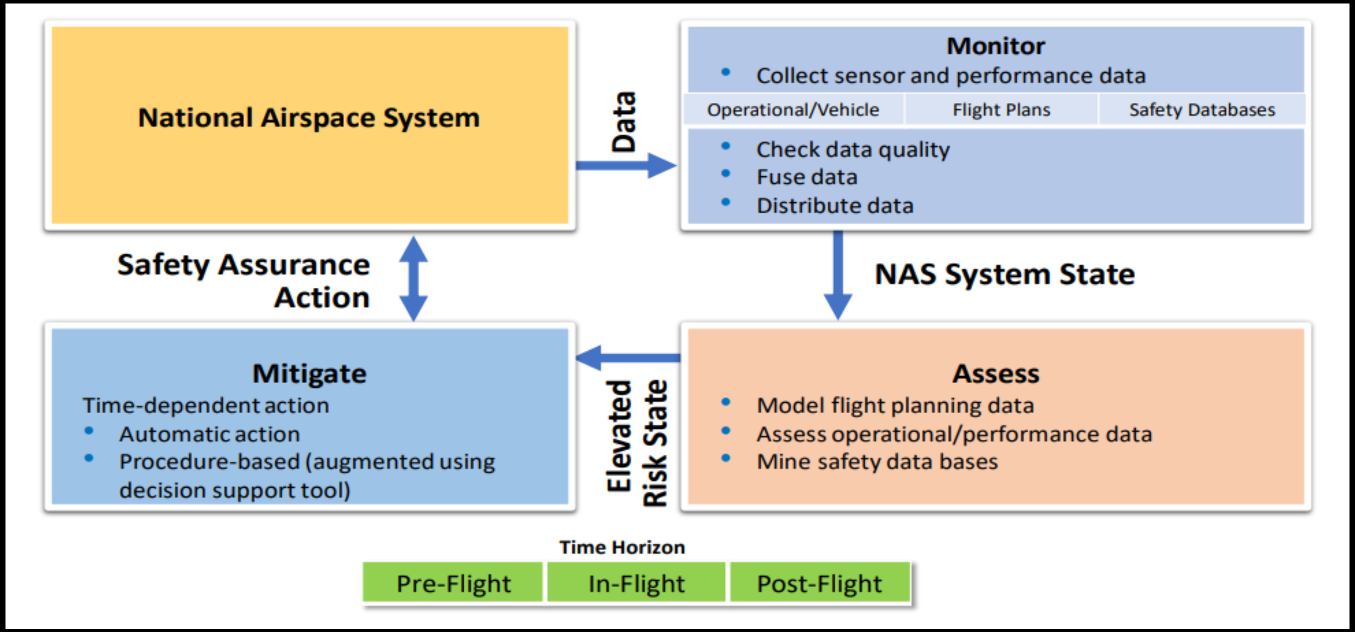
POC: ersin.ancel@nasa.gov

"Ground Risk Assessment Service Provider (GRASP) Development Effort as a Supplemental Data Service Provider for Urban Unmanned Aircraft System (UAS) Operations," Ancel, et. al., AIAA/IEEE DASC, 2019.

Summary

SWS is conducting R&D toward advanced safety management systems (a.k.a. "IASMS" and "ISSA").

The concept calls for new services, functions, and capabilities (SFCs) that enable more timely Hazard Mitigation – during operations.



For micro-weather, several SFCs rely on Wind information

- Pre-flight Planning (Areas and/or Times to avoid); In-Flight (Effect on Risk of Hazard encounter; Contingency options); Post-flight (feedback To improve service performance)

Currently focusing on how to integrate In-House with Partner work

Project welcomes ideas to collaborate with other relevant activities and interested partners