NRI INT: Safe Wind-Aware Navigation for Collaborative Autonomous Aircraft in Low Altitude Airspace

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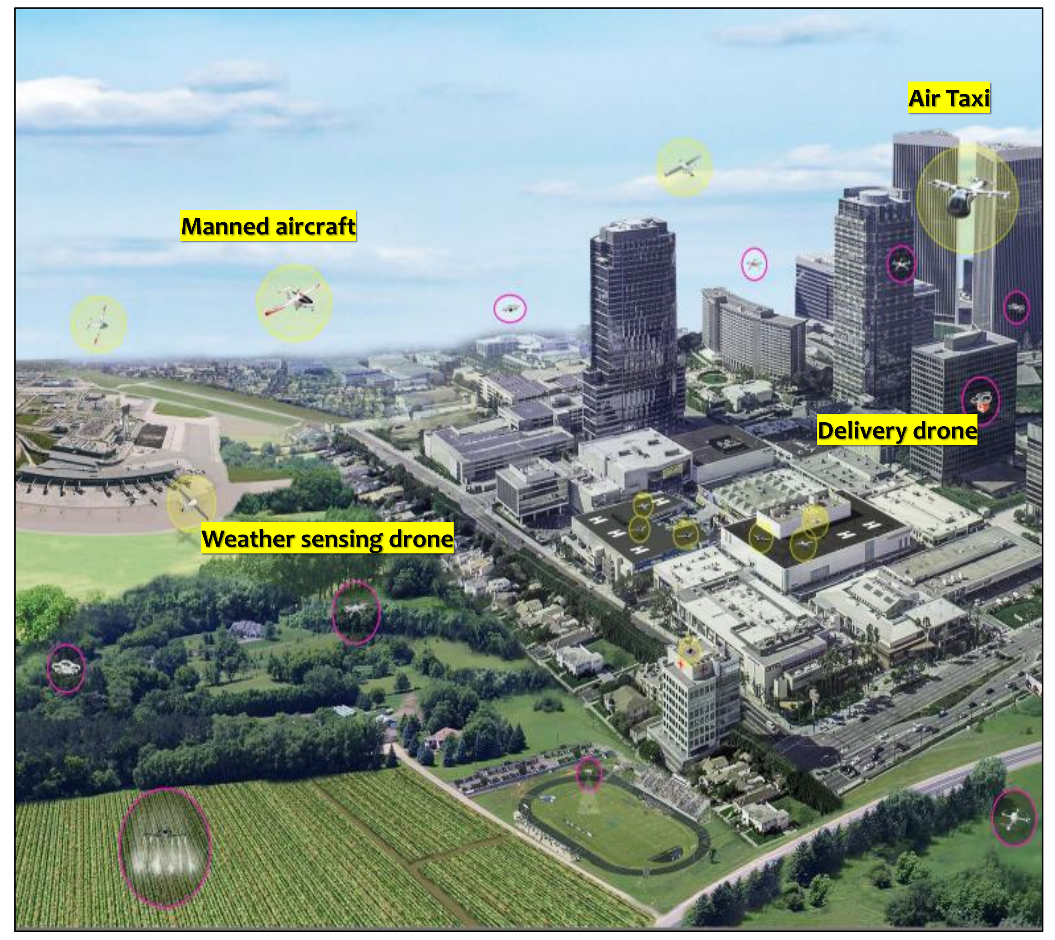
Background and Challenges

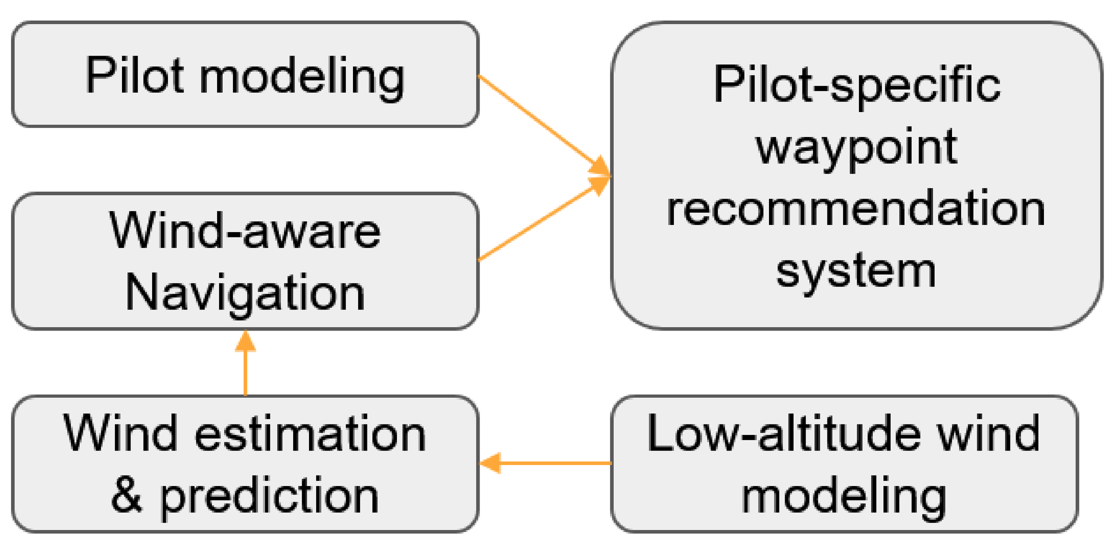
- Small unmanned aircraft systems (sUAS) technologies found many civil, commercial, and military applications.
- Infrastructure, such as NASA UAS traffic management (UTM) for low-altitude airspace management and monitoring, is being developed.
- Safety and efficiency of sUAS operations are strongly impacted by low-altitude gusts:
  - Negatively affect pilot operations, reduced flight time, damage.
  - Airspace management and allocation made conservative and inefficient.

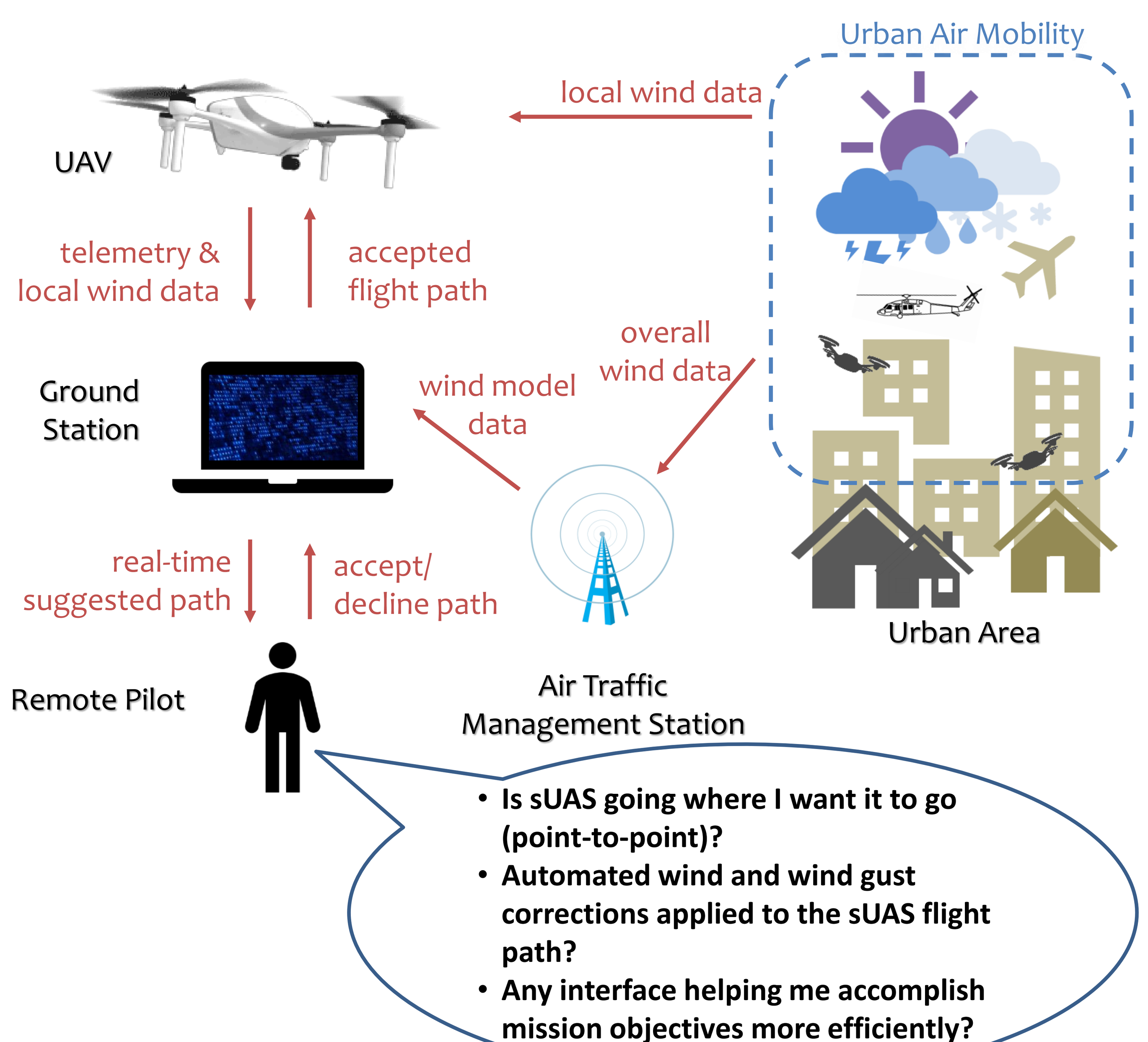
Improve safety and efficiency of low-altitude UAS operations



Technical Approach and Progress

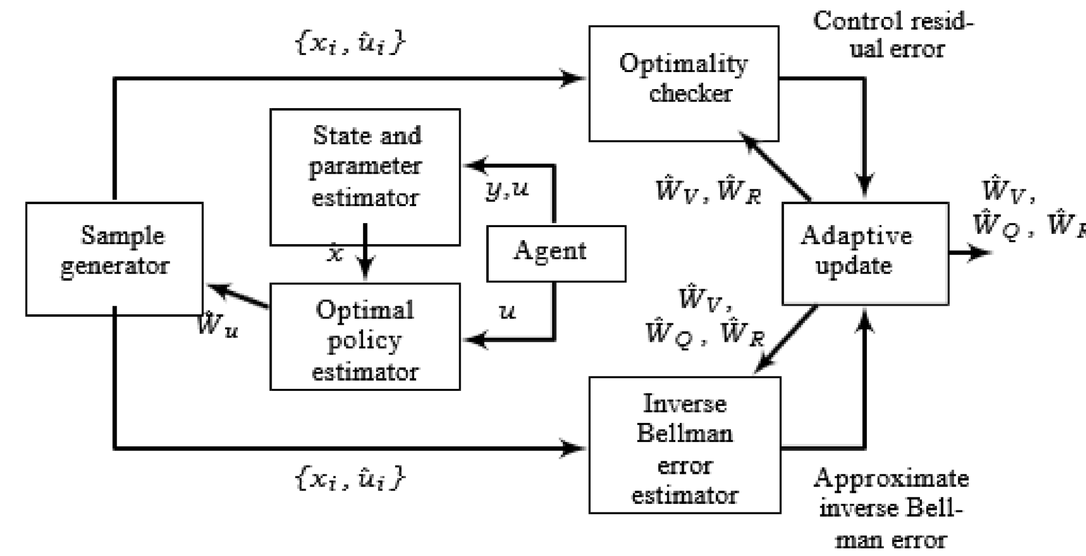
'In-time' or 'real-time' wind field information, communicated effectively to pilots and traffic management, can enhance safety, efficiency, and robustness of future sUAS operations in low-altitude airspace.

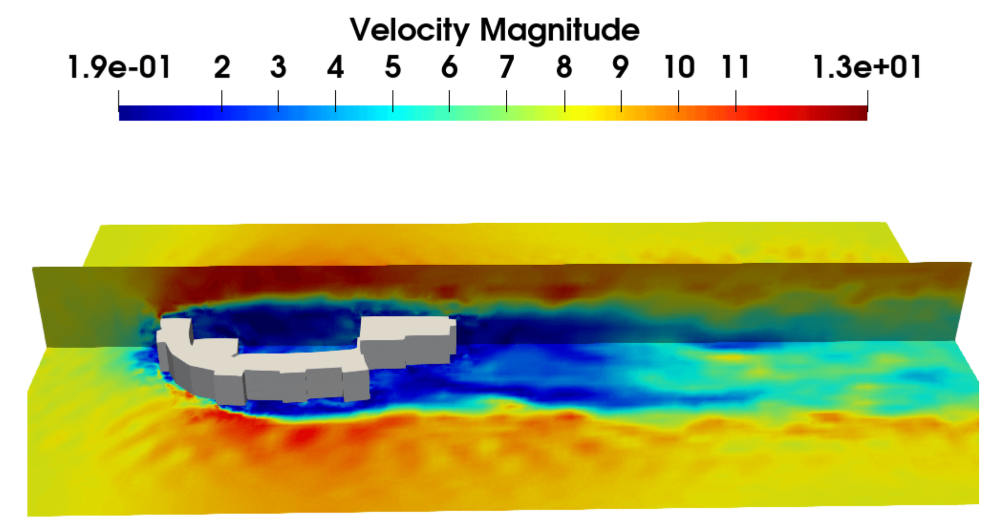




Pilot intent modeling

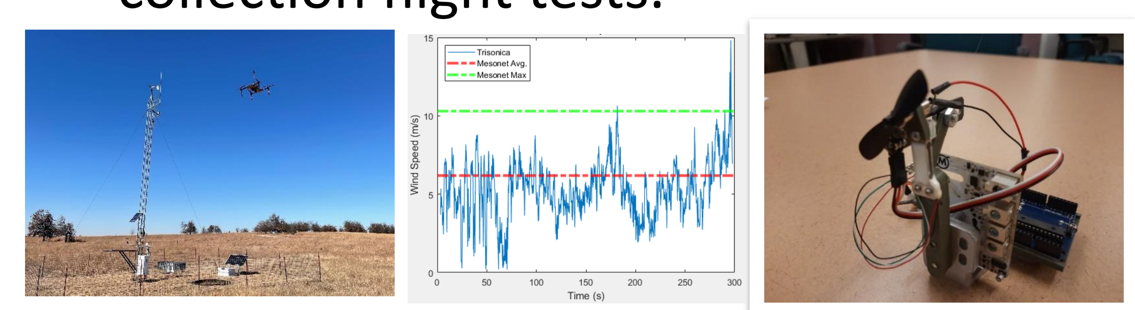
- Developing inverse reinforcement learning (IRL) techniques to support pilot intent modeling:
  - Observer, Robustness, Feedback-driven.
  - Despite a large cost function estimation error, the trajectories from the estimated cost function closely follows the observed trajectories.
- Conducted a survey of sUAS pilots: mechanical turbulence due to structures; projected future trajectories.





Quadcopter wind estimation

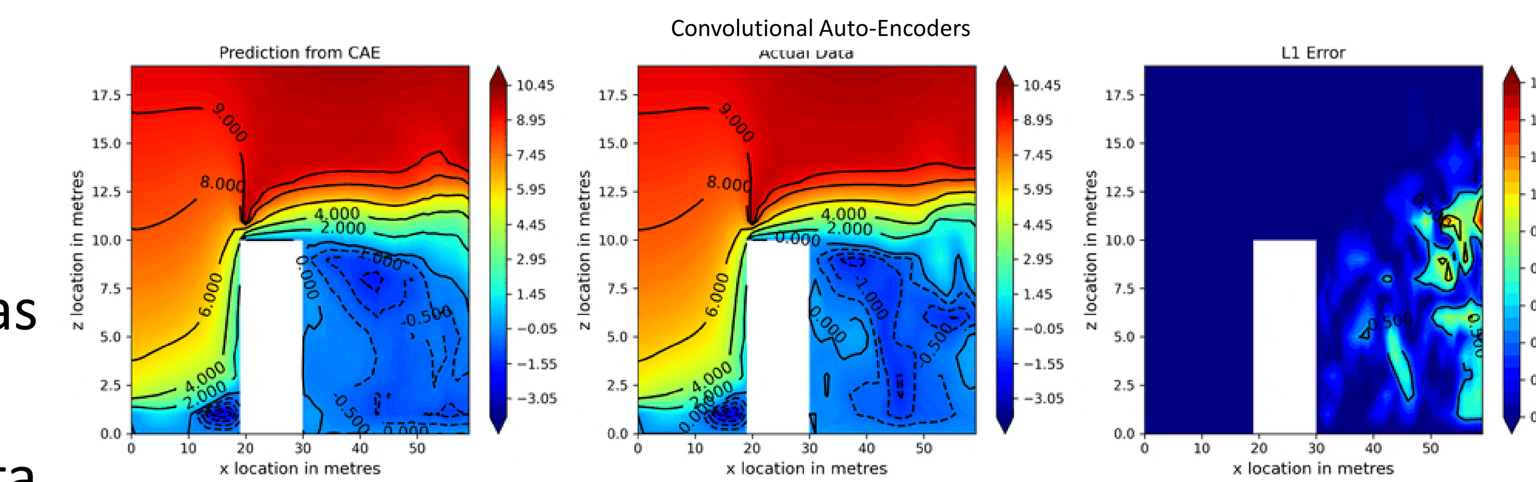
- Designed invariant EKF with IMU Bias and various thrust models.
- Developed platforms to conduct data collection flight tests.



- Pilot-in-the-loop simulator in AirSim: QGC with wind display (left), wind display options (middle), trajectory buffer (right).

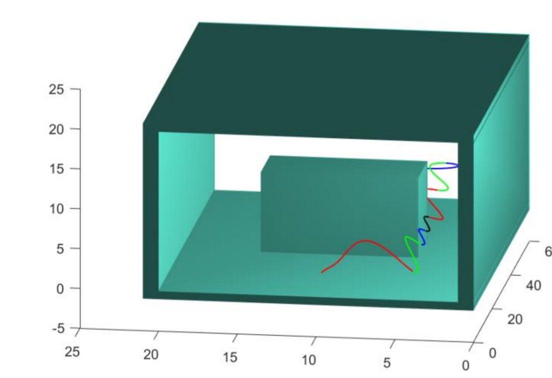
Wind modeling, simulation and prediction

- High-fidelity data from large eddy simulation for complex buildings and structures.
- Non-Intrusive Reduced Order Modeling and machine learning framework for wind field prediction.



Wind-aware path planning

A modified Kino-dynamic Fast Marching Tree (kino-FMT) for stationary wind fields.



Scientific and Broader Impacts

- Wind field data compression using neural networks can result in significant reduction in computational cost for on-board deployment, pilot awareness and predicting adverse wind patterns in complex urban setup.
- Potential enhancement of low-altitude wind estimation, prediction towards precise micrometeorology and atmospheric sensing.
- Enhanced simulators in AirSim and ROS.
- sUAS integration into the National Airspace, particularly challenging low-altitude urban environments.
- Impacts on UTM and Urban Air Mobility (UAM) efforts, package delivery, reconnaissance, etc.
- Contribute to future aviation networks and other applications, e.g., sUAS-assisted wireless communication, first response, etc.

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