

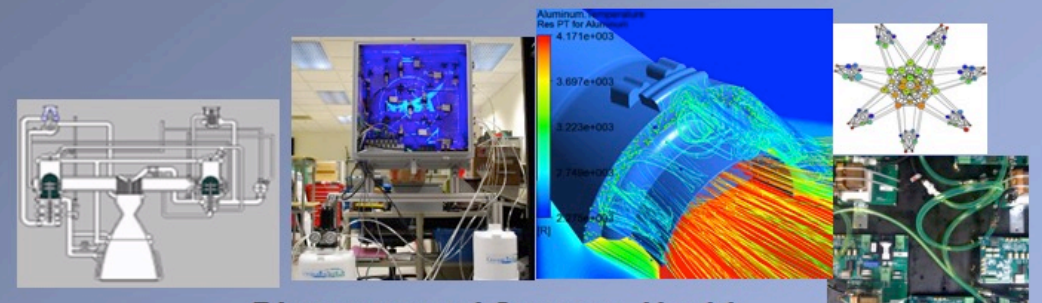
Intelligent Systems Division Overview

Lead NASA's intelligent systems work through mission-driven research, development of innovative technologies, and use of our capabilities to enable NASA's missions.

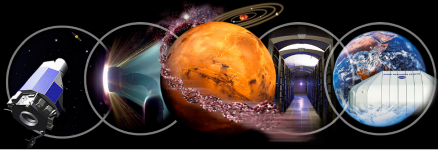
Autonomous Systems And Robotics
(adaptive system level performance enhancements;
flight and ground control)



Robust Software Engineering
(systems assurance; formal and scalable V&V tools)



Discovery and Systems Health
(real-time monitoring with diagnostics & prognostics; analytics;
resilience & physics-based modeling)



Intelligent Systems Division



Division Chief
David Alfano

Deputy Chief
Scott Poll

Asst. Chief, Operations
Sonie Lau

Software Management Office
Robert Duffy

Assoc. (Aero. Syst.)
Joseph Totah

Assoc. (Expl. Syst.)
Dr. Michael Lowry

Assoc. (Mission Syst.)
Dawn McIntosh

Assoc. (Science)
Dr. Joseph Coughlan

Tech Areas:

Autonomous Systems & Robotics

Lead: *Diana Acosta*
Deputy: *Diana Acosta*

Collaborative and Assistant Systems

Lead: Richard Papasin
Deputy: Khai (Peter) Tran

Discovery and Systems Health

Lead: Dr. Kai Goebel
Deputy: *Dr. Anupa Bajwa*

Robust Software Engineering

Lead: Dr. Guillaume Brat

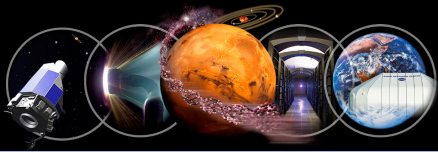
Groups:

- Advanced Control and Evolvable Systems
- Deployable Automation Technologies
- Intelligent Robotics
- Planning and Scheduling

- Data Repository Systems
- Decision Support Systems
- Enterprise Information Management
- Ground & Flight Data Systems
- Information Integration

- Data Sciences
- Diagnostics & Prognostics
- ISHM Technology Insertion Projects
- Applied Physics & Quantum Computing

- Core Avionics and Software Technologies
- System Thinking, Architecture and Collaboration
- Models and Algorithms for Reliable Software
- Assured Autonomy



Autonomous Systems and Robotics (ASR)

Charter/Goals/Objectives: NASA Vision calls for closer cooperation between humans and aerospace systems than ever before. Creating automated and autonomous behaviors via robotic assistants, robust avionics, intelligent planning and scheduling, and advanced control technologies are the focus of the ASR technical area. This endeavor requires building systems that can adapt their behaviors to environments that are complex, rapidly changing, and not well-understood. ASR has unique capabilities and agency leadership in applying autonomy and robotics expertise to NASA missions, and terrestrial demonstrations.

Products/Deliverables:

- Avionics software
- Adaptive and optimal control and estimation
- Advanced flight management systems
- Automated planning and scheduling
- Control agent architectures
- Computer vision & digital mapmaking
- Distributed and multi-agent systems
- Drilling automation
- Embedded software systems
- Evolvable systems
- Geospatial data systems
- Model Based Flight Software Development
- Space robotics (planetary rovers & free-flyers)

Customers/Projects/Partners: ASR Executes over 30 projects for various mission directorates and external partners.

ARMD Projects -- Performance Adaptive Aeroelastic Wing; Reduced Crew Operations; small UAS Autonomy; Autonomous Aircraft Operations;

SMD Projects -- Biosentinel Avionics FSW; EuCrops FSW; Sporesat II FSW; Visual Science-Ops for MSL & MRO; Drilling and Sampling Automation; Planetary Lake Lander; DragonEye UAVs for Airborne Science;

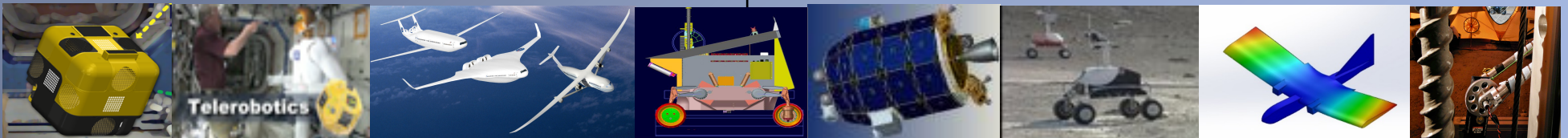
STMD Projects -- EDSN/NODES FSW; SPHERES/Astrobee; Autonomous Systems Planning and Diagnostics; Tensegrity Robots; Resource Prospector Rover;

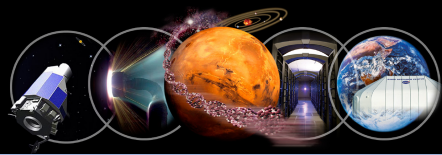
HEOMD Projects -- Autonomous Systems and Operations; AES Modular Power Systems (AMPS); GeoCam Space;

External -- Google Crisis Mapping (CM); Disaster Response; Moon Express FSW; Nissan Self-Driving Car

Resources: Greater than 20 Million Dollars
Workforce (FTE/WYE): 32/50
Facilities/Labs:

1. Advanced Control Technology Labs
2. Flight Software and Avionics Lab
3. NASA UAS Research Complex
4. Robotics labs and Roverscape

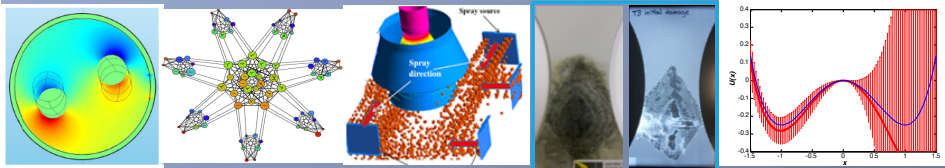




Discovery and Systems Health (DaSH)

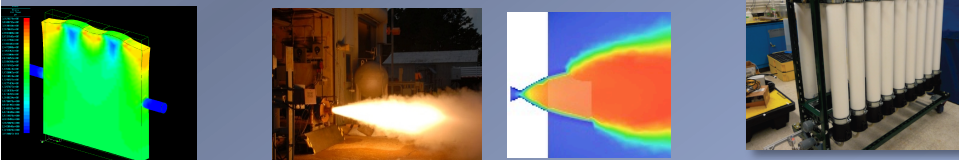
Charter/Goals/Objectives

- Develop methods, models, and tools to understand complex engineered systems and large-scale data problems
 - Physics-based, data-driven and hybrid modeling for Integrated Systems Health Management (ISHM)
 - Machine learning, data mining, text mining, statistical pattern recognition, and exploratory data analysis
 - Quantum computing
- Dramatically improve ability to solve difficult optimization problems for NASA's missions



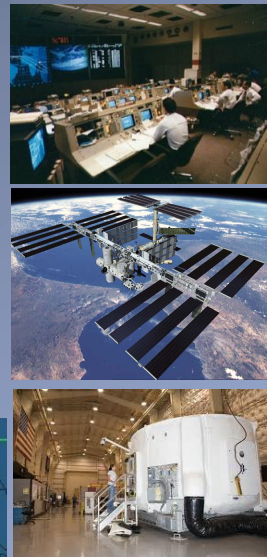
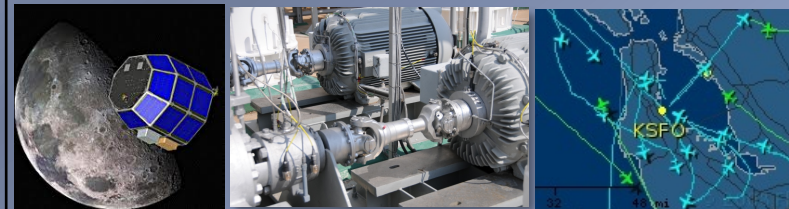
Products/Deliverables

- Analysis of complex physical phenomena
- Mathematical models representing physical systems
- Novel algorithms for health management, analysis of large data, quantum computing
 - Experimental Data (released on data repositories)
- Improved engineering and scientific processes
 - Integrated software products for flight and ground mission support



Customers/Projects/Partners

ARMD: AAVP/ACP; AOSP/ATD, SASO, SMART-NAS;
TACP/Seedling, VIPR3;
HEOMD: AES/AMPS, APL, ASO, RESOLVE, RPM;
ESD/AGSM, SLS; SLPS/SporeSat2;
STMD: GCD/ACAWS, ACLO, RVSM, SAFEM, MGI;
DoD: AFLR; DARPA, IARPA;
NESC; NSF; USGS;

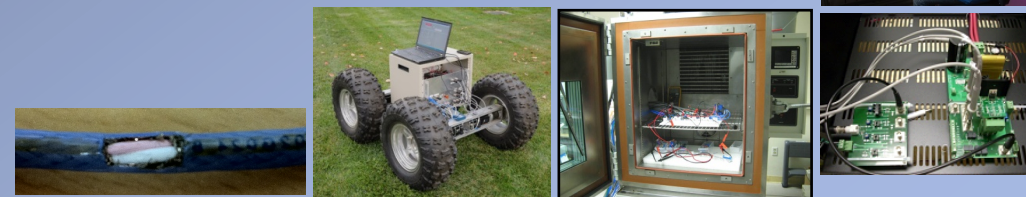


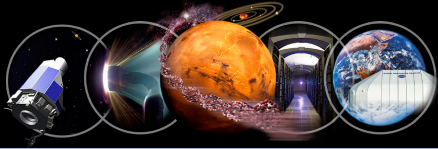
Resources

Workforce: 26 FTE / 41WYE

Facilities/Labs:

- SHARP Lab
- Custom aging facilities for mechanical devices (valves, electronics, electrical systems, batteries, wires, electro-mechanical actuators, etc.)
- Hardware-in-the-loop experiments for algorithm benchmarking
- Quantum Computer (shared resource, in Code TN)





Robust Software Engineering (RSE)

Charter/Goals/Objectives

- Our goal is to dramatically increase the reliability and robustness of software in NASA missions and in the aviation industry, and the productivity of its software engineering, through the research, development, application, and transfer of automated software engineering technology that scales to meet NASA's software challenges.
- Lead research in formal analysis of cyber-physical systems
 - Lead research in multi-agent systems
 - Infuse in NASA missions and aviation industry

Products/Deliverables

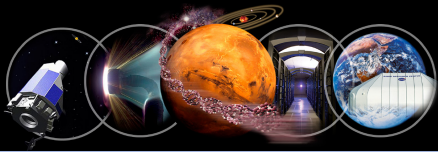
- Research in formal software analysis, from requirement analysis to automated testing.
- Research in system engineering, including software/hardware interactions, design for V&V, human-system interaction analysis, and argument-based safety assurance methods.
- Mission software, including common plug-and-play software bus and advanced V&V tools and processes.
- Research in assures autonomy, including tensegrity, multi-agent systems, UAV swarms, and collaborative autonomous systems

Customers/Projects/Partners

- ARMD
- AOSP program: SMART-NAS and SASO projects
- TAP program, CAS project: Cloud in the Clouds study
 - STMD
- SSTP program: Propulsion Path Finder
 - Moon Express and Catalyst
 - Other collaborations:
- Lockheed Martin, Boeing, GE, Nissan
 - Air Force Research Lab,
- ONERA, Toulouse U. (France), Middlesex U. (UK)

Resources

- Workforce (FTE/WYE)
 - 11 FTEs
 - 21 WYEs
- Facilities/Lab
 - RSE lab (N269, rm 131)
- Advanced Systems Technology Lab (N269, rm 271)



Collaborative Assistant Systems (CAS)

Charter/Goals/Objectives

Develops information technologies and collaboration tools that facilitate and enable the specialized work of distributed teams in NASA mission settings.

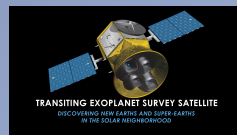
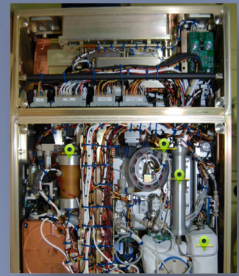
Mission Statement: The goal of the collaborative and assistant systems technical area is to design and develop information management technologies and collaboration tools that facilitate the process by which NASA engineers, scientists, and mission personnel collaborate in their unique work settings. The research and development activities in this area focus on applying information management, artificial intelligence, enterprise architecture, and computer-supported cooperative systems that are more usable, augment human cognition, and facilitate the specialized work of distributed teams in NASA mission settings.

Area	Project	Start Date	End Date	Status
ATM Data Integration	ATM Data Integration	2010	2012	Completed
Agency Web Services Architecture	Agency Web Services Architecture	2010	2012	Completed
ARC Life Sciences Data Archive (ALSDA)	ARC Life Sciences Data Archive (ALSDA)	2010	2012	Completed
Autonomous Mission Operations Support	Autonomous Mission Operations Support	2010	2012	Completed
Cog E for AMMOS	Cog E for AMMOS	2010	2012	Completed
Flight Opportunities Reporting System	Flight Opportunities Reporting System	2010	2012	Completed
GeneLAB Data Architecture	GeneLAB Data Architecture	2010	2012	Completed
HRP ExMC EMSD Development	HRP ExMC EMSD Development	2010	2012	Completed
HRP IT Architecture	HRP IT Architecture	2010	2012	Completed
HRP OnePortal	HRP OnePortal	2010	2012	Completed
IMS (Inductive Monitoring System) Support	IMS (Inductive Monitoring System) Support	2010	2012	Completed
IRIS Flight Control and GDS	IRIS Flight Control and GDS	2010	2012	Completed
ISS Operations Center (ISOC)	ISS Operations Center (ISOC)	2010	2012	Completed
IT Labs	IT Labs	2010	2012	Completed
Kepler SOC	Kepler SOC	2010	2012	Completed
TESS SPOC	TESS SPOC	2010	2012	Completed



CAS Customers/Projects/Partners

- Aeronautics (Airspace Systems)**
- HQ/Agency-wide (OCIO)**
- Human Exploration and Operations**
 - HRP – IT Arch, OnePortal, ExMC Lab Analysis & Middleware
 - AMO development support
- Science mission support**
 - Airborne Science**
 - ISOC MMOC: PGS BioScience, Rodent Research**
 - SOFIA**
- Space mission support**
- NOAA, NRL, ONR, DOE**



Products/Deliverables

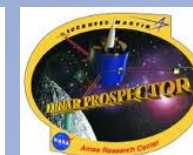
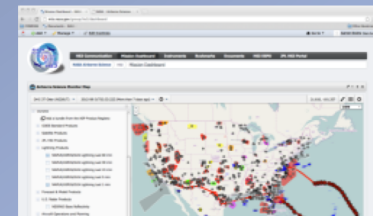
- ATM Data Integration
 - Agency Web Services Architecture
 - ARC Life Sciences Data Archive (ALSDA)
 - Autonomous Mission Operations Support
 - Cog E for AMMOS
 - Flight Opportunities Reporting System
 - GeneLAB Data Architecture
 - HRP ExMC EMSD Development
 - HRP IT Architecture
 - HRP OnePortal
 - IMS (Inductive Monitoring System) Support
 - IRIS Flight Control and GDS
 - ISS Operations Center (ISOC)
 - IT Labs
 - Kepler SOC
 - TESS SPOC
 - Learning Automation/Airspace
 - Mission Control Technologies
 - Mission Tool Suite (MTS)
 - NASA's Technology Transfer System (NTTS)
 - OCIO Open Innovation
 - Open MOS
 - Planetary Data System (PDS) Tools
 - Program/Project Management Tool (PMT)
 - RPM MOS
 - RPM GDS
 - SOFIA MCCS/PIS
 - Transiting Exoplanet Survey Satellite (TESS) SOC
- ❖ Blue indicate CAS PI/PM led

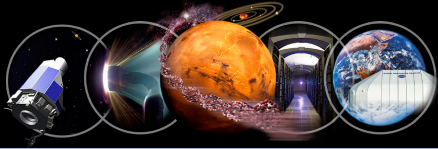


Resources:
23 CS/25+ WYE

Facilities/Labs:

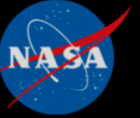
Mission Control Technologies Laboratory
Mission Tool Suite Laboratory
HRP IT Arch & ExMC Development Lab
NTTS & PMT Workspace and Helpdesk
SOFIA MCCS/PIS Development Lab





Intelligent Systems Division

Science and Human Exploration Highlights



Kepler (K2)/ TESS
TI leads SOC, responsible for processing instrument data to allow identification of exoplanets.

IRIS
Ground Data System and Mission Operations Support



LADEE

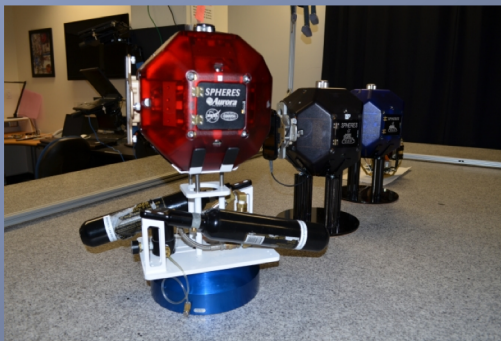
Flight software, ground data systems and mission ops for successful mission to map the lunar atmosphere and dust environment



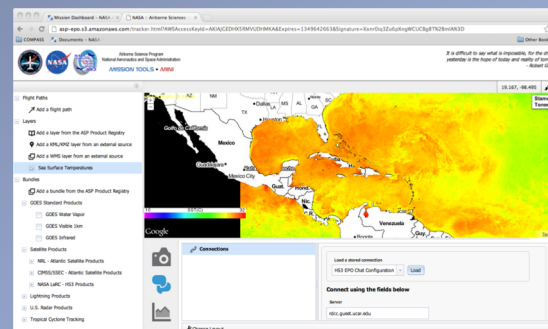
Rodent Research Project
Payload Ground System (PGS) software for operational ISS facility



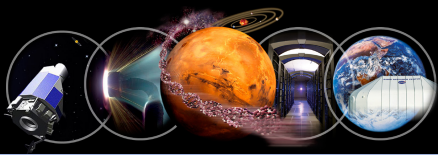
Human Exploration Technologies
First successful demonstration of astronaut orbital control of a planetary rover



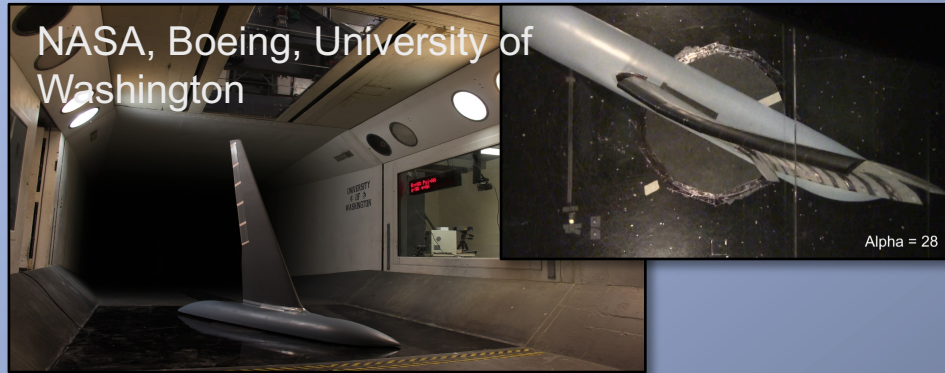
Smart SPHERES
Power, propulsion, computing, and navigation for free-flying robots to augment and support ISS crew activities



Mission Tools Suite
Web-based software tools supporting airborne science observations



Intelligent Systems Division Aeronautics Highlights

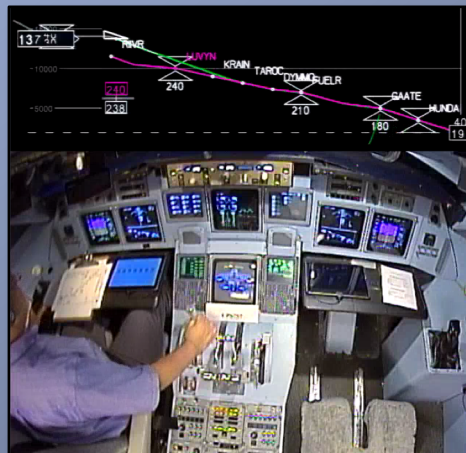



NASA, Boeing, University of Washington

Variable Camber Continuous Trailing Edge Flap Tests at the University of Washington Aeronautical Lab Wind Tunnel. (FAP/FW). – POC: N.Nguyen



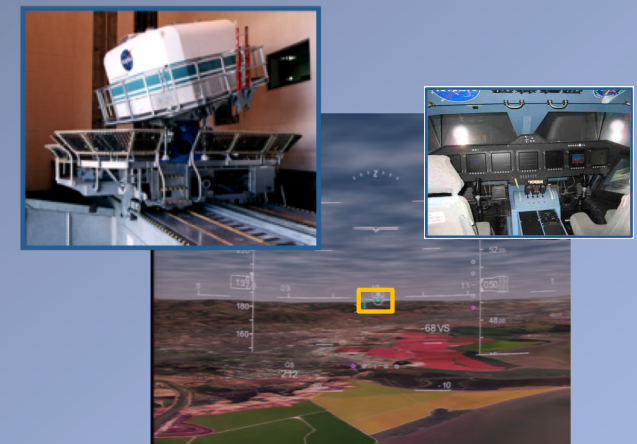
Physics Based Methods Group Successfully Demonstrates On-Line Wire Chafing Fault-Detection Technology on C-17 Jet Engine (AvSafe/VSST). – POC: S. Schuet



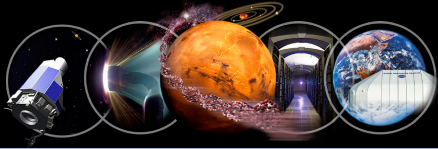
Simulation Experiment on Evaluation Methods and Tools for Reduced Crew Operations in the Advance Concepts Flight Simulator (ASP/CTD). – POC's: M. Feary and J. Kaneshige



Programmable Structures Could Unlock Potential of Morphing Wings
PoC: Kenny Cheung



Loss of Control Prediction and Cueing: A Pilot in the Loop Motion-Based Simulation Test in the Vertical Motion Simulator (AvSafe/VSST). – POC: K. Krishnakumar



Intelligent Decentralized Survey of Volcanic Plumes

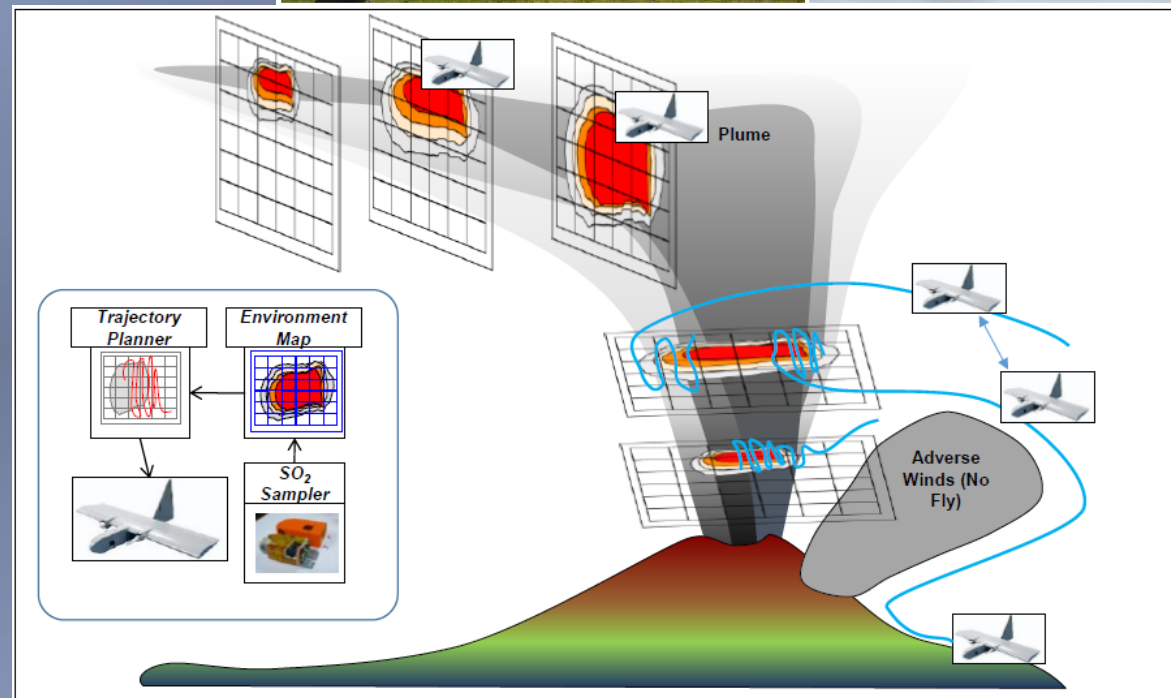
Goal: Characterize a volcanic plume to validate 3D models and space based observations (ASTER sensor)

Case study: for autonomy research to intelligently coordinate UAVs with sensor in-the-loop feedback and distributed control

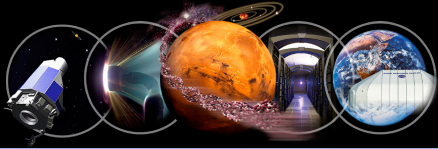
Approach: Coordinate in situ measurements from multiple (3) unmanned aerial vehicles to study emission, transport, composition, of volcanic plumes

UAV flight follows simulated/expected plume shape with sensor in the loop feedback to guide multiple UAV coordination

STMD project leverages the multiple UAV coordination capabilities and access to volcanic airspace & mission support

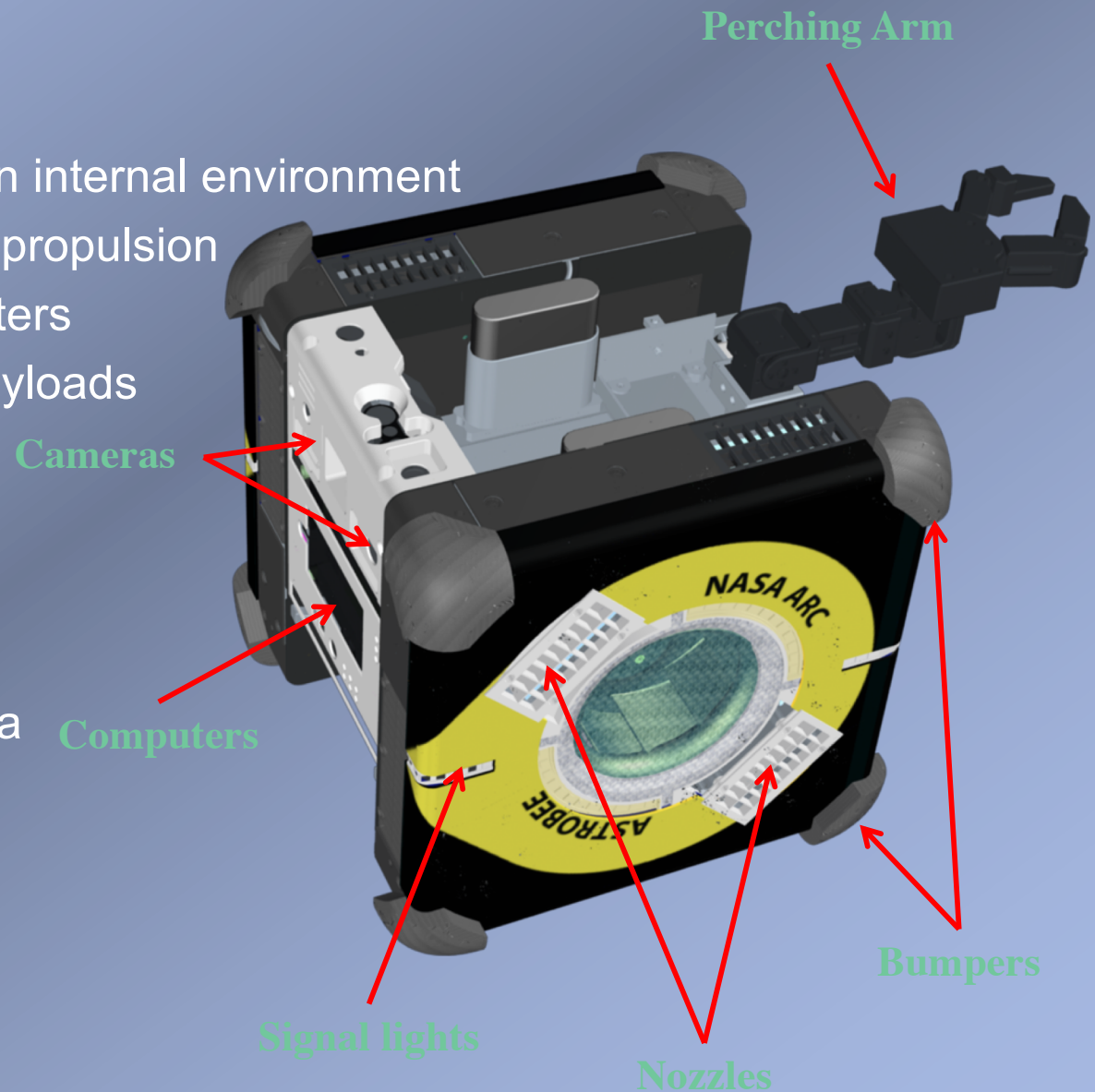


UAV sampling guided by a computer model of expected plume shape and intensity. NASA Airborne Science ARC & Earth Surface and Interior Focus Area HQ.



Astrobee

- Free-flying space robot
 - International Space Station internal environment
 - All electric with fan-based propulsion
 - Three smartphone computers
 - Expansion port for new payloads
 - Open-source software
 - ~30x30x30 cm, ~8 kg
- Uses
 - Mobile sensor
 - Remotely operated camera
 - Zero-G robotic research
- Autonomy
 - Docking & recharge
 - Perching on handrails
 - Vision-based navigation



Tensegrity SUPERball for Earth Science: Monitoring Hazardous Environments

Lightweight: backpack into remote site

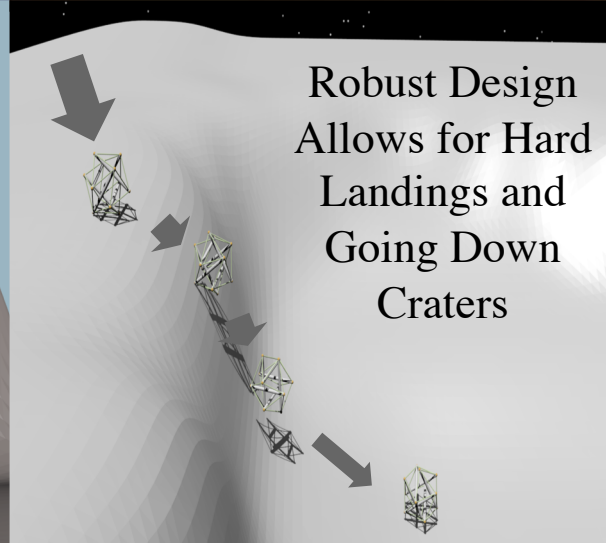
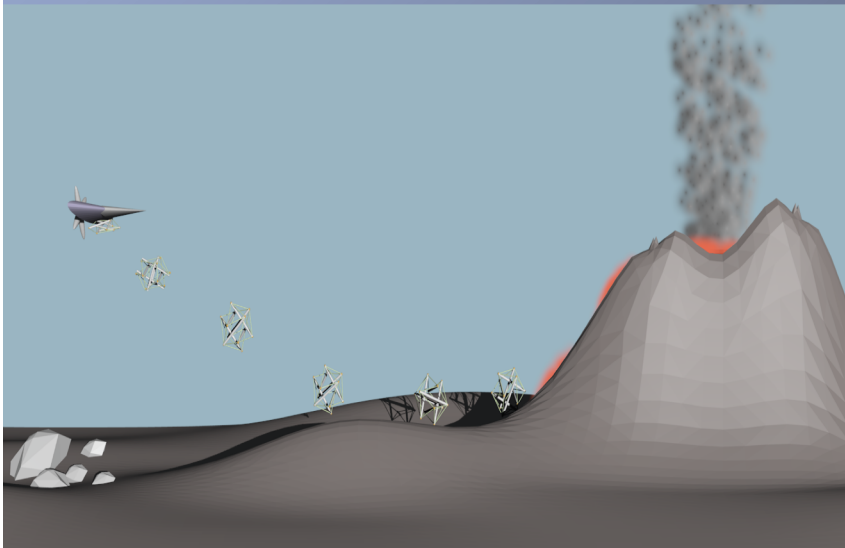
Roll or drop into craters or crevasses

Move to science site after landing

Sample locations unsafe for staff
such as volcano vents or avalanches

Drop from drone or airplane

Superball 2.0 ready summer 2017 will be able to
fall 10-20 feet safely and have greatly improved
locomotion and control capability.

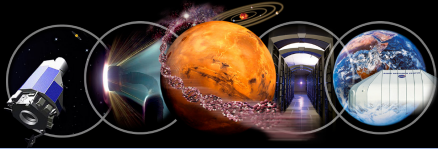


Robust Design
Allows for Hard
Landings and
Going Down
Craters

Self-Roll to Final Destination



**An unintended
slip or fall is no
longer fatal to the
mission.**



Machine Learning/Data Mining Research and Development (R&D) for application to NASA problems (Aeronautics, Earth Science, Space Exploration, Space Science)

Example Problems

- **Aeronautics:** Anomaly Detection, Precursor Identification, text mining (classification, topic identification) for commercial aviation, relating pilot fatigue to aircraft performance, identifying patterns in RNAV waypoint compliance
- **Earth Science:** Filling in missing measurements (e.g., ground-based pollution sensors) through relationships with other measurements (e.g., satellite remote sensing), anomaly detection, graph mining to find teleconnections and changes in them, learning relationships between vegetation and climate variables through symbolic regression
- **Space Science:** Kepler and TESS planet candidate identification
- **Human Space Exploration:** system health management (monitoring ISS using in-house Inductive Monitoring System), vascular structure identification for astronaut health, machine learning within Advanced MultiMission Operations System (AMMOS)
 - Open-sourced algorithms, papers, project information available on Dashlink (<https://e3.nasa.gov/dashlink/>)
 - Collaborators: NASA (multiple centers and divisions), Univ. Minnesota, Univ. Vermont, CSUMB, UCSC, ASU, UC Berkeley, Stanford, SJSU, ASRS (BAH), SWA, easyJet, HP, MITRE