The Micro-Inspector Spacecraft: An Overview

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Micro-Inspector Project Overview

Project Objective: Demonstrate in a ground-based space related environment at TRL 6, an ultra-low mass micro-inspector spacecraft for vehicle inspection to enhance safety and reduce risk of future human and robotic space exploration missions.

Micro Spacecraft Highlights:

• Ultra-Low Mass and Size: ~5 kg
  – Through use of multi-functional and micro-systems

• Celestial Attitude Determination
  – Allow operations beyond Earth orbit and in deep-space
  – Uses Micro Sun Sensor, Star-Tracker, Gyro

• Continued Operation in Sun at 1 AU
  – Solar powered with Li-Ion battery backup
  – Ultra Low power consumption: ~ 10 watts nominal

• Safety
  – Laser-based active collision avoidance system
  – Low-pressure, low leakage liquid butane propulsion system
  – Low (~ 30 m/s) delta-v and spacecraft accelerations
  – 4-10 m nominal proximity autonomous operations

• Visual Inspection and Monitoring
  – 6 cameras: wide/narrow angle & star-tracker
  – ~4mm – 10 cm resolution from ~ 10 m distance

• Partnership
  – JSC, Boeing, Vacco and Ashwin-Ushas

Outer dimensions 8.4” x 8.4” x 2.6”
Spacecraft Description

- Sandwich structure (8.4” x 8.4” x 2.6”)
  - Multifunctional Tank (MFT)
  - Multilayer Circuit Board (MCB)
  - Solar Panel Assembly (SPA)
- Solar panel is thermally isolated from tank
  - Thin fiberglass standoffs provide structural support
  - Long, small gauge wires connect antenna, solar cells, and temperature sensor from SPA to circuit board
- Electrochromic surface mounted to bottom side of tank
- Payload components mounted on standoffs over circuit board underneath solar panel and mounted through tank
  - Battery assemblies (x2)
  - Gyro
  - Cameras (x6)
  - Micro Sun Sensor
  - Laser

Outer dimensions 8.4” x 8.4” x 2.6”
Operational Concept

1. Launch and Transport
µIns. launches attached to host and powered off until needed

2. Deployment
After verifying µIns. health, the host severs electrical/mechanical connection and µIns. is ejected away from the host

3. Orientation and Calibration
µIns. locates and tracks the position of both the host and sun and performs on orbit calibrations as necessary

4. Inspection and Communication
µIns. performs through commanded sequences for external inspection of the host vehicle. Downlink of inspection pictures and health data telemetry, uplink of commands.

5. End of Mission Disposal
Final maneuvers place µIns. safely away from the host. This helps mitigate additional risk to the host with the presence of a non-operational hazard.
Micro-Inspector Operations

Distance to view entire host in 25 deg FOV picture

Maximum required range for HA operation

Nominal inspection operating range

Minimum Keep-Out-Sphere

Nominal minimum operating dist.

HA accuracy becomes worse than 0.5 m

1 cm resolution with 25 deg FOV camera

Host

- 2 m
- 4 m
- 10 m
- 12 m
- 68 m

-~30 m

FOV: Field of View
HA: Hazard Avoidance
Featured Technologies

• Multifunctional tank
  – Structural backbone
  – Propellant storage
  – Docking interface
  – Payload component mounting
• Thin film electrochromic surface
  – Voltage applied at electrodes changes the emissivity of the surface between a low-e (IR-transparent) and high-e (IR-absorbing) state
• Low pressure butane propulsion system
  – Low power thrusters
  – Low-pressure propellant tank design for safety and utility
Featured Technologies, con’t.

- Low-power radiation hardened avionics
  - Reconfigurable module based on Xilinx FPGA with dual processor
  - SEU mitigation technique through compared processors and EDAC
- Novel peak power tracking circuit to maximize efficiency of small solar array
- Low-power UHF short range telecom system with high data rate for sending images
  - <150 mW power consumption
  - 1-2 Mbps data rate (coding dependant)
  - 8 kbps commanding rates
Featured Technologies, con’t.

- Miniature celestial and inertial sensors for navigation
  - Micro-Inspector cameras double as star trackers
  - MEMS based 3-axis IMU from Honeywell
  - JPL developed 2-axis Micro Sun Sensor
- Structured light system for Hazard Avoidance
  - 400 laser beams emitted in a patterned grid
  - Camera at set baseline from laser grating locates spot placement and triangulates distance
Micro-Inspector Hardware Development

Avionics and Sensor Integration Demonstration

Vacco Piezoelectric Butane Thruster Prototype on JPL Micro-Newton Thrust Stand

Micro-Inspector Collision Avoidance Demo Hardware Displaying Laser Pattern

Mars Micro Transceiver High Data Rate Transmission Demo

Micro Sun Sensor Demonstration
Current Hardware Testbed
Summer SURF Student Projects

Ashley Smetana- Univ. of Michigan
Jason Kephart- Caltech
Chris Schantz- Caltech
Jesse Way- Montana State Univ.
Lauren Bowers- Univ. of Illinois

- Mission concepts and operational scenarios
- Spacecraft transport dock and low-shock separation mechanism
- Refined design of the multifunctional tank
- Design of a RadHard buck regulator for avionics module
- Algorithm and software development for spacecraft autonomy and control

- Impact testing to determine possible damage to host
- JSC Air Bearing Sled
  - Similar setup used for Mini AERCam
  - Sharpest protrusion of Micro-Inspector used for testing - corner of solar array assembly
  - Force transducers measure impact
  - Multiple velocities measured - nominal inspection (1 cm/sec), traverse (2 cm/sec), and worst case (1 ft/sec)
  - Visual inspection of test article post impact for damage. Shuttle tile used as preliminary material
Micro-Inspector Safety & Operations: Future Air-Bearing Testing

- For proximity operations and collision avoidance algorithms (safety) and sensors
- JPL Formation Control Testbed (FCT) robots with 6 DOF motion
  - For sensor verification/calibration and algorithm development (use FCT thrusters for motion)
  - FCT robot sensors act as verification
  - Vertical translation under development
  - Micro-Inspector small part of entire system
  - Need to compensate for rotation axes offset from Micro-Inspector axes
  - Floor size 10 ft x 15 ft with plans to expand to 30 ft. diameter
- JSC 2D Air Bearing Table
  - Used for Mini AERCam
  - Video monitoring system in place
  - Need to fabricate a new Air Bearing Sled with custom thrusters for atmosphere/1g environment
  - For algorithm verification and validation
  - Floor size 8 ft x 10 ft