MIT
Space
Engineering
Research
Center

THE MIDDECK ACTIVE CONTROL EXPERIMENT (MACE):

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SERC Steering and Technical Representative Meeting

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N93-27896

PROGRAM OBJECTIVES

- Science Objective

  To develop a verified set of methods that will allow designers of CSI/CST spacecraft, which cannot be dynamically tested on the ground in a sufficiently realistic 0-g simulation, to have confidence in the eventual orbital performance of such spacecraft.

- Implications

  Understand direct and indirect gravity effects and the relation between control authority and manifestation.

  Develop procedures for predicting on-orbit performance.

  Quantify prediction accuracy achievable through analysis and ground tests.

  Develop techniques for on-orbit identification.

  Quantify performance improvement through control redesign based upon on-orbit identification.

PROGRAM FEATURES

Milestones

Preliminary Design Review (PDR)	April, 1992
Critical Design Review (CDR)	December, 1992
Launch	July, 1994

Participants

M.I.T. SERC	PI and science development
Payload Systems Inc.	Fabrication and Integration
Lockheed, Sunnyvale	Co-Investigator
McDonnell Douglas	Co-Investigator
Integrated Systems Inc.	AC-100 and design tools
CSA	Suspension

Hardware Phases

Development Model	science development
Engineering Model	flight prototyping
Flight Model	two flight hardware units

FLIGHT EXPERIMENT FEATURES

- Middeck experiment stored in four lockers
- Test article deployed on middeck with umbilical connection to Experiment Support Module (ESM)
- ESM contains:
  - experiment and realtime control computers
  - actuator power amplifiers and sensor signal conditioning
  - data storage
  - human and host computer interfaces
- Duration of three 8-hour days
- On-orbit timeline

Identification	Day 1
Downlink ID data	Day 1
Implement same algorithms as on ground	Day 1
Implement algorithms adjusted for lack of gravity	Day 2
Uplink ID based control algorithms	Day 3
Implement new measurement based algorithms	Day 3

- ESM provides reusable realtime control facility

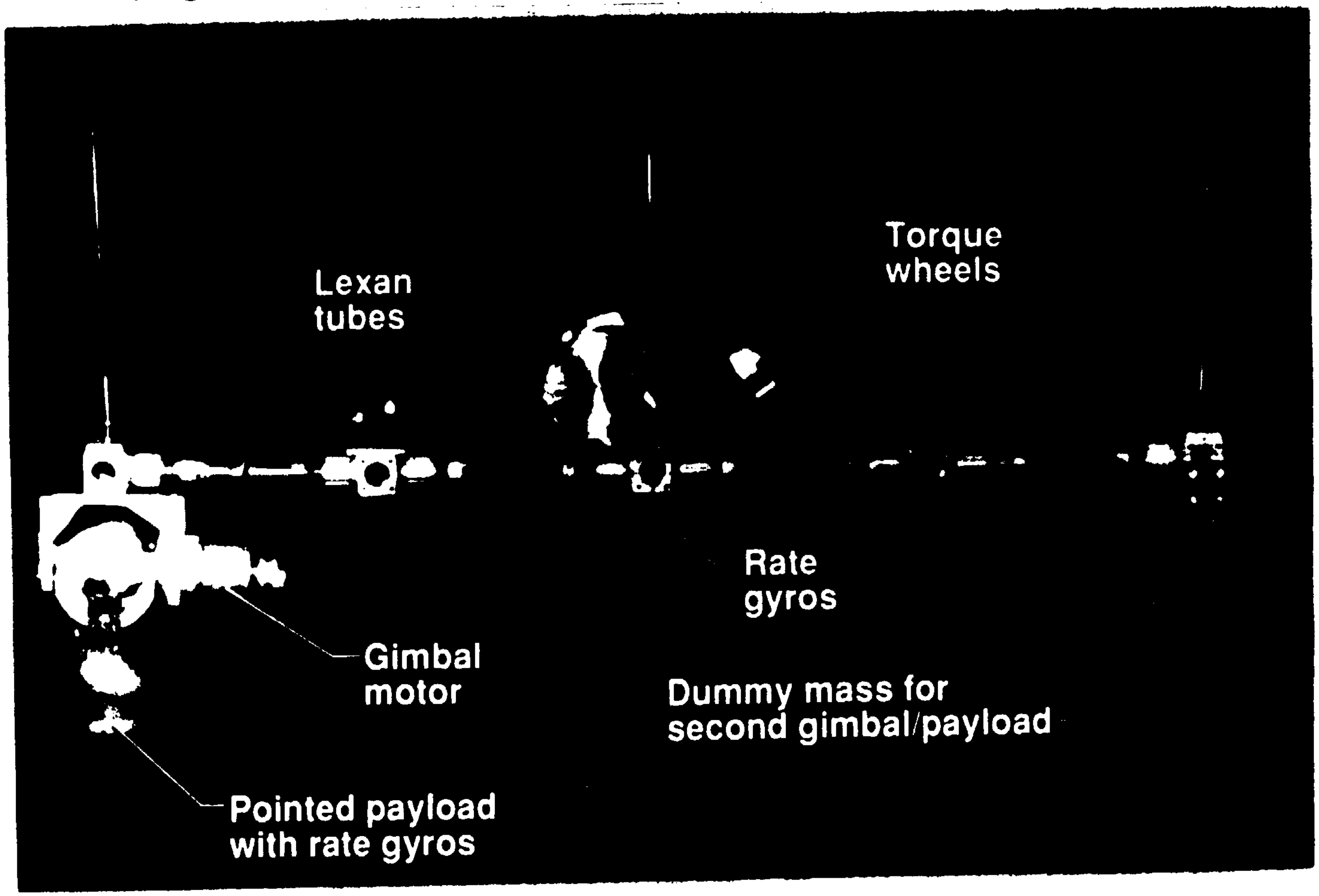
CURRENT ACTIVITIES

- Preliminary flight hardware design (PSI)
- Engineering Model gimbal acquisition (PSI, LMSC)
- Selecting on-orbit test configurations based upon desire to have gravity effects cause significant performance deviation from ground near midrange of control authority (Sepe)
- Incorporating gravity effects in Finite Element model (Rey)
- Development Model (DM) modern closed-loop control (Saarmaa, Miller)
- Command input shaping tests on DM (Chang)
- Formulation of 1-g and 0-g identification procedures (Karlov, Douglas)
- Study of multibody gravity effects (Quadrelli)
- Fabrication of active strut (PSI)

MIDDECK ACTIVE CONTROL EXPERIMENT (MACE)

Development Model Lab Testing

(Flight unit will have smaller torque wheels and gimbal motors)



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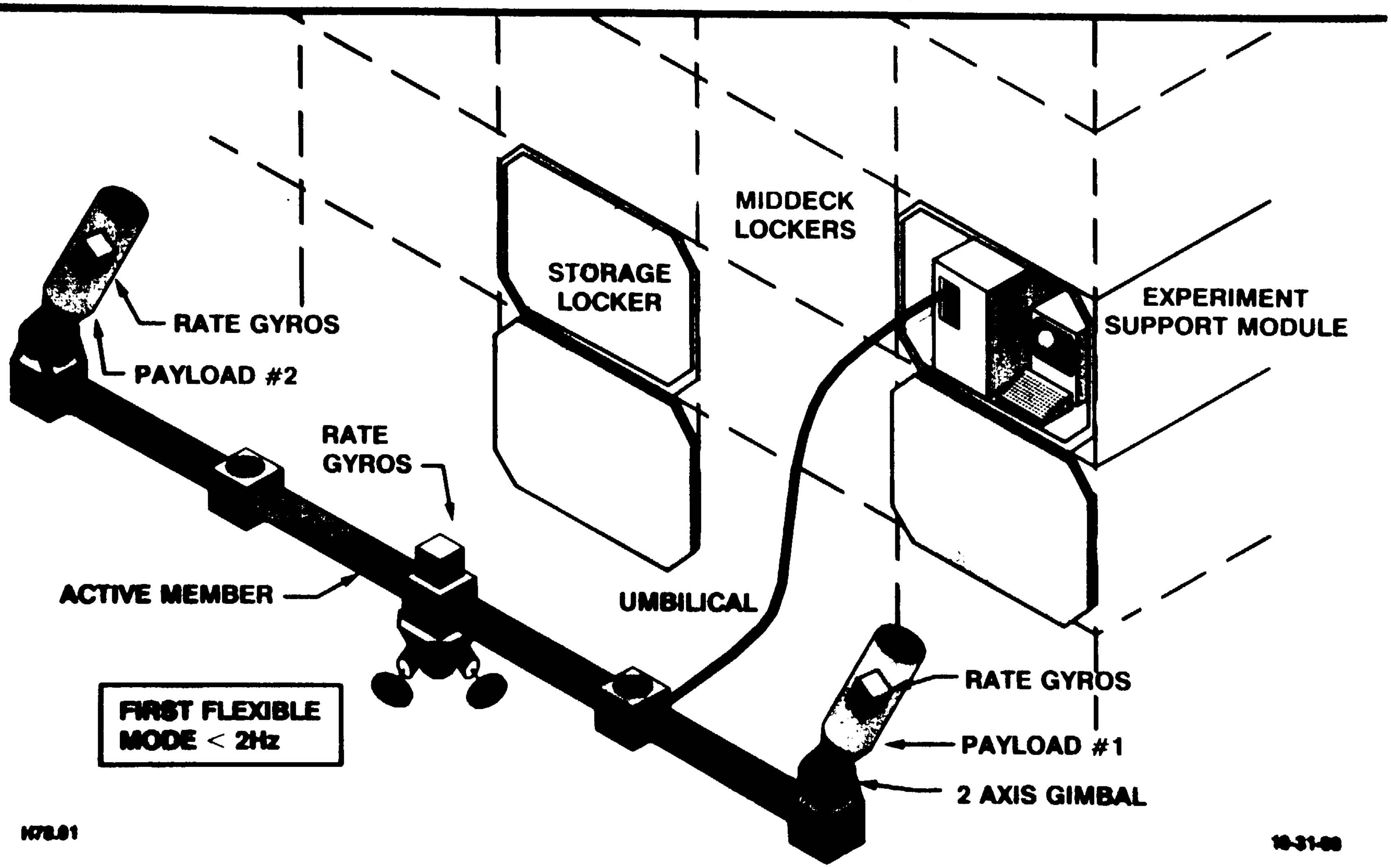
MACE TEST ARTICLE DEPLOYED ON THE STS MIDDECK



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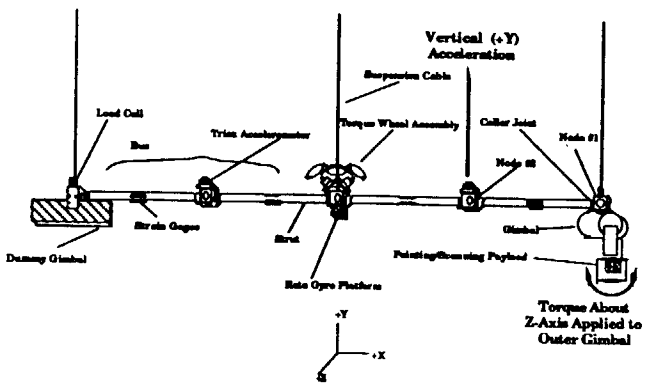
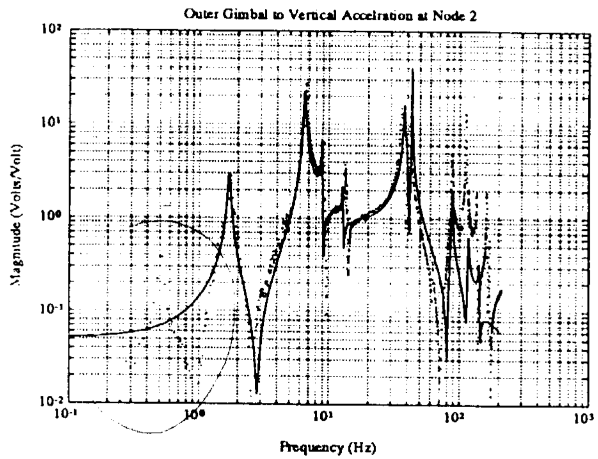
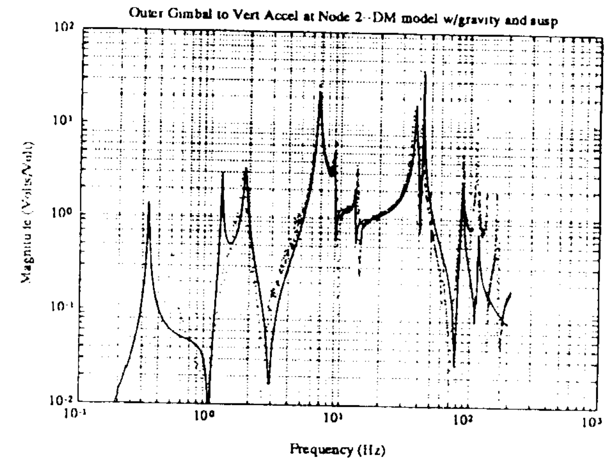
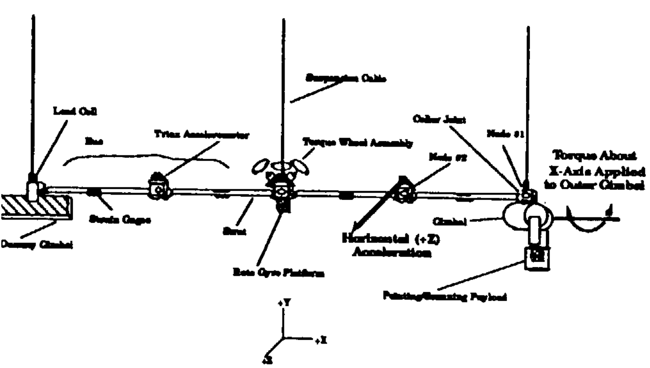
Finite Element Modelling and Measurement Verification

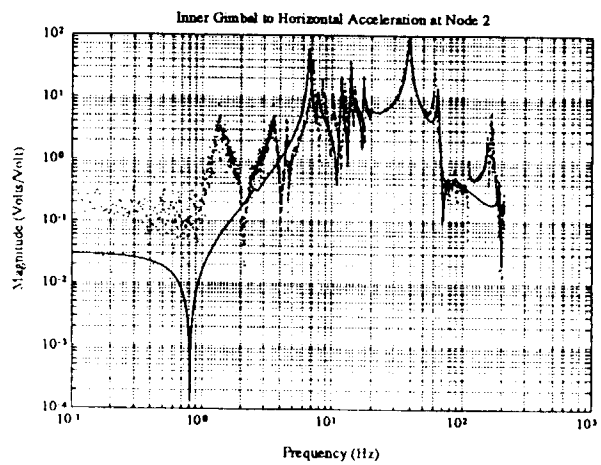
Data Channel	0-g model, 1-g data	1-g model, 1-g data

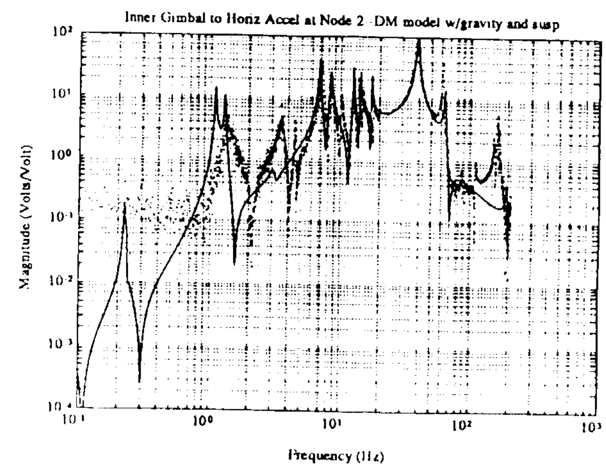








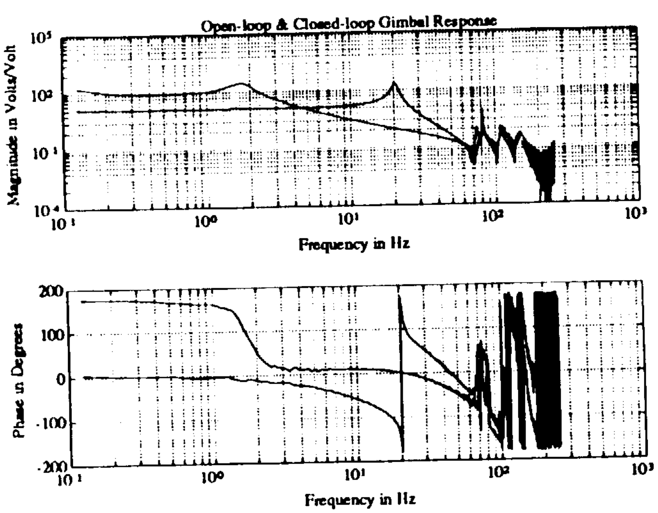




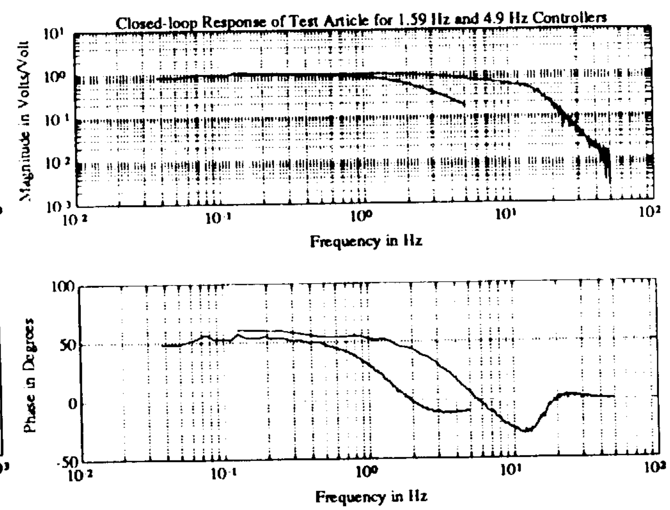
DEVELOPMENT MODEL TESTING

Component Control Work

Gimbal Control



Torque Wheel Control



Baseline Control

Torque Input Axis	Z	Z	Z	Y
Input Voltage RMS (volts)	0.1	0.3	0.1	0.2
Input Torque RMS (Nm)	0.00869	0.02606	0.00869	0.017371
Payload Output Axis	Z	Z	Z	X
Payload Angle RMS (degrees)	0.0389	0.0968	0.0357	0.1420
Payload Angle 3RMS (degrees)	0.1166	0.2904	0.1070	0.4529
Payload Clamped Angle	+45 deg about Z	+45 deg about Z	-45 deg about Z	0 deg (down)

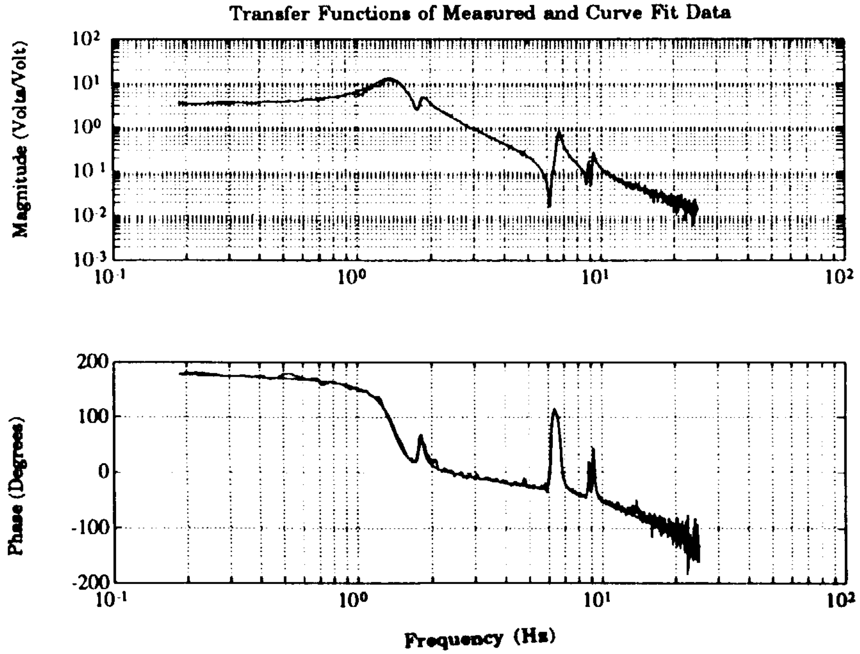
DEVELOPMENT MODEL TESTING

Single Input, Single Output Control (localized topology)

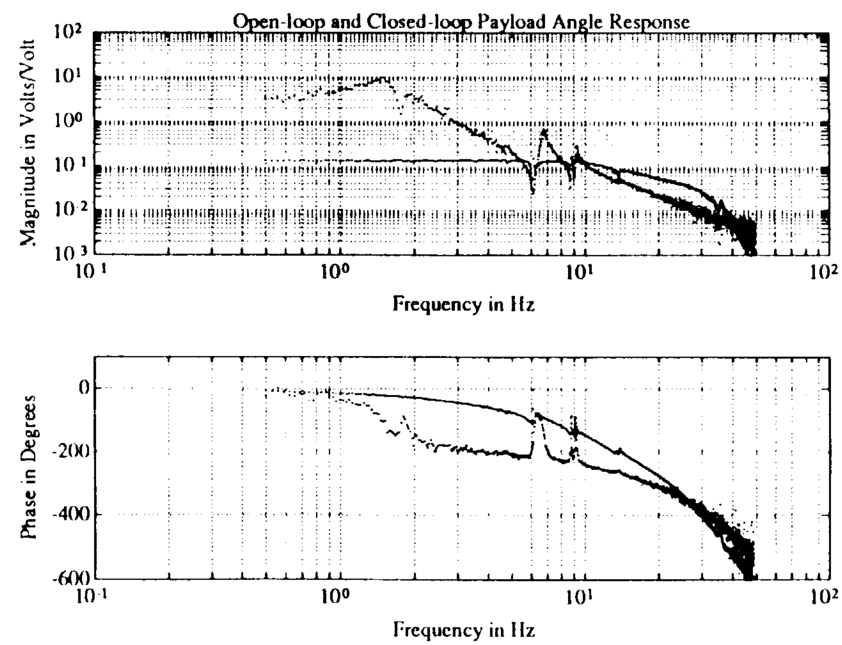
Description:

- Penalize payload inertial angle
- Feed payload inertial angle to gimbal outer stage motor
- Torque disturbance additive with gimbal control signal
- Formulate Linear Quadratic Gaussian Control (LQG)

Measurement Model



Performance

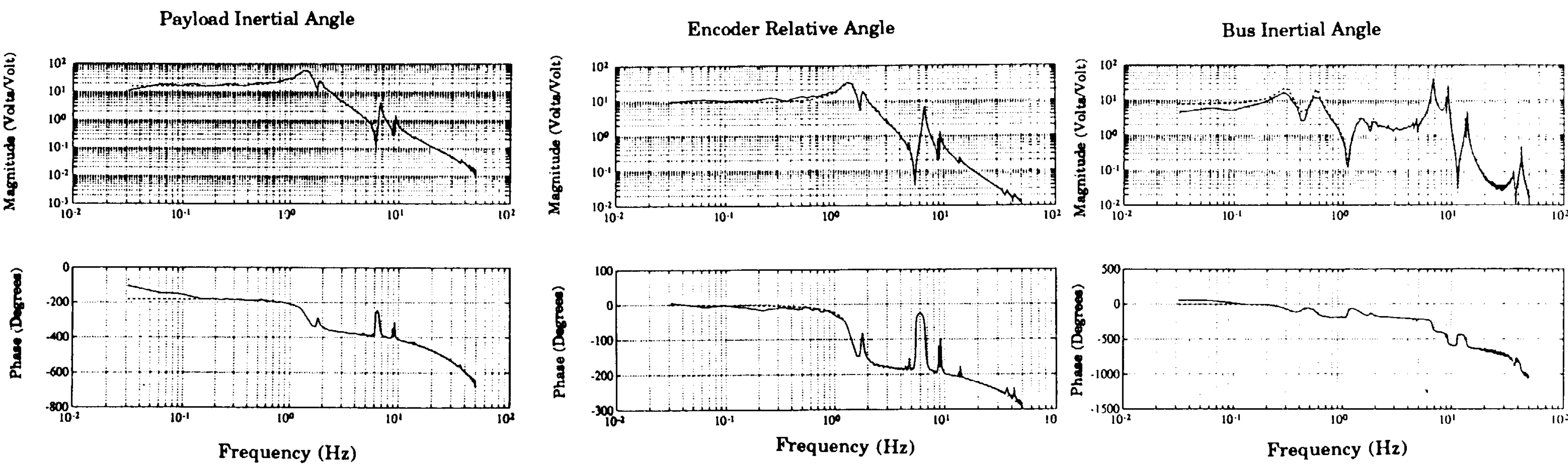


DEVELOPMENT MODEL TESTING

Single Input, Two Output Control (centralized topology)

Description:

Feed relative gimbal and inertial bus angles to gimbal outer stage motor
Torque disturbance additive with gimbal control signal
Since poles common to all transfer functions, must be averaged measurement model



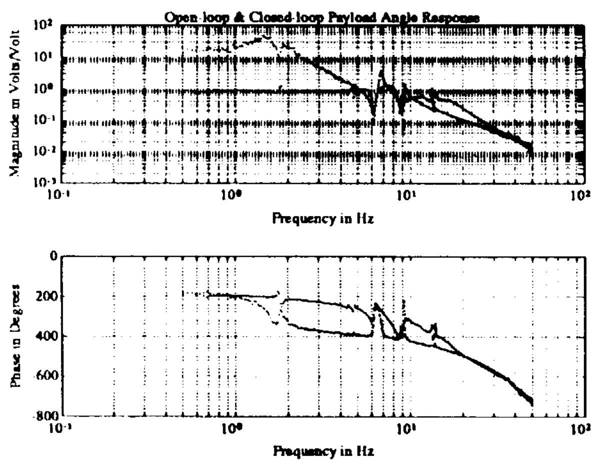
DEVELOPMENT MODEL TESTING

Single Input, Two Output Control (cont'd)

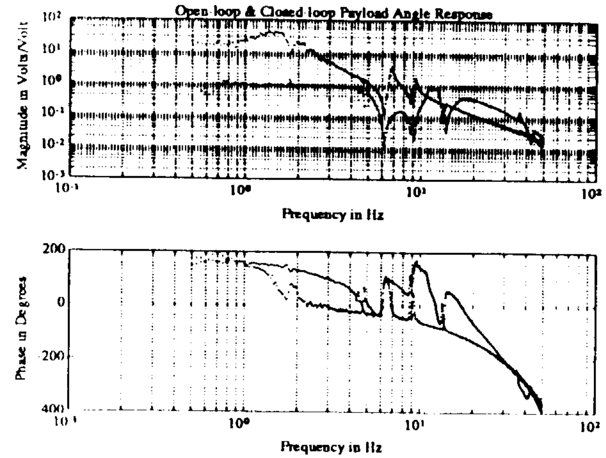
Description:

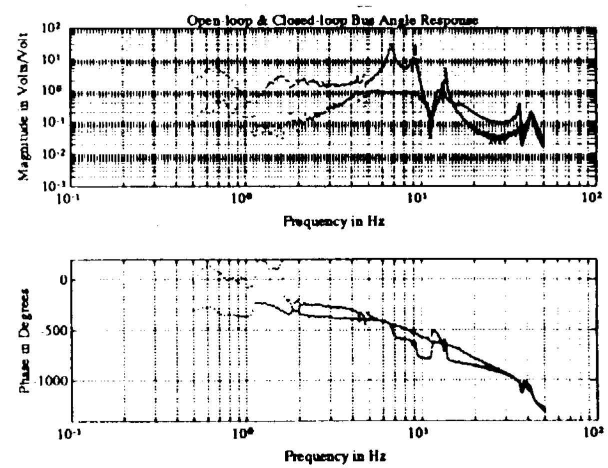
Formulate Linear Quadratic Gaussian control (LQG)

penalize payload inertial angle



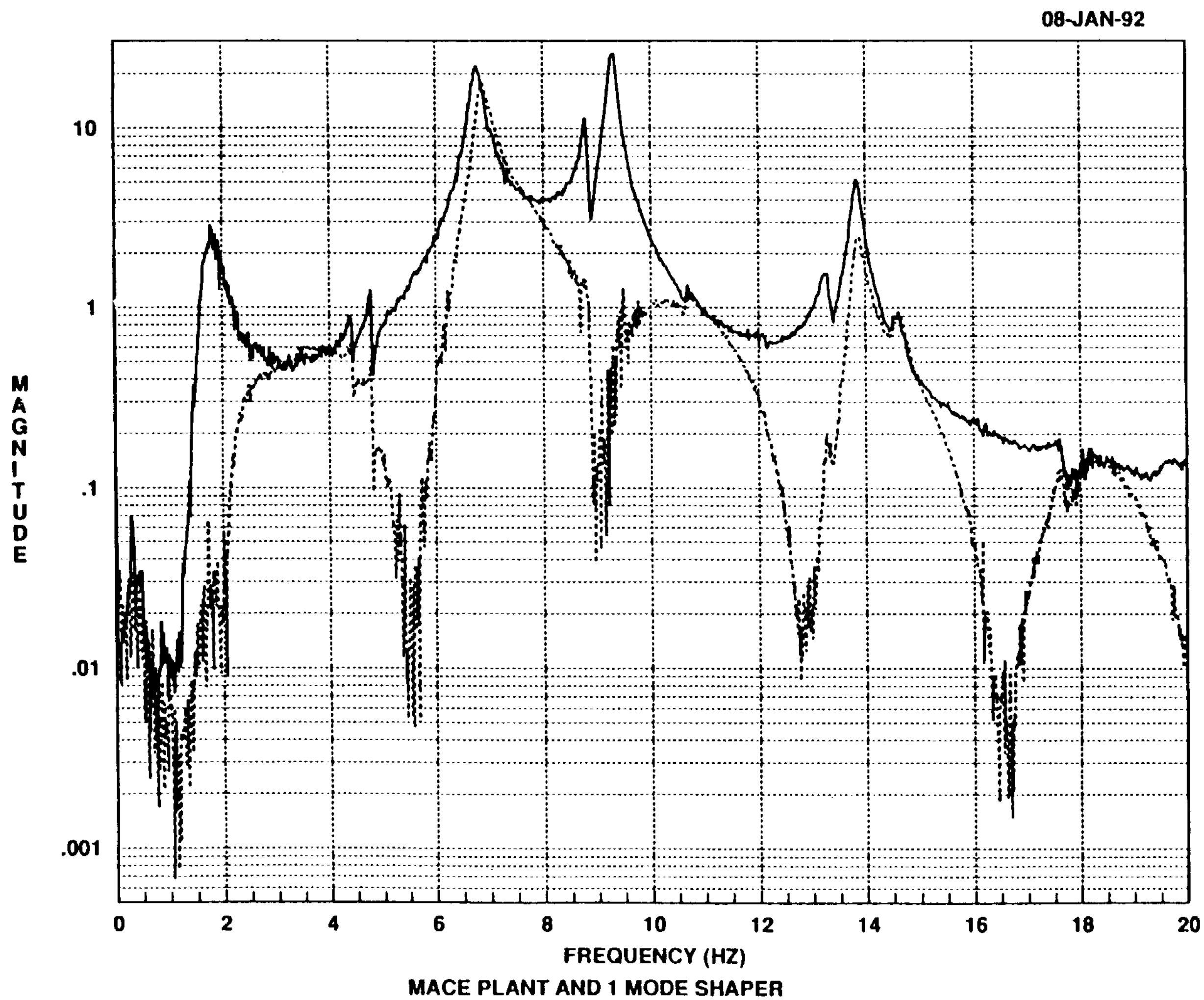
penalize payload and bus inertial angles





DEVELOPMENT MODEL TESTING

Slew Command Shaping



FUTURE DEVELOPMENT MODEL WORK

- Closed-loop control based on finite element model (Grocott, Glaese, Miller)
- Development of multi-input, multi-output measurement models (Karlov, Douglas, Athans)
- Classical control design using successive loop closure (Campbell, Crawley)
- Robust control using multi model and other uncertainty approaches (MacMartin, Hall)
- Constrained order and topology control (Mercadal, Vander Velde)
- Slew command shaping for minimizing excitation of flexibility (Chang, Seering)