MCS 4-6-414

N87-22714

OPTIMUM MIX OF PASSIVE AND ACTIVE CONTROL OF SPACE STRUCTURES

FOR

WORKSHOP ON STRUCTURAL DYNAMICS AND CONTROL INTERACTION OF FLEXIBLE STRUCTURES

AT
NASA MARSHALL
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PACOSS-RELSAT FUNDING PROFILE ($K)

	FY83	FY84	FY85	FY86	FY87	FY88	TOT.
PACOSS	390	421	518	1349	640	154	3472
RELSAT-GE	75	325	450	310	30	–	1190
RELSAT-BOEING	74	375	194	433	30	–	1106
							5768

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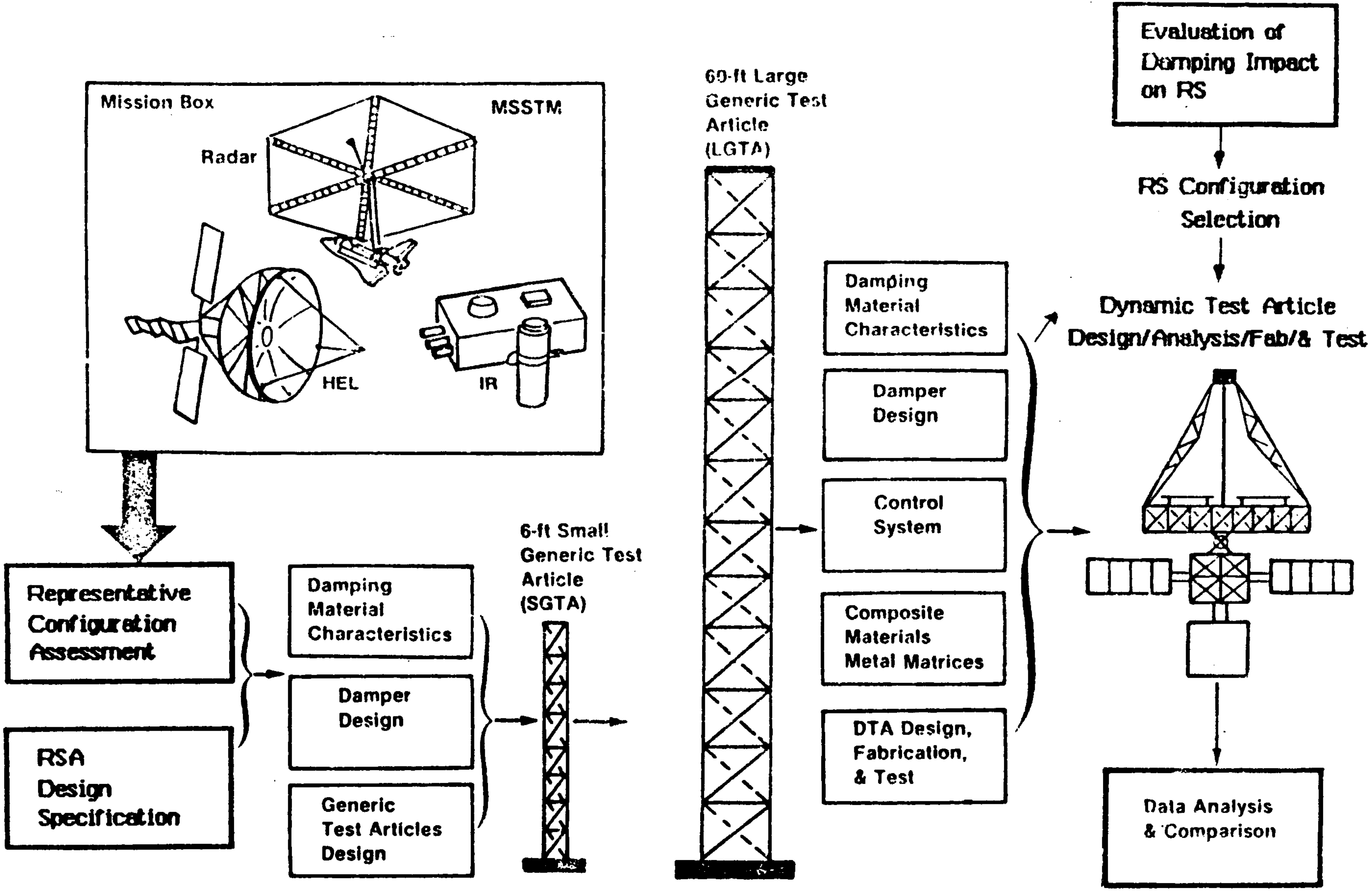
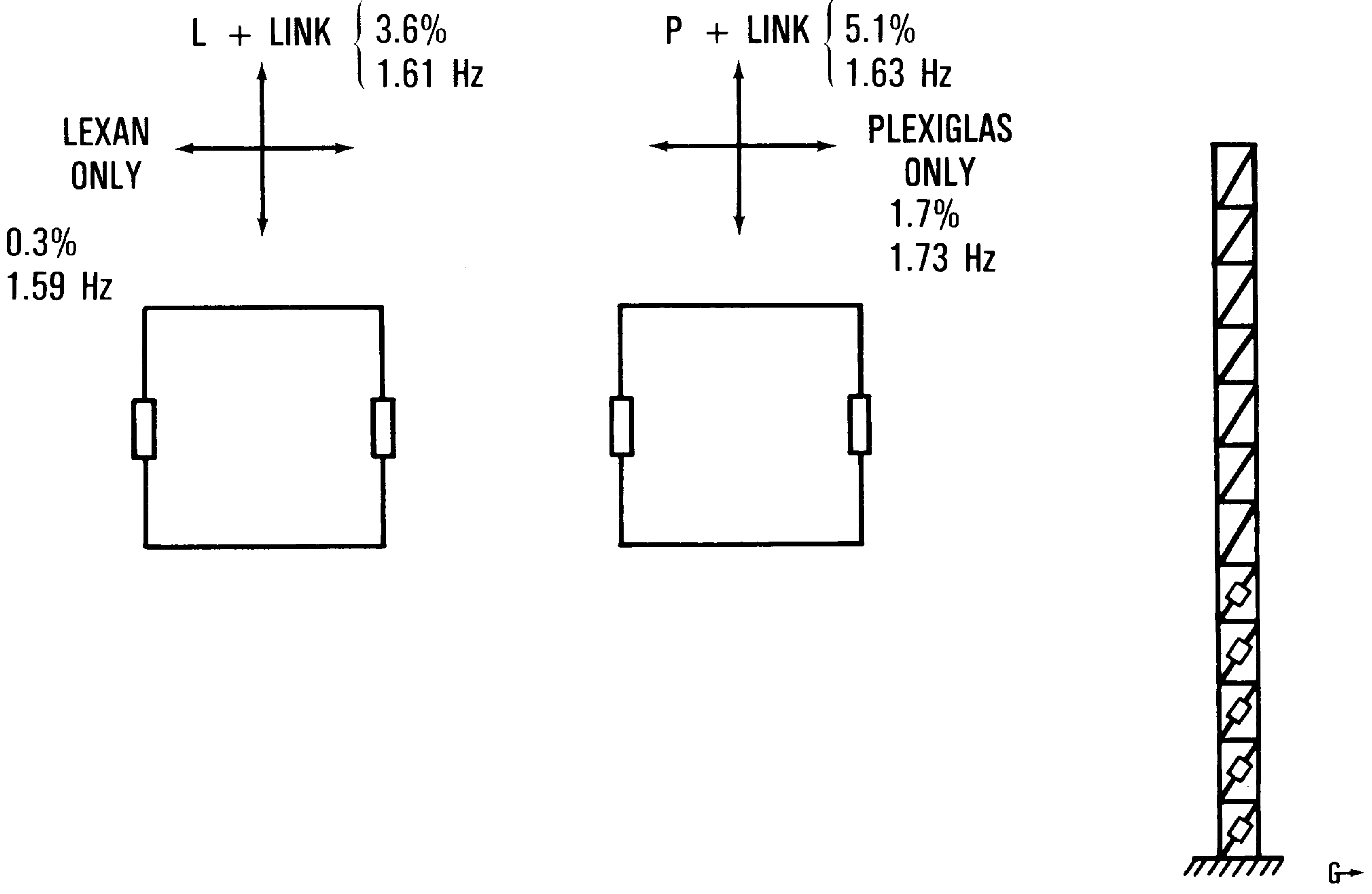
PACOSS - SIMPLIFIED FLOW DIAGRAM



LARGE GENERIC TEST ARTICLE



L + LINK { 3.6%
1.61 Hz

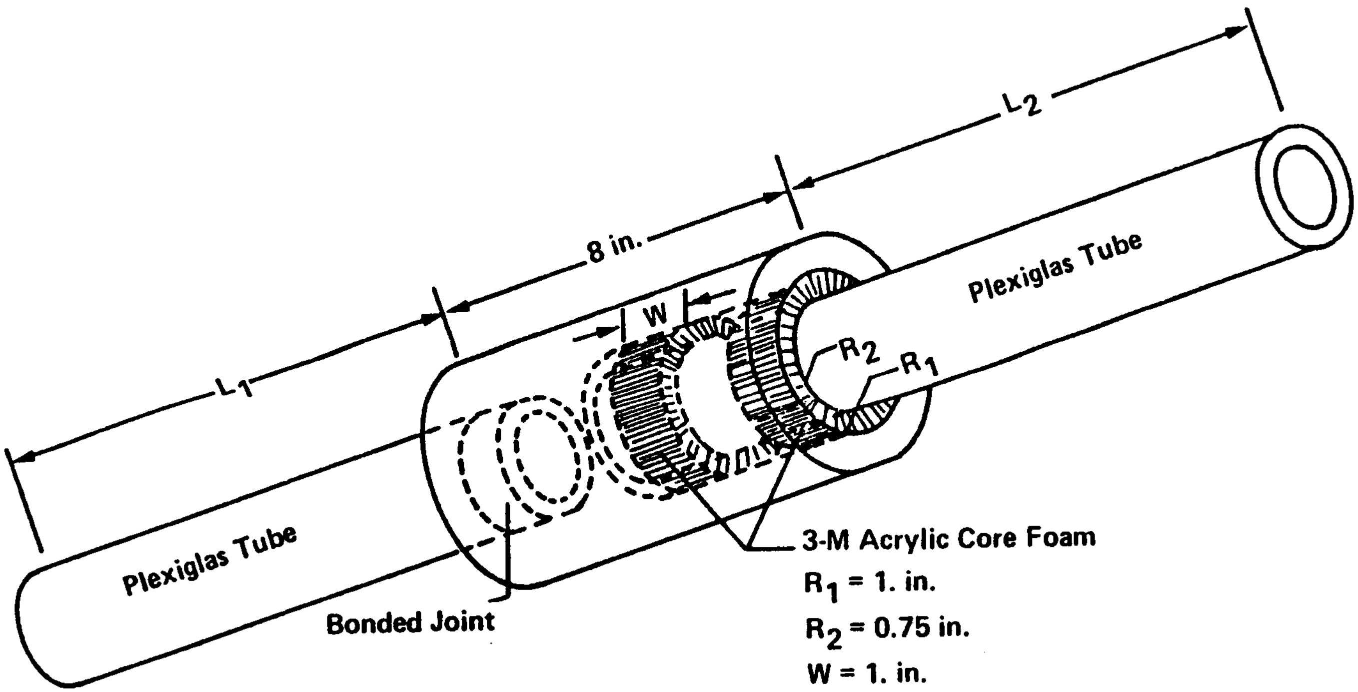
LEXAN
ONLY

0.3%
1.59 Hz

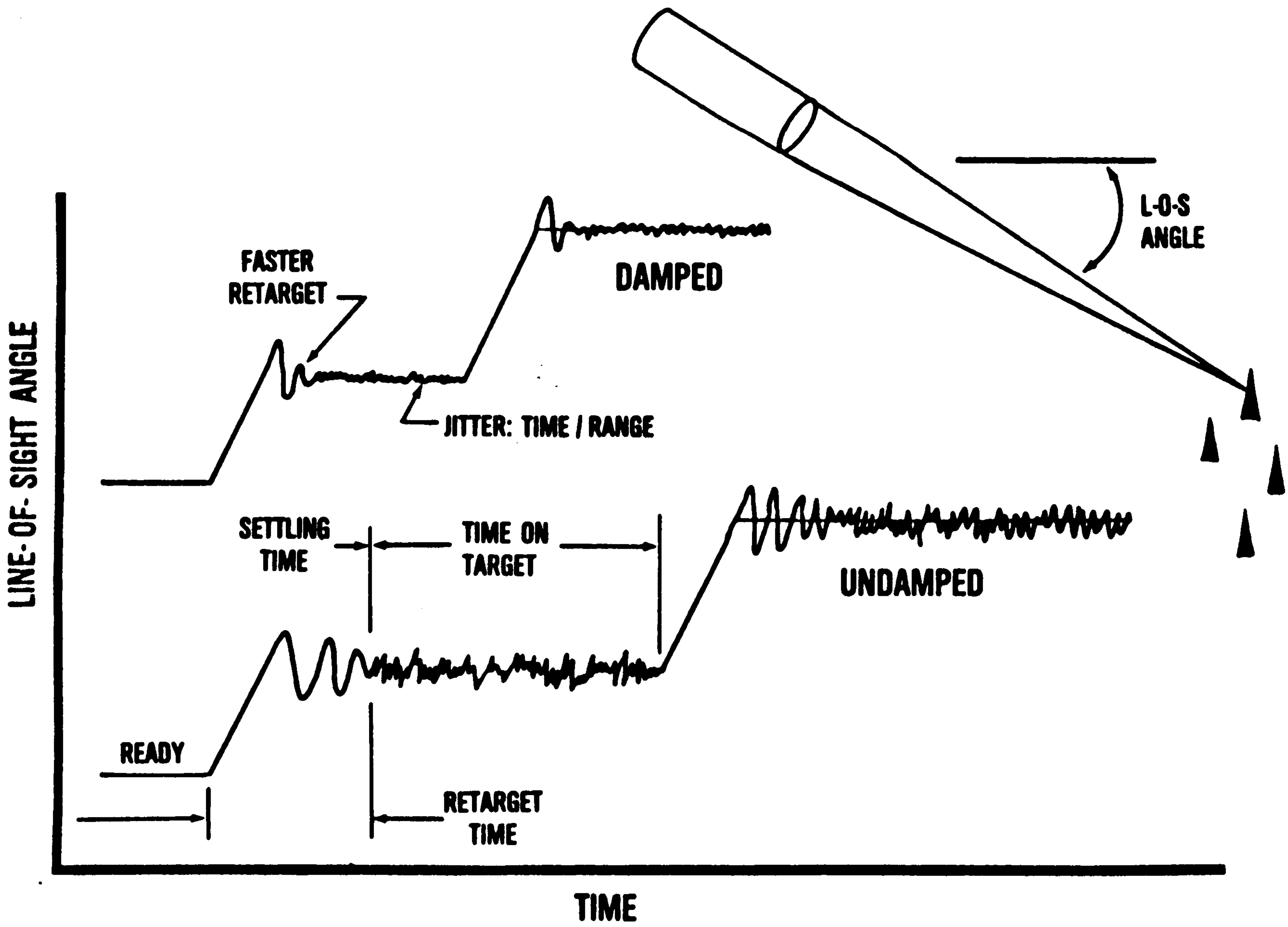
P + LINK { 5.1%
1.63 Hz

PLEXIGLAS
ONLY
1.7%
1.73 Hz

PACOSS - DISCRETE DAMPER CONFIGURATION



PAYOFF OF DAMPING



- THE CHALLENGE: VIBRATION SUPPRESSION (SETTLING TIME AND JITTER) OF A STRUCTURE CHARACTERIZED BY LOW FREQUENCY HIGH GLOBAL MODAL DENSITY

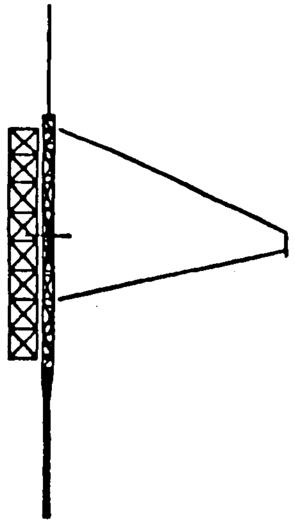
DEFINITION

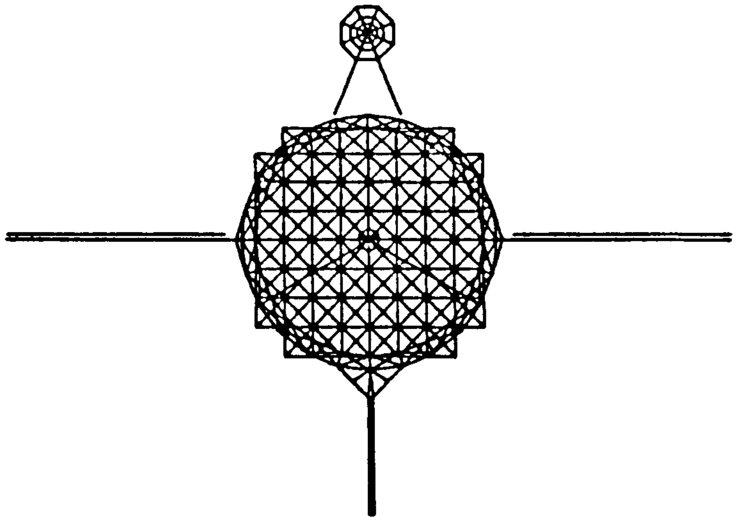
- FLEXIBLE STRUCTURE: STRUCTURES WHICH HAS NATURAL VIBRATION FREQUENCIES IN THE PASSBAND OF THE CONTROL SYSTEM

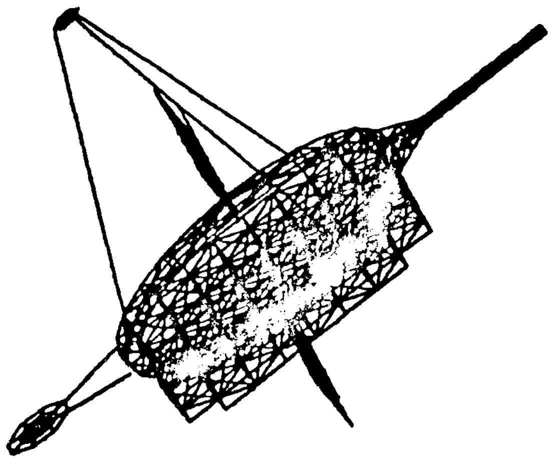
DEFINITION

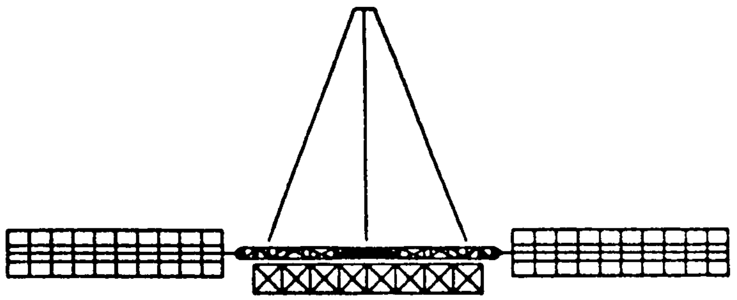
- **PRECISION STRUCTURE: STRUCTURE CARRYING OBJECTS WHICH MUST FLY IN PRECISE FORMATION**

DTA PRELIMINARY FINITE ELEMENT MODEL









MARTIN MARIETTA

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SUMMARY OF FINAL DTA DIMENSIONS

COMPONENT	DIMENSION (M)	MASS (KG)
1) BOX TRUSS	2.59 x 2.59 x 0.324	146
2) RING TRUSS	DIAMETER: 2.9	59.7
3) TRIPOD	DIAMETER AT BASE: 2.59 HEIGHT: 2.59	29.4
4) EQUIPMENT PLATFORM	LENGTH: 1.295	7.00
5) ANTENNA	DIAMETER: 0.648	4.52
6,7) SOLAR ARRAYS	LENGTH: 2.59	12.0

PACOSS DAMPING CONCEPTS

DAMPING CONCEPT	APPLICATION COMPONENTS
CONSTRAINED LAYER TREATMENT	ANTENNA SUPPORT TUBES TRIPOD LEGS
JOINT DAMPING	BOX TRUSS CORNER JOINTS BOX TRUSS / RING TRUSS INTERFACE
ELONGATIONAL DAMPING ELEMENT	TENSION MEMBERS
EXTENSIONAL SHEAR DAMPER	EQUIPMENT PLATFORMS SUPPORT TRUSS
TUNED MASS DAMPER	SOLAR ARRAYS

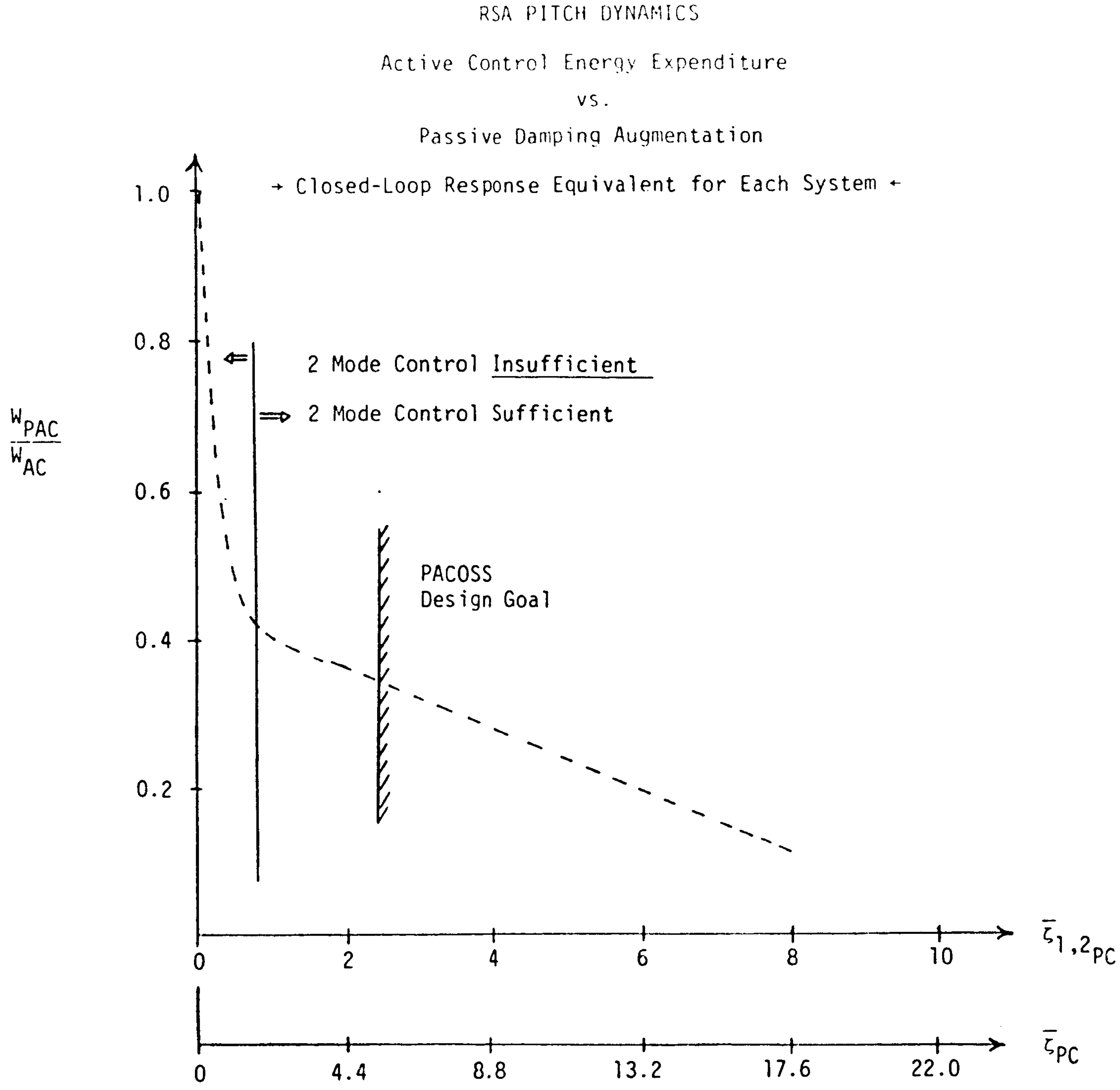
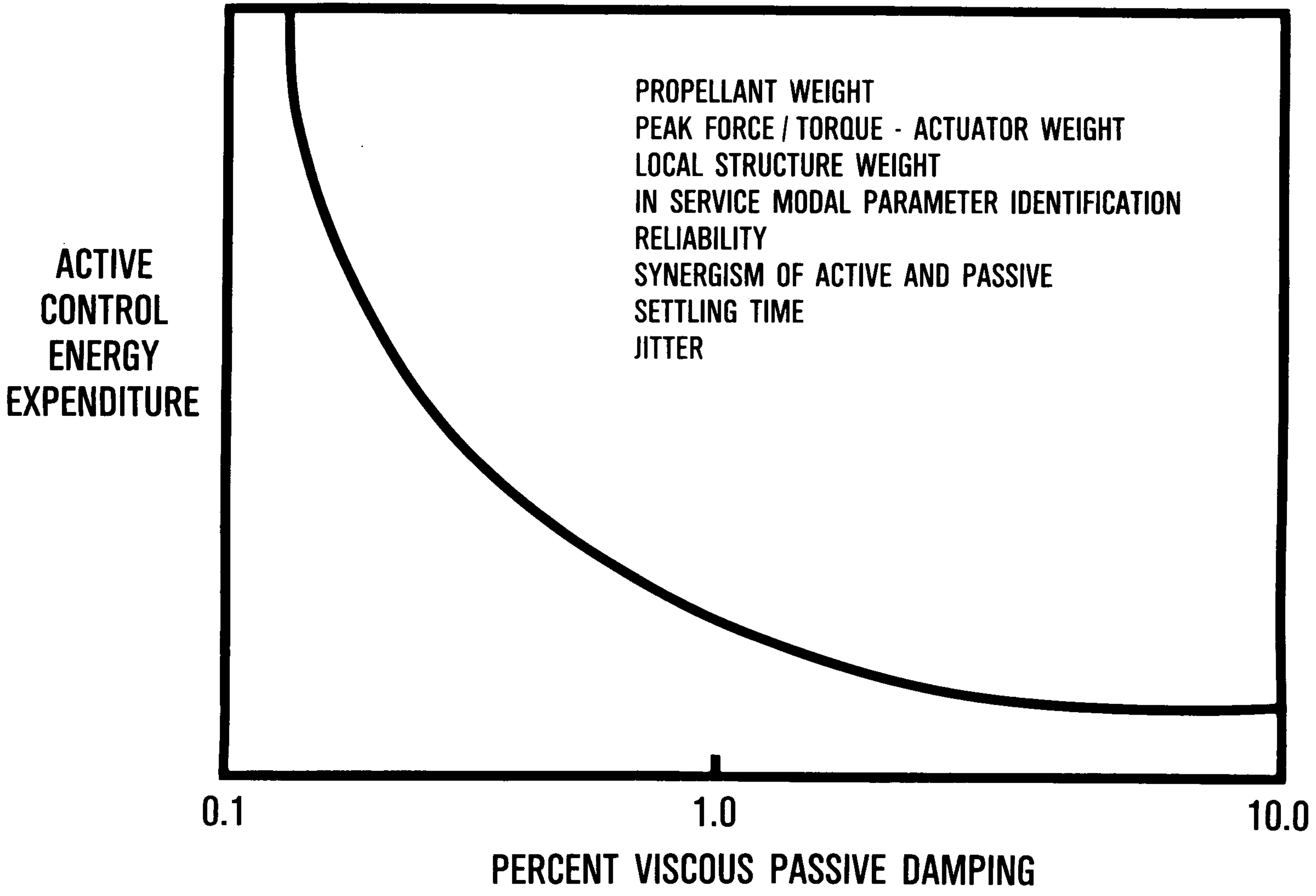


Figure 3 Active Control Energy Expenditure

SYSTEM LIFE CYCLE OPTIMUM



PROPELLANT WEIGHT
PEAK FORCE / TORQUE - ACTUATOR WEIGHT
LOCAL STRUCTURE WEIGHT
IN SERVICE MODAL PARAMETER IDENTIFICATION
RELIABILITY
SYNERGISM OF ACTIVE AND PASSIVE
SETTLING TIME
JITTER

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SUMMARY

- ANALYZED, TESTED AND CORRELATED 5% PASSIVE DAMPING IN LARGE TRUSS
- RSA RE-TARGET ANALYSIS SHOWS PAYOFF OF PASSIVE DAMPING
- LSS MUST INCORPORATE PASSIVE DAMPING FROM THE OUTSET (RELATIVE STIFFNESSES MUST BE TAILORED)
- SYSTEM PERFORMANCE WILL NOT BE MET BY EITHER ACTIVE OR PASSIVE ALONE

2. In 1983, the Flight Dynamics Laboratory at Wright-Patterson AFB initiated three contracts in passive damping in space. The two RELSAT (Reliability for Satellite Equipment Under Vibration) contracts (GE Valley Forge and Boeing Aerospace) use integrally damped equipment support structure to suppress vibratory disturbances on equipment. Vibration levels have been reduced 50-70%. RELSAT technology would be useful to design passive damping into local modes, which may or may not be significant. A contract with LTV has designed, built, tested, and qualified for flight, damped laminated skin for an A7 aircraft leading edge flap, three of which are now flying.

3. The PACOSS contract examined future Air Force missions and systems for needed passive damping technology. The truss type construction is typical and a pair of free standing 60 foot tall truss towers were built and tested early in the contract. These tests established that five per cent viscous damping was very practical for these proper size of space type truss construction. High global modal density interacting with active control is judged to be the challenge. PACOSS will design, build, and test a Dynamic Test Article (DTA) which incorporates an active control system.

4. The Twin Towers were designed to have close natural frequencies and a range of modal damping for various modes.

5. The link dampers were carefully designed to have the correct stiffness relative to the rest of the structure. The design process is based on modal strain energy. The damping results from energy dissipation in the viscoelastic material (VEM).

6. Qualatively, the payoff of damping, whether passive or active, is self evident. Damping reduces settling time and jitter, which results in less system time per target.

7. The challenge is vibration suppression/settling time and line-of-sight [JOS] jitter) of a space structure which possesses low frequency, high density of global vibration modes.

8. "Flexible structure" is defined as any structure which has natural vibration frequencies in the passband of the control system. This includes all satellites, because low frequency appendage (solar arrays, antennas, equipment booms) modes interact with the "rigid borly" attitude control system.

9. "Precision structure" is defined as any structure carrying objects (e.g., mirrors) which must fly in precise formation. Note that the structure itself is not necessarily precise.

10. The Dynamic Test Article (DTA) has been carefully designed to have high density of global vibration modes appropriate to the vibration properties of a broad class of system. The ring truss, the box truss, the tripod, the solar arrays, the equipment boom, and the antenna have been sized. Sensors, actuators, and other control system components will be included.

11. The DTA dimensions and weights are carefully selected to fit the shuttle cargo bay. Launch of this particular DTA is not appropriate.

12. Five types of damping concepts, including the link of the 60' Twin Towers, will be integrally designed into the DTA.

13. Analysis of the Representative System Article (RSA), which is dynamically similar to the DTA, for a retargeting maneuver has shown that modest levels of passive damping dramatically reduce the control energy required.

14. More trade studies are needed for specific retargeting and/or LOS jitter due to dynamic disturbances. These studies should investigate control energy required as a function of percent of viscous passive damping over a range of 0.1 - 10.%. Ideally, a system level like cycle merit function could be developed, which properly weights all related effects.

15. In summary, the payoffs of passive damping and its synergism with active control is beginning to be understood.

REFERENCES

1. Rogers, L. C. et al, "Passive Damping in Large Precision Space Structures," AIAA Paper 80-0677, presented at the AIAA/ASME/ASCE/AHS 21st Structures, Structural Dynamics and Materials Conference, Seattle WA, May 1980.

2. White, C. W., Martin Marietta Denver Aerospace, Denver CO, "Analysis of Damped Twin Towers," The Shock and Vibration Bulletin, No. 55-Part 1, June 1985, pp. 119-130.

3. Gehling, R. N., and Morgenthaler, D. R., "Representative System Report," MCR-84-541, Martin Marietta Denver Aerospace, Denver CO, November 1985.

4. Gehling, R. N., and Harcrow, H. W., "Effects of Passive Damping on Active Control Design," Presented at 26th AIAA/ASME/ASCE/AHS Structures, Structural Dynamics, and Materials Conference, Orlando FL, 15-17 April 1985. AIAA-85-0776-CP.