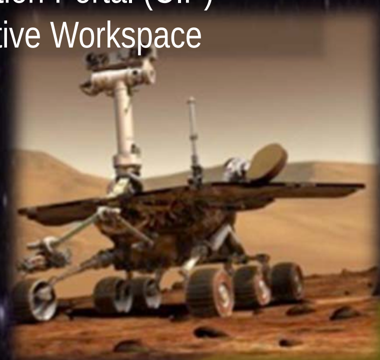
Autonomy @NASA

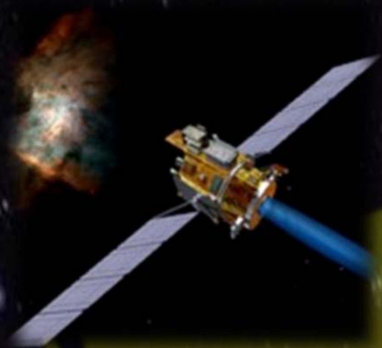
Autonomy for Space Exploration

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

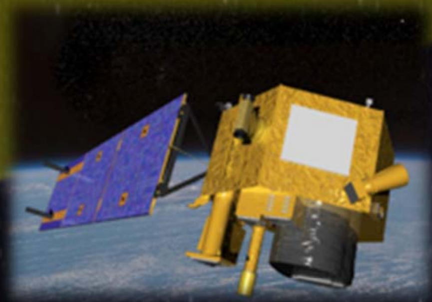


2007 Phoenix Lander
Ensemble:
Rover activity planning & scheduling

2018 Astrobee Free-Flyer
Autonomous nav, docking and recharge, and mobile sensor IVA work on the ISS.



1997 Deep Space 1 Remote Agent
The first demonstration of an onboard autonomous spacecraft control system



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

2012 Mars Science Lab
Ensemble:
Rover activity planning & scheduling

2015: AMO
Demonstrate crew autonomy protocols and technology onboard ISS

Deep Space 1 – Remote Agent (1997)

TA 4.5.1, 4.5.2

The first onboard artificially-intelligent adjustably-autonomous flight system to control a spacecraft – 1999 NASA Software of the Year winner

Planner/Scheduler
Expert Systems,
e.g., Navigation

Remote Agent

Integrated Reasoning Engines

Planner/
Scheduler

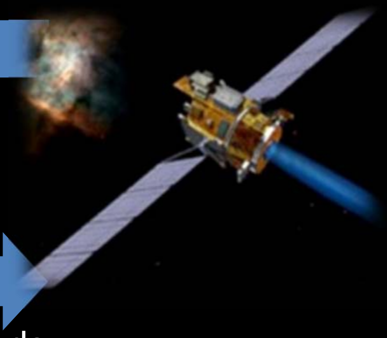
Smart Executive

State Estimation,
Mode & Fault ID,
Recovery Expert

Observations / Command Responses

Goals, high or low-level commands and command sequences

Commands



Capabilities

- Planner expands high-level goals into flexible plans
- Executive decomposes plans into low-level spacecraft commands and monitors that the states commanded to are achieved and maintained
- Logically-Consistent State Estimator and Fail-operational fault recovery
- Identifies faults and suggests recoveries that the Executive uses to continue plan execution
- If necessary, Executive requests the Planner to generate a new plan

ISS Astrobee Space Robot

Overview

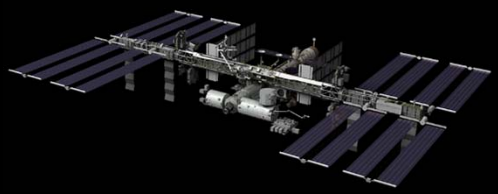
- Free flying robot for inside the ISS
- Astrobee will be used by flight controllers for mobile IVA sensing
- Astrobee will be used as a robotic testbed (like SPHERES)

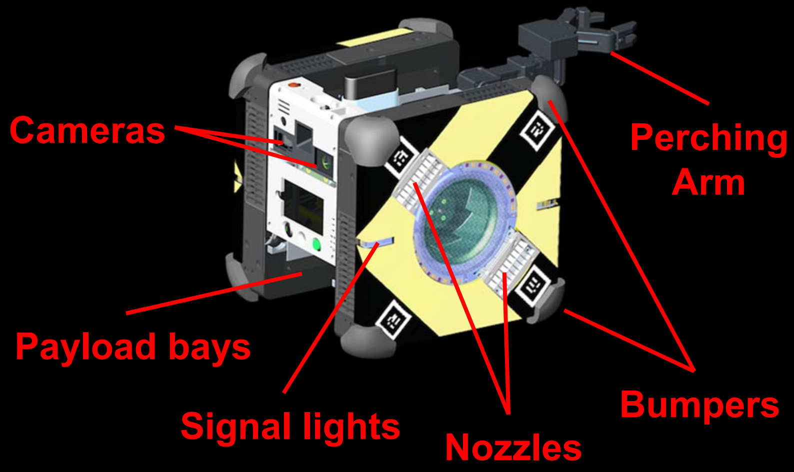
Safe autonomous operations

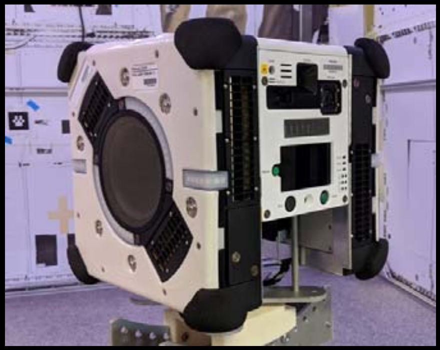
- Task execution / notification
- Perching & station keeping
- Docking & resupply

Concept of operations

- Mission control uploads plans to robot for autonomous execution
- Astrobee has on-board fault recovery (stop, terminate, return)
- Mission control can remotely intervene if needed







Certification Unit (8/2018)

Two Astrobees moving cargo (artist concept)

Autonomy for Robotics

2002 Single Cycle Instrument Placement

Approach and place an instrument in one command cycle. Method has sin ER.

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 Self Driving Car

Adapt space robotics technlology to "fleet management" use.

2005 Autonomous Visual Inspection

Robotic "walk around" inspection for future lunar sortie operations. Universal Executive and PLEXIL.

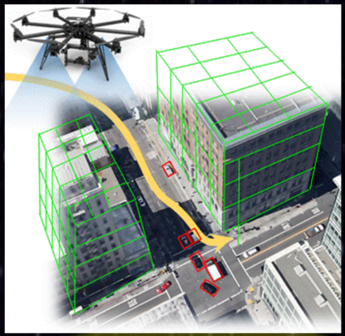
2010 ATHLETE Footfall Planner

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.

Ames Autonomy for Aeronautics



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

2015- UAS Autonomy

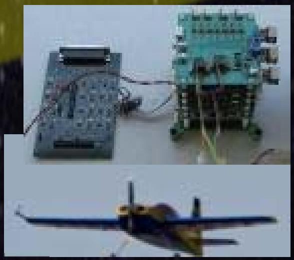
Fully Autonomous urban deployment of UAS—Vehicle Technologies and Airspace Management

1999 Neural Net Learning

Dynamic Cell Structure NN based learning for adaptive control

2010 Emergency Landing Planner

Decision support to the pilot of a damaged commercial transport aircraft

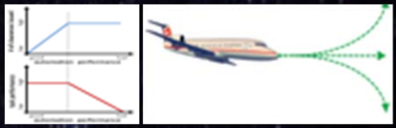


2011 Real-Time Prognostics

Predict remaining useful battery life

2013 Prediction Uncertainty

Operators compensating for imperfect autonomy

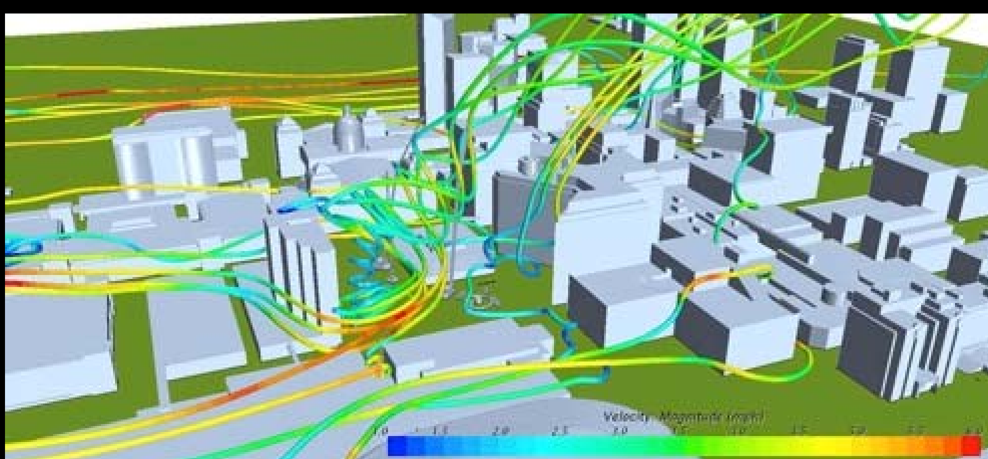


UAS Autonomy (2015-)

The UTM architecture addresses mission planning and execution strategies for Small UAS (sUAS) operations to encompass:

>> Non-autonomous sUAS operations – for spontaneous launching of one or more sUAS by operator(s) to address an urgent need (e.g., for law enforcement and first responder scenarios)

>> Autonomous sUAS operations – for deliberate planned autonomous sUAS flights (e.g., search & rescue, cargo delivery, surveillance).



<u>Research Focus:</u>

1. Beyond visual line-of-sight
2. Reservation of airspace volume
3. Urban environments, higher density
   - >> Wind Accommodation
   - >> Sense and Avoid
   - >> On-board Autonomy

Human-Autonomy Teaming for Space Exploration

2007 Phoenix Lander
Activity planning & scheduling by science teams

2012 ISS MCC
Integrated Attitude, Power and Crew Activity Planning for Mission Operations at JSC, MSFC, ESA and JAXA

2014-15 NEEMO
Mars analog demonstration with simulated time delay

Mars 2020
Goal-based rover activity planning

2003 Mars Exploration Rovers
Constraint Editor for Mission Planning and Long-Term Planning

2012 Mars Science Lab
Virtual collaborative activity planning & scheduling by science teams

LADEE 2012
Assisted re-planning

2018 ISS Crew Self-Scheduling
Six month on-board study of assisted planning and scheduling system for crew

ISS Crew Self-Scheduling

Autonomous crew scheduling

- ISS astronauts can self-schedule mission activities independent of ground control
- Intelligent support system for planning to avoid and de-conflict plan violations and allow for rapid re-planning
- Technology demo on the International Space Station using tablet computers

Future human exploration missions

- Deep space missions (Mars, etc) will require crew to be more autonomous of mission control
- Activity scheduling is critical for mission execution and operations, but is tedious and complex
- Tools that support crew self-scheduling are essential for mission success