

UAV Research at NASA Langley:

Towards Safe, Reliable, and Autonomous Operations



Carlos G. Dávila

NASA Langley Research Center, USA



Aviation, Engineering on a High Level

Simon Stevin Symposium

Eindhoven, 16 October 2016



Location of NASA Centers



**NASA Headquarters
Washington, DC.**

Ames Research Center

Lewis Research Center

**Jet
Propulsion
Laboratory**

Goddard Space Flight Center

**Capabilities
Distributed
Agencywide**

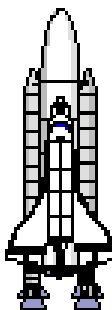
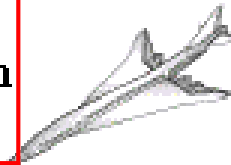
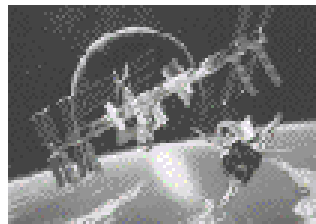
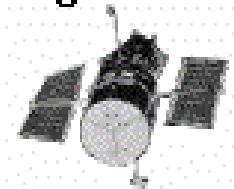
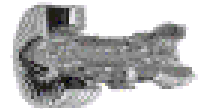
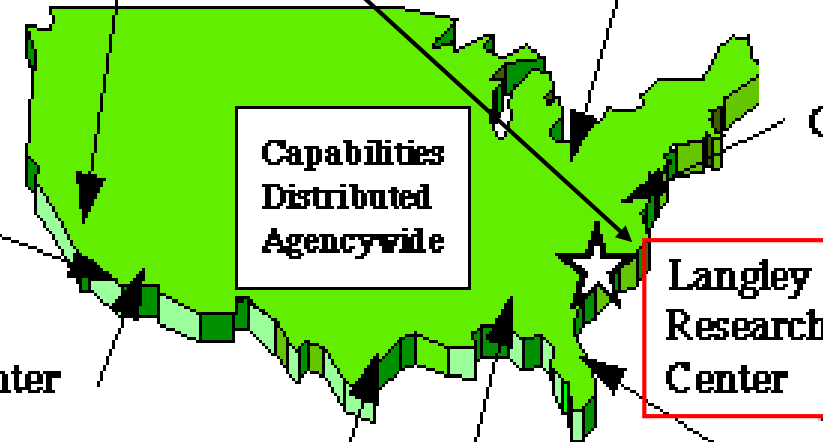
**Langley
Research
Center**

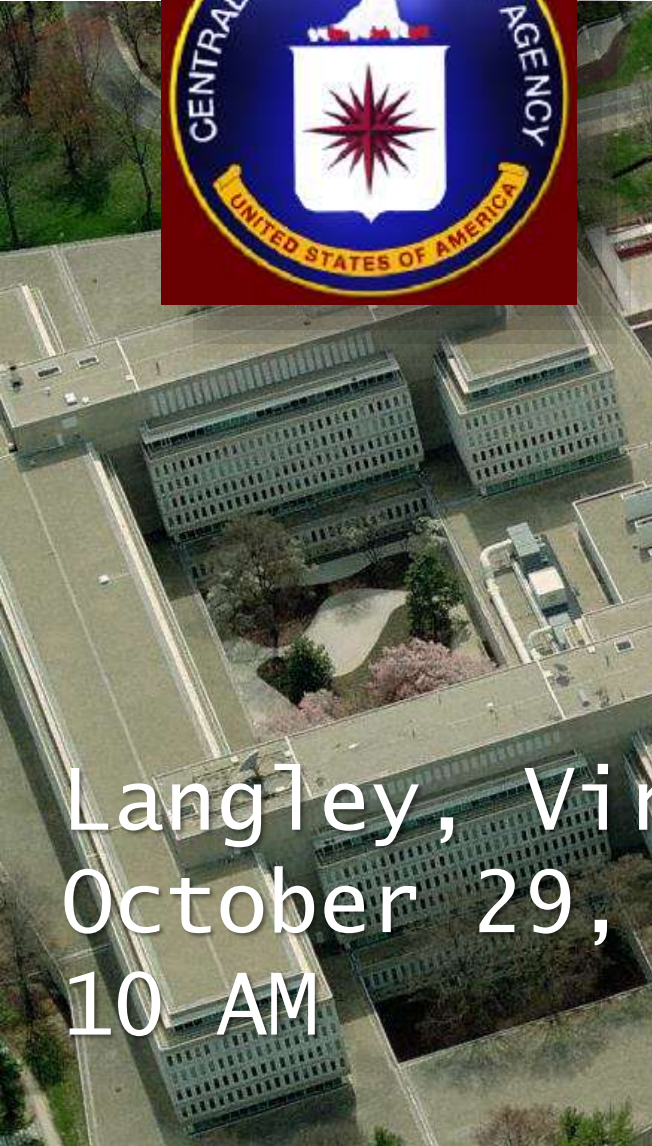
Dryden Flight Research Center

Kennedy Space Center

Johnson Space Center

**Marshall
Space
Flight
Center**





Langley, Virginia
October 29, 2015
10 AM



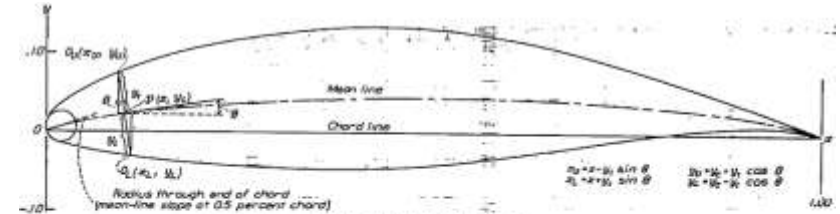
NASA Langley Research Center



Aerodynamics



1920



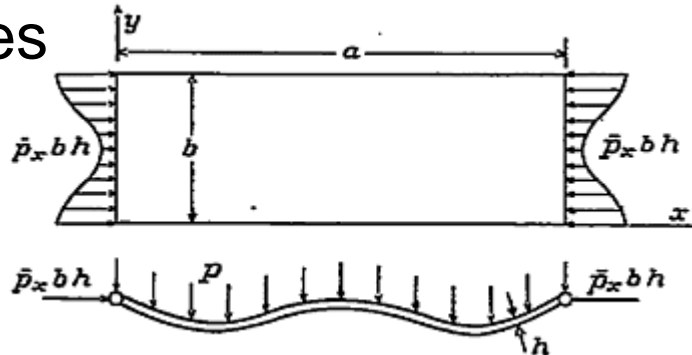
SAMPLE CALCULATIONS FOR DERIVATION OF THE NACA 2412 AIRFOIL

x	$\frac{y}{c}$	$\frac{t}{c}$	tan θ	tan ϕ	tan $\theta - \phi$	$\frac{d}{c}$	$\frac{d^2}{c^2}$	$\frac{d^3}{c^3}$	$\frac{d^4}{c^4}$	$\frac{d^5}{c^5}$	$\frac{d^6}{c^6}$
0	0	0	0	0	0	0	0	0	0	0	0
.05	.1124	.0200	-.2500	0.2000	-.0500	.0025	-.0000	-.0000	-.0000	-.0000	-.0000
.10	.2000	.0200	-.2000	.1600	-.0400	.0050	-.0000	-.0000	-.0000	-.0000	-.0000
.15	.2600	.0200	-.1500	.1200	-.0300	.0075	-.0000	-.0000	-.0000	-.0000	-.0000
.20	.3000	.0200	-.1000	.0800	-.0200	.0100	-.0000	-.0000	-.0000	-.0000	-.0000
.25	.3200	.0200	-.0500	.0600	-.0100	.0125	-.0000	-.0000	-.0000	-.0000	-.0000
.30	.3200	.0200	0.0000	.0400	-.0400	.0150	-.0000	-.0000	-.0000	-.0000	-.0000
.35	.3000	.0200	.0500	.0200	-.0300	.0175	-.0000	-.0000	-.0000	-.0000	-.0000
.40	.2600	.0200	.1000	.0000	-.1000	.0200	-.0000	-.0000	-.0000	-.0000	-.0000
.45	.2000	.0200	.1500	-.0200	-.1300	.0225	-.0000	-.0000	-.0000	-.0000	-.0000
.50	.1200	.0200	.2000	-.0400	-.1600	.0250	-.0000	-.0000	-.0000	-.0000	-.0000
.55	.0200	.0200	.2500	-.0600	-.1900	.0275	-.0000	-.0000	-.0000	-.0000	-.0000
.60	0	.0200	.3000	-.0800	-.2200	.0300	-.0000	-.0000	-.0000	-.0000	-.0000
.65	0	.0200	.3500	-.1000	-.2500	.0325	-.0000	-.0000	-.0000	-.0000	-.0000
.70	0	.0200	.4000	-.1200	-.2800	.0350	-.0000	-.0000	-.0000	-.0000	-.0000
.75	0	.0200	.4500	-.1400	-.3100	.0375	-.0000	-.0000	-.0000	-.0000	-.0000
.80	0	.0200	.5000	-.1600	-.3400	.0400	-.0000	-.0000	-.0000	-.0000	-.0000
.85	0	.0200	.5500	-.1800	-.3700	.0425	-.0000	-.0000	-.0000	-.0000	-.0000
.90	0	.0200	.6000	-.2000	-.4000	.0450	-.0000	-.0000	-.0000	-.0000	-.0000
.95	0	.0200	.6500	-.2200	-.4300	.0475	-.0000	-.0000	-.0000	-.0000	-.0000
1.00	0	.0200	.7000	-.2400	-.4600	.0500	-.0000	-.0000	-.0000	-.0000	-.0000

* Thickness distribution obtained from ordinates of the NACA 2412 airfoil.
 * Ordinate of the mean line, 0.5 of the ordinate for $c_p=1.0$.
 * Slope of mean line through end of chord.

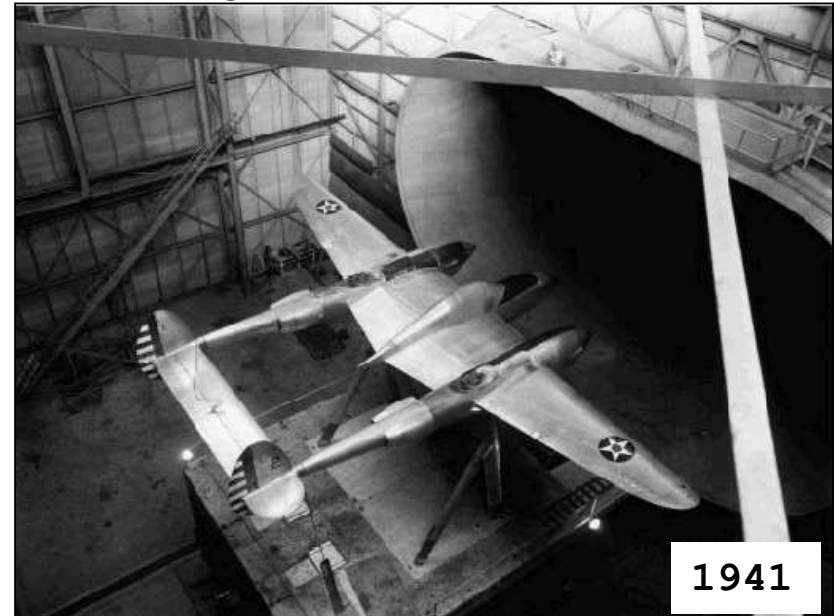
Flutter, engine performance

Structures



$$\epsilon_x^1 = \frac{1}{E} \left(\frac{\partial^2 u}{\partial x^2} - \nu \frac{\partial^2 v}{\partial x^2} \right)$$

$$\epsilon_y^1 = \frac{1}{E} \left(\frac{\partial^2 v}{\partial x^2} - \nu \frac{\partial^2 u}{\partial x^2} \right)$$



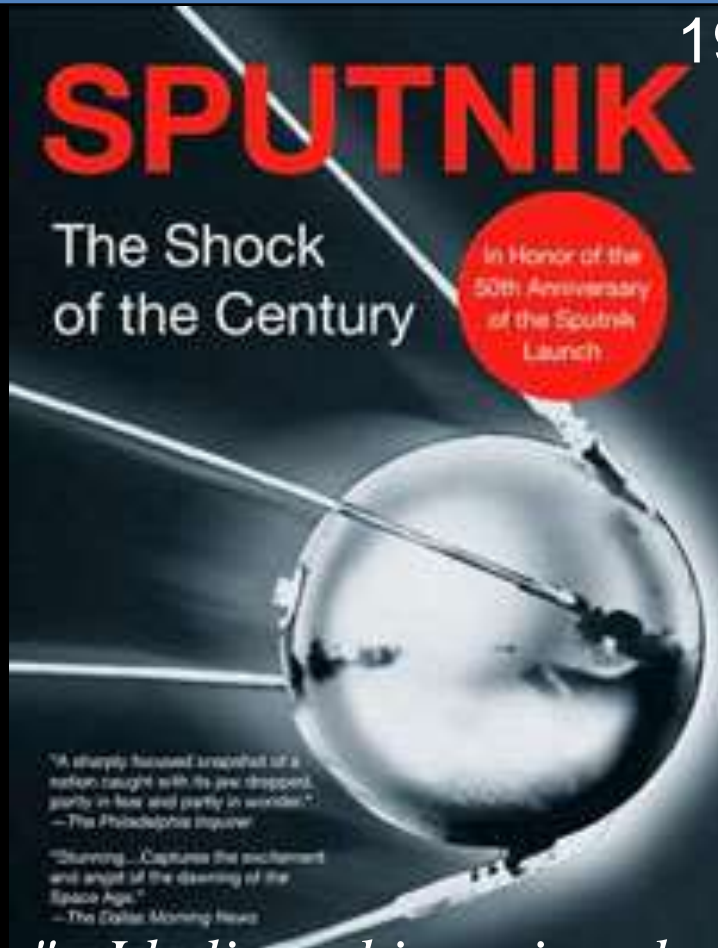
1941



NACA to NASA



1957



1961



"...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



Neil Armstrong At The Lunar Landing Research Facility
NASA Langley Research Center

1/28/1970

Image # EL-1996-00192





Landing and Impact Dynamics Facility





Drones @ LaRC

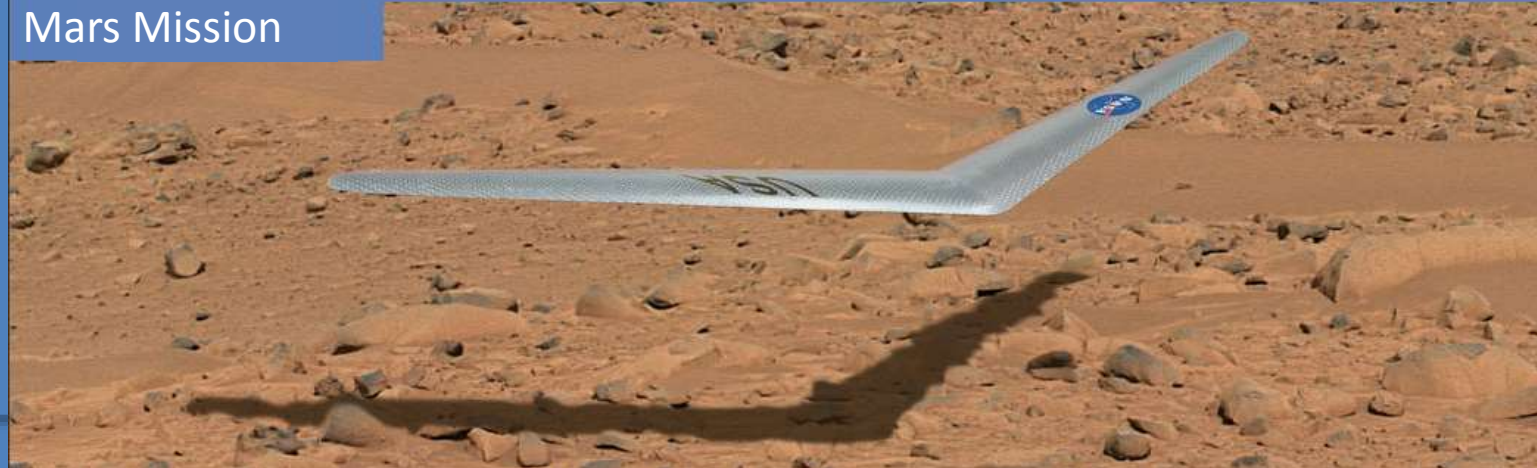
Future Aircraft



Flight Dynamics



Mars Mission



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





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

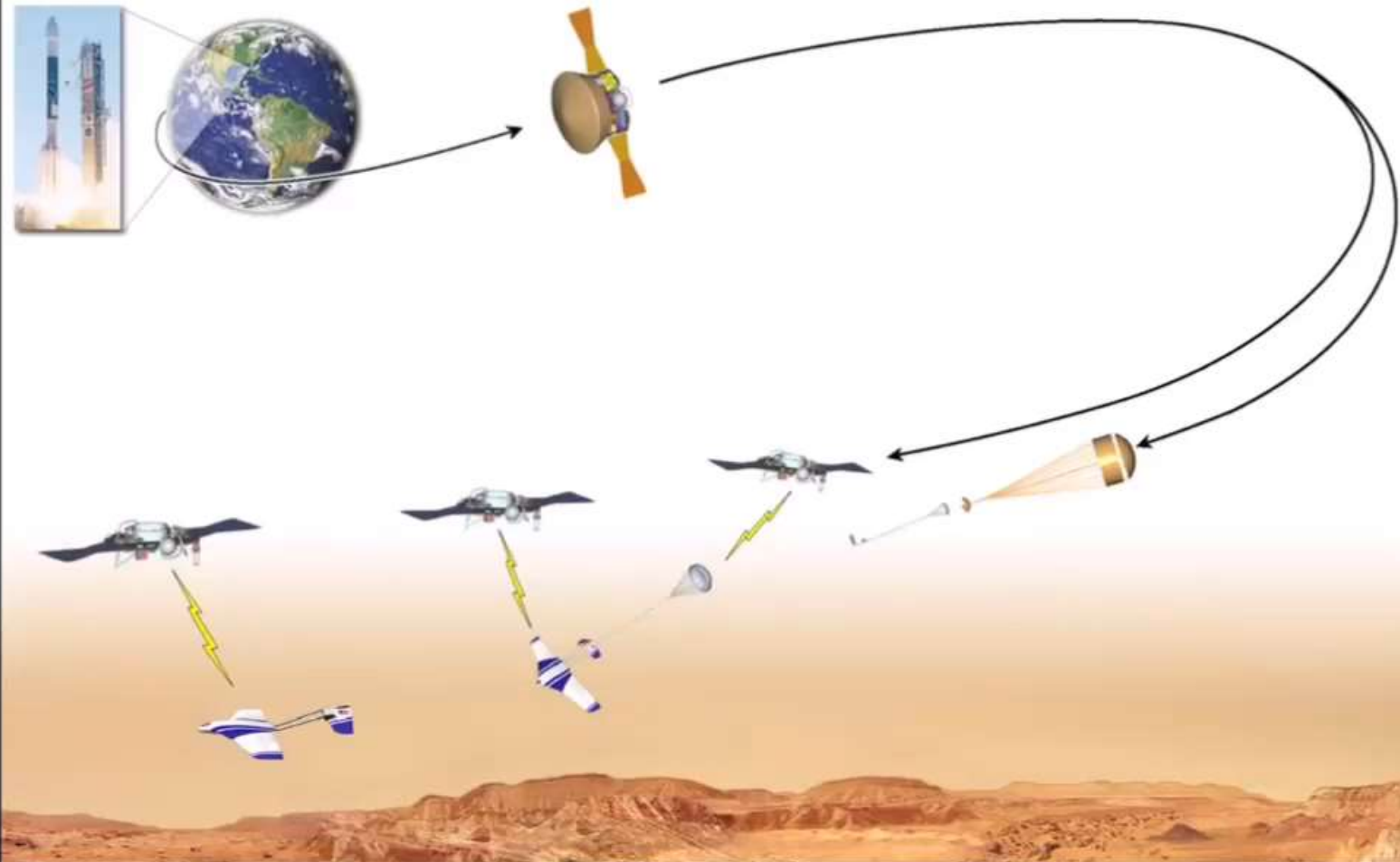
Status: Phase IV operations were wrapped up in 2013 with a total of 50+ research flights successfully completed. A flight demonstration of Beyond Visual Range capability (4000 ft AGL and 6 nm) along with several research experiments was completed.





NASA AirSTAR
**5.5% Generic Transport
Model Airplane**
Flight Research Deployment
September 2010
Flight #48

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



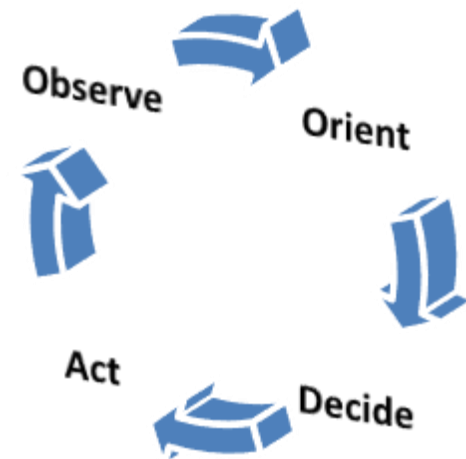
3. Create a Testbed for Autonomous Systems

- Open Software Architecture (AEON)
- Test range: CERTAIN

Autonomy Challenges

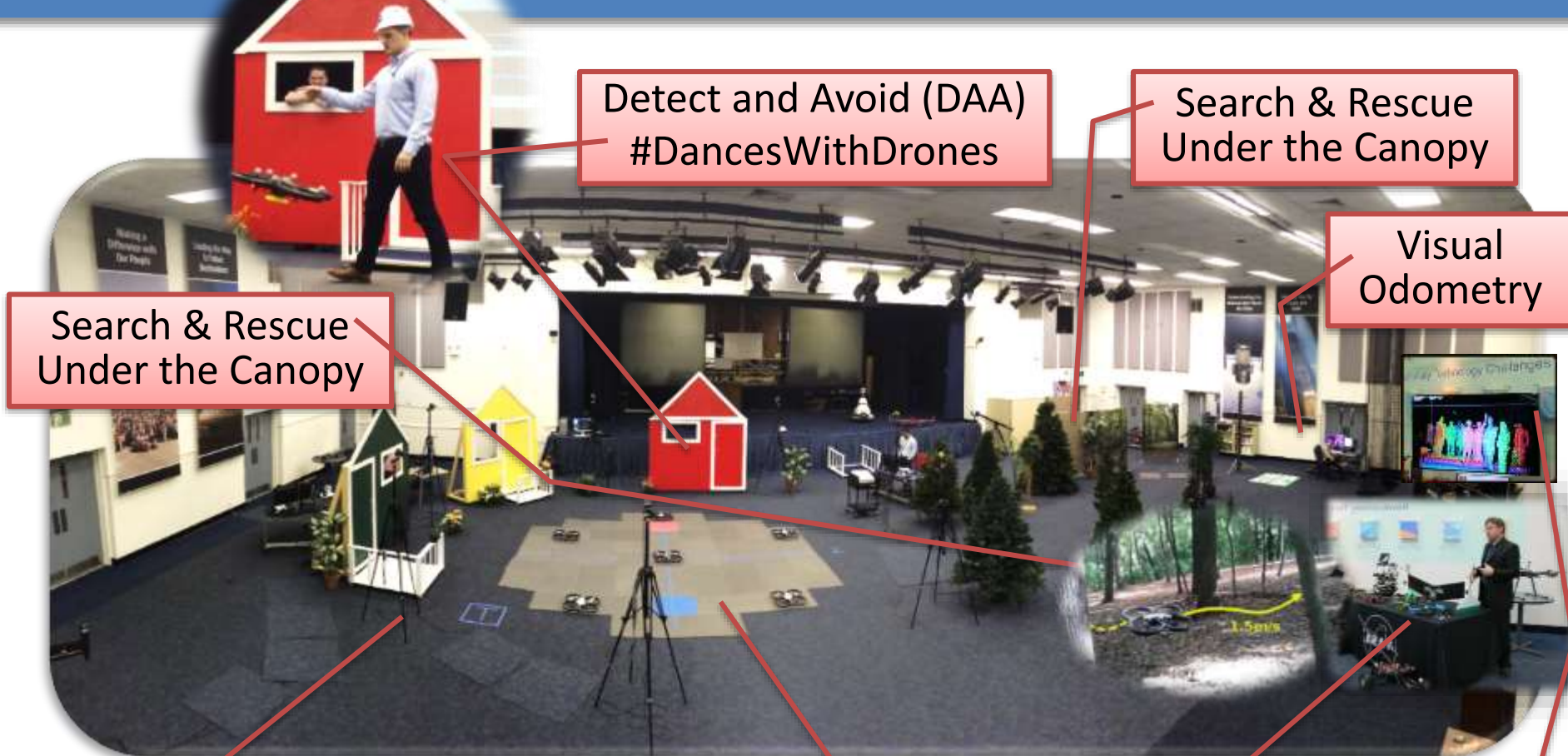
- **Human-Machine Interaction**
- **Data-rich/degraded/deprived environments**
- Size, Weight And Power (SWAP)
- Sensor Fusion
- Adaptive Control
- Geo-containment
- **Sense/Detect and Avoid (DAA)**
- **Precision navigation**
- **Localization**
- **Adaptation and Learning**
- Performance Standards
- 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

Search & Rescue
Under the Canopy

Package
Delivery

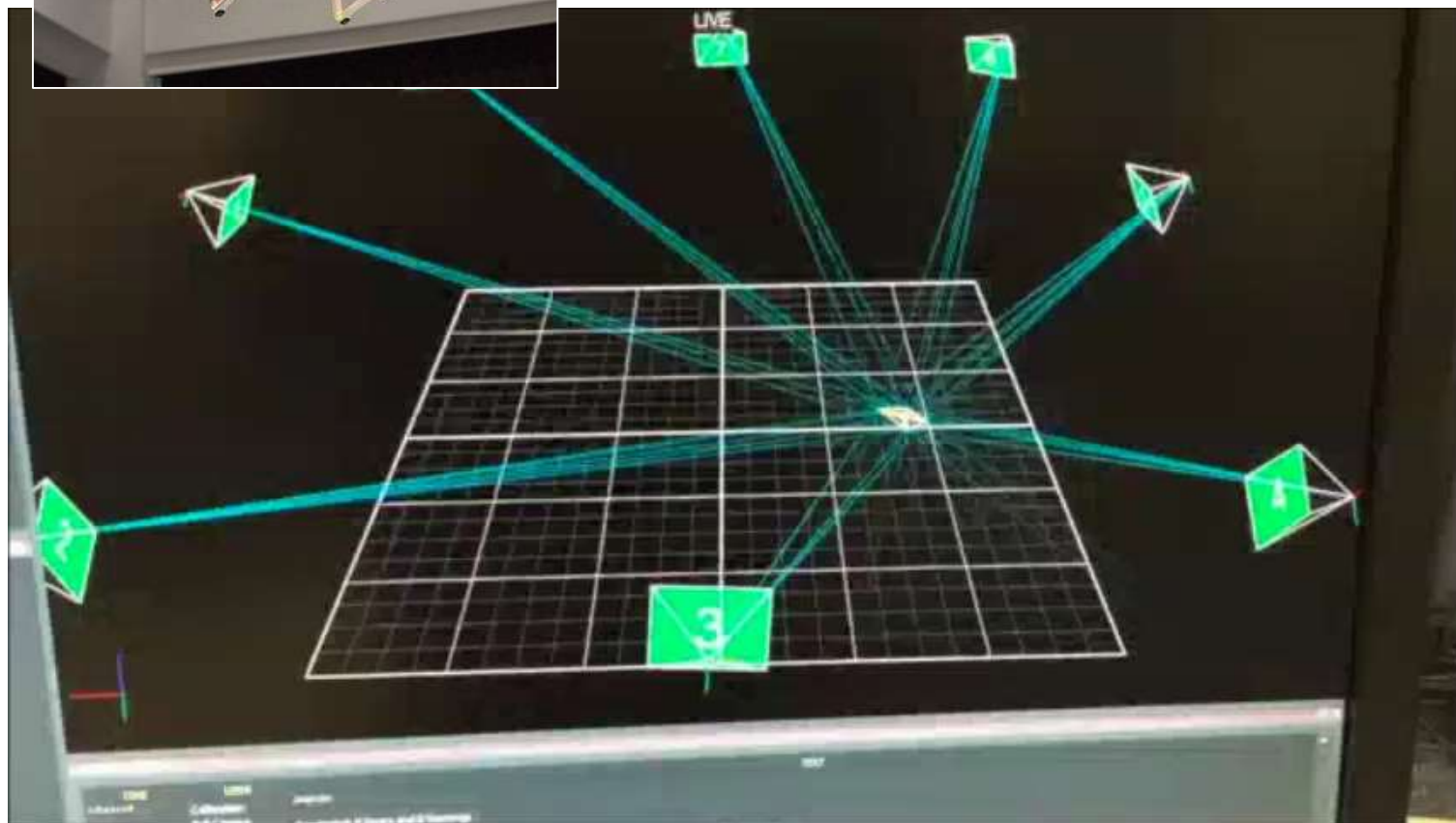
Real-time
Collaborative
UAVs

Sensors

Innovative
Vehicles

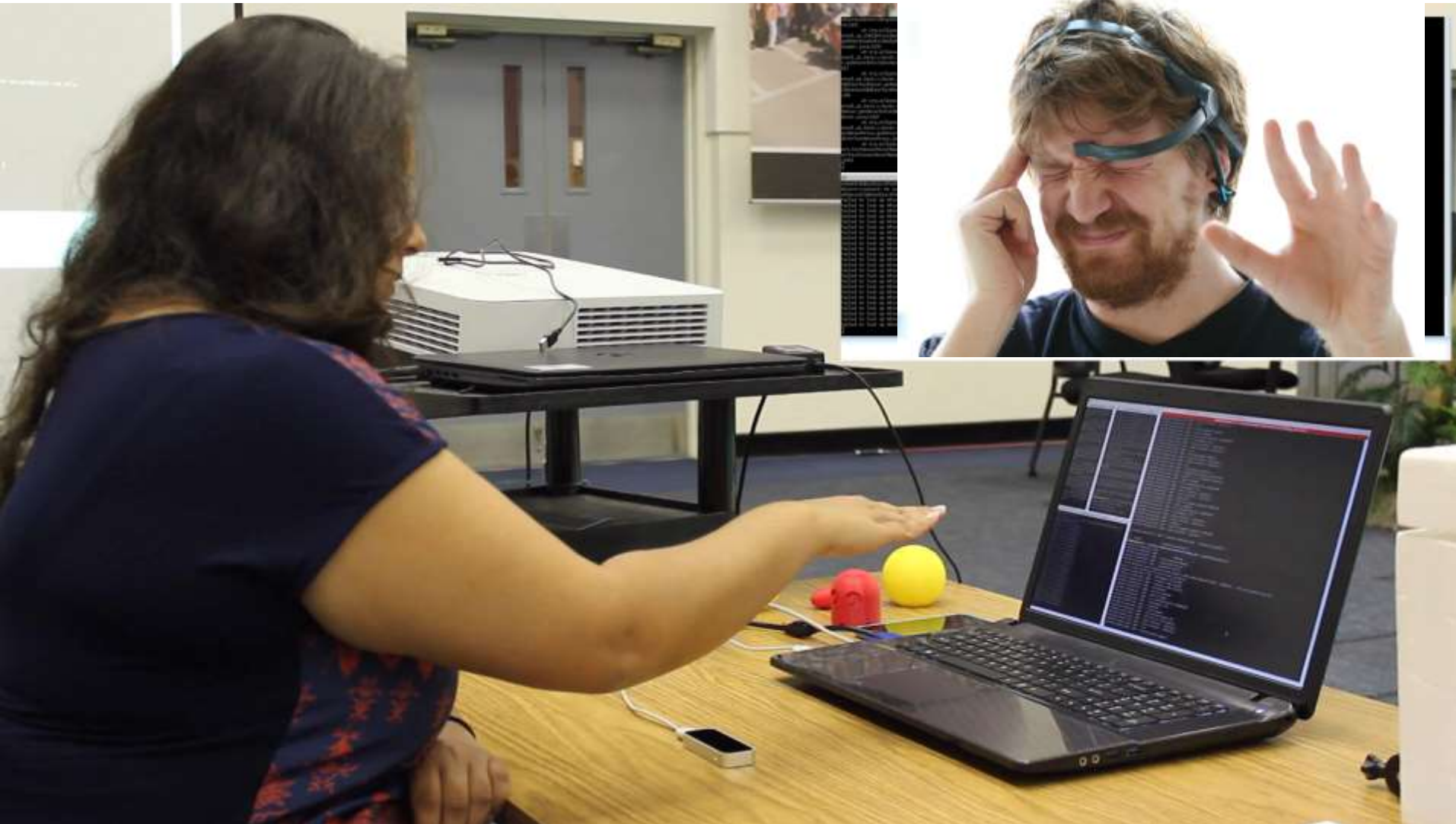


Vicon camera system





Human Machine Teaming





Air Quality Monitoring Sensors



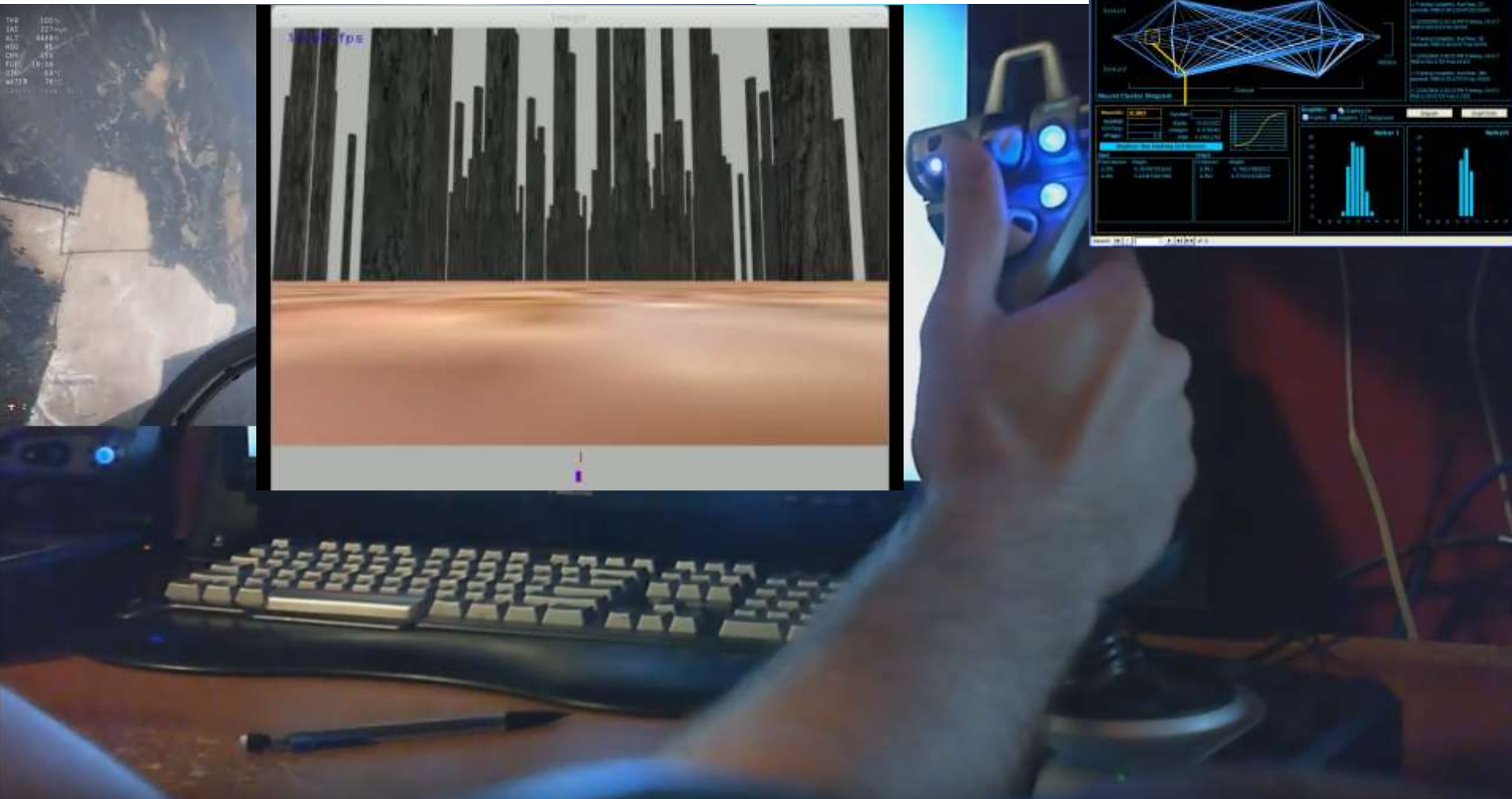
- Multi-vehicle
- Data-denied
- Measurements



Detect and Avoid (#TreeDodging)



Pilot trains UAV's neural network





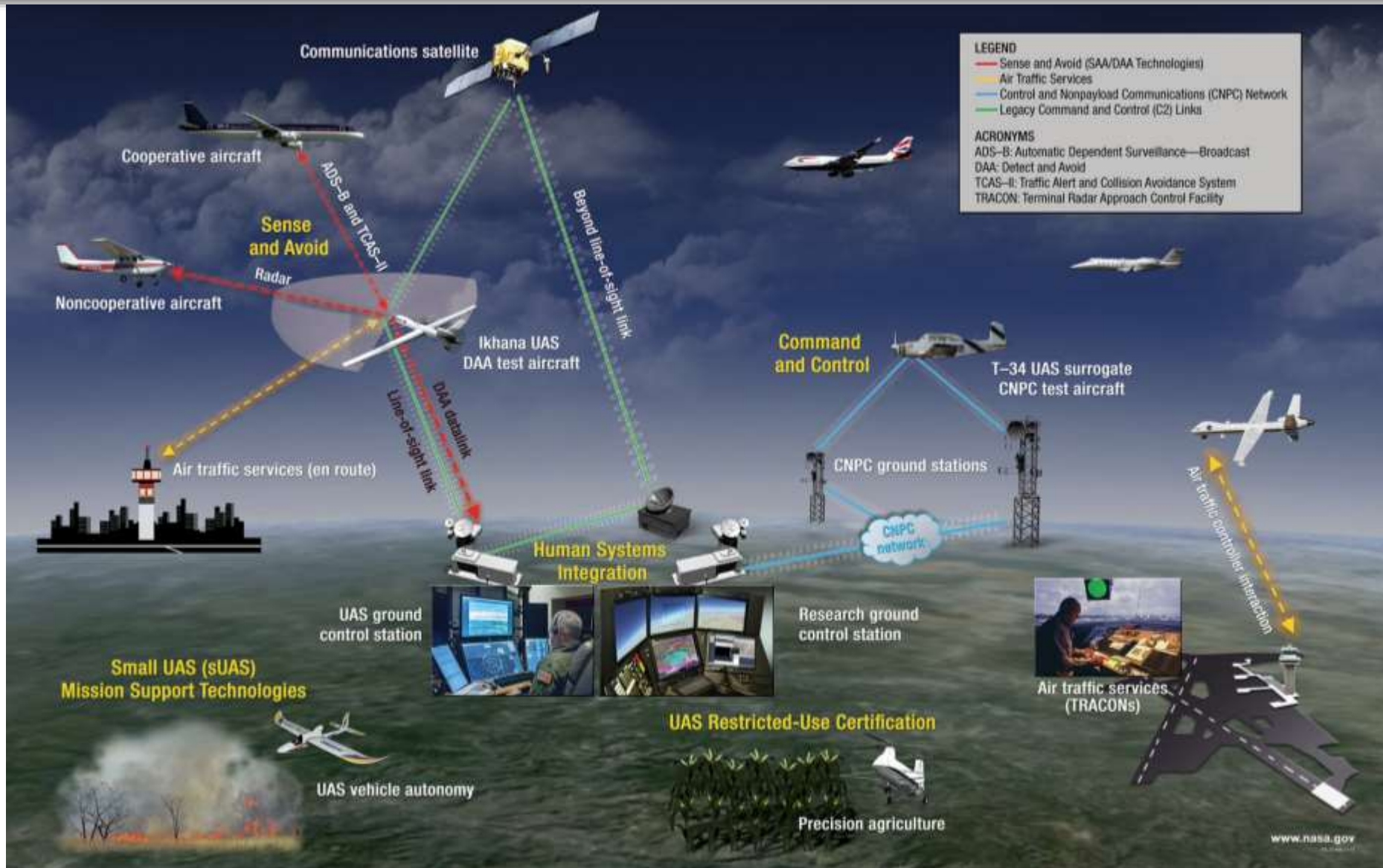
Detect and Avoid

(#DancesWithDrones)





UAS Integration in the National Airspace



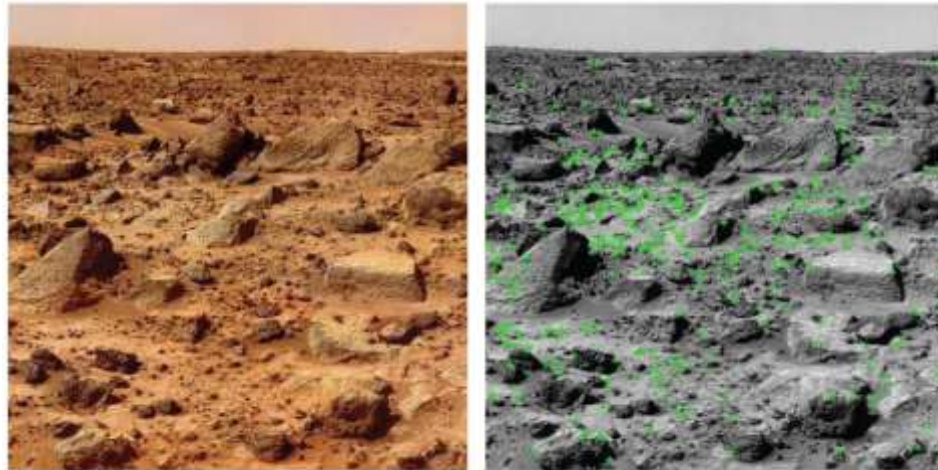
www.nasa.gov



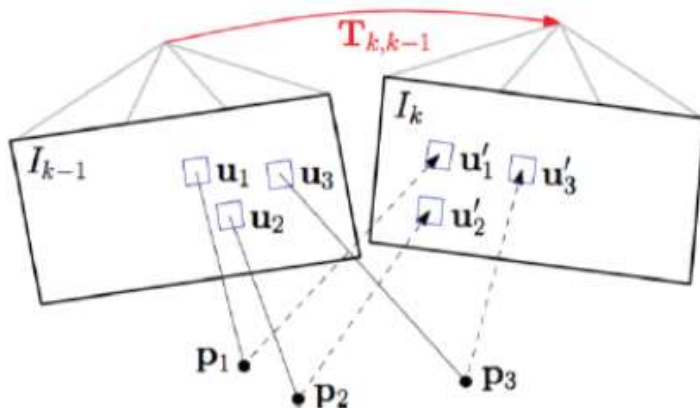
Precision Navigation and Interaction



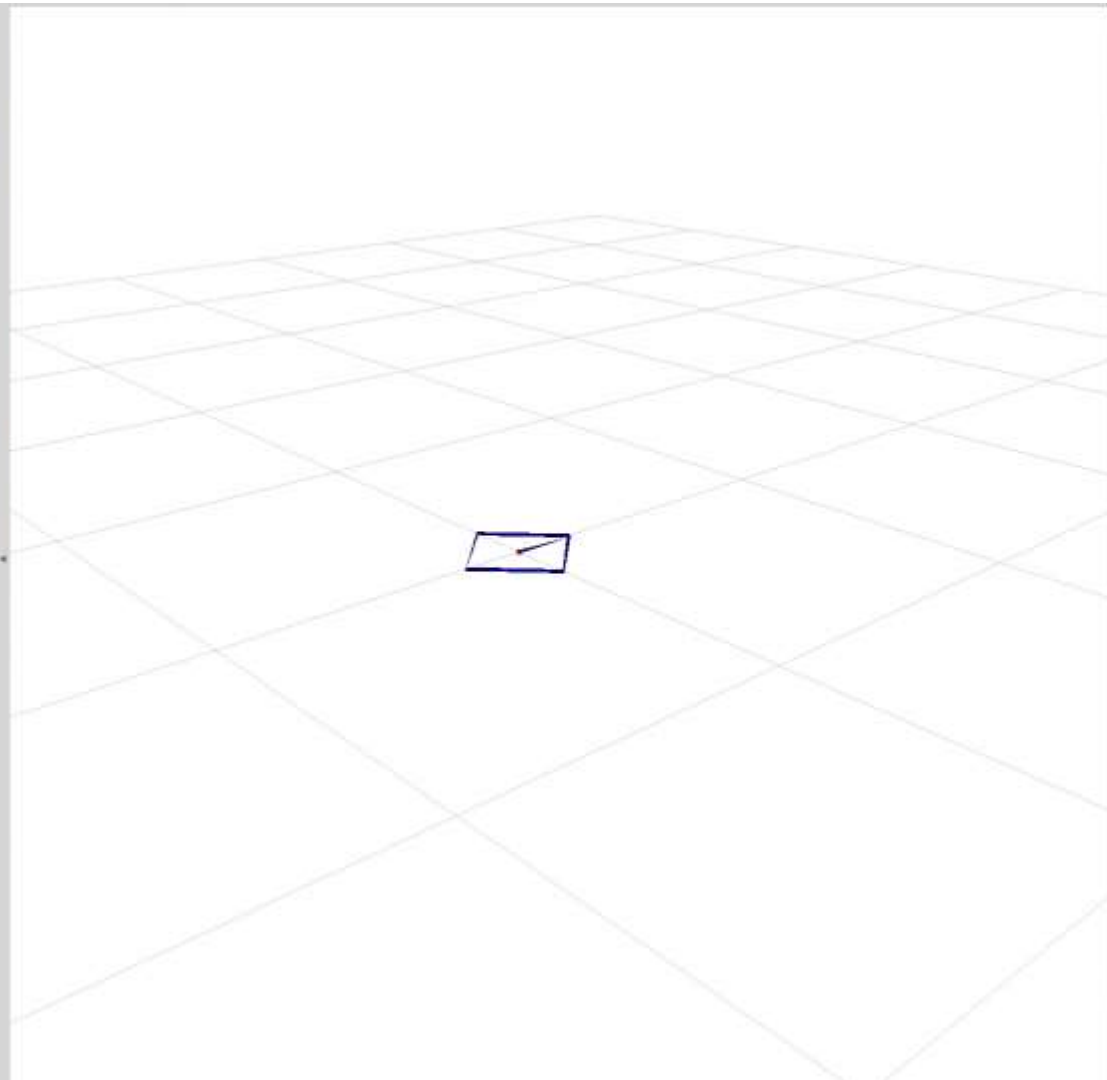
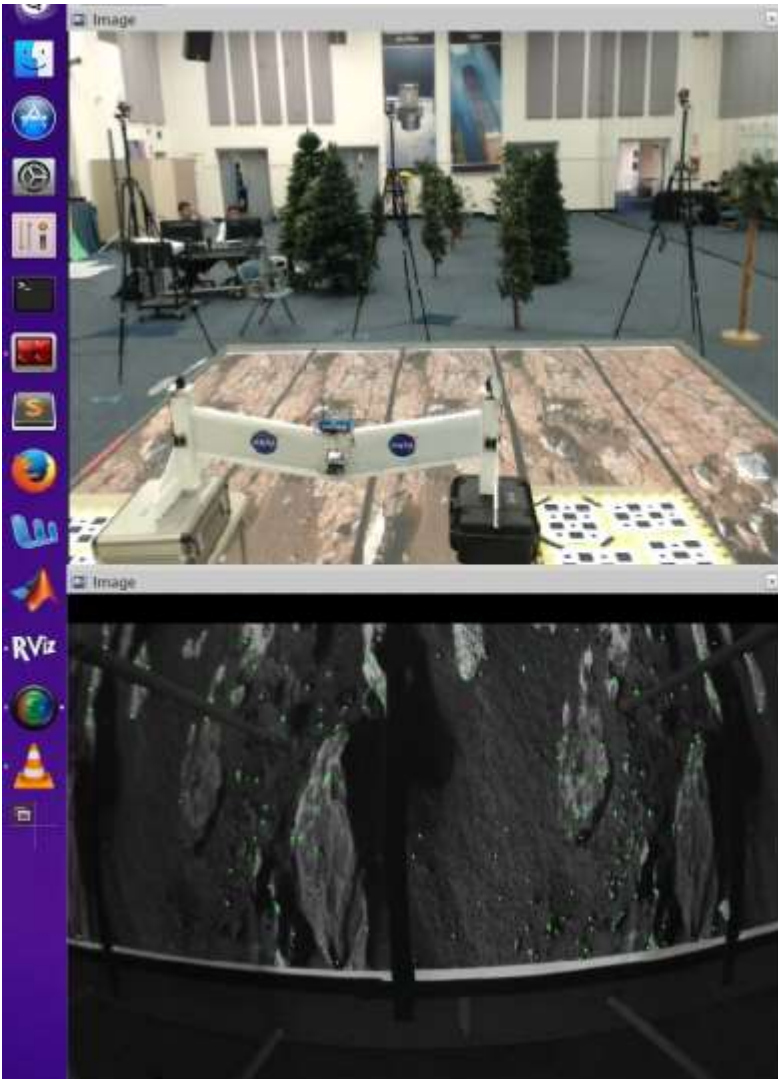
Visual Odometry: process of determining the position and orientation of a robot by analyzing the associated camera images



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.

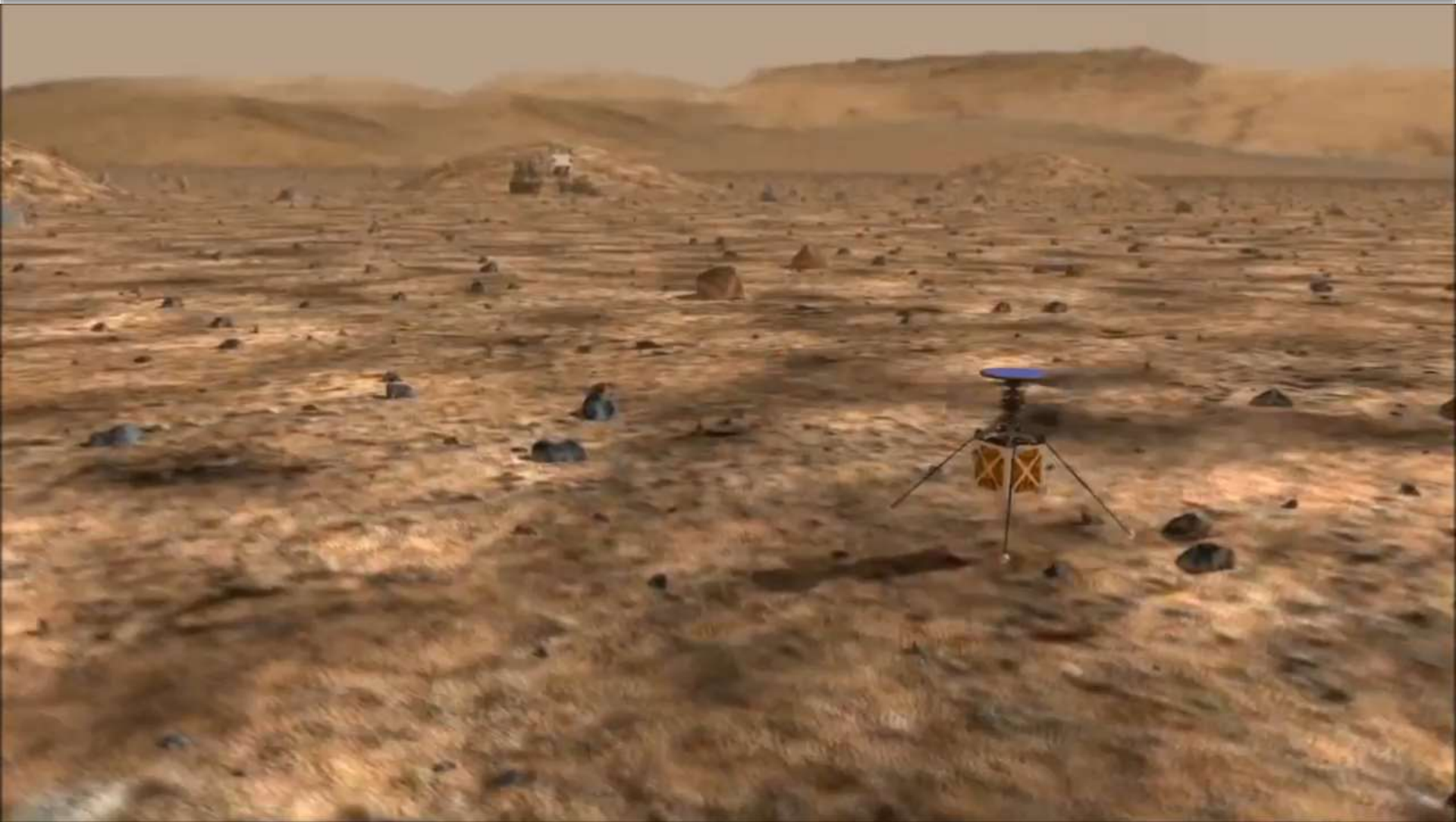


Simulation of Mars exploration using visual odometry

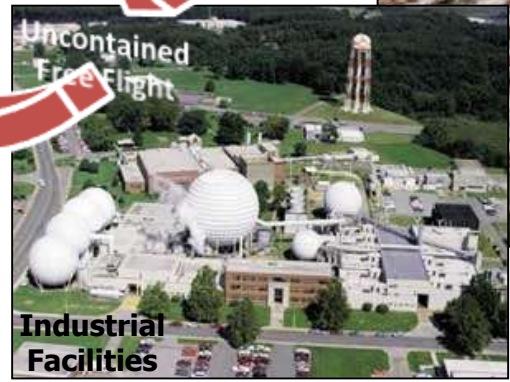




Mars Helicopter



CERTAIN - City Environment for Range Testing of Autonomous Integrated Navigation







- 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

