UAV Research at NASA Langley:
Towards Safe, Reliable, and Autonomous Operations

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Aviation, Engineering on a High Level
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Location of NASA Centers

NASA Headquarters
Washington, DC.
Aerodynamics

Flutter, engine performance

Structures
"...I believe this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to the Earth."

J.F. Kennedy, May 25, 1961
NASA Langley Research Center

Founded in 1917
• First civil aeronautical research laboratory

Programs
• ~$760 M total annual budget

Facilities
• ~800 acres, ~150 Buildings
• $2 billion replacement value

Programs
• ~3,700 employees
NASA Langley Research Center
Landing and Impact Dynamics Facility
Drones @ LaRC

Future Aircraft

Flight Dynamics

Mars Mission
UAS Research at Langley

Unmanned Air Vehicle (UAV) - Unmanned Aerial System (UAS)

- **Vehicle Centric**
  - Autonomous Operations
  - Health Monitoring and Prognostics
  - Mission (Capability) Driven Airframe Design
  - Flight Dynamics and Controls

- **Airspace Integration**
  - UAS in the NAS / Traffic Management
  - Sense and Avoid
  - Contingency Operations
  - Certification

- **Research Payload Platform**
  - Atmospheric Science
  - Wildfire Detection
  - Acoustic Signatures
Future Aircraft Concepts
NASA Aviation Safety Program

**Research Goal:** The goal of the project was to develop a dynamically-scaled, **subscale testbed** with remote pilot-in-the-loop capability to conduct flight dynamics and control experiments.

**Status:** Phase IV operations were wrapped up in 2013 with a total of 50+ research flights successfully completed. A flight demonstration of Beyon Visual Range capability (4000 ft AGL and 6 nm) along with several research experiments was completed.
NASA AirSTAR

5.5% Generic Transport Model Airplane

Flight Research Deployment

September 2010

Flight #48
Mars Plane

Straightforward Mission that Maximizes Use of Proven Technologies and Existing Infrastructure
Automation vs. Autonomy

“There is a paradigm shift from automated to autonomous: automation is relegation; autonomy is delegation…”

“... safe and trusted systems than can perceive their environment for situational awareness and assessment, make decisions on uncertain and inaccurate information, act appropriately, learn from experience and adapt their behavior…”

“...[certification] is about behavior and probability... we will need new methods of verification and validation.”
1. Build a Multi-Disciplinary Team
   • Mechanics/Electronics/Controls
   • Computer Science/Programming
   • Psychology/Machine Learning
   • Signal Processing/Computer Vision

2. Enable new missions in
   • Space
   • Aeronautics
   • Science

3. Create a Testbed for Autonomous Systems
   • Open Software Architecture (AEON)
   • Test range: CERTAIN

Autonomy Challenges
   • Human-Machine Interaction
   • Data-rich/degraded/deprived environments
   • Size, Weight And Power (SWAP)
   • Sensor Fusion
   • Adaptive Control
   • Geo-containment
   • Sense/Detect and Avoid (DAA)
   • Precision navigation
   • Localization
   • Adaptation and Learning
   • Performance Standards
   • Verification and Validation (V&V)
   • Certification/Trust
   • Test and Evaluation (T&E)
• **Human intelligence** applied to supervision, control, and intervention of operations will **no longer** be **viable** due to system/mission complexity, short reaction/decision time, communication delays, distance, or hostile environments.

• **Systems with machine intelligence:** capable of responding to expected and unexpected situations:
  – trusted and certified-safe systems capable of
  – sensing and perception
  – situation assessment/awareness
  – decision-making
  – taking action
  – and knowledge acquisition (learning)
  – **teaming with humans**
Autonomy Incubator

- Detect and Avoid (DAA) #DancesWithDrones
- Search & Rescue Under the Canopy
- Visual Odometry
- Innovative Vehicles
- Sensors
- Real-time Collaborative UAVs
- Package Delivery
- Search & Rescue Under the Canopy
Telemetry – Motion Capture

Vicon camera system
Human Machine Teaming
Earth Science Mission

Air Quality Monitoring Sensors

- Multi-vehicle
- Data-denied
- Measurements
Detect and Avoid
(#TreeDodging)
Machine Learning

Pilot trains UAV’s neural network
Detect and Avoid (#DancesWithDrones)
**Visual Odometry:** process of determining the position and orientation of a robot by analyzing the associated camera images.

Features on the left video frame are matched with their corresponding features on the right video frame. Parallel lines indicate correct matches. Intersecting lines indicate mistaken matches.
Fast Semi-Direct Monocular Visual Odometry

Dual function of VO:
- Navigation
- Simultaneous mapping
Navigation by Visual Odometry

Simulation of Mars exploration using visual odometry
Mars Helicopter
Test and Evaluation

CERTAIN - City Environment for Range Testing of Autonomous Integrated Navigation

LaRC Gantry

Outdoors Contained. Intended

Urban/Suburban Land Use

Uncontained Free Flight

Industrial Facilities

March 2016

Simon Stevin Symposium, TU Eindhoven
CERTAIN Test Range
Test: Search and Rescue Mission

Alternate Targets

Delivery of payload
In Conclusion…

- UAS related research, development and operations are a dynamic environment both in Technology and Regulation
  - Technology is increasing in capability and decreasing in cost
  - Rules and regulations are hard pressed to keep up with technology
- UAS are being utilized at Langley in a variety of research areas:
  - Technology testbed
  - Platform for sensors
  - Safe integration into the National Airspace
- Safe operation of UAS is:
  - Dependent on the organization
  - Necessary as we march toward integration into our everyday lives