Status Report of RMS Active Damping Augmentation

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STATUS REPORT OF RMS ACTIVE DAMPING AUGMENTATION

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Workshop on Selected Topics in Robotics for Space Exploration
March 17-18, 1993

ACKNOWLEDGEMENTS

Charles Stark Draper Laboratory / Cambridge, MA
Janet Lepanto
Karl W. Flueckiger
Kevin M. Gift
Richard W. Metzinger
Lockheed Engineering & Sciences Company / Houston, TX
Mary C. Jensen
Jesse M. Moon
K. K. Rob
Susan B. Rogers
John M. Teel
Sam V. Veerasamy
NASA Johnson Space Center / Houston, TX
Elizabeth Bains
Ying M. Kuo
Ann E. Madison
NASA Langley Research Center / Hampton, VA
Michael A. Scott
Lockheed Engineering & Sciences Company / Hampton, VA
Georgette W. Watts

BRIEFING OUTLINE

Introduction

- Objectives
- Benefits
- Schedule

Summary of technical accomplishments

- Study parameters
- Astronaut evaluations

Fiscal 93 plans

- Heavy payload (SSF) studies
- Needed feasibility/cost data

ACTIVE DAMPING AUGMENTATION

Objective :

Improve RMS operational capability by reducing vibration decay time

Approach :

Apply Controls-Structures Integration (CSI) technology

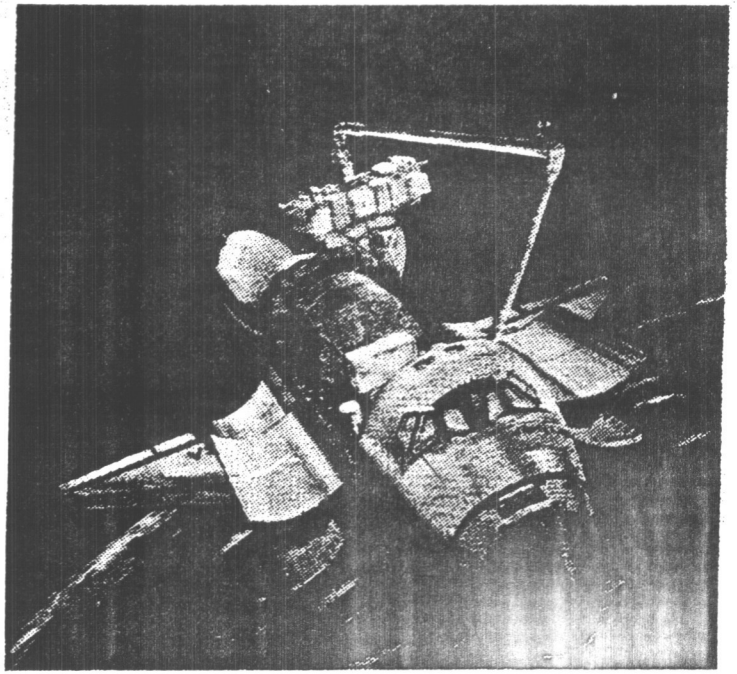
- sense the vibratory motion

- implement a feedback of the sensed motion to drive the joint servos and increase damping

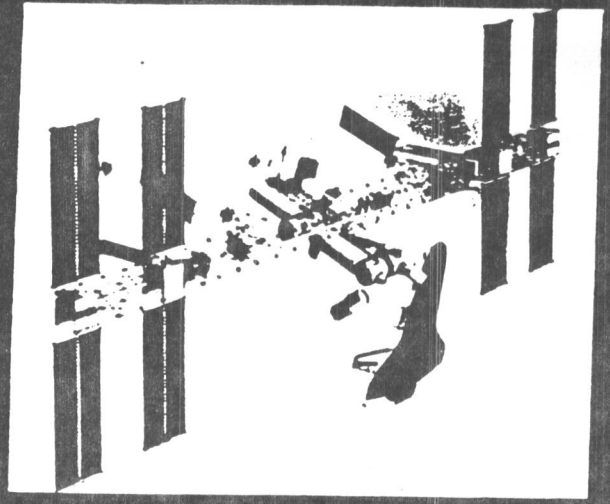
Joint LaRC / JSC program

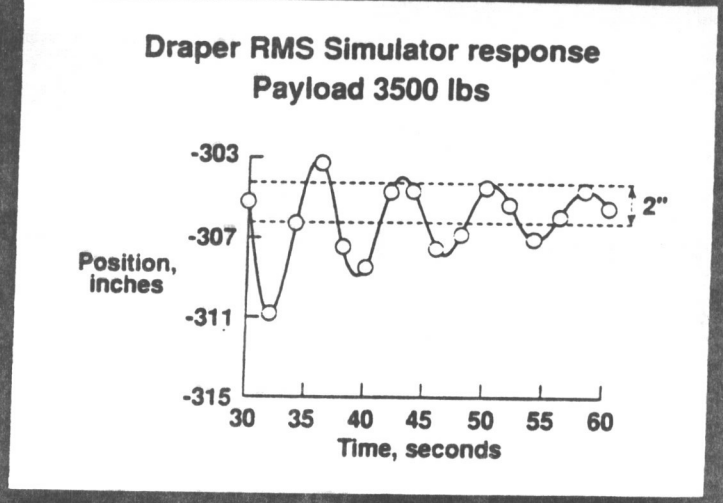
BENEFITS OF RMS ADA

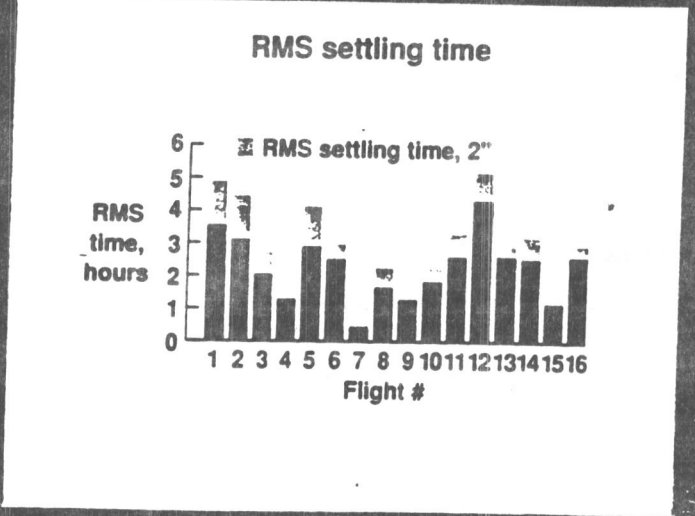
- **Reduced vibration decay times (improved operational timelines) following**
  - Commanded RMS maneuvers
  - Shuttle thruster firings
- **Reduced RMS loads**
- **Improved precise payload positioning capability**
- **Reduced RMS / Shuttle FCS interaction potential**
- **Reduced crew training time**

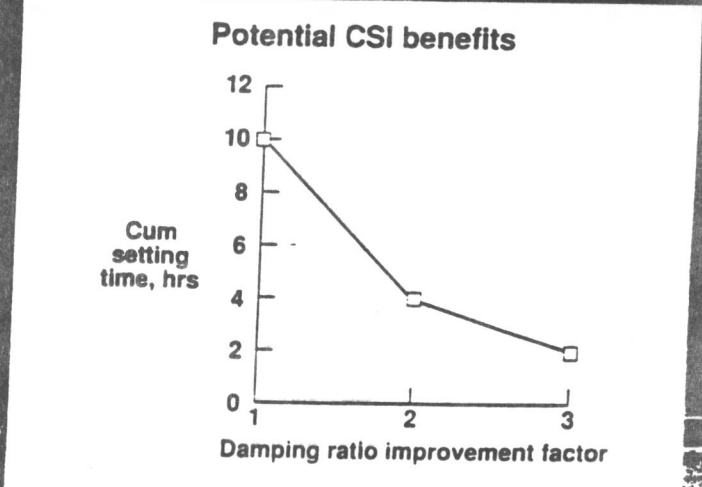


POTENTIAL SPACE STATION ASSEMBLY BENEFITS DUE TO CSI (Timeline)

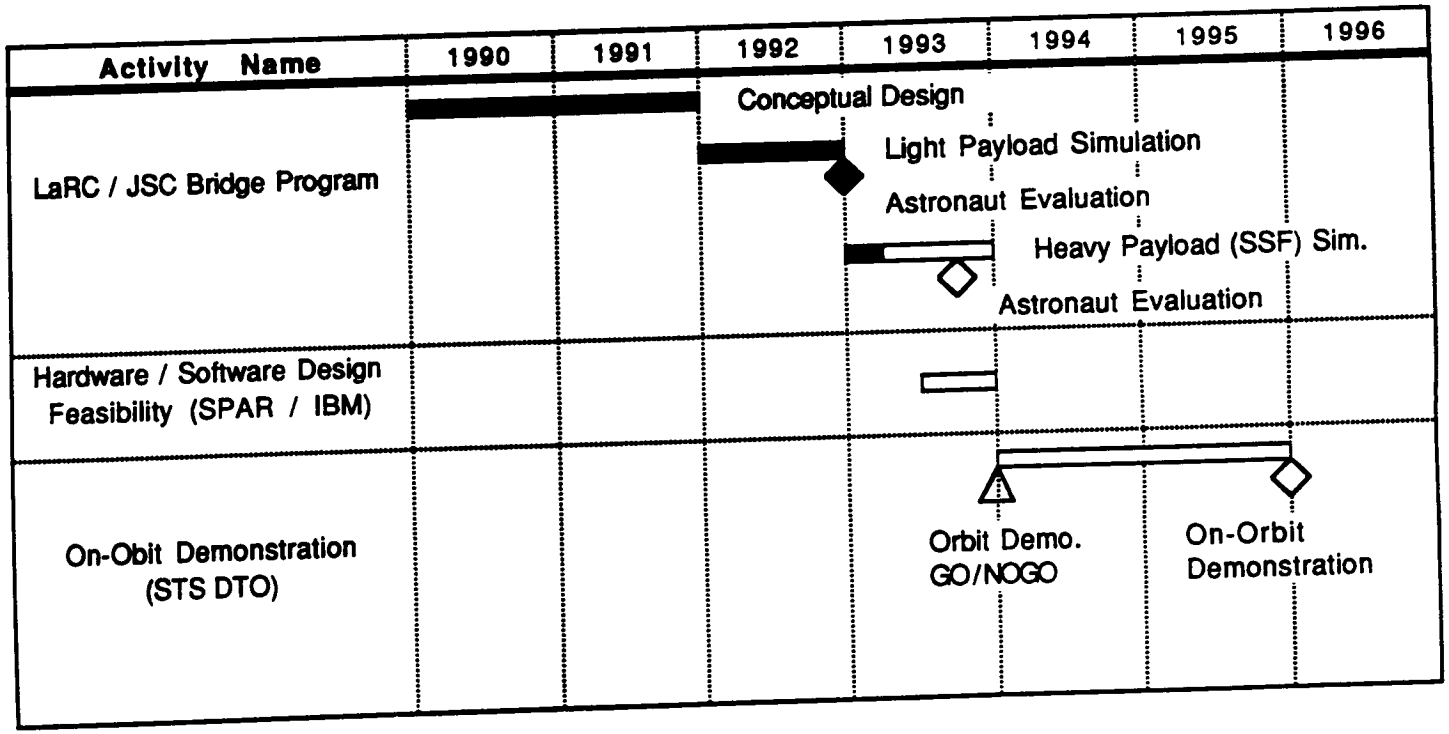






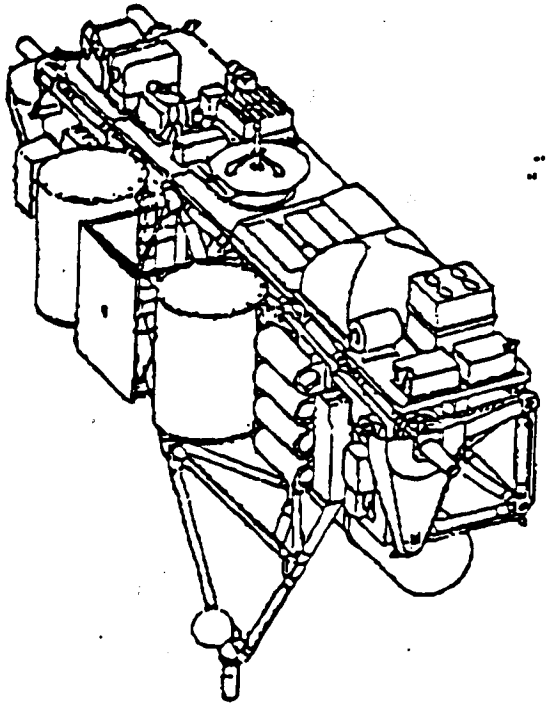


RMS ACTIVE DAMPING AUGMENTATION SCHEDULE

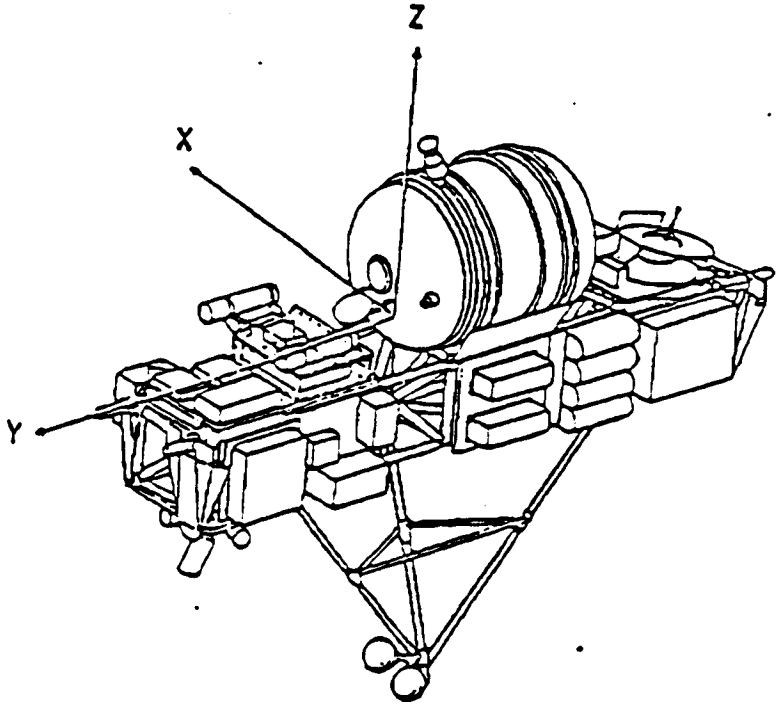


SIMULATED PAYLOAD REDEFINITION

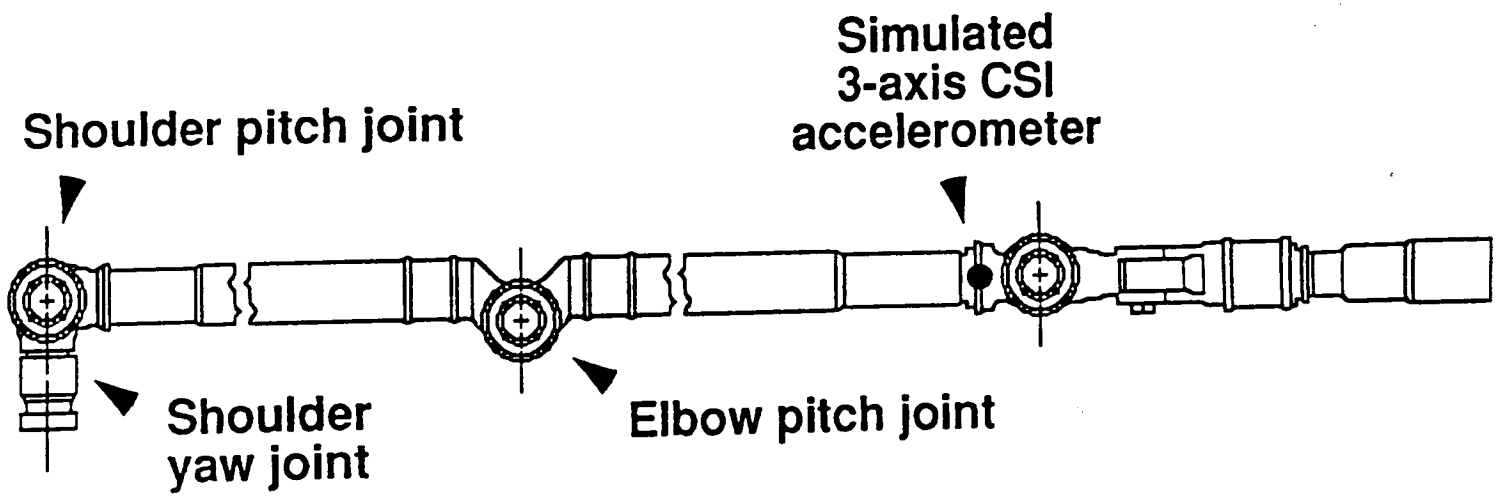
SPAS - 01 (STS - 7)



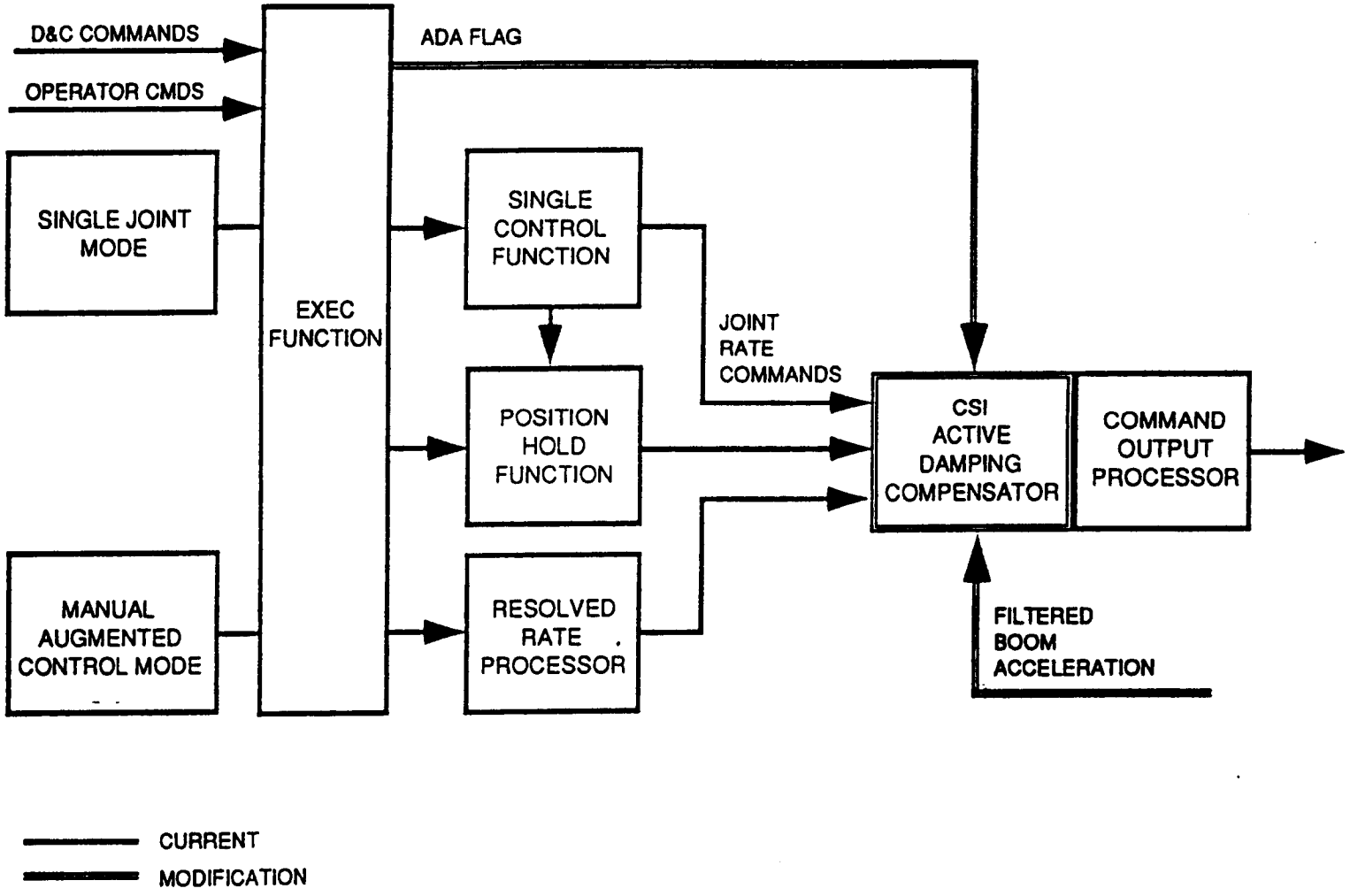
SPAS - 02 (IBSS, STS - 39)



SENSOR AND ACTUATOR DEFINITION



CSI CONTROLLER IMPLEMENTATION



ADA CONTROL LAW DESIGN

- **Exercised several control law design methodologies**
- **Used linear design models identified from simulated response data**
  - Consistent with on-orbit flight demonstration approach
  - Control laws checked on flight verified on nonlinear, non-real-time simulation
- **Control design objectives for astronaut evaluation**
  - 1st - Robustness to RMS configuration changes
  - 2nd - Damping performance

SES REAL-TIME SIMULATION

Plan:

Conduct man-in-the-loop simulation studies of active damping augmentation in the Shuttle Engineering Simulator (SES) at JSC

Goals:

- Obtain qualitative definition of performance improvement by astronaut operators
- Obtain supporting quantitative performance data

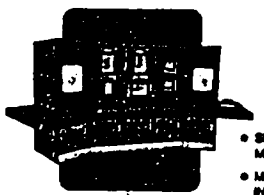
Objectives:

- Measure reductions in RMS vibration decay time following RMS maneuvers and Shuttle thruster firings
- Identify reductions in predicted RMS loads
- Insure no adverse interaction with Shuttle FCS

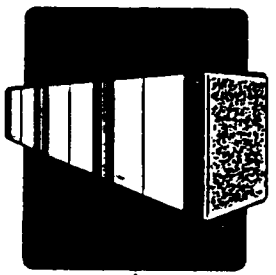
SHUTTLE ENGINEERING SIMULATOR - ON-ORBIT

SES ON-ORBIT FEATURES

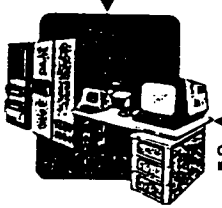
- THREE-BODY SIMULATION OF:
  - ORBITER
  - FREE-FLYING PAYLOAD
  - MANNED MANEUVERING UNIT
- ON-ORBIT OPERATIONS CAN INCLUDE ANY OR ALL OF THE FOLLOWING:
  - RENDEZVOUS
  - PROXIMITY OPERATIONS
  - PAYLOAD DEPLOYMENT AND RETRIEVAL WITH RMS
  - MMU OPERATIONS
- PAYLOAD MODELS DEVELOPED AS REQUIRED:
  - VISUALS
  - MASS PROPERTIES
  - PLUME IMPINGEMENT
  - AERO DRAG
  - RADAR SCATTER CHARACTERISTICS
  - CONTROL SYSTEM



- SIMULATION DATA MONITORING
- MALFUNCTION INSERTION
- SCENE MONITORS
- COCKPIT CRT MONITOR

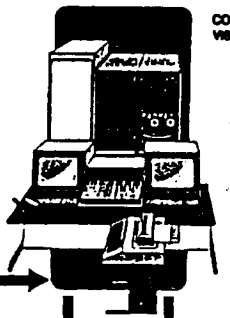


- EQUATIONS OF MOTION:
  - ORBITER
  - PAYLOAD
  - MMU
- ORBITER SUBSYSTEMS:
  - RADAR
  - IMU
  - ST
  - CDAS
  - RCS
  - OMS
- GN&C FLIGHT SOFTWARE
- FLEX RMS
- ENVIRONMENT
- PLUME IMPINGEMENT
- MMU SUBSYSTEMS
- PAYLOAD CONTROL SYSTEM

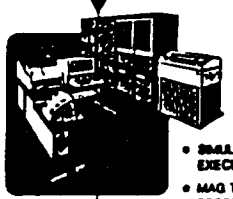


CONTROL CONSOLE INTERFACE

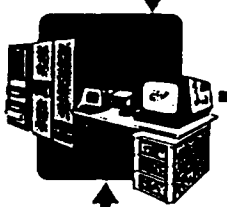
SHARED MEMORY

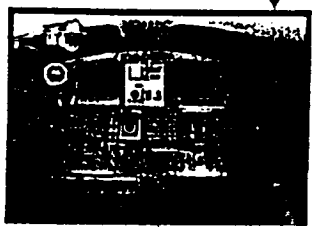


COMPUTER GENERATED VISUALS:
- ORBITER OVERHEAD VIEWS
- RMS AFT VIEW
- ORBITER CCTV'S
- MMU VIEW

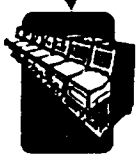


- SIMULATION EXECUTIVE
- MAG TAPE DATA RECORDING
- STRIP-CHART RECORDING
- REAL-TIME PRINT
- SNAPSHOT PRINT





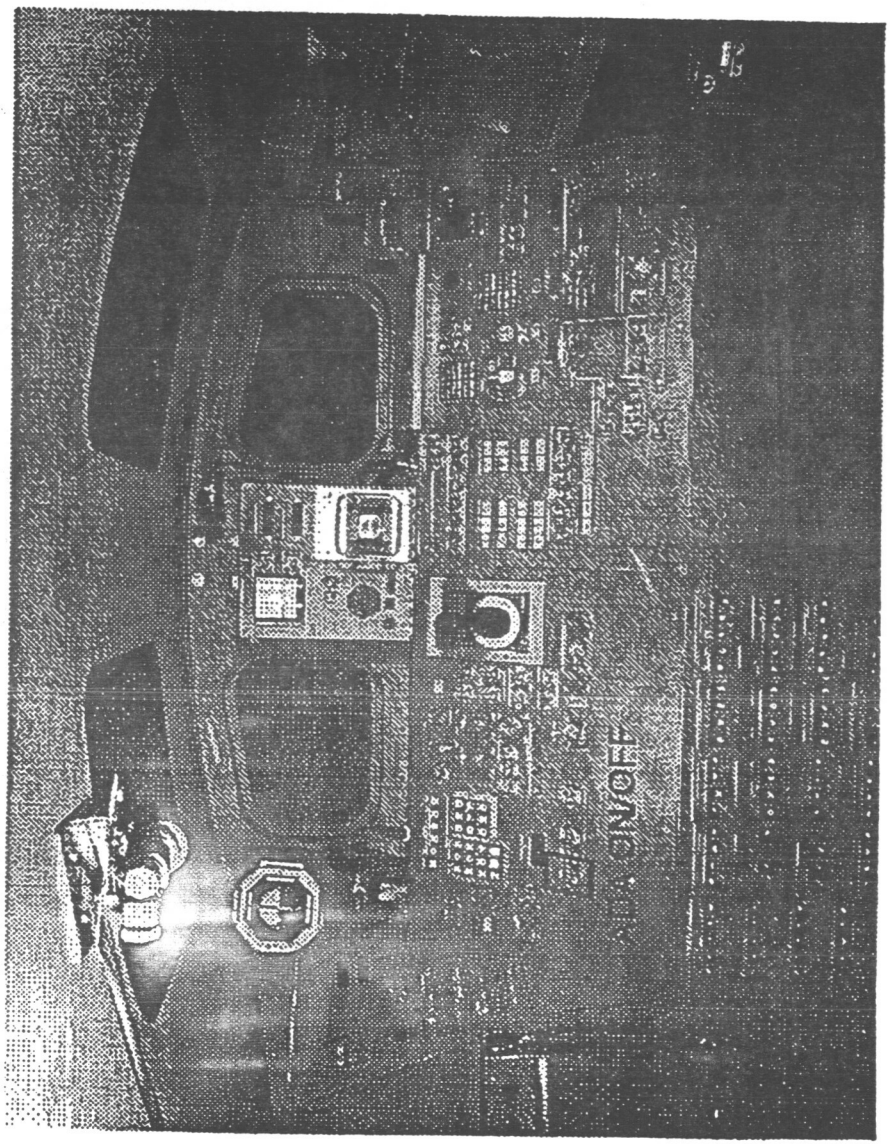
- CREW STATION INTERFACE
- COCKPIT CRT DISPLAYS
- SCENE INTERFACE



64-CHANNEL STRIP-CHART RECORDERS

CREW STATION INTERFACE

ADA SWITCH IN SES COCKPIT



STUDY STATUS

Phase 1 (completed April 3, 1992)

- SES familiarization
- Acceleration validation
- Collected data for system identification

Phase 2a (completed July 7-9, 1992)

- Compensator implementation logic validated
- Acceleration filter validated
- 5 baseline control sets evaluated
- Astronaut trainer evaluation (Ann E. Madison)

Phase 2b (completed September 22-24, 1992)

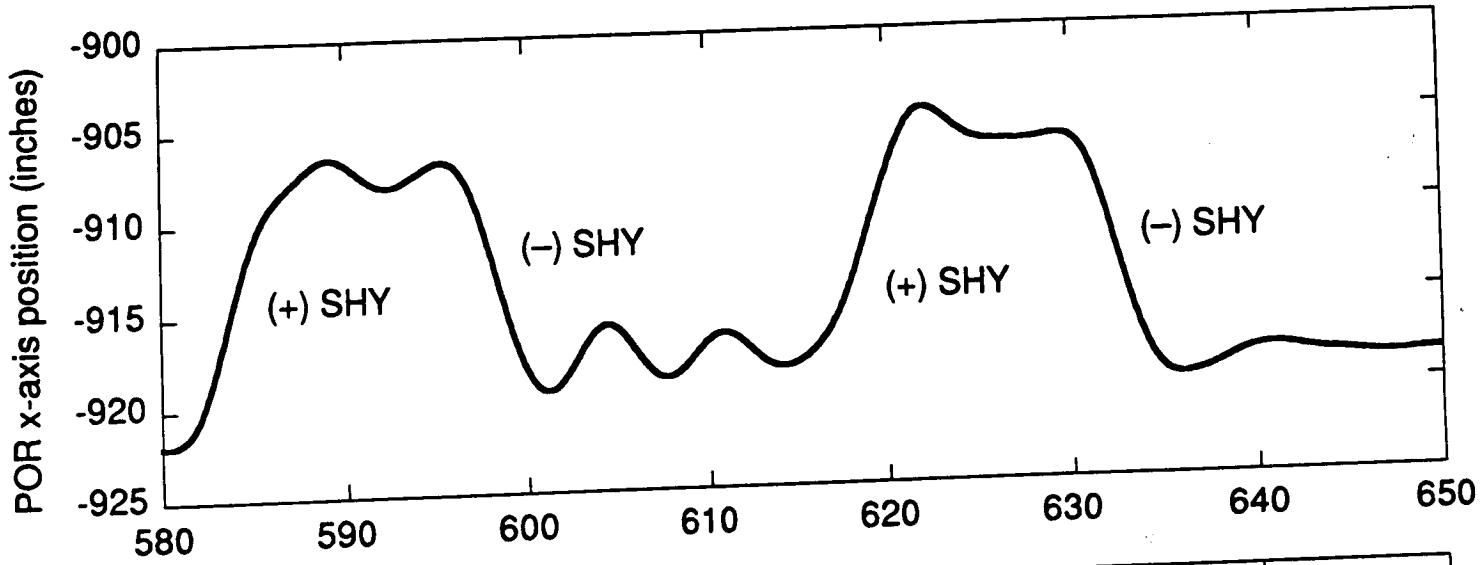
- Multi-point control law testing
- Astronaut evaluation of RMS ADA

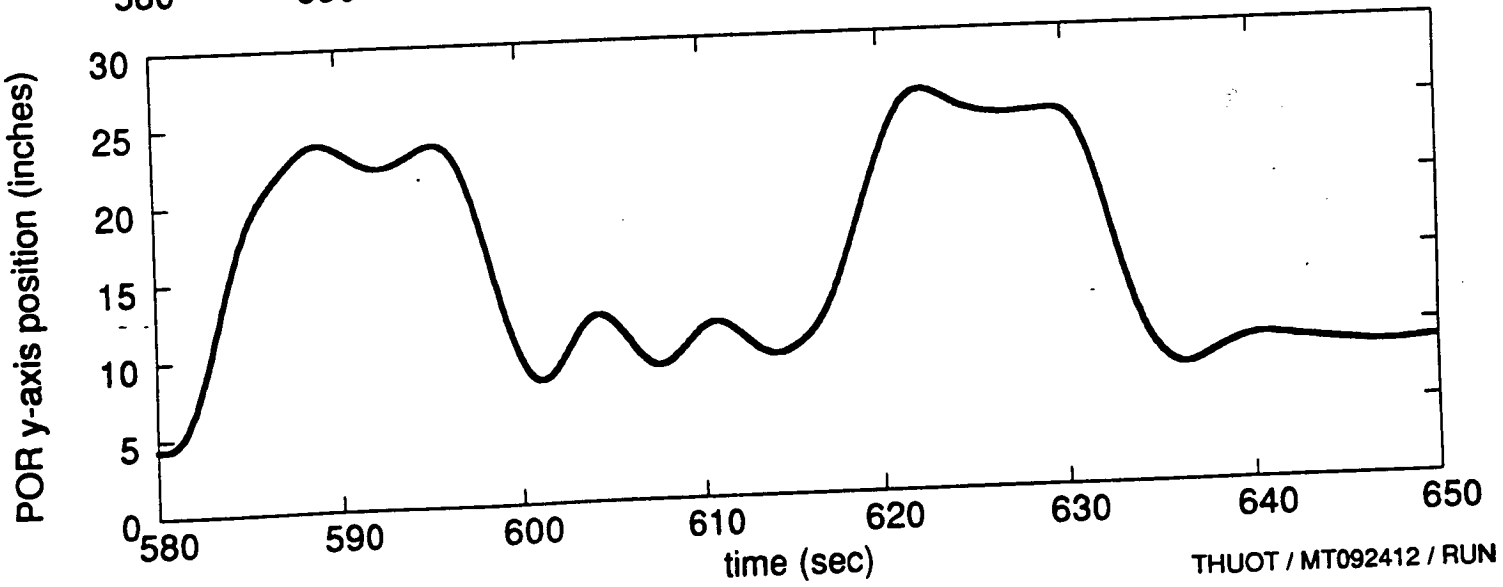
ASTRONAUT EVALUATION

- Six astronauts briefed on ADA and participated in qualitative evaluation of ADA performance. (Thagard, Brown, Sherlock, Godwin, Reightler, and Thuot)
- Evaluated performance of a single ADA control law designed to work over a range of configurations.
- Examined ADA following Single and Manual RMS maneuvers and ADA disturbance rejection of Shuttle PRCS firings.
- Some astronauts were reluctant to deviate from conservative operating practices while others were more aggressive and willing to "push the envelope".
- Comments on ADA's potential operational benefit ranged from *"limited"* to *"a big improvement"*.
- Unanimous recommendation to **evaluate ADA with heavy payloads.**

Astronaut Evaluation:

+/– Shoulder Yaw (SHY) Single Joint Maneuvers

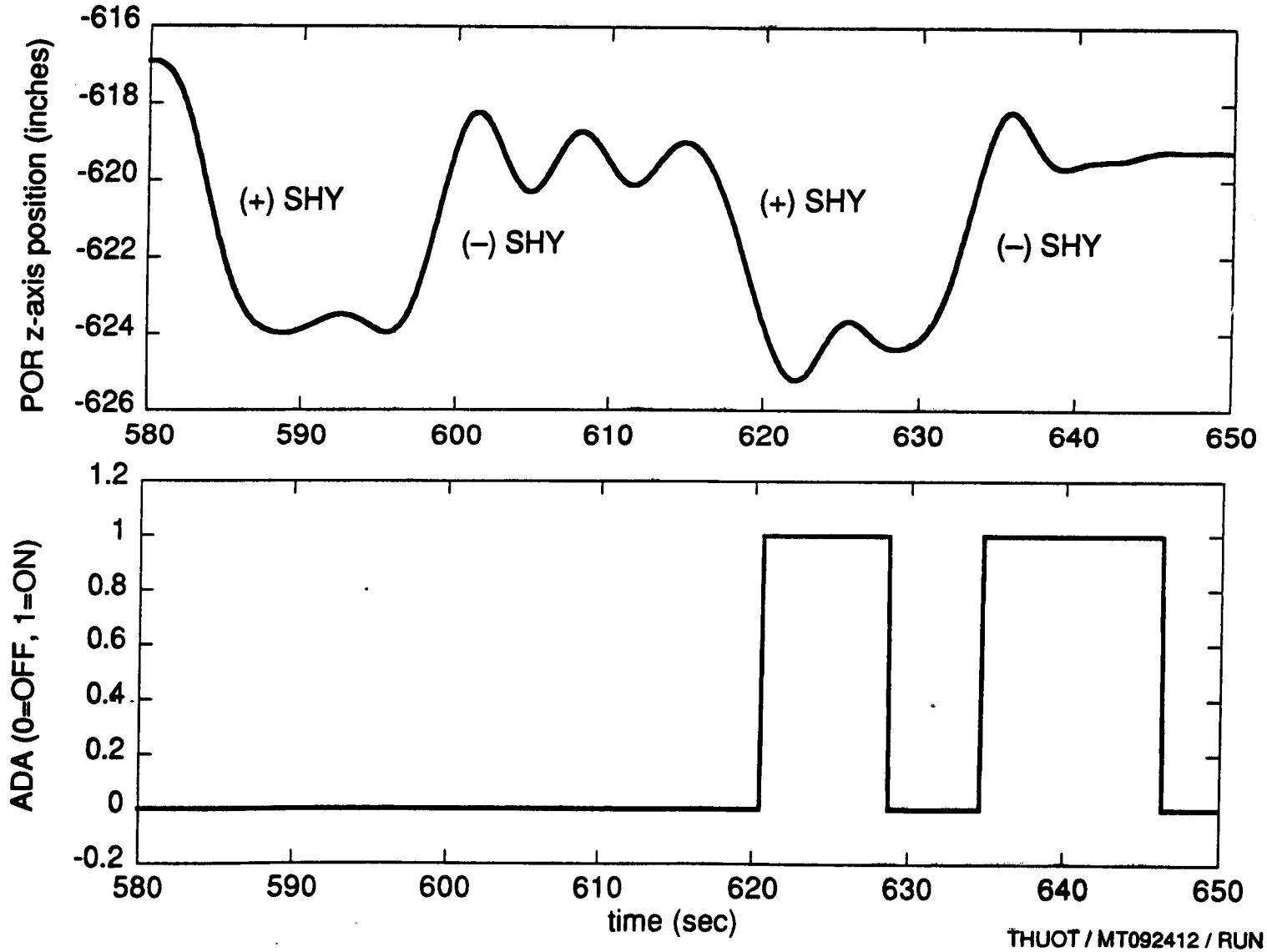




THUOT / MT092412 / RUN 1 / MASC2

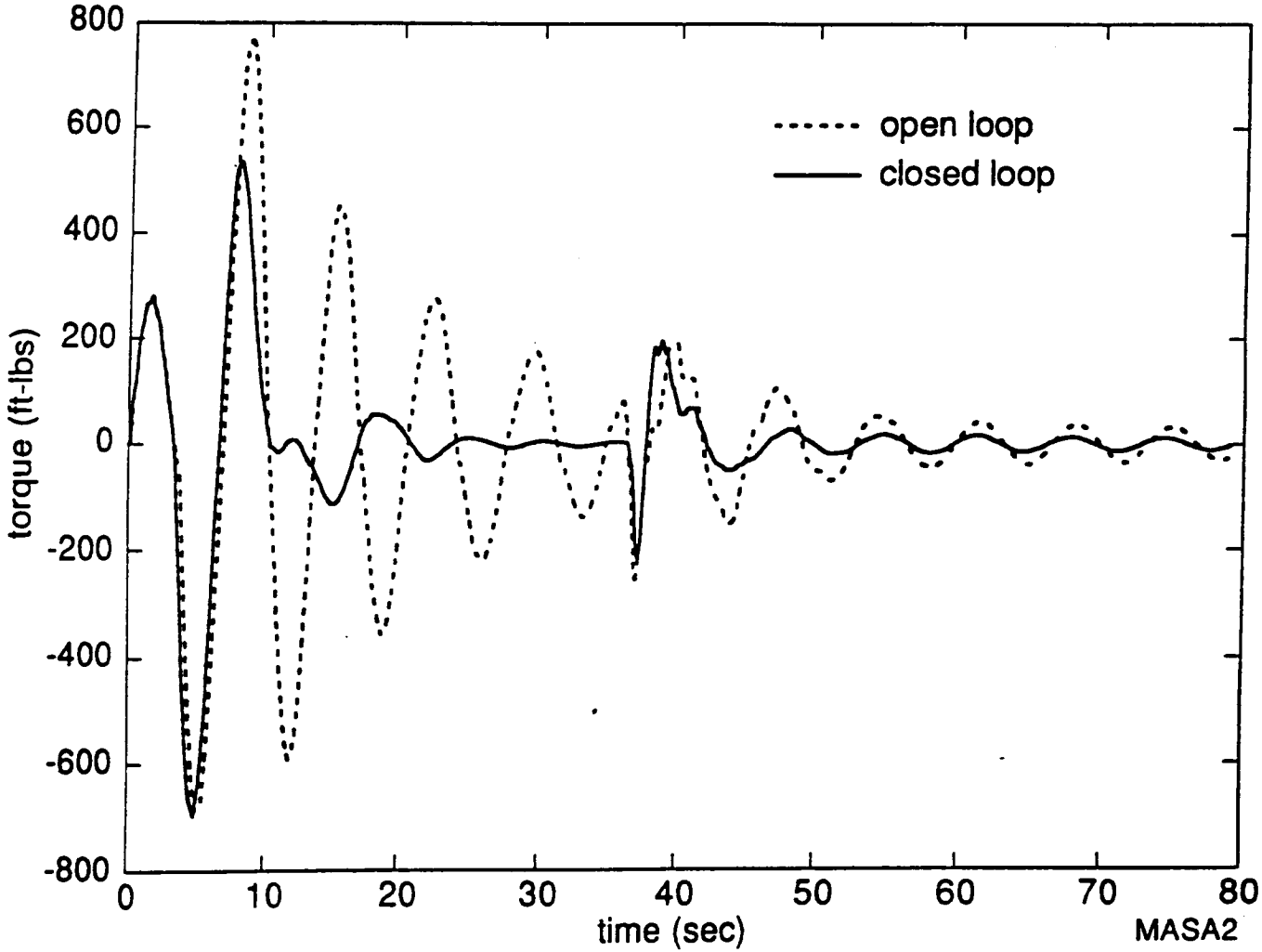
Astronaut Evalution: (cont'd)

+/– Shoulder Yaw (SHY) Single Joint Maneuvers



THUOT / MT092412 / RUN 1 / MASC2

PHASE 2a SES RESULTS: Joint Torque

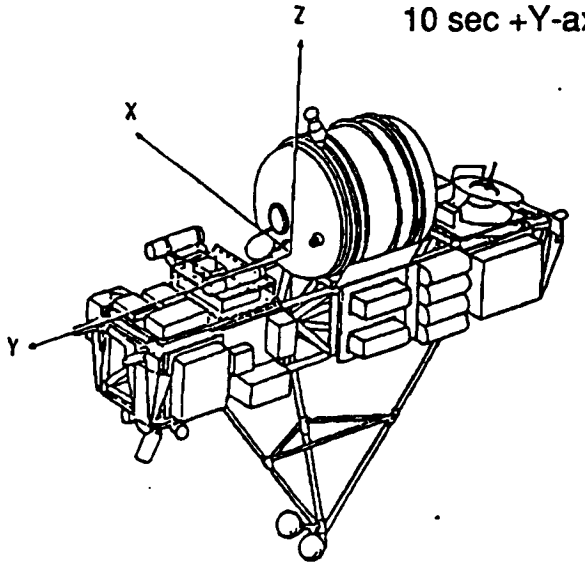


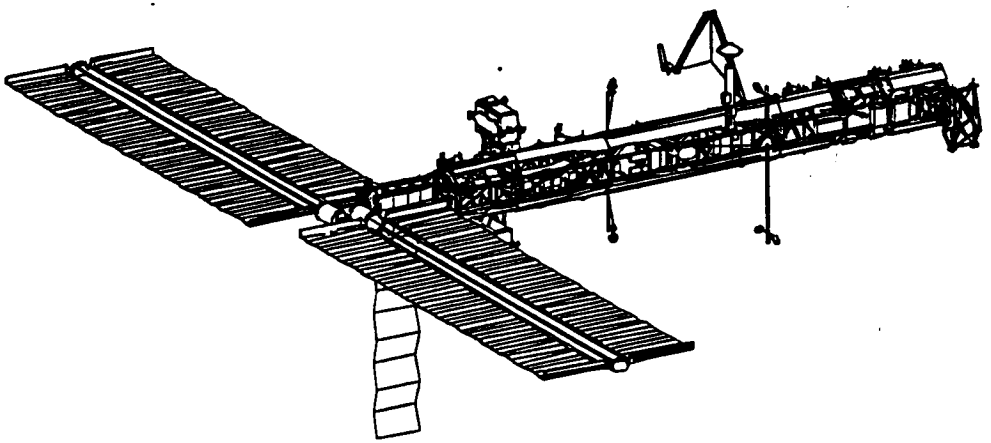
ASTRONAUT RECOMMENDED SSF ASSEMBLY STUDY

- **Unanimous concern**
  - may enable single-joint mode backup assembly operations
- **Study underway**
- **Includes RMS upgrades**
  - Position hold submode improvements
  - Wrist joint servo upgrades
  - POSH mode (no direct influence)
- **Continued CSDL support**
- **Uses SC-4 SSF payload**
- **Astronaut evaluation scheduled for June 1993**

Typical Response: SPAS-02 vs. SC-4

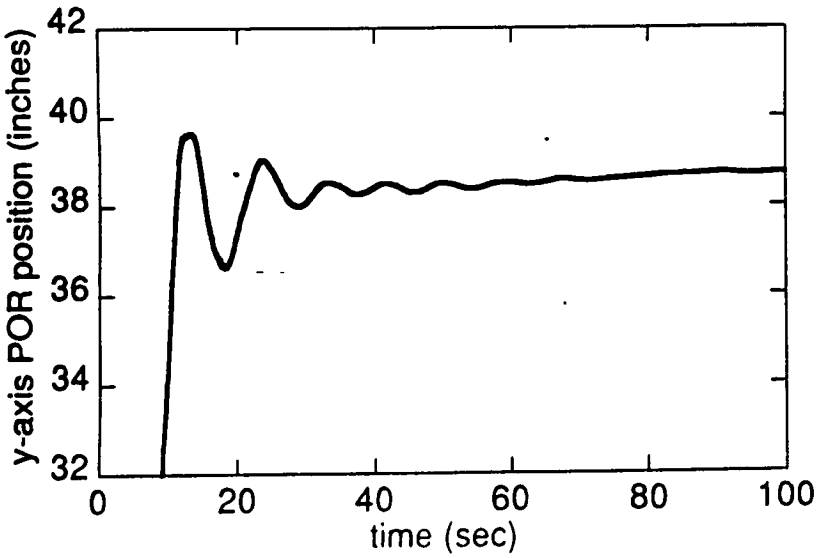
10 sec +Y-axis THC Manual Mode Maneuver

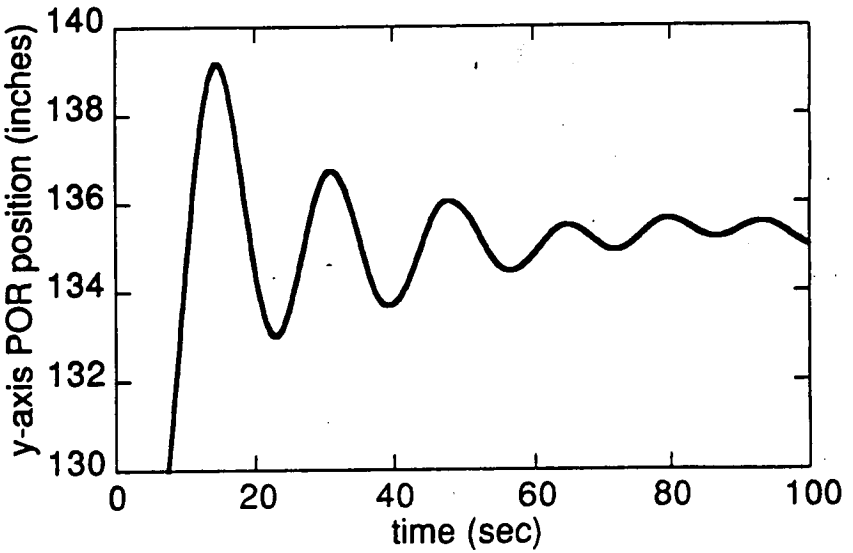




SPAS - 02 (IBSS, STS - 39)
3,990 lbs.

SC-4 Space Station
131,000 lbs.





INFORMATION NEEDED FOR FLIGHT DEMO DECISION

→ User interest / benefit

- Independent evaluation
- Accelerometer installation feasibility
- Flight software accommodation
- Cost estimates (flight demonstration)

CONCLUDING REMARKS

- **Heavy payload system identification and control design is ongoing**
  - Expect linear models for control design by mid-April
  - Expect candidate control laws mid-May
- **Heavy payload SES testing is scheduled**
  - Late May: Control law validation testing
  - Late June: Astronaut performance evaluations
- **Briefed Director of SSF (R. Kohrs) on status 2/3/93**
  - Value for SSF assembly
- **Looking for flight demonstration feasibility/cost information**
  - IBM for GPC software implementation of ADA
  - SPAR for accelerometer installation and overall approach