Technology Drivers for Flight Telerobotic System Software

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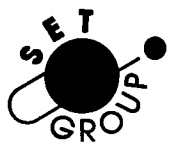
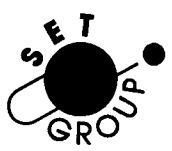
Selected Topics In
Robotics For Space Exploration

3/18/93 LaRC



Introduction

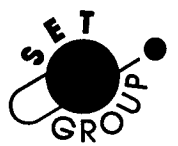
- Major Software Drivers in a Flight Manipulator System
  - Control Algorithms
  - Distributed Hardware Architecture
    - Bus Loading
    - Margin/Performance Requirements (10ms/20ms)
  - Data Management
    - Telemetry/Data Recording
    - Operator Interface
  - Safety
  - Fix It in Software



Flight Software Lines of Code

- Estimated at 40K Ada Statements
- Approximately 22K in Development Library at Start of Technology Capture Effort

Function	Lines of Code	Percentage
Control Algorithms	5.5K	13.8%
Operator Interface	10.0K	25.0%
Safety	5K	12.5%
Data Management	7K	17.5%
Misc. Hardware Control	5.5K	13.8%
Common Utilities	5K	12.5%
ROM	2K	5.0%



Flight Computer Architecture

- Distributed 80386-80387s
  - 8 Controllers
    - Custom Design
    - 512K Bytes RAM
    - Joint Controllers Embedded in Arm
    - 4x4 in. Surface Mount Boards
  - Space Station Standard Data Processor
    - 3 CPUs with 4M Bytes RAM each
- MIL-STD-1553B Busses Connecting CPUs
  - Workstation Bus
  - Telerobot Bus
- PGSC Used for Display and Initial Program Load

System Safety

- Critical Items Required To Be Two Fault Tolerant
  - One Path Outside of Computer System
  - Other Two in Independent Systems
- FTS Safety Requirements
  - Safe Return Of Orbiter
    - Doors Must Be Able To Close
    - System Must Be Safe For Landing (Caged)
  - Inadvertent Release of Hardware
    - Manipulator Grasp of Object
    - Object Caging Mechanism
  - Correct Operation of Manipulator
    - No Unplanned Contact with Environment
    - Planned Contact at Safe Forces and Torques

Safety Critical Parameters

Parameter	Monitored By	Hazard Mitigated
Cartesian Position	TRCC/TRRC	Unplanned Contact
Cartesian Velocity	TRCC/TRRC	Unplanned Contact
Cartesian Force (6 DOF)	Joint Controllers (H/W)	Excessive Force
Joint Position	Joint Controllers (H/W)/TRRC	Unplanned Contact
Joint Velocity	Joint Controllers/TRRC	Unplanned Contact
Joint Torque	Joint Controllers (H/W)	Unplanned Contact, Excessive Force
Joint Motor Current	Joint Controllers (H/W)	Unplanned Contact, Excessive Force
End Effector Gripping Force	Joint Controllers (H/W)	Excessive Force
End Effector Grip Current	Joint Controllers (H/W)	Excessive Force
Joint Position Variance	Joint Controllers	Unplanned Contact
FTT-A versus FTT-B Variance	TRCC	Excessive Force
Actuator/EE Temperature	TRCC	Failure to Stow
Processor Temperature	TRCC	Failure to Stow, Unplanned Contact
Processor Health	TRCC/TRRC/PM	Unplanned Contact

System Safety – Software Functions

- Cartesian Safety
  - Position/Boundary Management
    - Check Arm Position versus Environment
  - Velocity Limits
  - Force Applied to Environment
- Manipulator Joint Safety
  - Position versus Joint Stops
  - Consistency of Three Position Sensors
- Communications
  - Heartbeat Between Critical Computers
  - Checksum of All Messages
- Temperatures

System Safety – Software Functions (cont.)

- Operational Checks
  - Tighter Bounds than Safety Limits
  - Violation Results in Limited Value or Soft Stop
- Safety Checks
  - Violation Results in Emergency Shutdown
- Hardware Checks Can Also Produce Emergency Shutdown (ESD)
  - Need to Report Sensor Which Caused ESD
- Ada Run-time Checks Not Sufficient for Detection of Problems
  - Corruption of Code
  - Execution of Non-code
- DDC-I Use of 80386 Protected Mode
  - Code in Read Only Segment
  - Access Outside of Segment Trapped by Hardware

Fix It in Software

- Coarse Encoder Calibration Curves
  - Position Dependent Error
  - Varied with Temperature
  - Varied with Time
- Augmented Damping
  - 1000Hz
  - Multiple Digital Filters
- FTT Decoupling
- Safety
  - Force Limiting
  - Third Instance of Collision Avoidance
- Power Switch Control
- Power/Thermal Problem