Safe and Autonomous Drones for Urban Flight

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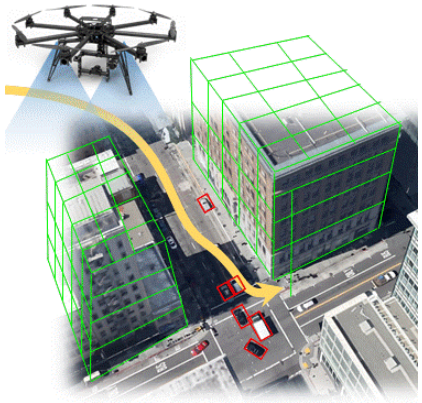
Moffett Field, CA
NASA Ames Research Center

Outline

Ames Research Center

Autonomy Applications

Self-Driving Cars



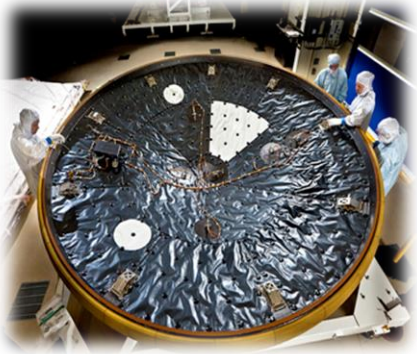
Autonomous Drones

Autonomy at Ames

- Ames has a 25+ years heritage of conducting autonomy R&D and deploying autonomy in support of NASA's aeronautics and space missions
- Autonomy is one of Ames' 8 core competencies.
- Ames has a robust and engaged autonomy activity:
  - Workforce: Over 300 staff members
  - Partnerships: Over 50 active partnerships with industry, academia, and government

Core Competencies @ Ames

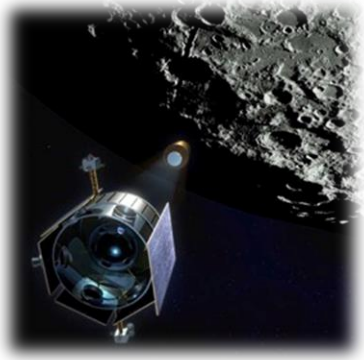
Air Traffic Management



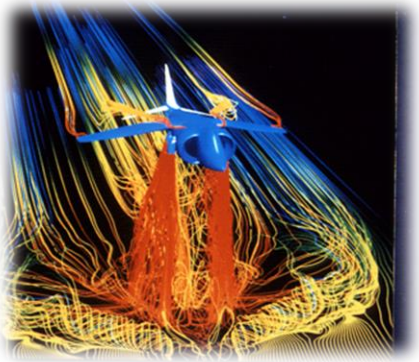
Entry Systems

Advanced Computing & IT Systems

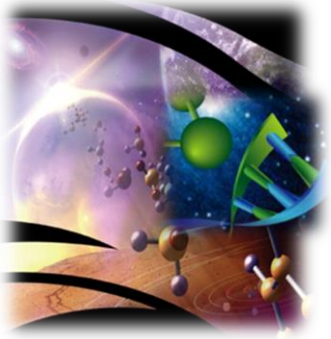
Intelligent / Adaptive Human & Robotic Systems



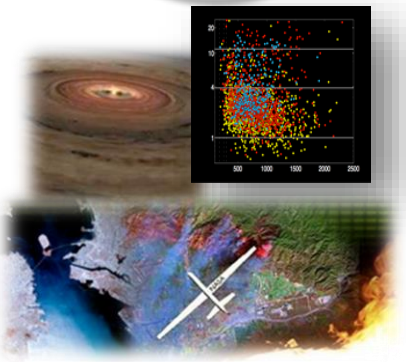
Low-Cost Space Missions



Aerosciences



Astrobiology and Life Science



Space and Earth Sciences

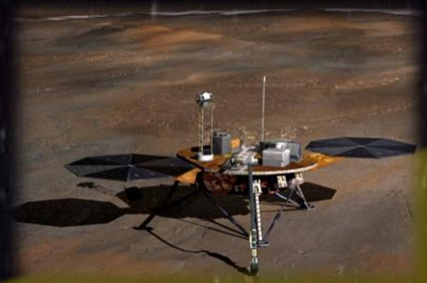
Ames Autonomy for Space Exploration

2003 Mars Exploration Rovers

Mixed-Initiative Activity Planner (MAPGEN)
Collaborative Information Portal (CIP)
MERBoard Collaborative Workspace

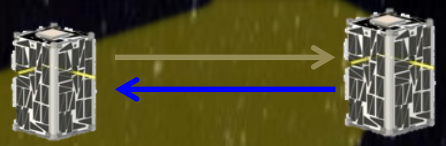
2007 Phoenix Lander

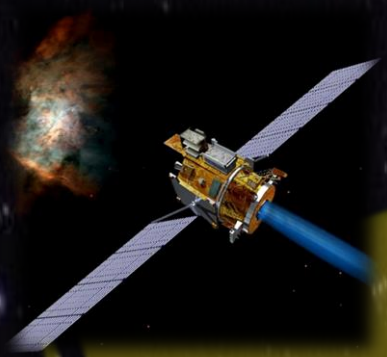
Ensemble:
Rover activity planning & scheduling



2016 NODES

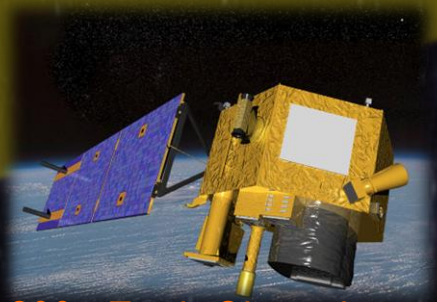
Spacecraft swarm relaying ground commands and science data between satellites while autonomously determining order of satellite network communication





1997 Deep Space 1 Remote Agent

The first demonstration of an onboard autonomous spacecraft control system



2005 Earth Observing - 1

Livingston on-board model-based diagnostic

2012 Mars Science Lab

Ensemble:
Rover activity planning & scheduling

2015: AMO

Demonstrate crew autonomy protocols and technology onboard ISS

Ames Autonomy for Robotics

2002 Single Cycle Instrument Placement

Approach and place an instrument in one command cycle. Method has since been used on Mars with MER.

2007 Robotic Site Survey

Systematic autonomous survey with rovers. Field testing at Haughton Crater.

2014 Planetary Lake Lander

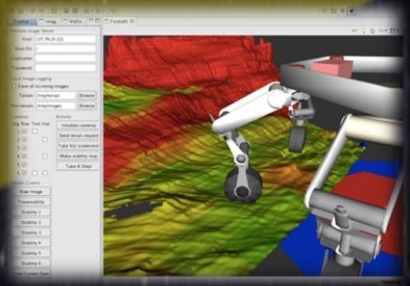
Adaptive science for dynamic phenomena in deep-space missions. Field testing in Chile.

2015 Astrobee Free-Flyer

Autonomous nav, docking and recharge, and mobile sensor IVA work on the ISS.

2005 Autonomous Visual Inspection

Robotic “walk around” inspection for future lunar sortie operations. Universal Executive and PLEXIL.



2010 ATHLETE Footfall Planner

Safe, energy-efficient walking with the ATHLETE robot on rough terrain.

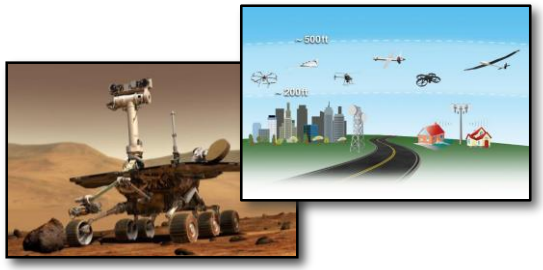
2014 Advanced Navigation

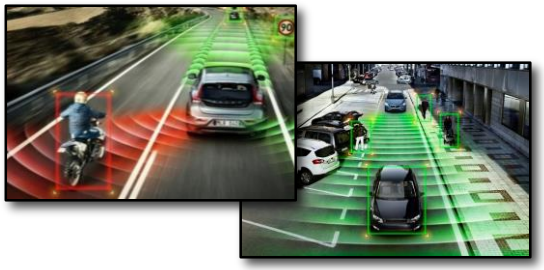
Autonomous map and feature-based localization for future planetary rover missions.

2015 – 19 Self Driving Car

Adapt space robotics technlology to “fleet management” use.

Self-Driving Cars and NASA





NASA Missions

Planned human-machine interaction

Natural and time delayed environments

Aerial, space, and planetary navigation

On-board and ground control autonomy

Cyber-security for "one-off" systems

…

Common Technologies

Autonomy
Advanced Planning & Scheduling Algorithms, etc.

Human-Autonomy Teaming
Robotic Supervision including Human/Robotic Interactions, etc.

Networked Operations
Remote Vehicle Management, etc.

Prognostics / Diagnostics
Including State Management, etc.

Sensors and Perception
Data Processing / Fusion Methodologies, etc.

Verification and Validation
Methodologies & Application Experiences, etc.

Self-Driving Cars

Diverse human-machine interaction

Structured environment

GPS & map-based navigation

Distributed and cloud-based autonomy

Cyber-security for consumer product

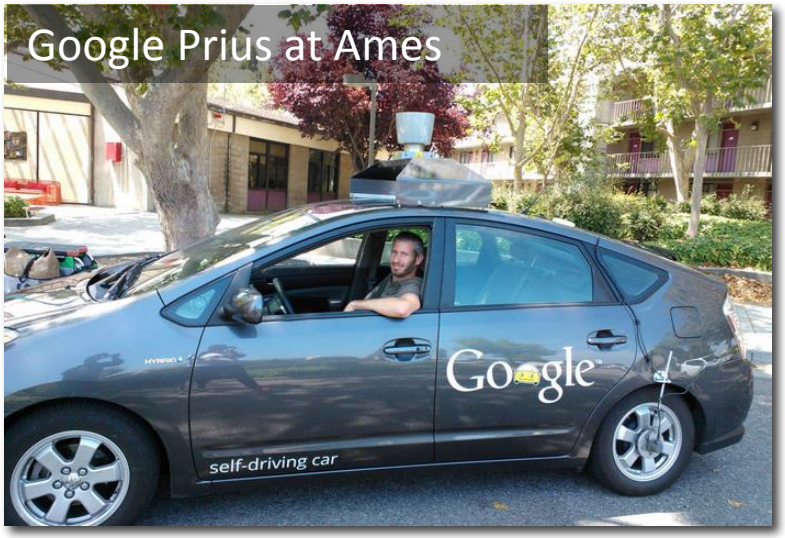
…

Self-Driving Cars at NASA Ames

- Public/private partnerships
  - Google (2014-15): collaborative testing of different sensors and vehicles
  - Nissan (2014-19): cooperative software development (NASA spin-off)

- Benefits to NASA
  - Expand knowledge of commercial **autonomous vehicle systems**
  - Develop protocols and best practices for safe testing and assessment of **real-world autonomy**
  - Facilitate spin-off of NASA robotics technologies (algorithms, software)

Nissan Leaf at Ames



Google Prius at Ames

Ames Autonomy for Aeronautics

2004 Autonomous Rotorcraft

Automated reasoning in the context of autonomous rotorcraft operations.

2012 Function Allocation

Automated ground-based separation assurance across increasing levels of autonomy

2015 sUAS Autonomy

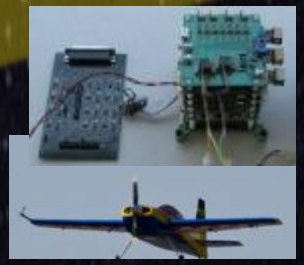
Fully Autonomous urban deployment of sUAS—Vehicle Technologies and Airspace Management

1999 Neural Net Learning

Dynamic Cell Structure NN based learning for adaptive control

2010 Emergency Landing Planner

Decision support to the pilot of a damaged commercial transport aircraft



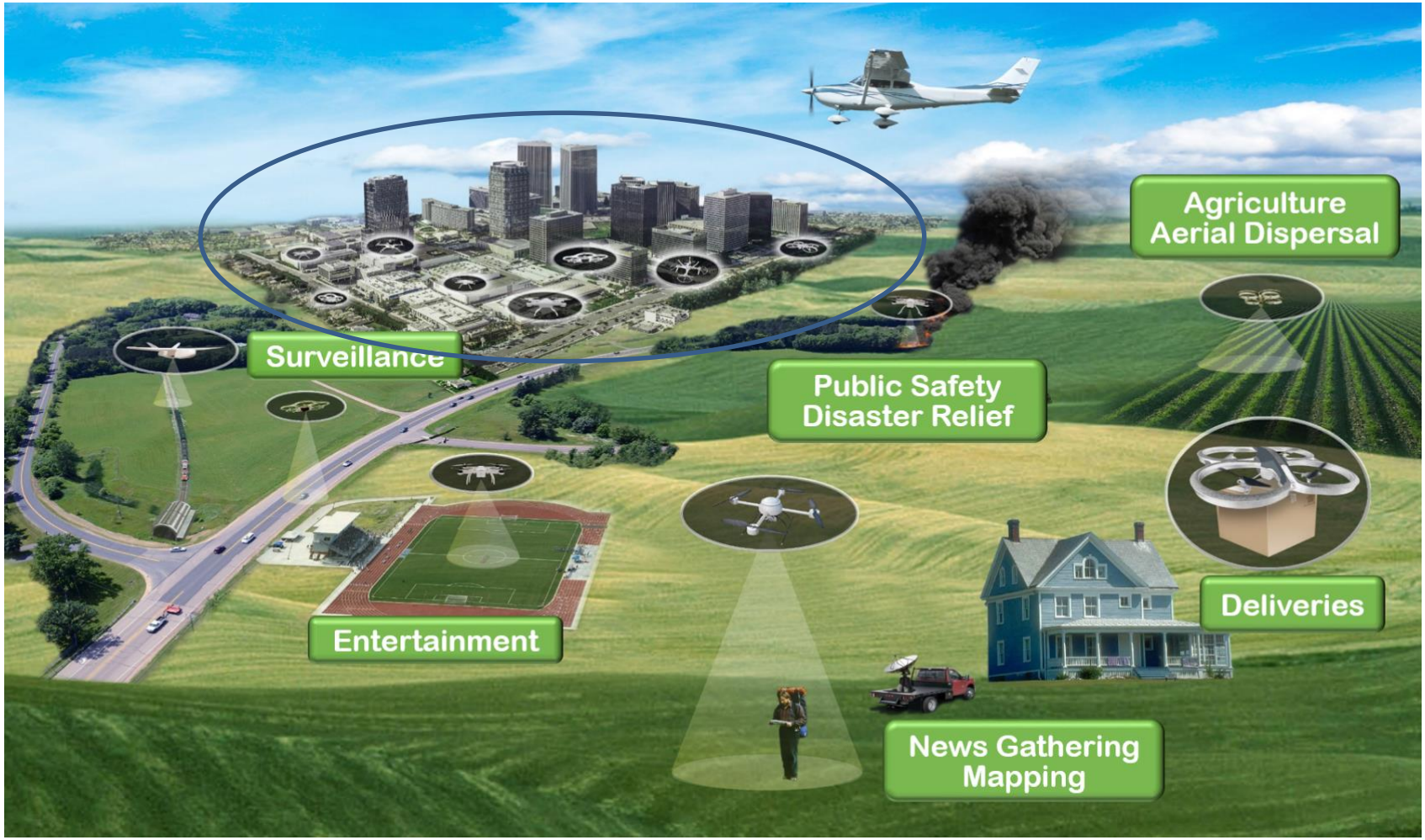
2011 Real-Time Prognostics

Predict remaining useful battery life

2013 Prediction Uncertainty

Operators compensating for imperfect autonomy

Unmanned A/C Systems Applications



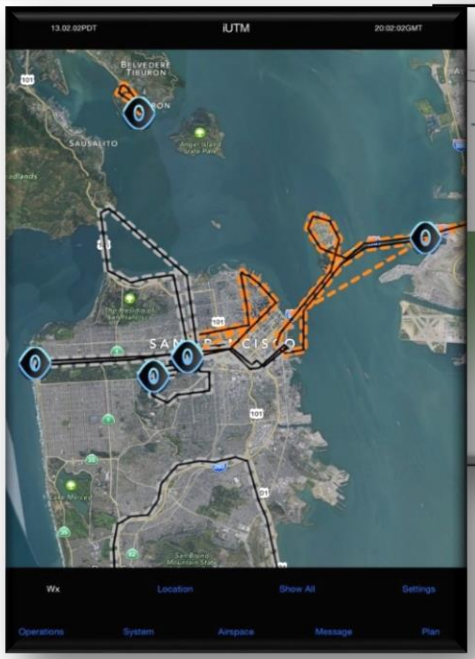
Low Altitude UAS Operations

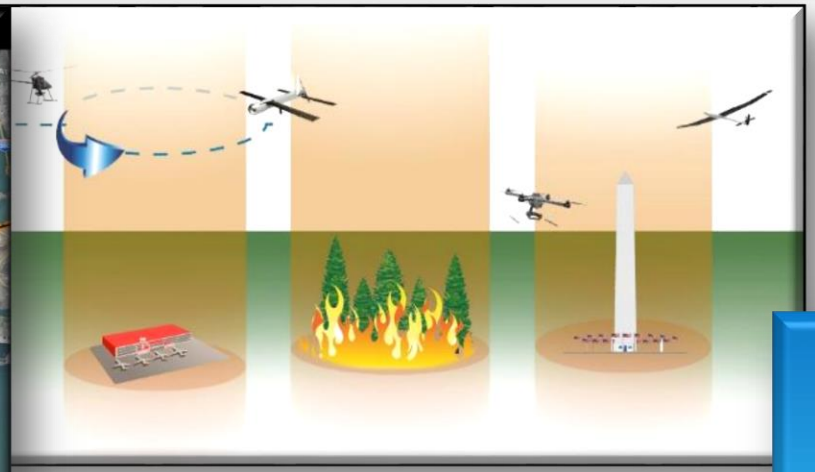
- Small UAS forecast – 7M total, 2.6M commercial by 2020
- Need a way to manage beyond visual line of sight UAS
- Vehicles are autonomous and airspace integration is necessary
- Operators want flexibility for operations
- Regulators need a way to put structures as needed

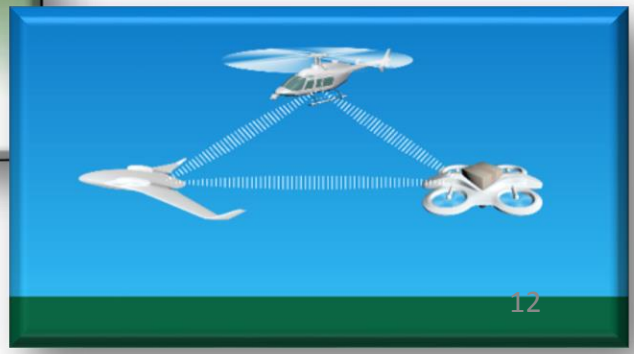
UAS Traffic Management (UTM)

Research Platform that

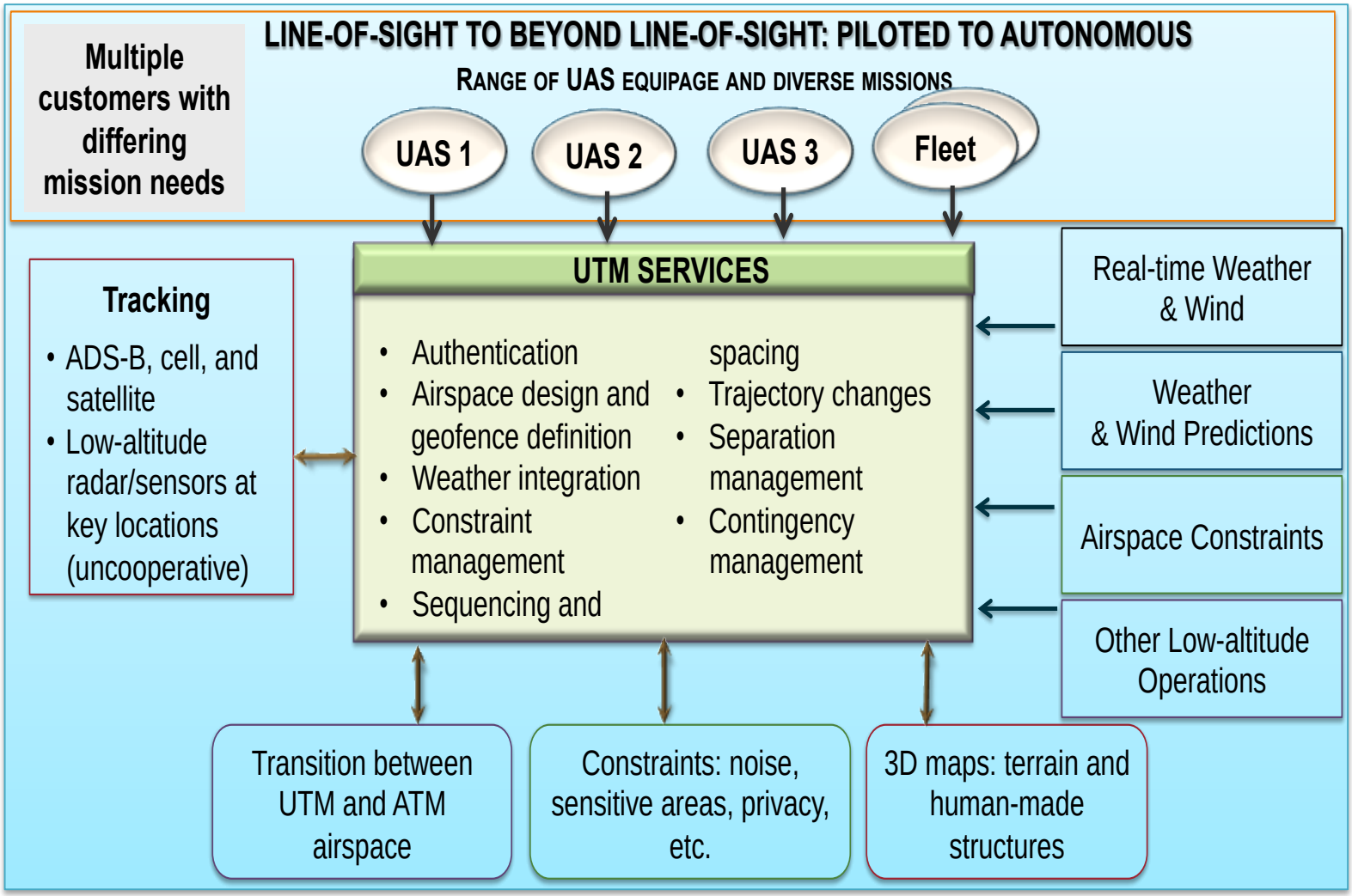
(1) Gives situational awareness of all airspace constraints and info about other operations to UAS operators, support service suppliers, and regulators
(2) Allows to exchange data among UAS operators as well as regulator
(3) Allows UAS operators to submit flight plans to execute a specific mission in low-altitude airspace, and
(4) Determines how to safely enable such single or multiple UAS operations either within visual line of sight or beyond visual line of sight
(5) Integrates airspace and vehicle operations



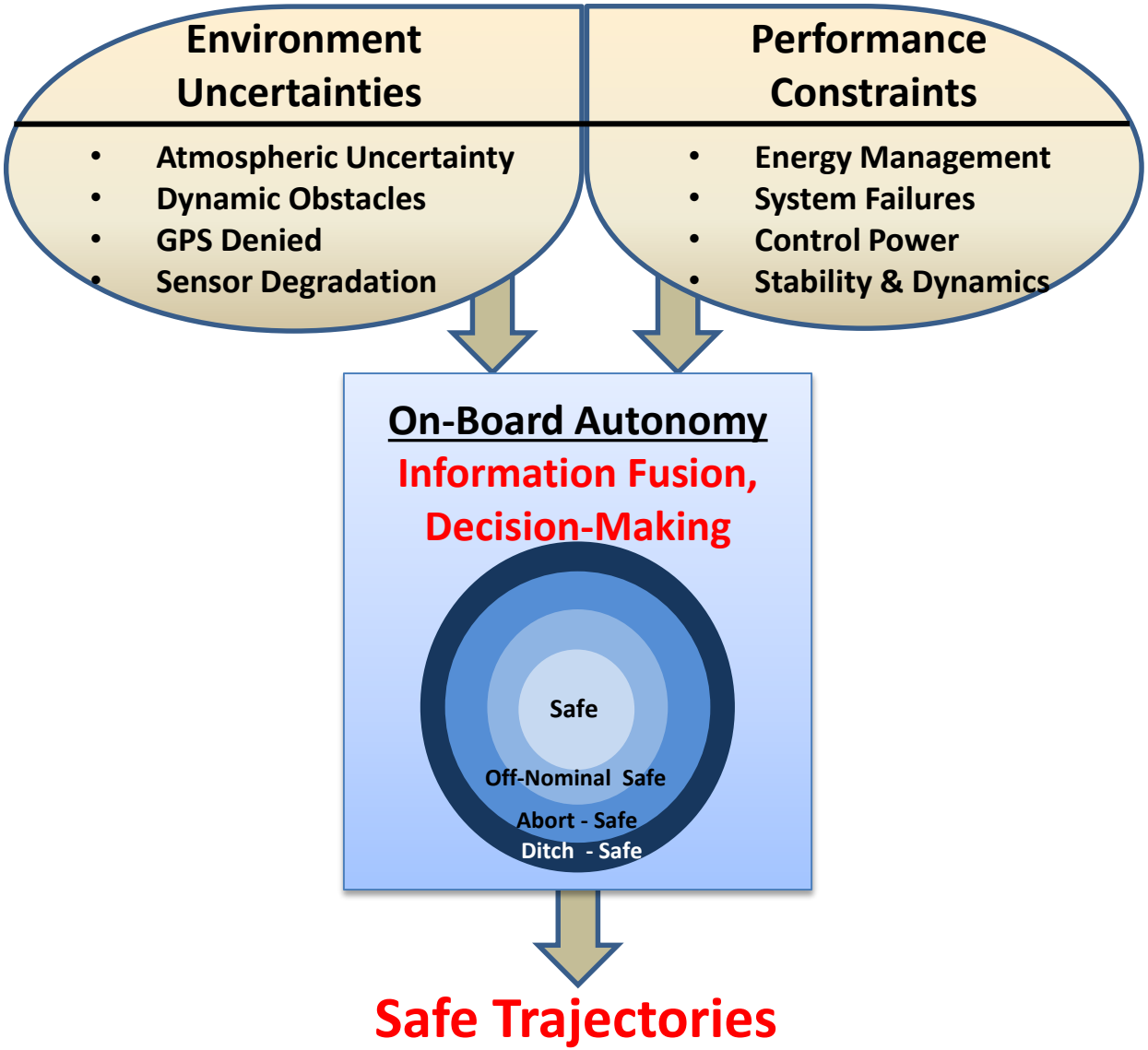




UAS Traffic Management (UTM)

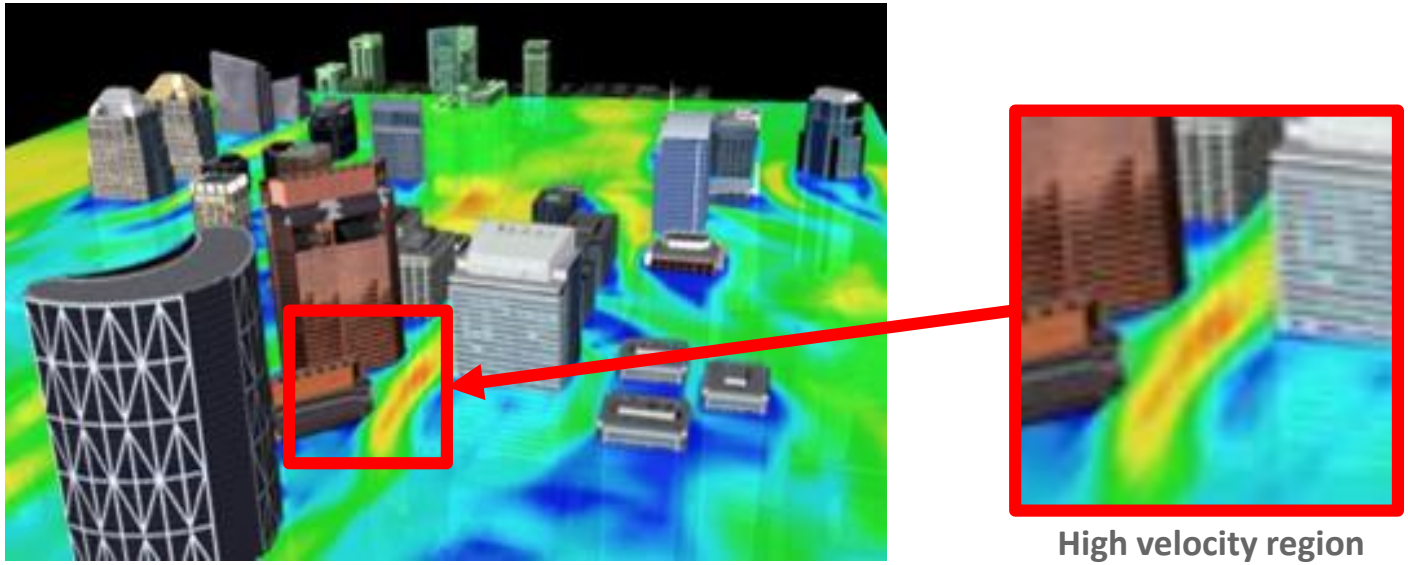


Safe & Autonomous for Urban Flight



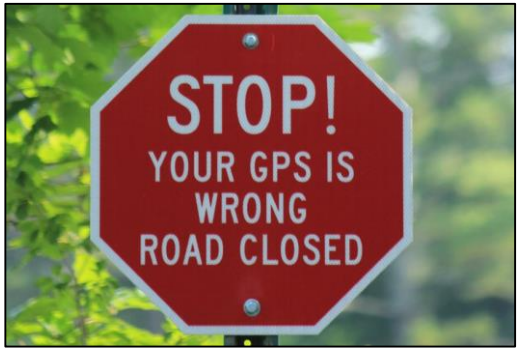
Research Challenges

1. UrbanScape Wind Uncertainties

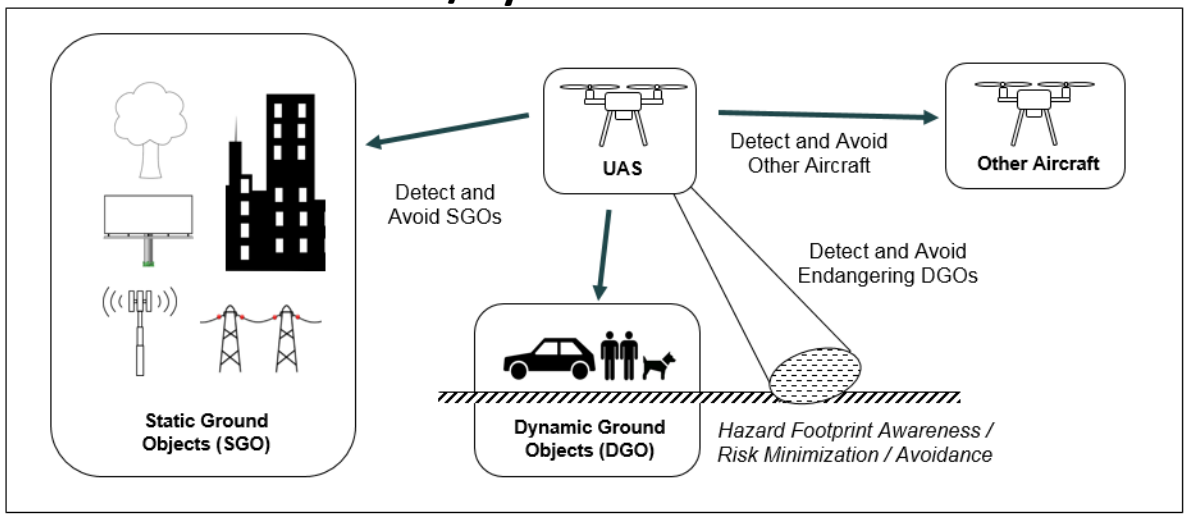


High velocity region

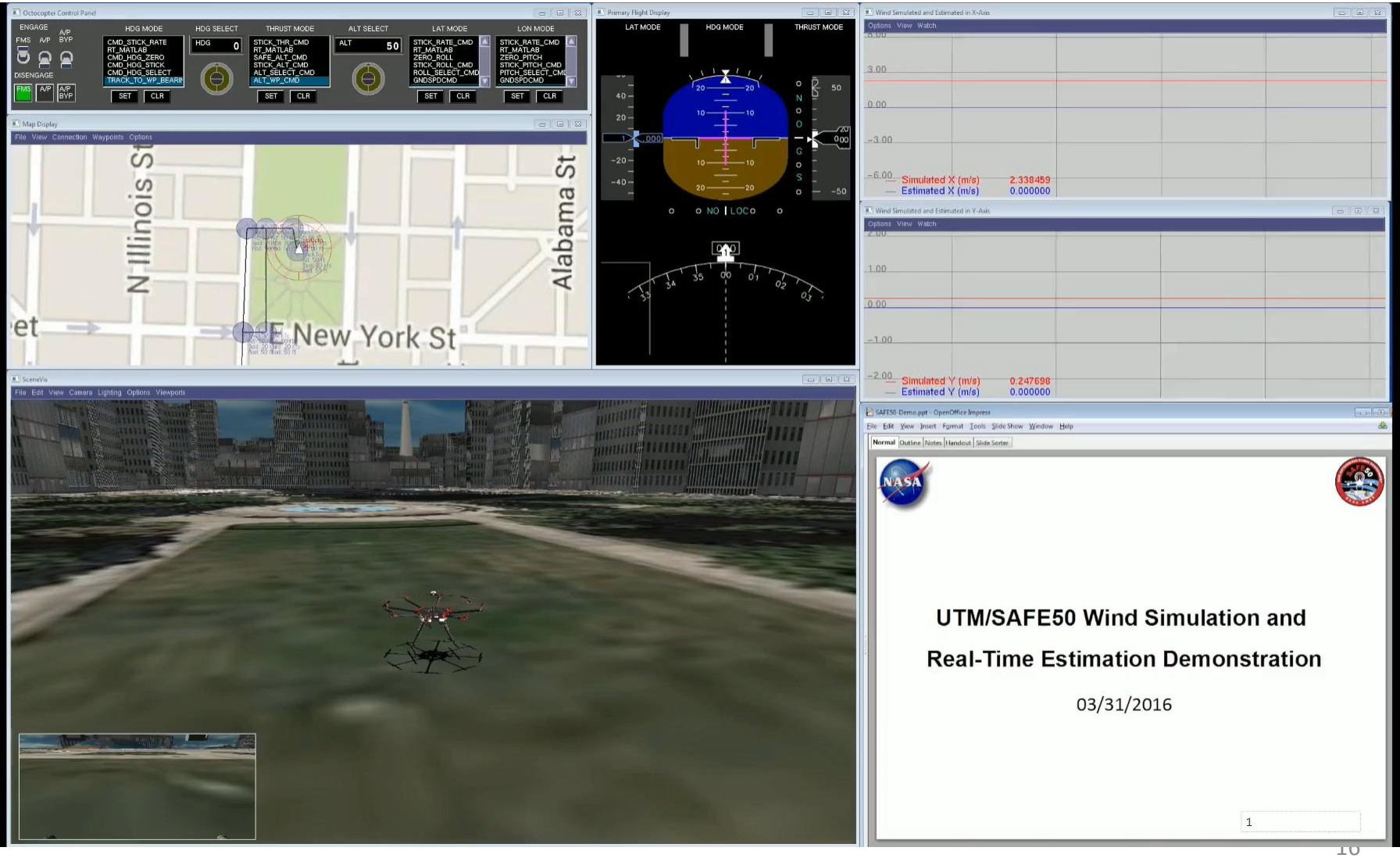
2. GPS Denied/Degraded



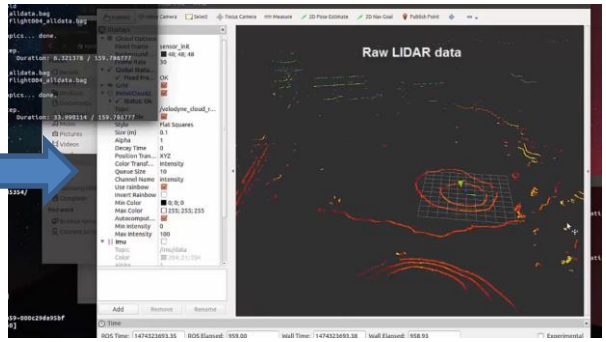
3. Static/Dynamic Obstacles

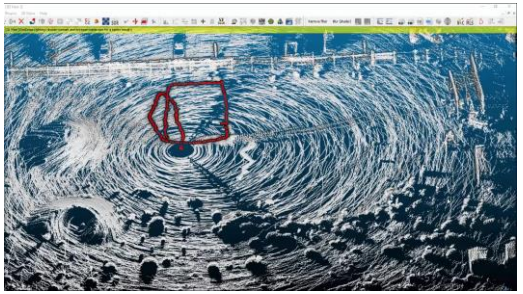


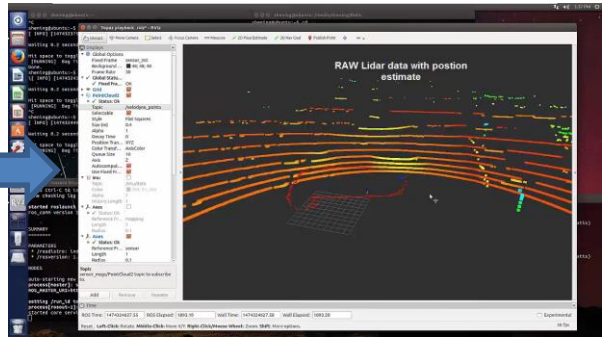
UrbanScape Wind Uncertainties



GPS Denied/Degraded Navigation

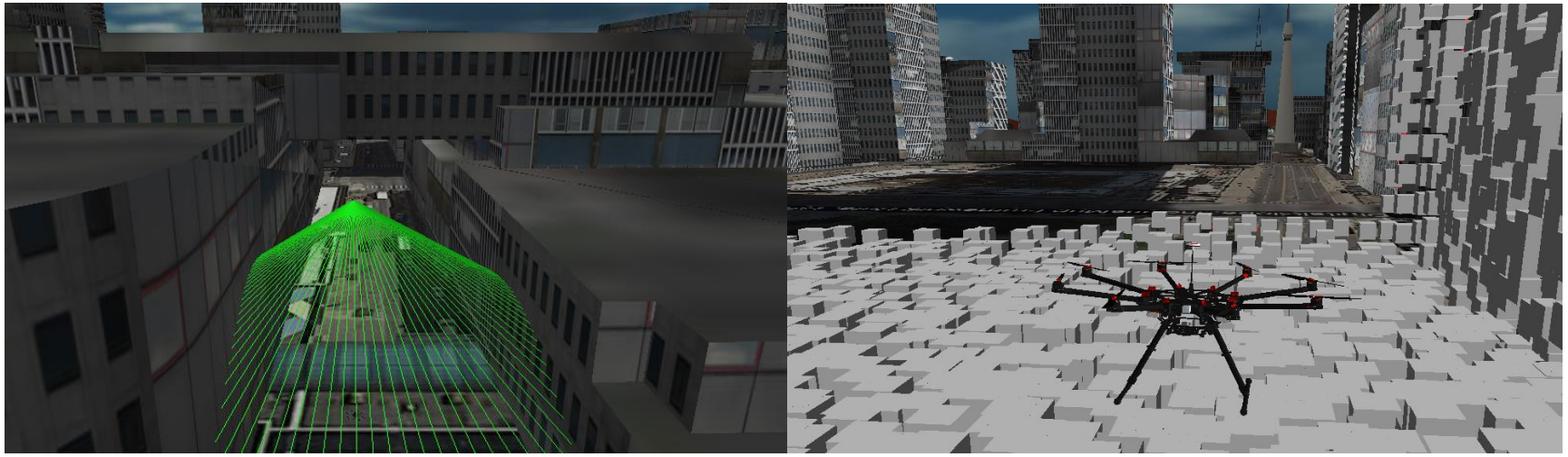


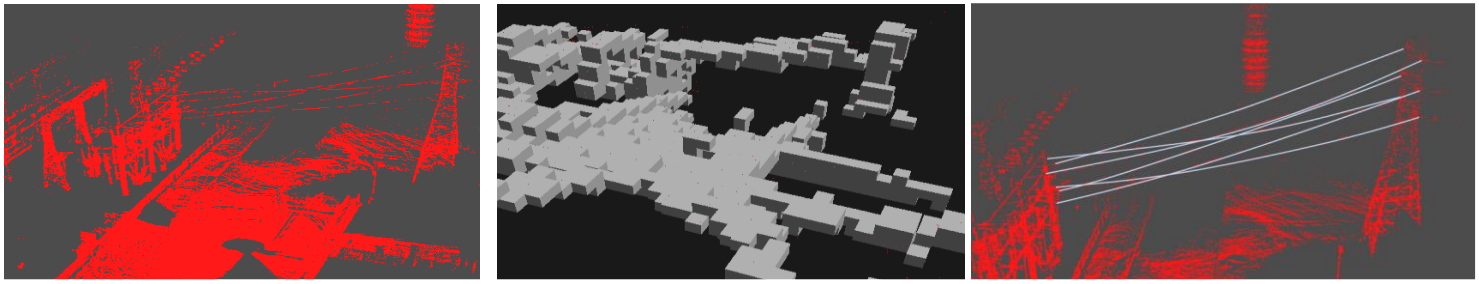




Static/Dynamic Obstacles

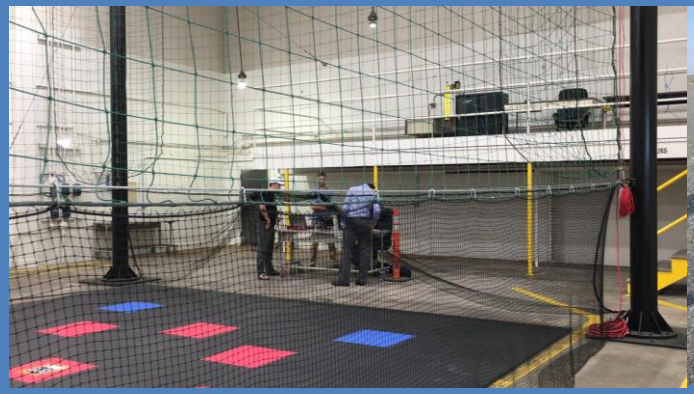
LiDAR Data and Voxel Representation





Powerline Identification and Reconstruction. Raw LiDAR point clouds (left), voxel processing (middle), reconstructed powerlines (right), at 20m (top)

Test Environments



Ames NUARC Facility

Ames Roverscape

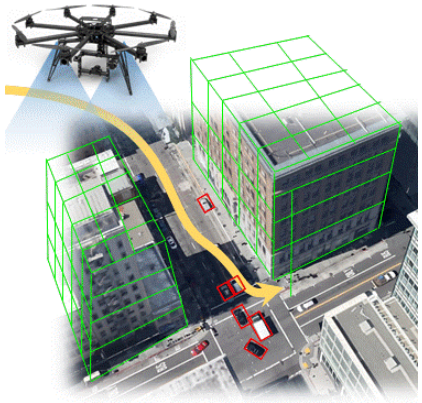
Ames DART Facility

Summary

Ames Research Center

Autonomy Applications

Self-Driving Cars



Autonomous Drones