Enabling Smarter Systems – Advanced Autonomy Research at NASA Ames Research Center

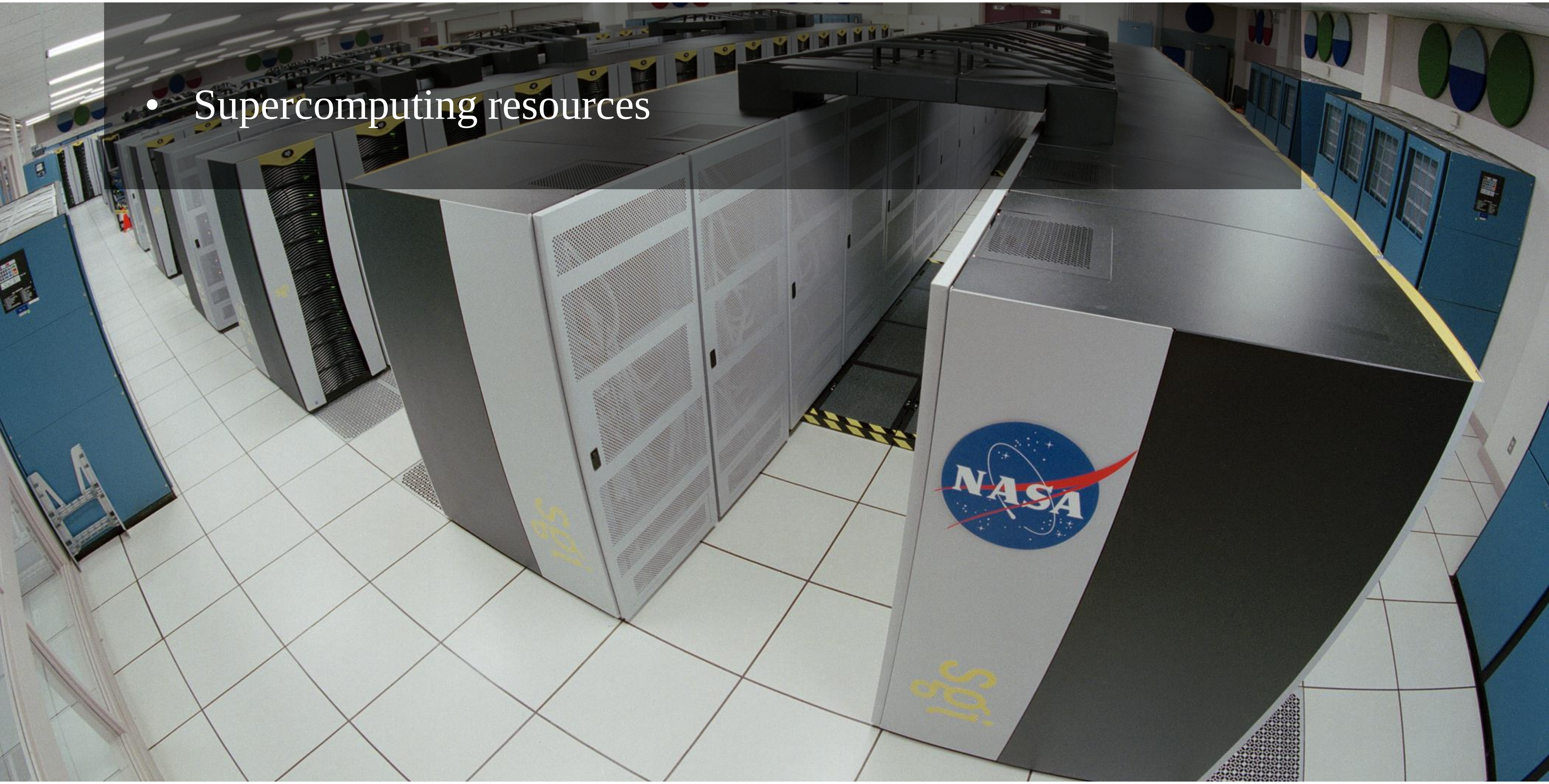
Dr. Corey A. Ippolito
Intelligent Systems Division
NASA Ames Research Center
Moffett Field, CA 94035
corey.a.ippolit@nasa.gov

NASA Ames Research Center is in the heart of Silicon Valley.

NASA brings cutting-edge technologies, world class scientists and technologists, and a broad research portfolio.

NASA Ames Research Center provides resources and capabilities to facilitate collaboration with industry, academia, and other government agencies to meet NASA’s strategic goals.

- Supercomputing resources



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- Airborne earth science campaigns (manned and unmanned)

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- Supercomputing resources
- Earth science modeling expertise
- Airborne earth science campaigns (manned and unmanned)
- Orbital and suborbital assets

External partnerships and collaborations help NASA Ames Research Center accomplish NASA's mission.

- NASA Research Announcements (NRA) and Research Solicitations
- Applications and spin-offs of research
- Aligned-research collaboration
- Networking and dissemination of research
- Incubators for grass-roots innovative research

Opportunities for cross-fertilization and innovation

- Autonomy, artificial intelligence, data mining

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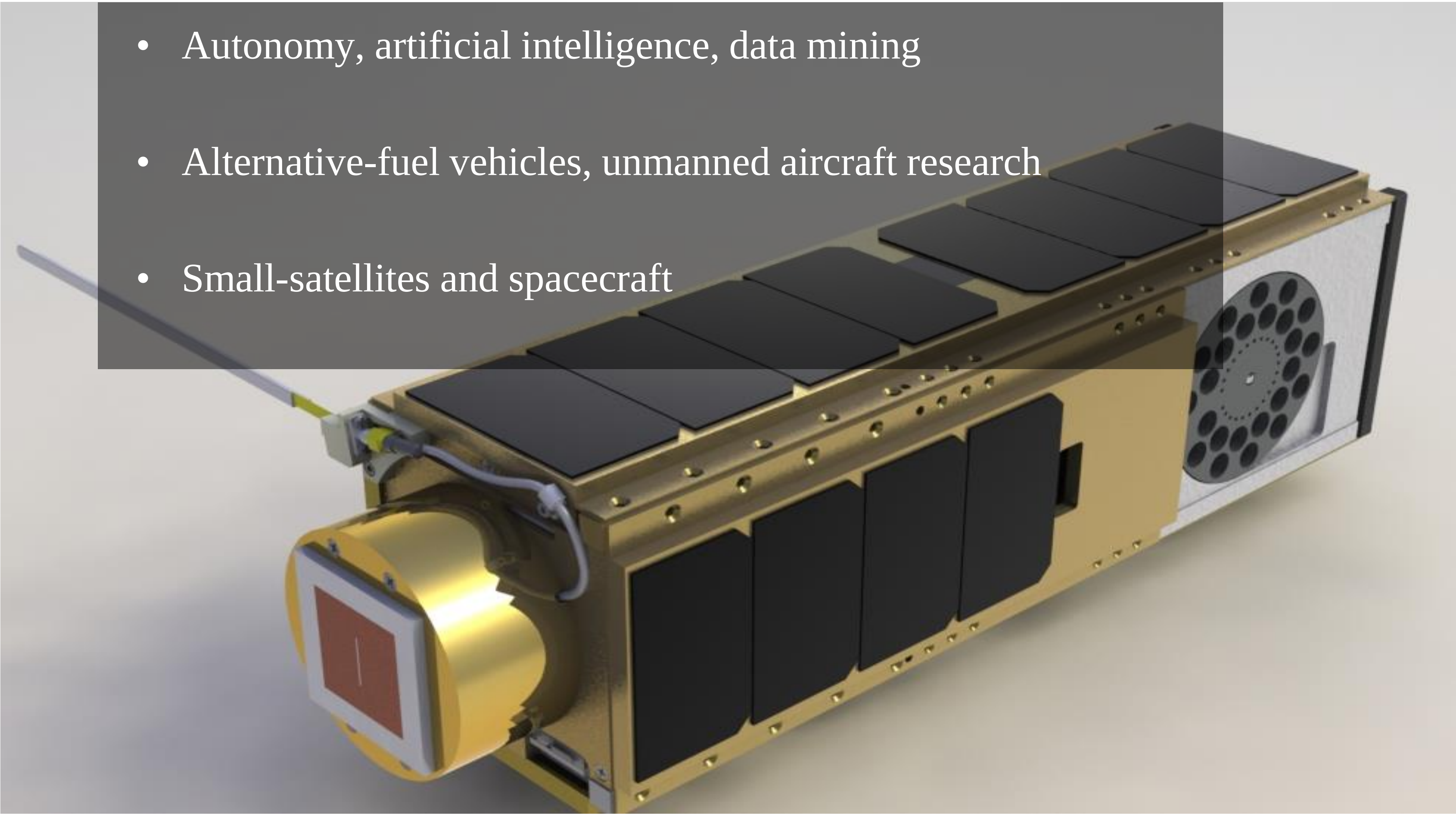
- Small-satellites and spacecraft



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- Alternative-fuel vehicles, unmanned aircraft research
- Small-satellites and spacecraft
- Remote robotics and collaborative interaction tools

Unmanned Aircraft Systems (UAS) Traffic Management (UTM)

Unmanned Aircraft Systems (UAS) Traffic Management (UTM) concepts are advancing toward flight over populated regions.

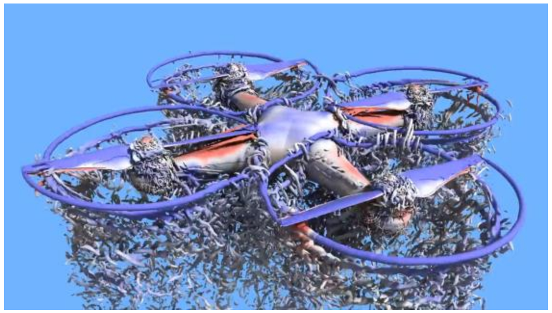
Significant technical challenges are imposed by these environments that makes traffic management difficult, particularly for low-altitude flight in high-density urban environments.

Studies anticipate high demand and economic growth potential in this market.

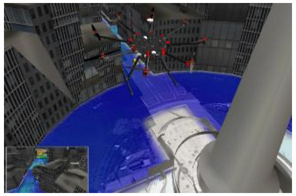
How do you facilitate routine, safe, and fair access to this high-demand airspace?

Dynamics Modeling and Simulation

Using computational fluid dynamics and wind tunnel experiments to created higher-fidelity and validated flight dynamics models.



Credit: Tim Sandstrom, NASA Ames Research Center



Simulation Models

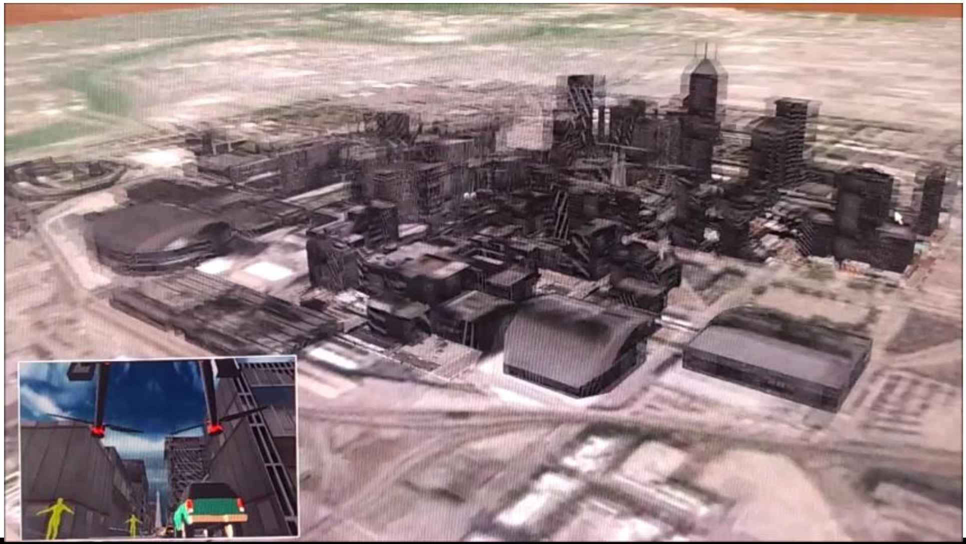
Figure 2. 3D Robotics SOLO.

Figure 5. Drone America DAx8.

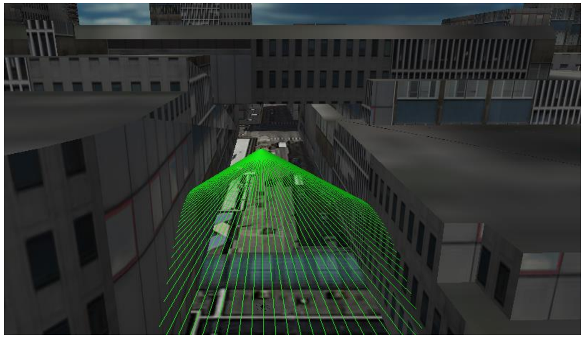
Figure 3. DJI Phantom 3 Advanced.

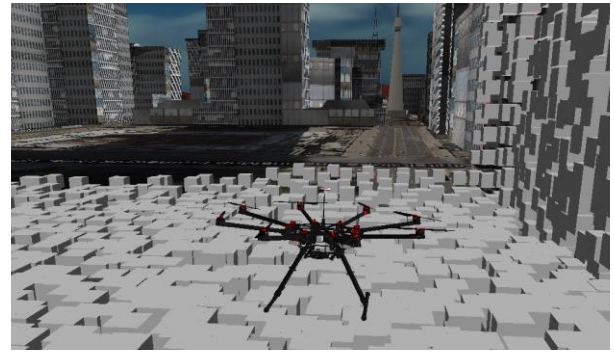
Figure 6. SUI Endurance.

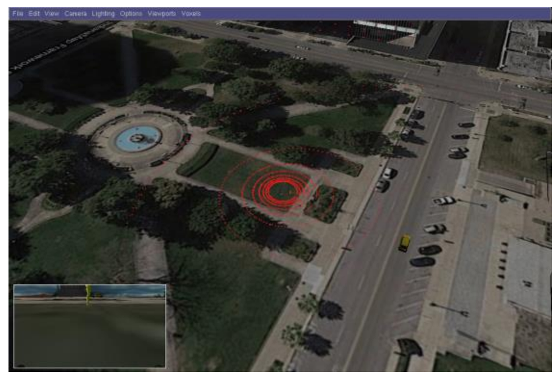
Vehicle Testing in 7x10 ft Wind Tunnel
Courtesy of Carl Russel, UTM, NASA Ames Research Center

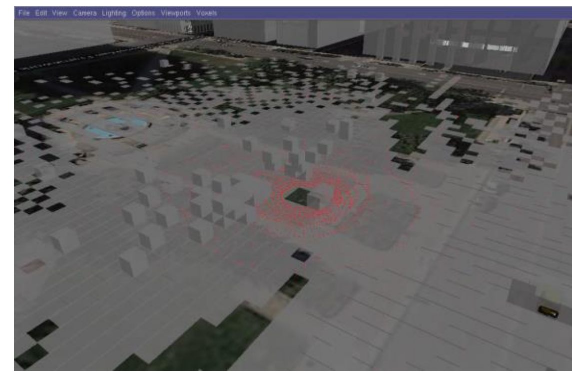


Autonomous Sensor Fusion, Environment Mapping and Hazard Characterization

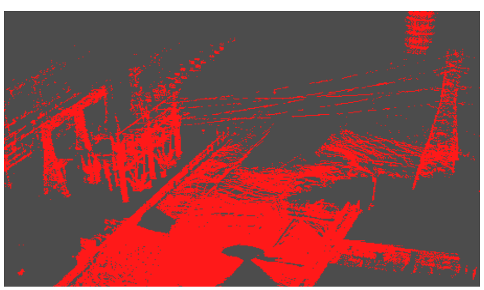


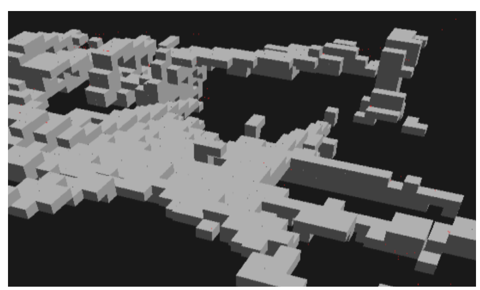


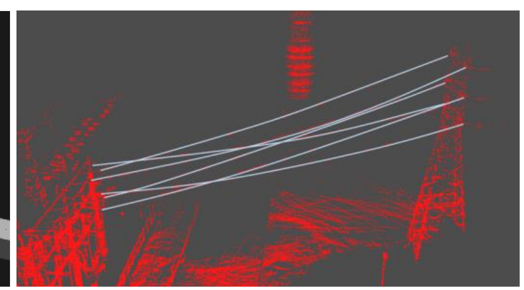




Environment Mapping Evaluations (LiDAR and Vision)

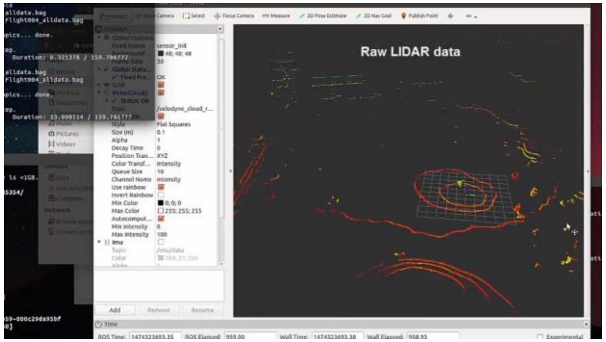


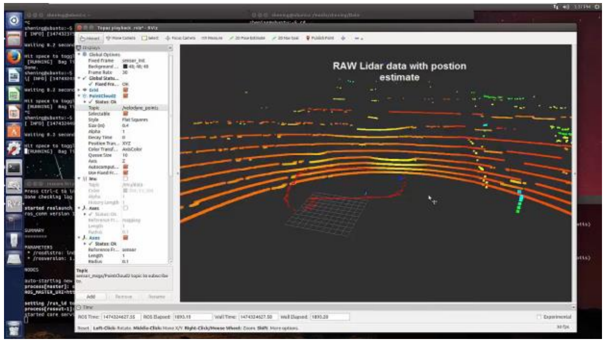




Powerline Identification and Reconstruction. Raw LiDAR point clouds (left), voxel processing (middle), reconstructed powerlines at 75m (right).

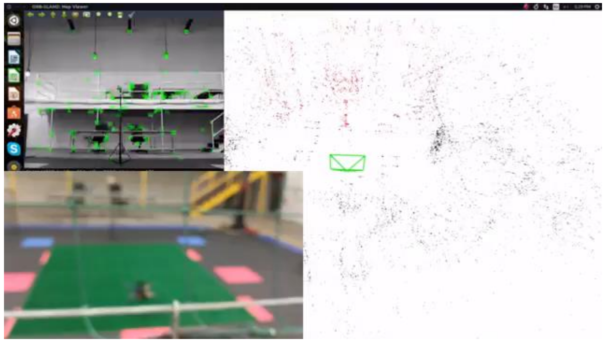
Investigating integrated GNSS, LiDAR and vision for robust simultaneous localization and mapping (SLAM)





LiDAR SLAM in NASA RoverScape Test Facility (collaboration with Near-Earth Autonomy, Inc.)

LiDAR SLAM in NASA Disaster Assistance and Rescue Team (DART) Training Facility



Vision-Based SLAM –
NASA NUARC Test Facility

Examples of grass-roots innovative research collaboration

- NASA research in intelligent vehicle autonomy
- USGS Menlo Park research into magnetic subsurface mapping
- CMU-Silicon Valley's research into mobile robotics

USGS science for a changing world

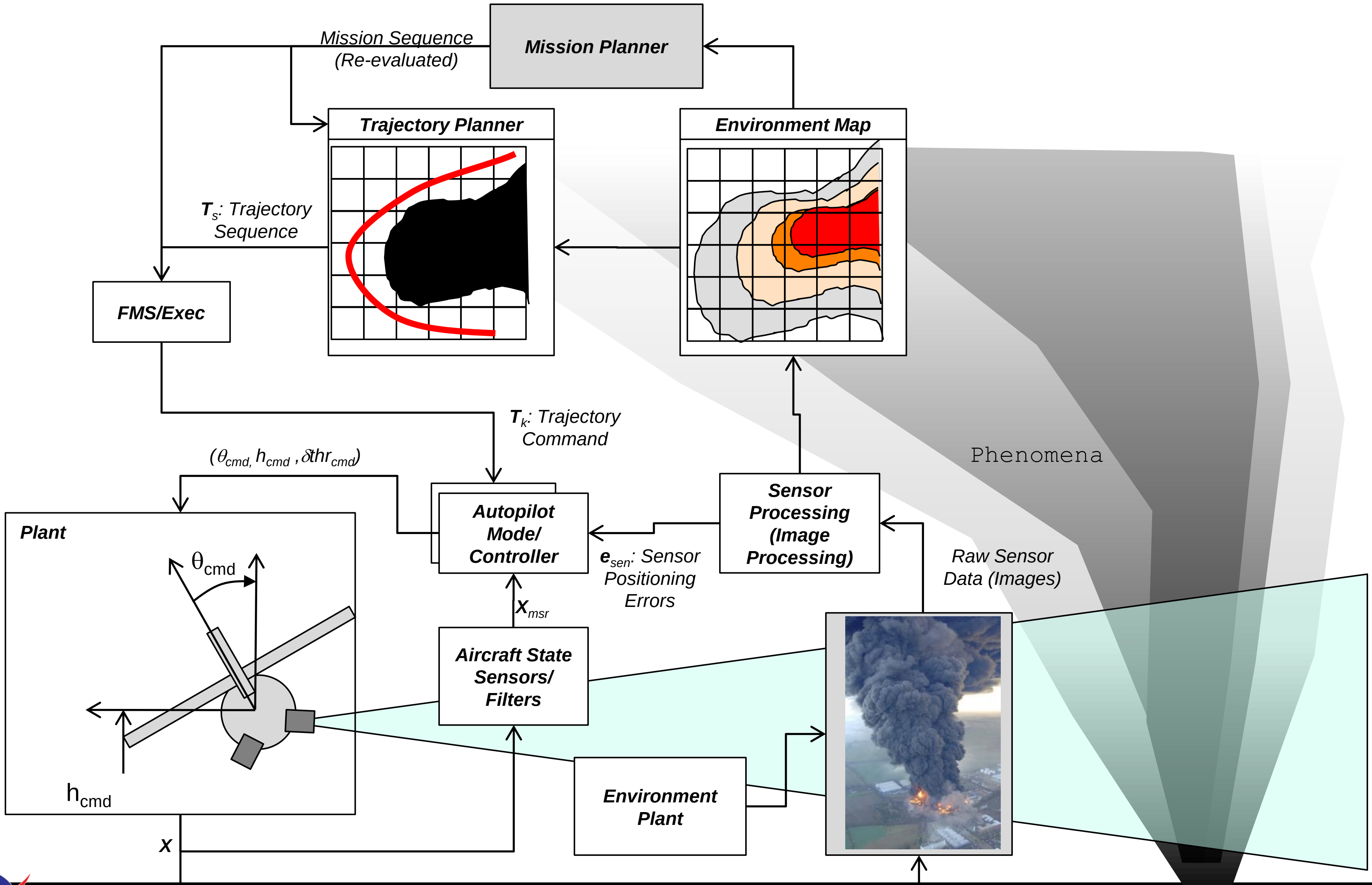
Scientific Objectives (Subsurface Mapping)

Intelligent Autonomy and Operational Capabilities

Carnegie Mellon University Silicon Valley

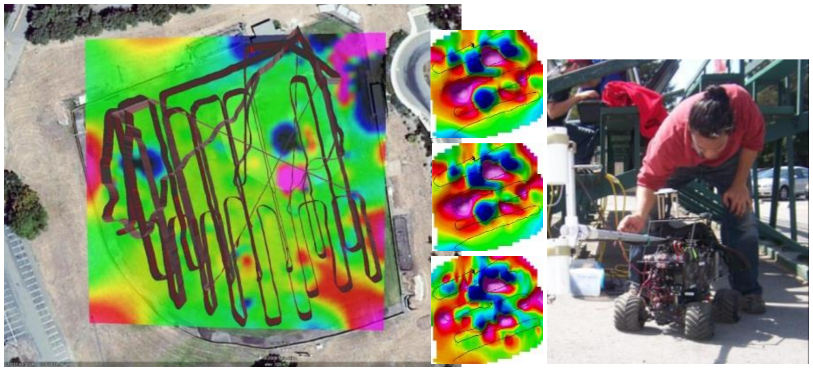
Mobility and Robotics

Sensing and Mapping Localized Dynamic Environmental Phenomena

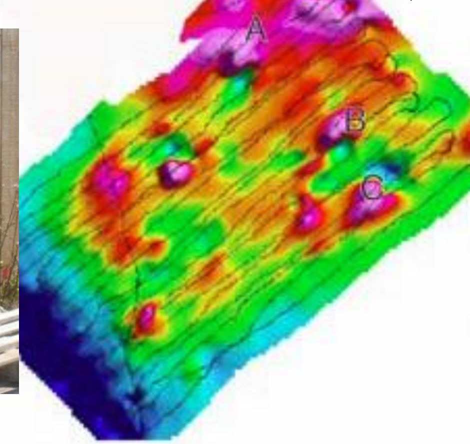


Impact of grass-roots innovative collaboration

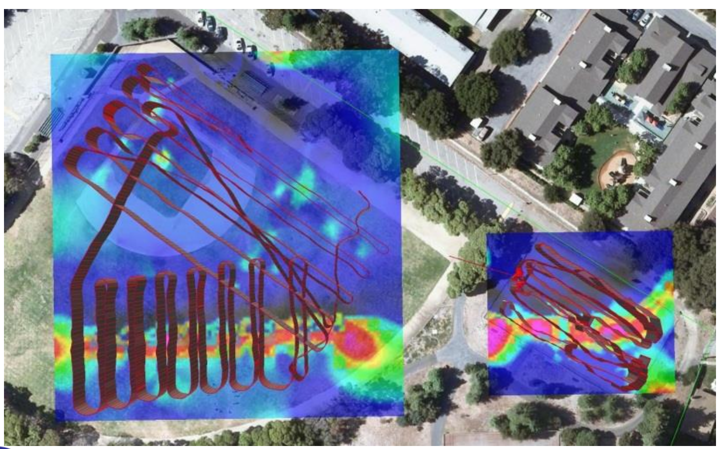
NASA Payload Directed Flight Control
(POC: C Ippolito, NASA ARC)



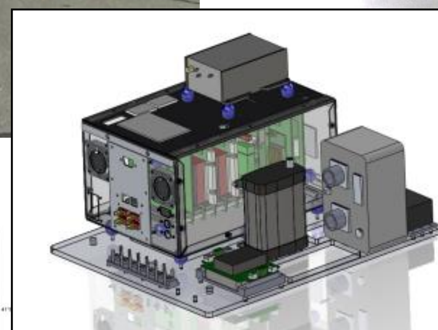
Alviso Crime Scene Murder Investigation (Santa Clara District Attorneys Office collaboration with USGS and NASA ARC)

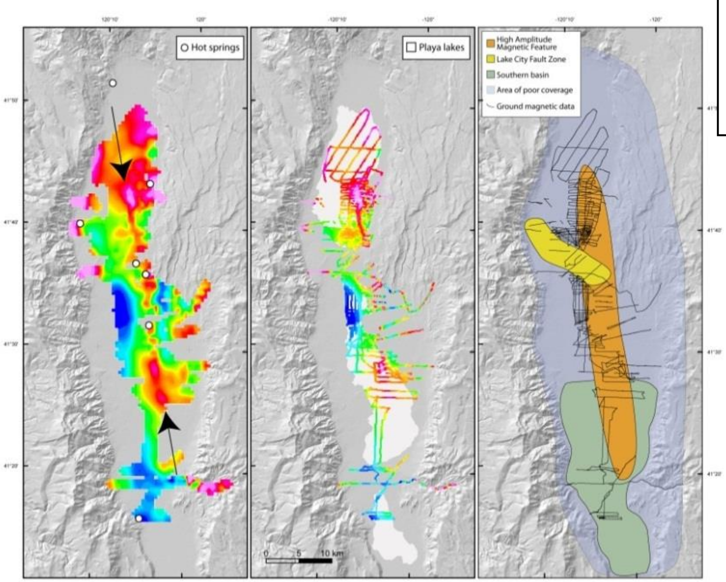


Magnetic mapping demonstration
(POC: G Phelps, USGS Menlo Park |
PI: C Ippolito, NASA ARC)



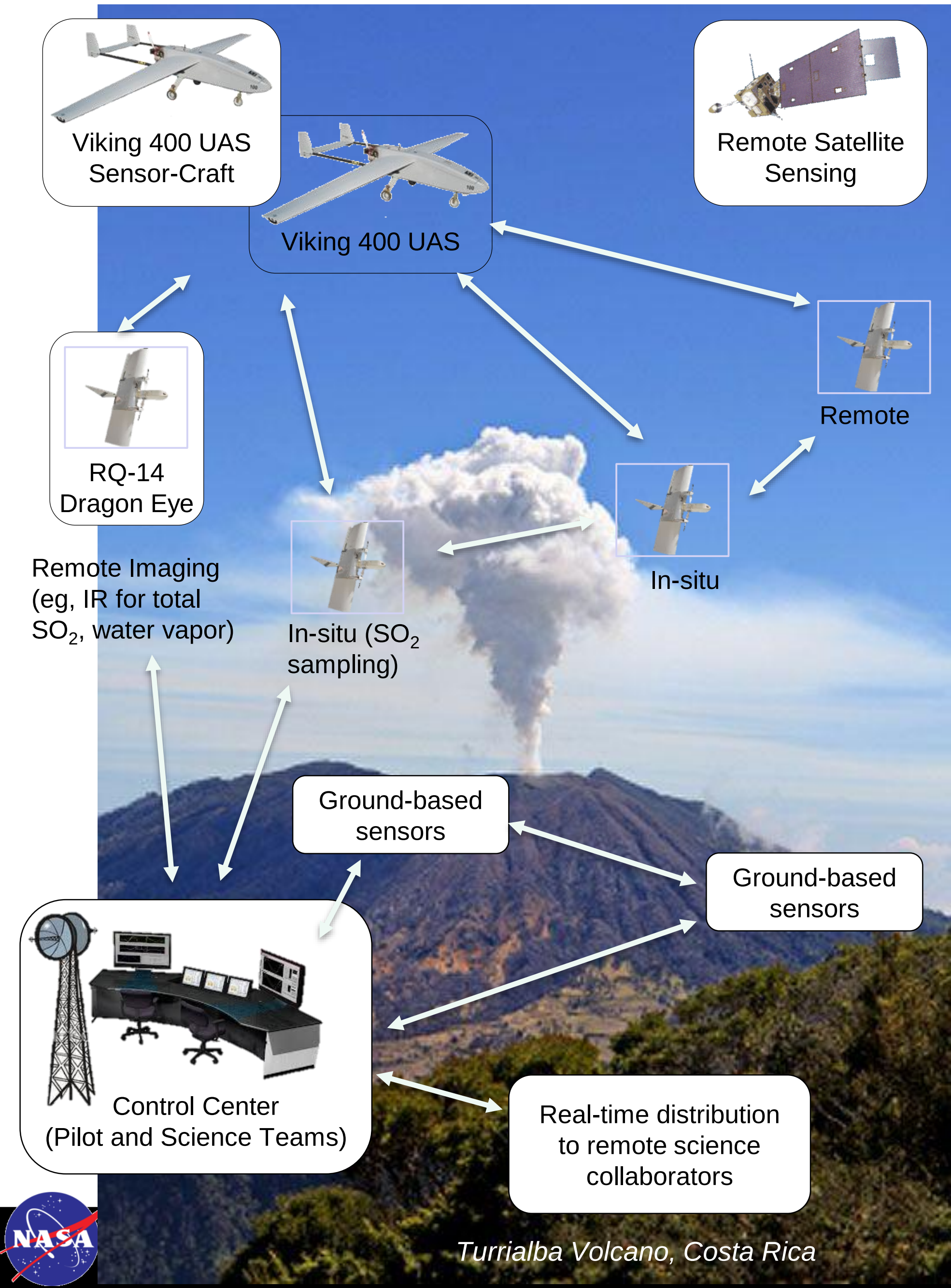
Surprise Valley Intelligent Autonomous Mapping for Subsurface Fault Lines (PI: J Glen, USGS Menlo Park |
CoPI: C Ippolito, NASA ARC)




Hot springs
Playa lakes
High Amplitude Magnetic Feature
Lake City Fault Zone
Southern basin
Area of poor coverage
Ground magnetic data
0 5 10 km

Distributed Collaborative UAS Swarms for Volcanic Monitoring and Hazard Prediction

C. Ippolito, M. Fladeland, R. Berthold, R. Kolyer, B. Storms (NASA/ARC), D Pieri (PI, NASA/JPL), G Bland (NASA/WFF), M. Teodorescu (UCSC)



Turrialba Volcano, Costa Rica

Need

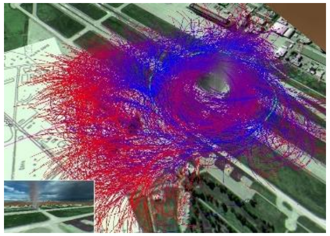
Gather in-situ validation data for NASA-METI Advanced Spaceborne Thermal Emission and Reflection radiometer (ASTER) instrument onboard the NASA Terra satellite.

Challenges

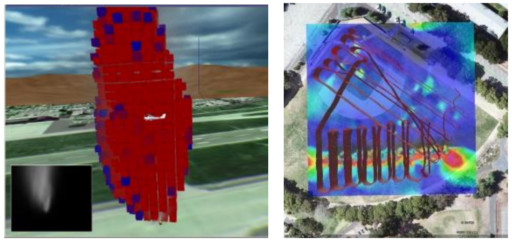
- Lack of in-situ validation data in and around plumes of drifting ash and aerosols resulting from volcanic eruptions
- Conditions are temporal, uncertain, dynamic, complex, spatially-diverse, and hazardous
- Not safe for autonomous aerial systems (UAS) or manned aircraft with current state-of-the-art technology.

Approach

- Self-structuring heterogeneous swarms of autonomous UAS
- Decentralized intelligent payload-directed autonomy for autonomous sensor placement
- Collaborative planning and control methodologies
- Distributed model estimation from real-time distributed sensors
- Airborne peer-to-peer wireless mesh-network and communication



Sensor-based real-time trajectory optimization



Real-time probabilistic modelling: plume-sensing (left), subsurface faults (right)

Deployment

- RQ-14 deployment at Turriabla Volcano, Costa Rica

Impact

- Transformative methodology and technology for earth-science investigations
- Aeronautics/NAS disruption-reduction from volcanic events
- Autonomy for hazard prediction and disaster response (wildfires, hurricanes/tornadoes)

Intelligent Integrated Space Habitat and Building Control

Hypothesis: Overall building performance can be improved, energy usage can be reduced, and individual occupant comfort can be better achieved through integrated building control utilizing intelligent, decentralized, and adaptive control strategies.

Building Supervisors

Web and Mobile Interface
Personal user preferences, monitoring, and control.

Decentralized Controllers
Distributed network of 802.15.4 local controllers

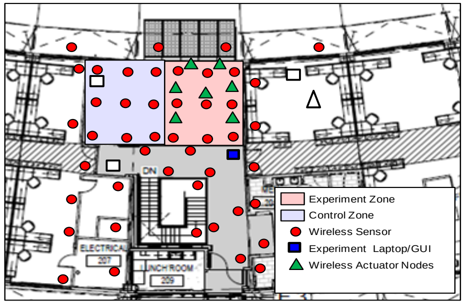
Building Actuators
Windows, shades, fans, HVAC, radiant cooling panels, heating panels, under floor vents, DOAS, lighting control, power plug control.

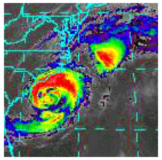
Schedules
User Calendars and Room Schedule Database

Numerical Optimizer
Multi-Objective Real-Time Numerical Optimization Engine

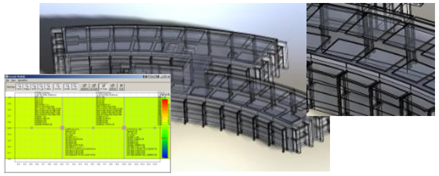
Building Occupants

Physical Building Environment





Weather Forecast



Modeling and Distributed Estimation
SAVANT: *Adaptive Topology Bayesian Fluid-Thermal Modeling and Estimation Engine*

Distributed Building Sensor Network
802.15.4 measuring pressure, temperature, humidity, light.

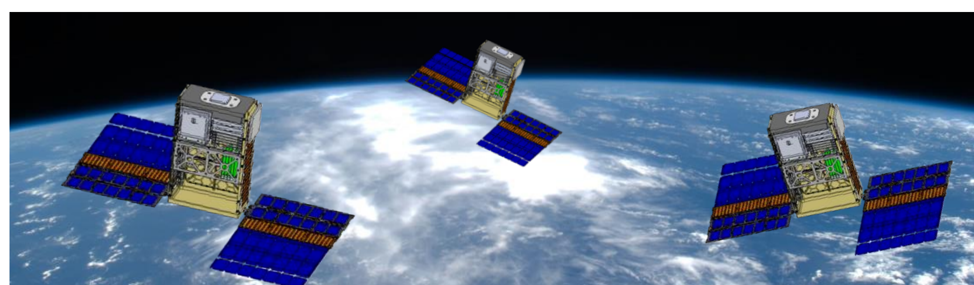
DiGiTaL 3U Cubesat Demonstrator Proposal – Decentralized Distributed GNSS-Based Navigation and Timekeeping for Swarming Satellites

Current State-of-the-Art

- Small Satellite
  - PRISMA: 150kg, 350W, 1.75 m x 1.54 m x 3.4 m
- Single Vehicle Solution
- Master/Slave Architecture
- Centralized Processing

DiGiTaL Demonstrator

- Miniaturize for Nanosatellites
  - Target Size: 0.5 U subsystem
  - Create a reusable module
  - Build off of NASA ARC FSW (LADEE heritage)
- Extend to Multiple Vehicle Solutions
  - Peer-to-Peer architecture
  - Decentralized processing
- Improve Real-Time Accuracy
  - Centimeter-level real-time navigation
  - Millimeter-level precision orbit determination



NASA Ames Research Center research lies at the intersection of science and technology.

Ames work spans from basic research to operational capability. We focus on mission-driven technology development.

Collaborative research partnerships helps Ames achieve NASA goals and missions.