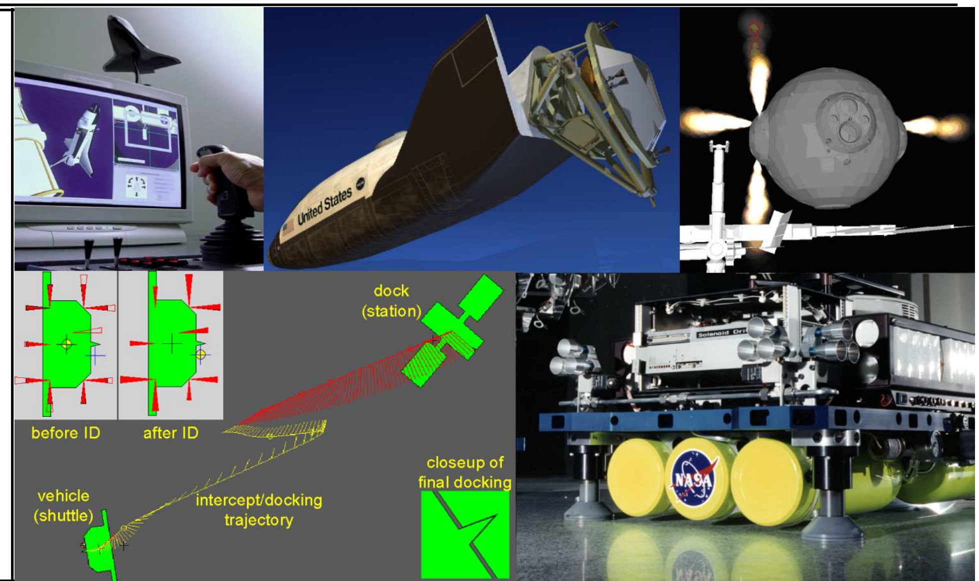
Neurocontrol Technologies for Spacecraft Navigation & Docking

(aka - Neurocontrol for Shuttle Docking)

Robert W. Mah, Ph.D./NASA Ames



Goal: Adaptive intelligent controllers that can learn in real-time changes in vehicle mass properties, thruster strengths, thruster failures, and other disturbances (leaks).

Objectives: 1) Fault tolerant control of spacecraft navigation & docking, 2) Capability to safely dock to a moving target, 3) Safer, more accurate, & more fuel efficient spacecraft navigation and docking.

Key Innovations: Robust on-line thruster FDIR and vehicle mass ID – under condition of significant variations in mass properties, thruster firings & sensor noise

NASA Relevance:

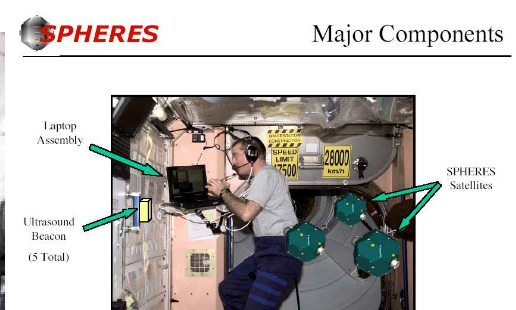
- Bill Readdy, NASA HQ, AA, Code M Office of Space Flight - funded 375K for the work with JSC Code EG
- Joint DOD/NASA Working Group on Autonomous Rendezvous & Capture – top managers very interested
- Invited to participate as PI on the MIT SPHERES - launch 6/03, experiments every 2 wks, 17 months long.

Accomplishments to date:

- Papers: 1) “Gyro-based maximum-likelihood thruster fault detection and identification,” 2002 American Control Conference, Alaska, May 2002. **Best paper;** 2) “On-line, gyro-based, mass-property identification for thruster-controlled spacecraft”, 45th IEEE International Symposium, Oklahoma, August 2002.

Schedule:

- FY01-FY02: Shuttle thruster FDIR; X38/CRV thruster FDI; MiniAERCAM thruster FDI, spacecraft mass ID
- FY03: ISS flight demonstrations using MIT SPHERES (thruster FDI, real-time mass ID, fault tolerant thruster reconfiguration); navigation sensor FDIR



X38/CRV application overview video

Maximum Likelihood FDI

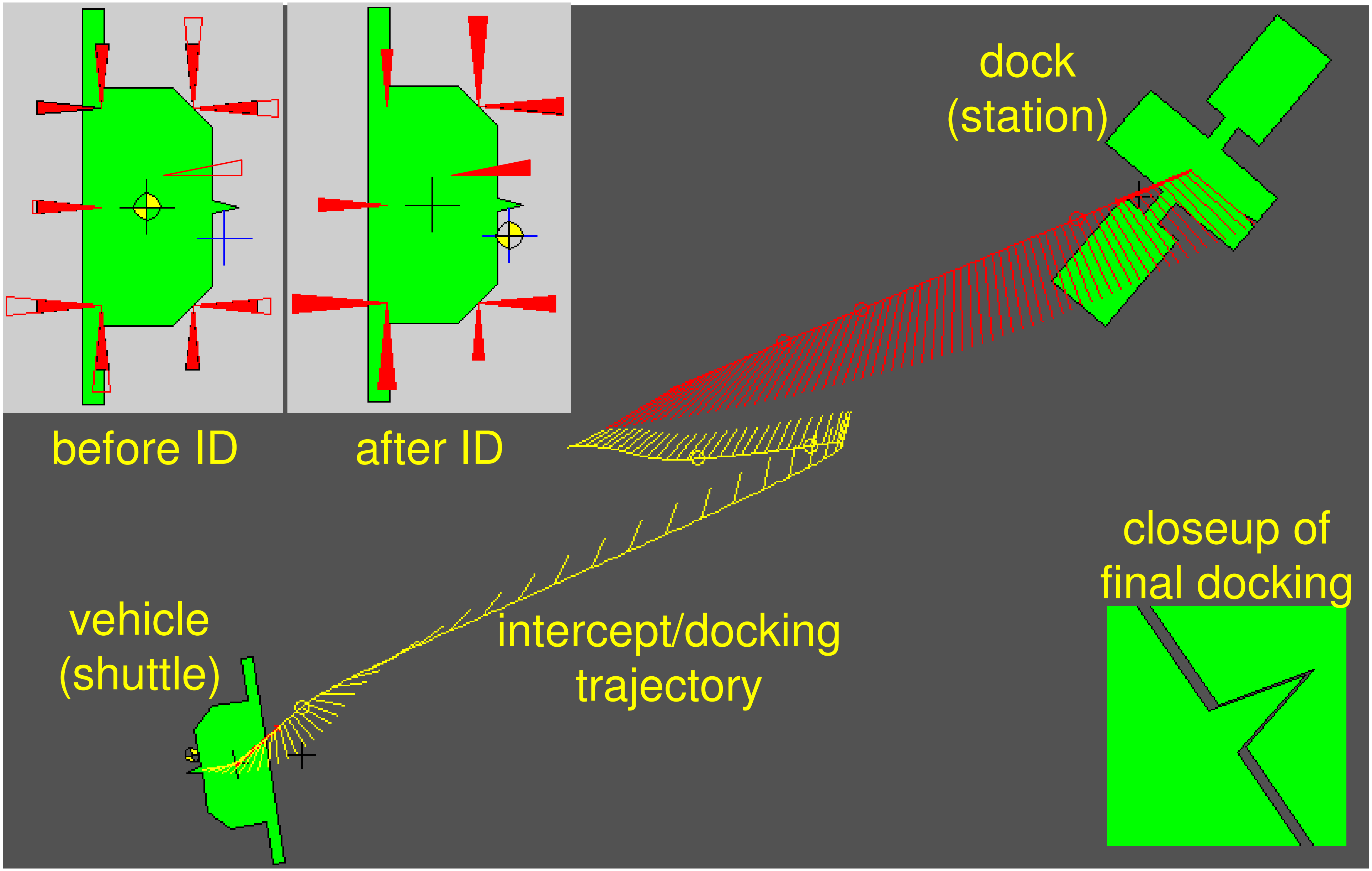
- Algorithm's **core** based on a 1976 paper by Deyst and Deckert on leak detection for the Space Shuttle Orbiter
- Calculates difference between expected and actual angular acceleration
- Compares this "disturbing acceleration" to that corresponding to the possible failure modes
- Due to low SNR and failure modes with similar disturbing accelerations, **filtering and windowing** data required
- Detection based upon generalized likelihood ratio (GLR) test for each failure mode
- Identification based on the likelihood calculation for each failure mode
- Excitation of thrusters required in some cases
- **Logic** to disregard some failures, select correct failure mode

Performance

- Generally detects failure within 1 second (active time) for X-38, faster for Mini-AERCam
- ID follows within 1-5 seconds for X-38 (slower when blowdown multiplier low)
- FDI developed on X-38, then easily “ported” to Mini-AERCam and S4. Significantly easier problem due to better SNR and fewer, less complex failure modes.
- Extended automatic testing run for X-38 – 99.98% accurate FDI (without miss or incorrect ID)
- MATLAB demo

2-D Software Simulation

On-line reconfiguration for mass/thruster properties



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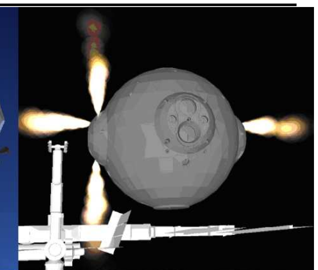

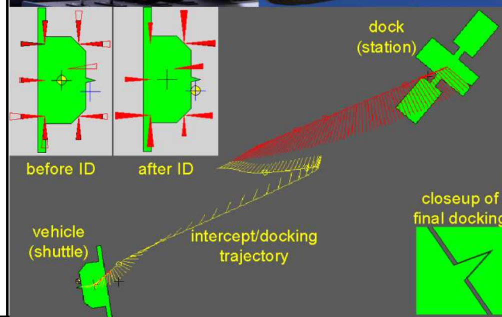

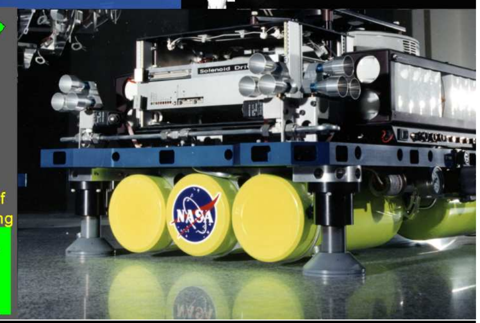

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