Safe and Autonomous Drones for Urban Flight

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NASA Ames Research Center
Outline

Ames Research Center

Self-Driving Cars

Autonomy Applications

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
- Low-Cost Space Missions
- Aerosciences
- Astrobiology and Life Science
- Intelligent / Adaptive Human & Robotic Systems
- Space and Earth Sciences
 Amec Autonomy for Space Exploration

2003 Mars Exploration Rovers
Mixed-Initiative Activity Planner (MAPGEN)
Collaborative Information Portal (CIP)
MERBoard Collaborative Workspace

2005 Earth Observing - 1
Livingston on-board model-based diagnostic

2007 Phoenix Lander
Ensemble:
Rover activity planning & scheduling

2012 Mars Science Lab
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

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 Astrobbe 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 technology to “fleet management” use.
Self-Driving Cars and NASA

**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.

**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

**Self-Driving Cars**
- Diverse human-machine interaction
- Structured environment
- GPS & map-based navigation
- Distributed and cloud-based autonomy
- Cyber-security for consumer product

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Self-Driving Cars at NASA Ames

- Public/private partnerships
  - Google (2014-15): collaborative testing of different sensors and vehicles

- 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)
Ames Autonomy for Aeronautics

2004 Autonomous Rotorcraft
Automated reasoning in the context of autonomous rotorcraft operations.

1999 Neural Net Learning
Dynamic Cell Structure
NN based learning for adaptive control

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

2010 Emergency Landing Planner
Decision support to the pilot of a damaged commercial transport aircraft

2013 Prediction Uncertainty
Operators compensating for imperfect autonomy

2011 Real-Time Prognostics
Predict remaining useful battery life

2015 sUAS Autonomy
Fully Autonomous urban deployment of sUAS—Vehicle Technologies and Airspace Management
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
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)

LINE-OF-SIGHT TO BEYOND LINE-OF-SIGHT: PILOTED TO AUTONOMOUS

- Authentication
- Airspace design and geofence definition
- Weather integration
- Constraint management
- Sequencing and spacing
- Trajectory changes
- Separation management
- Contingency management

Multiple customers with differing mission needs

Tracking
- ADS-B, cell, and satellite
- Low-altitude radar/sensors at key locations (uncooperative)

Transition between UTM and ATM airspace

Constraints: noise, sensitive areas, privacy, etc.

3D maps: terrain and human-made structures

Real-time Weather & Wind

Weather & Wind Predictions

Airspace Constraints

Other Low-altitude Operations

Range of UAS equipage and diverse missions
Safe & Autonomous for Urban Flight

Environment Uncertainties
- Atmospheric Uncertainty
- Dynamic Obstacles
- GPS Denied
- Sensor Degradation

Performance Constraints
- Energy Management
- System Failures
- Control Power
- Stability & Dynamics

On-Board Autonomy
Information Fusion, Decision-Making

Safe
Off-Nominal Safe
Abort - Safe
Ditch - Safe

Safe Trajectories
Research Challenges

1. UrbanScape Wind Uncertainties

2. GPS Denied/Degraded

3. Static/Dynamic Obstacles

- Detect and Avoid SGOs
- Detect and Avoid Endangering DGOs
- Hazard Footprint Awareness / Risk Minimization / Avoidance
GPS Denied/Degraded Navigation
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

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Autonomy Applications

Autonomous Drones