The Personal Satellite Assistant

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Outline

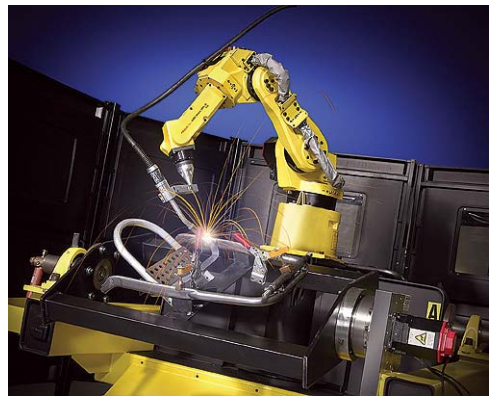
- Introduction
- Problem Statement
- Hypothesis
- Approach
- Development
- Testing
- Challenges
- Questions/Answers

Introduction

- What is a robot?
  - Electro-mechanical System
  - Sense
    - See, feel, hear, smell, taste environment
  - Decide
    - React to sensors
    - Figure out how to achieve goals
  - Act
    - Move around to achieve goals
    - Manipulate the environment
      - Use an arm to pick up and move something

Introduction

- What types of robots are there?
  - Service
    - Example: “NurseBots”
  - Industrial
    - Example: welding robots
  - Exploration
    - Example: MER
  - Military
    - Example: URBIE



Problem Statement

- Space is dangerous for humans
  - Outside spacecraft (EVAs)
  - Inside spacecraft
    - Bone loss, radiation, etc.
    - MIR fire example

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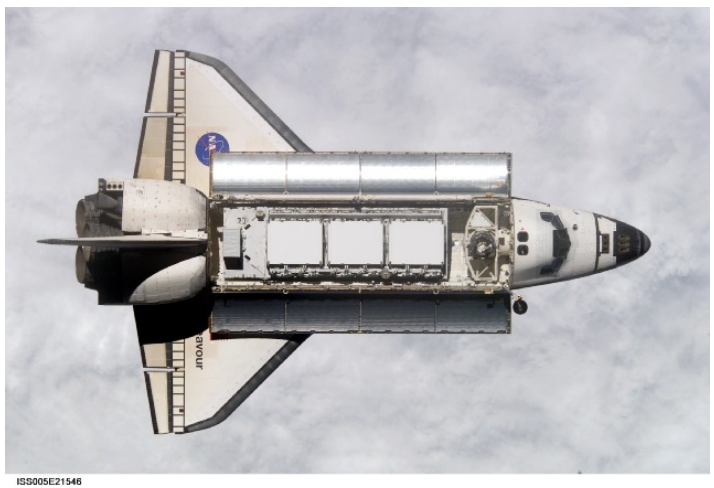
Problem Statement

- Astronaut time is valuable
  - Don’t let the humans do what a robot can
    - Check sensors
    - Track inventory
    - Videotape events
    - Manage astronaut schedules (like a PDA)
    - Read procedures to an astronaut
    - Virtual presence for ground scientists/engineers
    - Diagnose spacecraft problems
  - Let the humans focus on the hard things
    - Doing science
    - Testing technologies for future missions
    - Repairing and replacing equipment

Problem Statement

- Spacecraft are “undersensed”
  - Very complex systems (shuttle, ISS, JIMO, etc.)
    - Manned and unmanned
    - Need enough data to monitor
  - BUT, sensors need power, data lines
    - Sensors and wires start to weigh a LOT
  - Trade-off having enough sensor data
    - May have 1 sensor where many are needed



Hypothesis

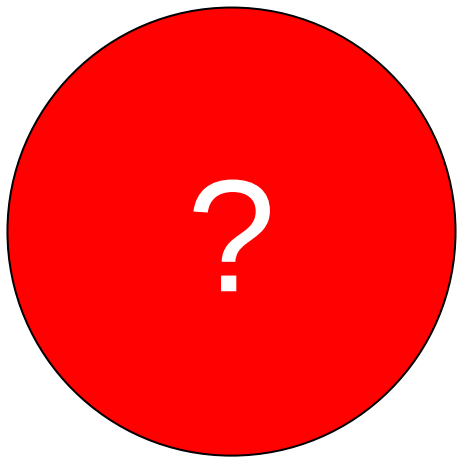
- Service robots aid space flight
  - Use robots when you can
    - Tend to unmanned spacecraft
    - Assist humans
  - Let robots take the risks
    - MIR fire example
  - Let robot do mundane work
    - Inventory tracking, etc.

Approach

- Target a robotic assistant for ISS crew
  - Inside ISS (easier to develop and test)
- Develop technologies on the ground
  - Much cheaper to test before flying
- Test fly on KC135 (“Vomit Comet”)
  - Show navigation, obstacle avoidance
- Test fly on ISS
  - Show operation with humans
  - Show long-duration experiments
- User studies with astronauts, controllers
  - Get feedback

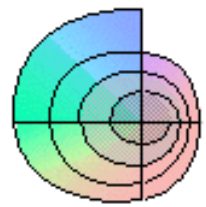
Development

- Start with safety
  - No arms, claws, etc.
    - Can't accidentally grab something it shouldn't
  - Spherical (no corners or protrusions)
    - Can't accidentally push a button or poke something
  - Worst-case failure is a floating ball
    - Crew simply grab it and stow it away if it breaks



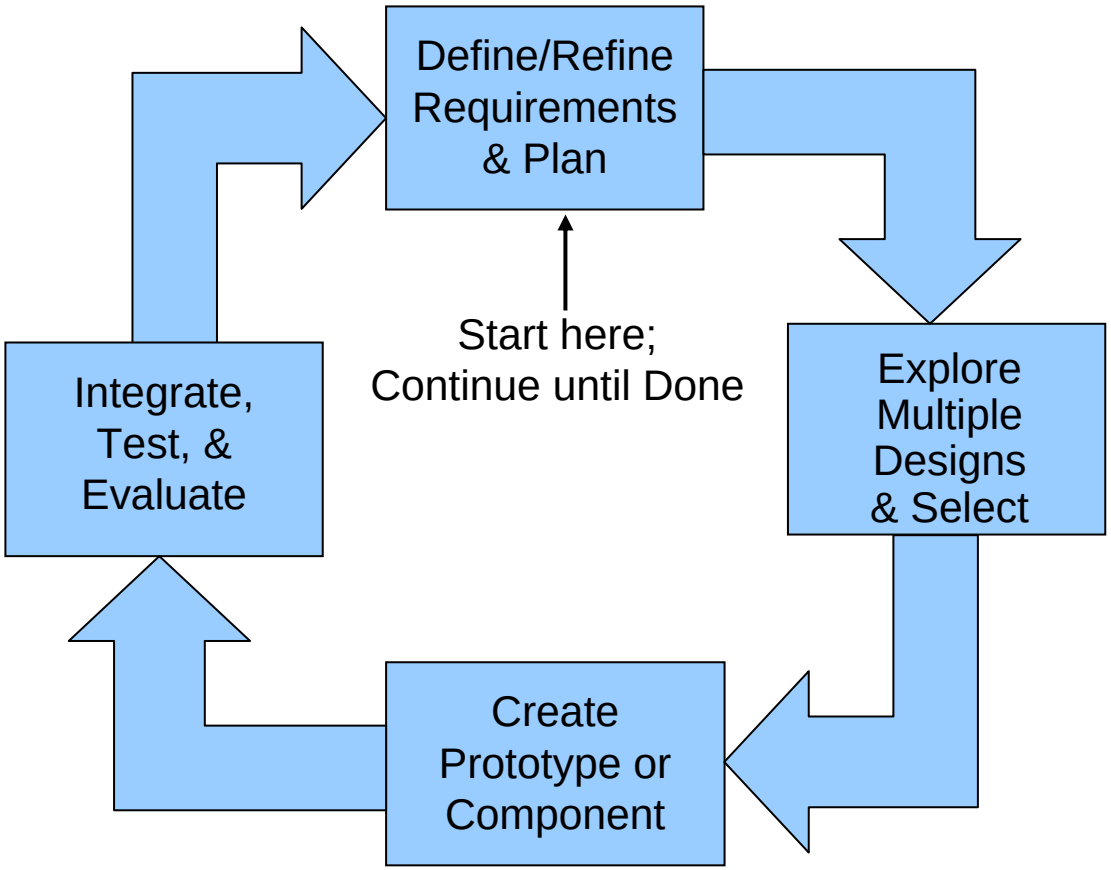
Development

- "Spiral" development
  - Don't try to solve entire problem at once
    - Break problem down into multiple design cycles
  - For each design cycle,
    - Try to solve risky part of the problem
    - Build a prototype
    - Test and evaluate the prototype
    - Come up with ideas for the next design cycle
  - Build increasingly complex system
    - Each design cycle adds more features



Development

- Design cycle



Development

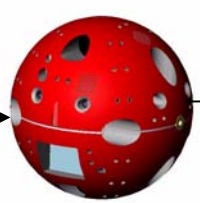
- Prototypes
  - Form prototypes
    - Show what it might look like
    - Great for getting ideas across
  - Functional prototypes
    - Test how ideas work
    - Sometimes build a specialized prototype
      - Test a *single* idea

PSA Prototypes

1998 1999 2000 2001 2002 2003 2004

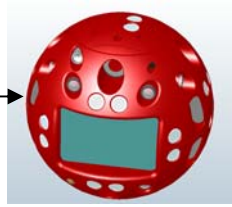
C1

M1



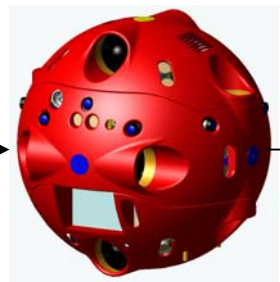
C2

C3

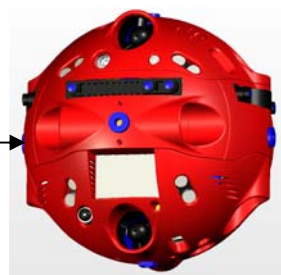


C4

M2



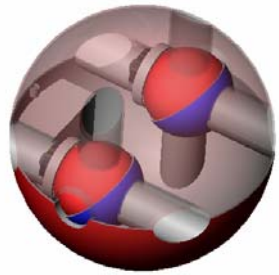
M2B



M2C

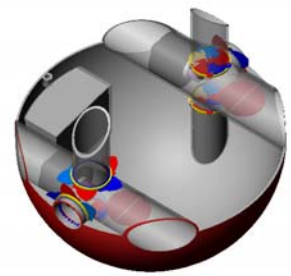
Propulsion Concepts

Single Fan Drive

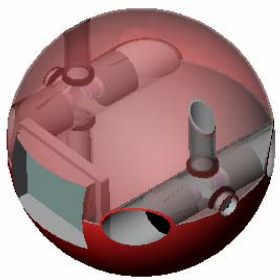


Dual Fan Axial Port Drive

Dual modified Flatpak Blower Drive



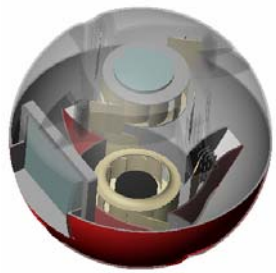
Dual Fan Iris Port Drive



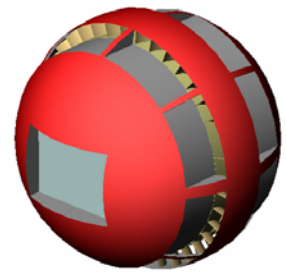
Quad Fan Iris Port Drive

Dual Modified Flatpak Blower Drive v. 2

Dual Radial Blower Drive

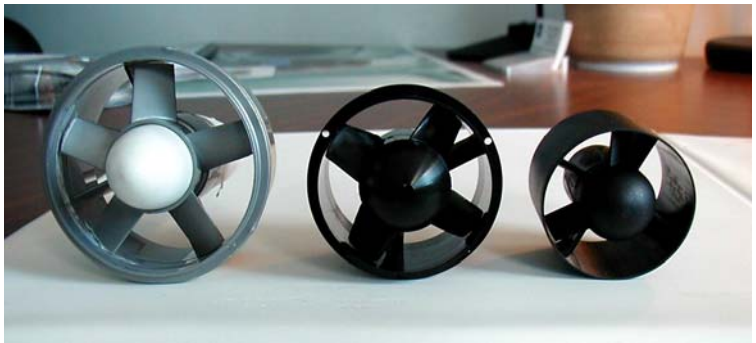


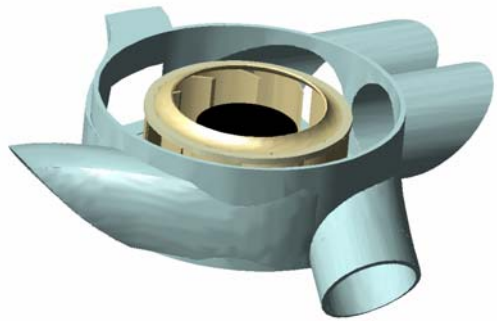
Dual Radial Blower Drive v. 2

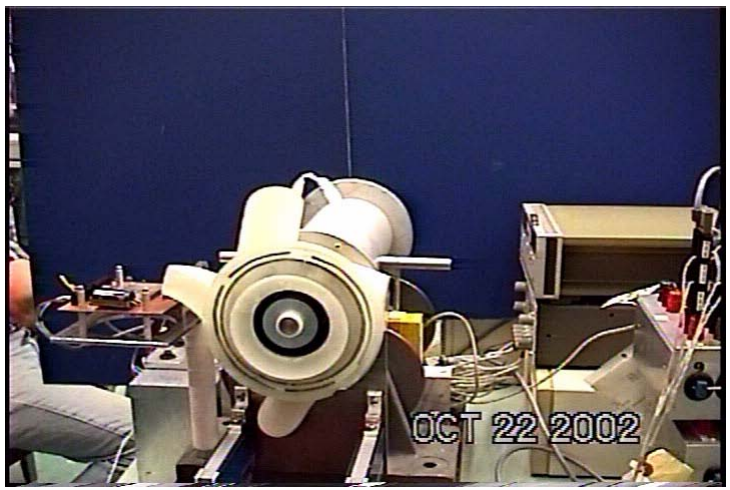


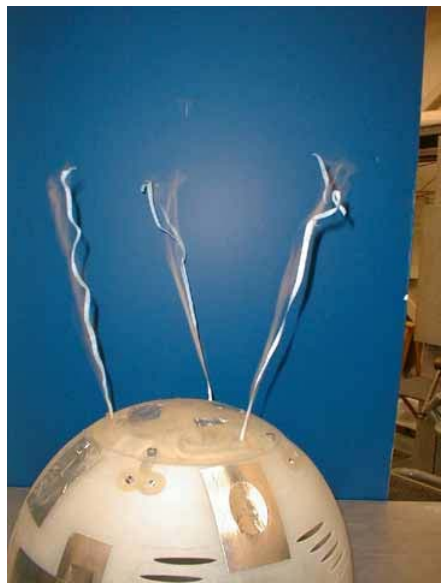
Bubba Jet Drive

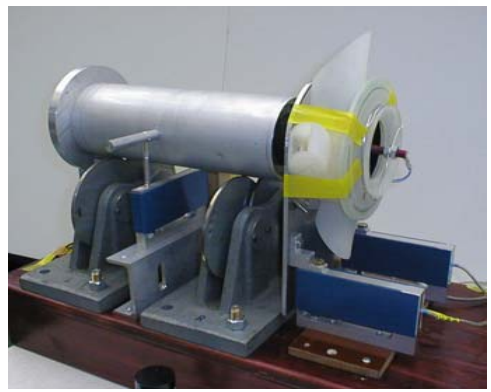
Propulsion Prototypes



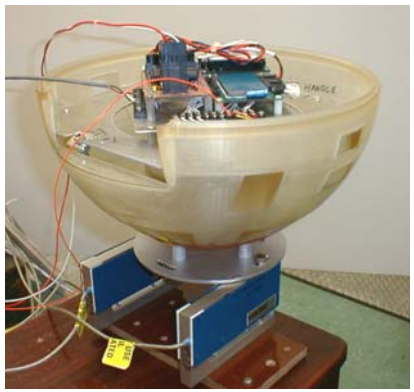


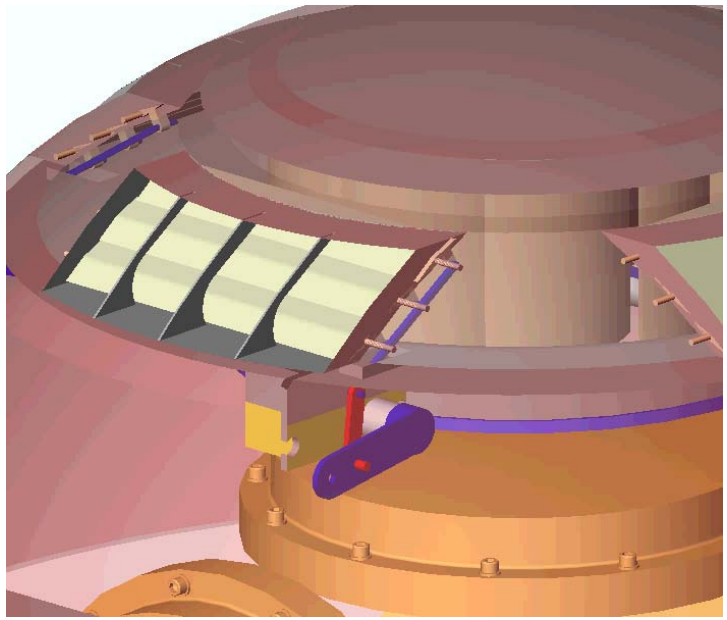


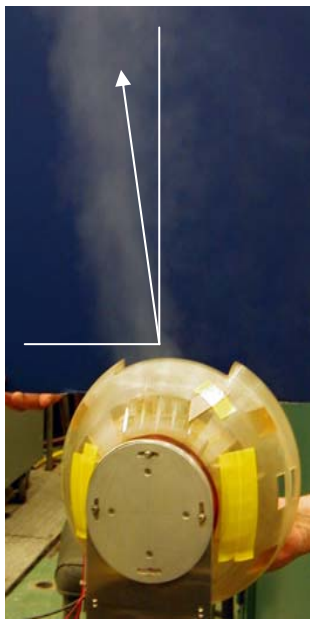


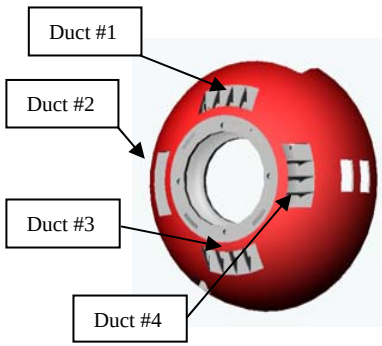


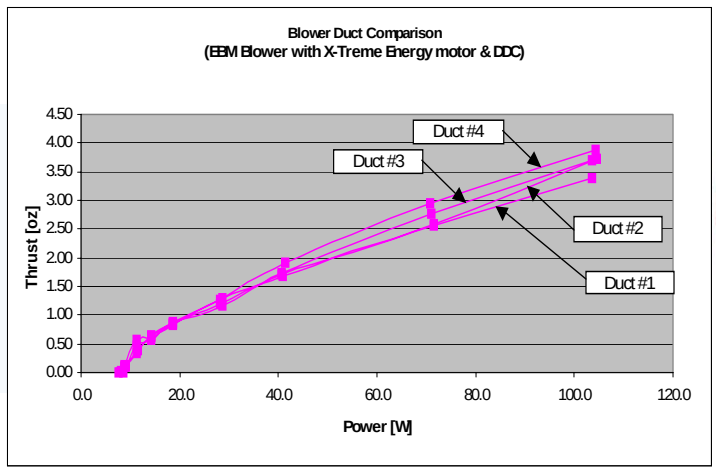
Propulsion Prototypes

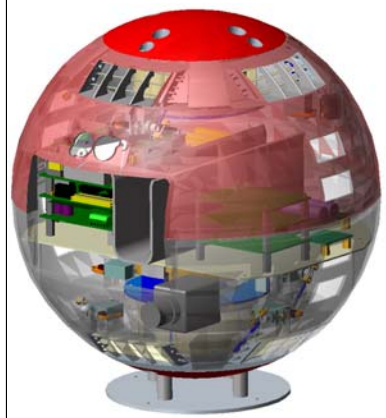






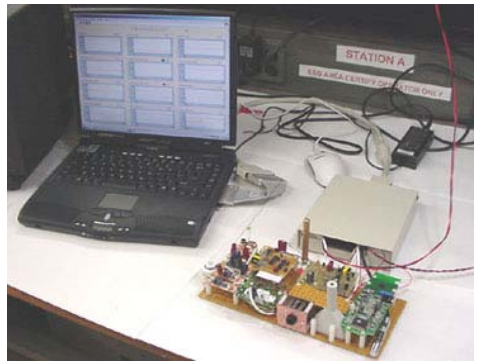




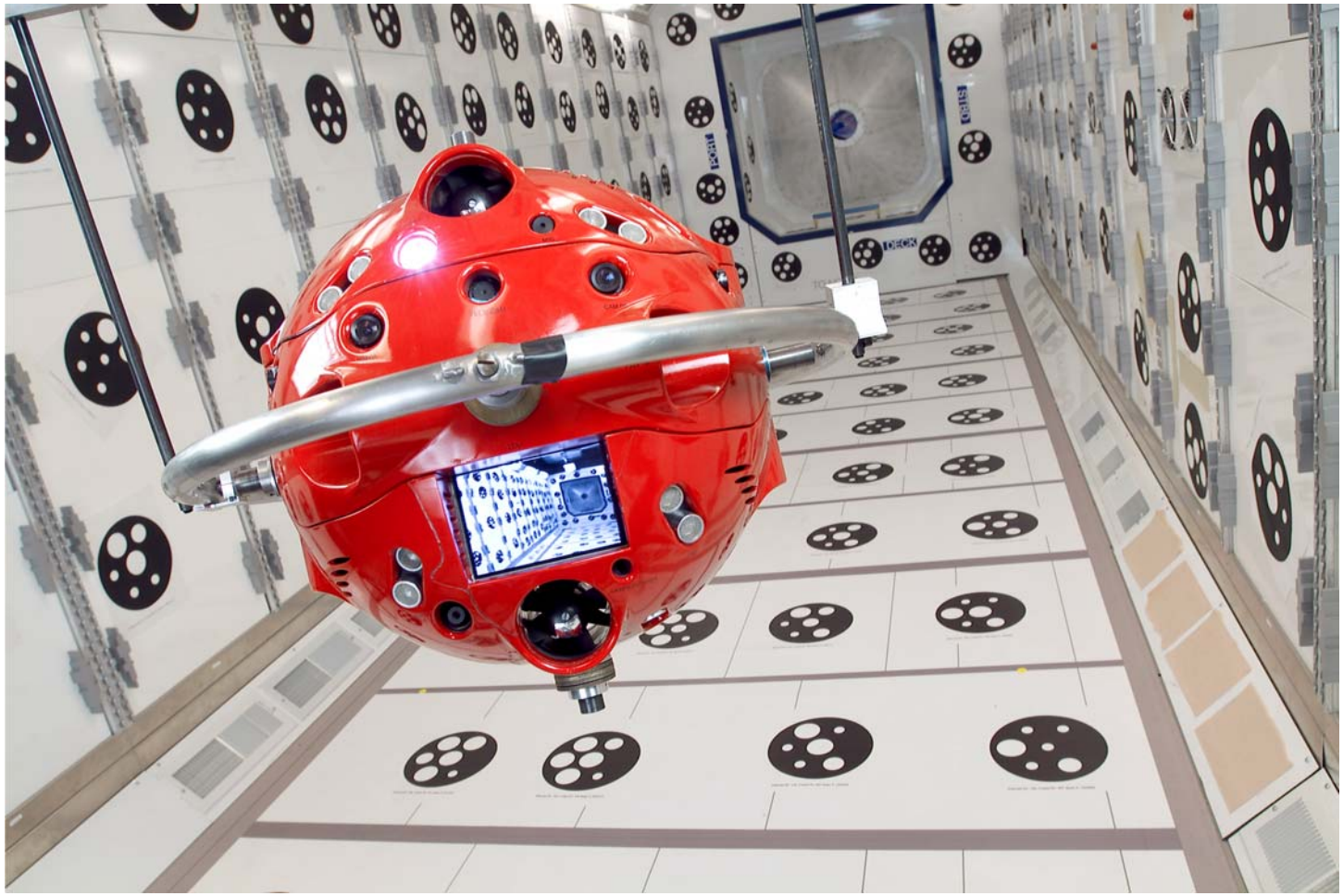


Sensor Studies

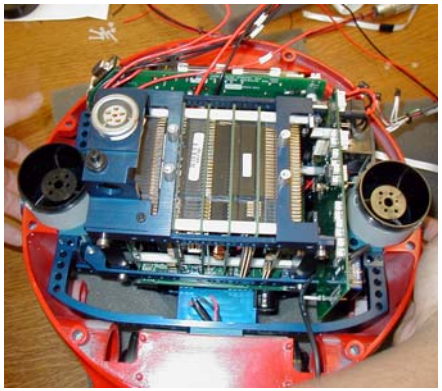
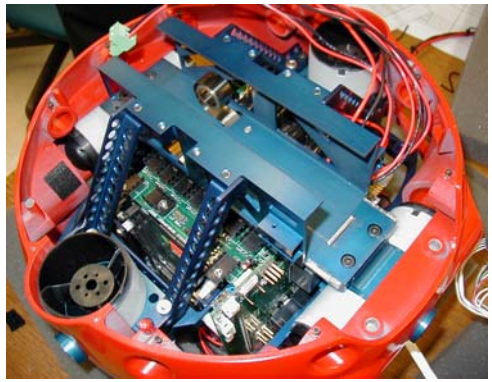
- Flame Detector (combustion monitor)
- Pyroelectric Detector (sense *changes* in infrared energy)
- Pressure Sensor
- Carbon Dioxide Sensor
- Humidity/Temperature Sensor
- Oxygen Sensor
- Light Sensor (Lighting control)
- Electric Field Sensor (ESD/RF monitor)
- Radiation Monitor
- Acoustic Sensor
- Capaciflector (obstacle avoidance)
- Spectrometer (atmosphere analysis)
- Teleconferencing Camera w/LED Lighting

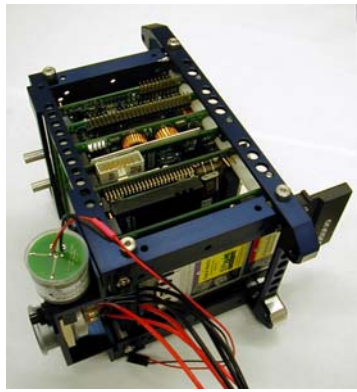


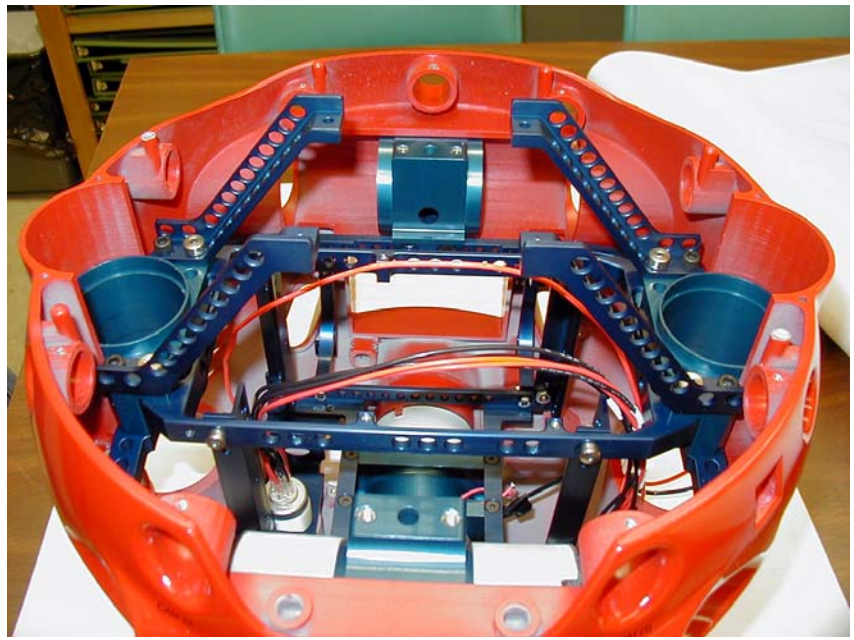
Model 2B



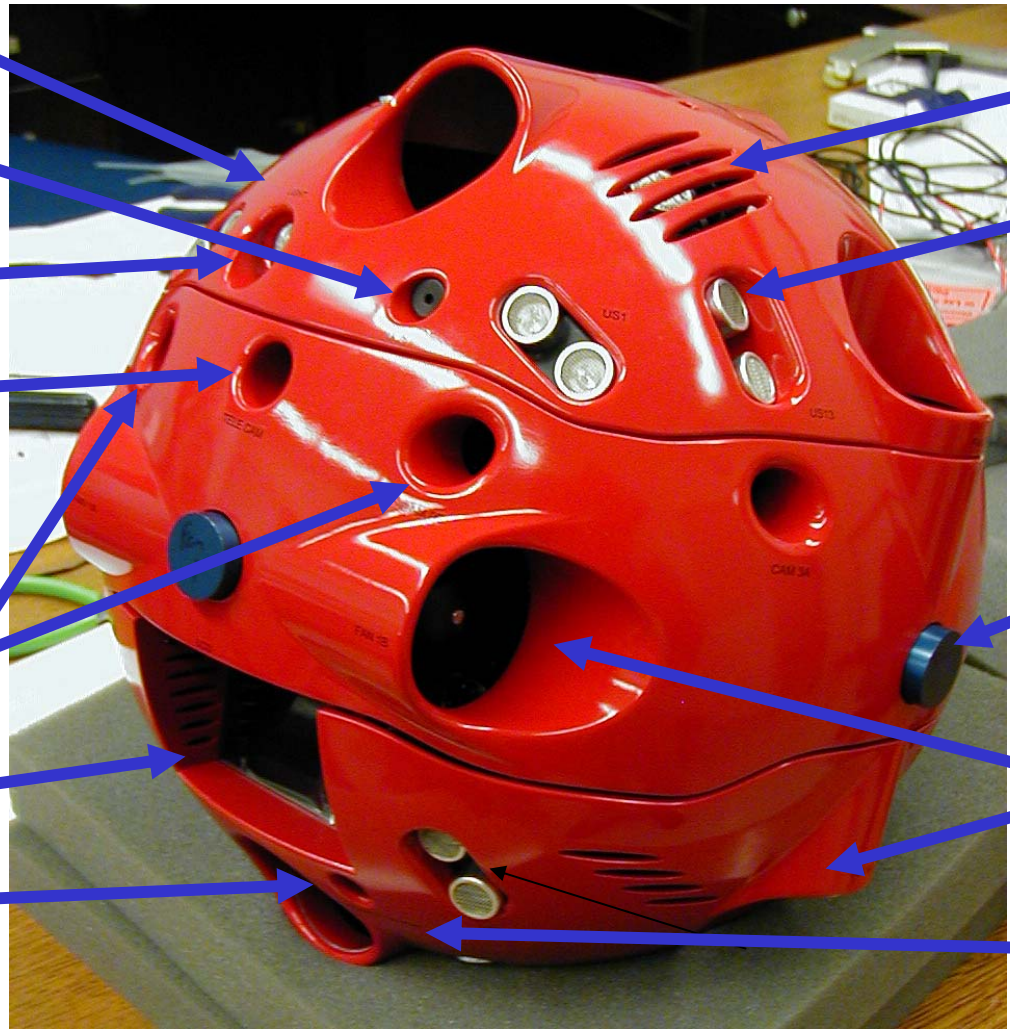
Model 2B





Model 2B


Speaker
Microphone
LED Spotlight
Telecon Camera
Stereo Camera
Video Display
Laser Pointer
Vent
US Sensors
Gimbal Mount
Propulsion Fans
Thermal Probe

Model 2B

- Navigation
  - Gyros + 8 cameras
  - Uses special marks for vision processing
  - Obstacle avoidance
  - Crew following
- Artificial intelligence (AI)
  - Detect and diagnose station problems
  - Schedule planning
  - Path planning
- User Interface
  - Graphical and speech

Latest Model 3 Concepts

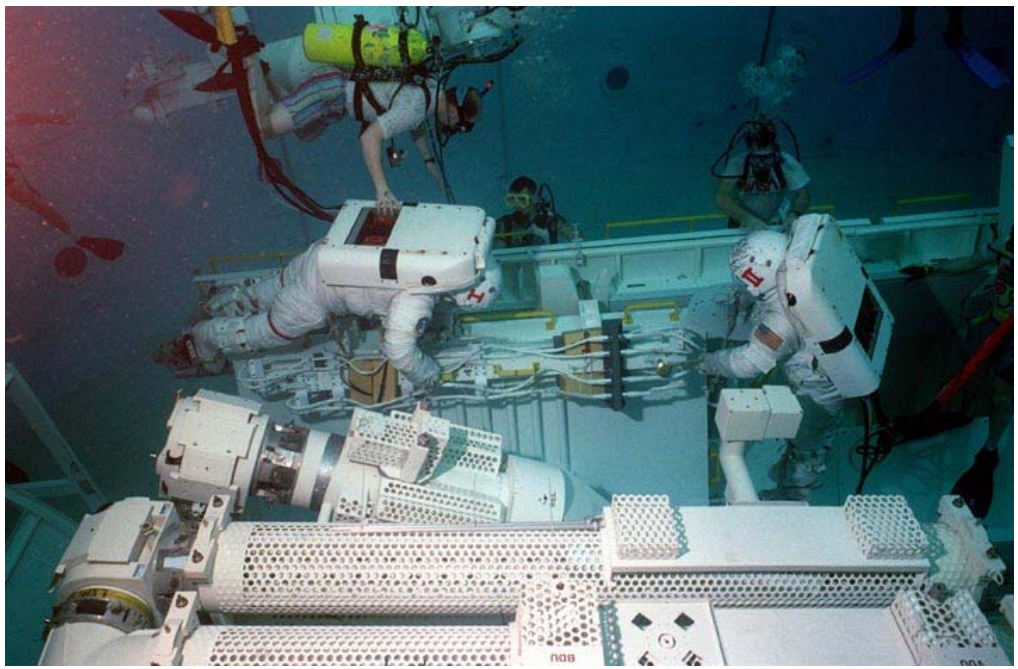
- Propulsion system
  - Blower with iris ports
    - Much quieter
  - Reaction wheels
    - Better orientation control
- Bigger LCD
- Lower-power electronics

Testing

- How do we test for space on Earth?
  - Need to simulate microgravity (zero-g)
    - Show robot moving itself
  - Need to simulate environment
    - Make it look like the real thing
  - Need to allow long-duration human interaction
    - Show how robot can help over many days

Microgravity Test Methods

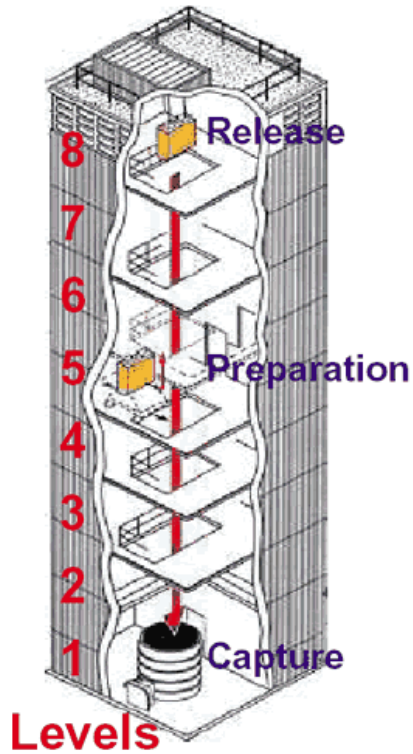
- Neutral Buoyancy Tank
  - Big swimming pool
  - Limited duration for divers
  - Expensive to operate and maintain



Microgravity Test Methods

- Drop Tower
  - 2.2 seconds of zero-g
  - Too short for most experiments
  - No human interaction

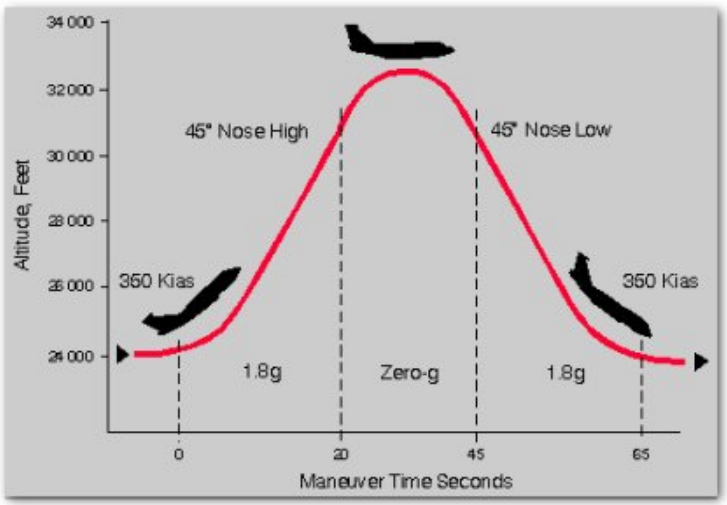
A view down the drop tower shaft showing an experiment being retrieved from the air bag.



A cutaway drawing of the 2.2 Second Drop Tower, showing the levels on which an experiment package is prepared, released, and captured.

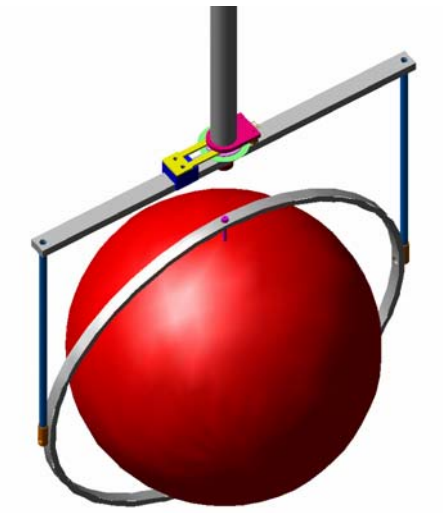
Microgravity Test Methods

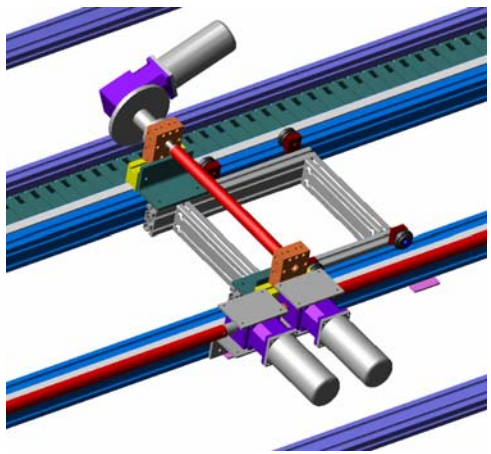
- KC135 “Vomit Comet”
  - 25 seconds of zero-g
  - Too short for most PSA experiments
  - Moderately expensive

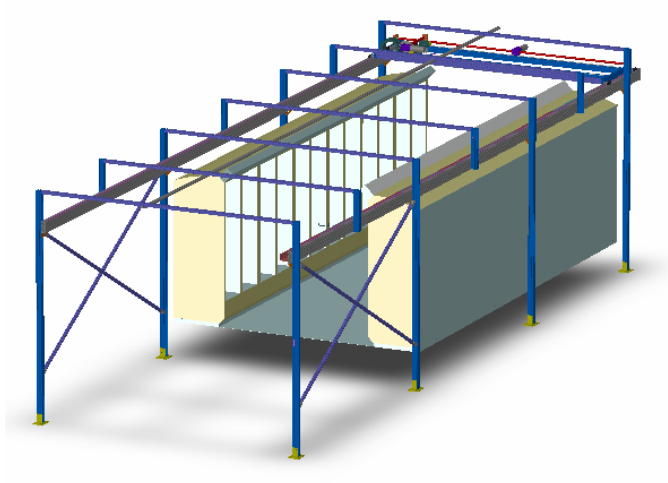


Microgravity Test Methods

- Force feedback crane
  - Micro-Gravity Test Facility (MGTF)
  - Mockup of Destiny US lab on ISS
  - Crane “feels” any force on PSA and moves
    - Cancels out gravity, self-inertia, friction

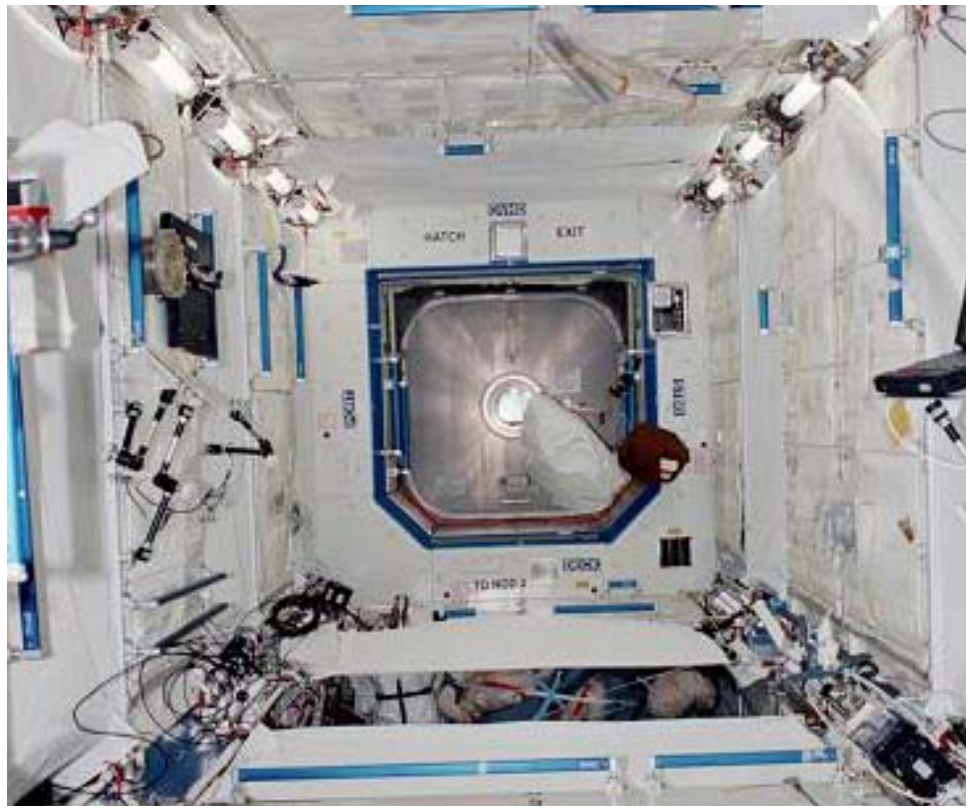






Microgravity Test Methods

PSA MGTF



ISS US Lab Module

Challenges

- Navigation
  - How does PSA know where it is?
  - Can’t use transmitters (like GPS)
- Artificial Intelligence
  - How does the PSA know what to do and when?
  - Can’t have an astronaut joysticking it
- Human interaction
  - How does the PSA know what to say and show?
  - Don’t want to annoy the astronauts

Summary/Future

- PSA is still a work in progress
- Spiral development
  - Allows rapid prototyping and testing
- Flight experiments
  - 2006: KC135 experiment
  - 2008: ISS experiment
- To learn more:
  - http://psa.arc.nasa.gov

Questions?