LMSC DAMMPS PROGRAM STATUS

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ABSTRACT

This paper summarizes the activities of the Damping and Metal Matrix for Precision Structures (DAMMPS) Program at Lockheed Missiles & Space Company. The objective of the program is to demonstrate dimensional precision for flexible aerospace structures undergoing dynamic and thermal disturbances. The approach, selection of demonstration articles, requirements are presented. The preliminary engineering activities, current achievements and future plans are also discussed.

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LMSC DAMMPS PROGRAM STATUS

Damping And Metal Matrix for Precision Structures

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The design requirements of most precision mounting platforms on satellites include both vibrational and thermal environments which dictate the use of advanced materials. For satellite programs the risks are high to insert these new advanced materials which do not have a long heritage on previous satellites. In recognition of this reluctance to use advanced materials the Wright Research And Development Center - Flight Dynamics Lab has instituted a program to introduce both metal matrix composites and passive damping technology in a parallel development effort to a structure on an on-going satellite. This program will then reduce the risk of introducing this technology on a later satellite. Lockheed Missiles & Space Co. (LMSC) has been awarded one of these contracts and this paper is a report of its progress. We have selected as our Demonstrating Structural Article (DSA) a high precision mounting platform which supports a sensor suite for the attitude control system of one its communication satellite programs. The DSA is basically a small box (about 12 inches on a side) which is attached to a simulated satellite bus panel. The passive damping requirements and design was derived using the Modal Strain Energy Method developed and validated during previous work on the PACOSS and RELSAT programs.

The current status of the program is the completion of the preliminary design phase which includes several trade studies as reported in an accompanying paper. Two potential candidate viscoelastic materials (VEM) have been characterized over a broad frequency and temperature range which is also being reported in an accompanying paper. In addition the candidate isotropic continuously reinforced GrAl panel was tested to validate the manufacturing process. The results of all the testing for both the VEM and the GrAl demonstrate the design is on solid ground. In the next phase twelve additional viscoelastic materials will be characterized, joining techniques will be validated and the final design will be optimized for thermal distortion, thermal conduction and damping.

DAMMPS

OBJECTIVE AND APPROACH

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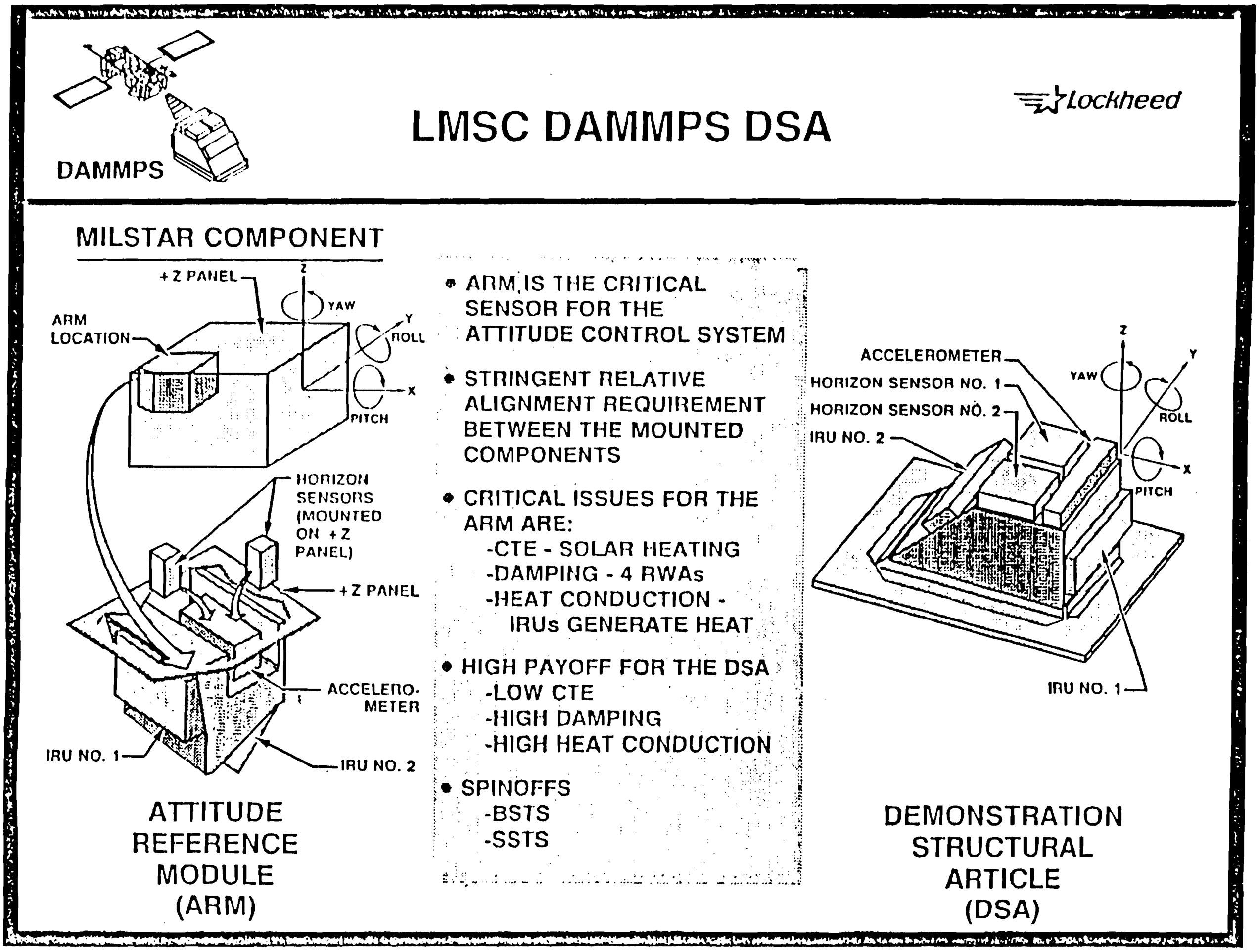
- DAMMPS OBJECTIVE
  - TO DEMONSTRATE DIMENSIONAL PRECISION FOR FLEXIBLE AEROSPACE STRUCTURES UNDERGOING DYNAMIC AND THERMAL DISTURBANCES.
- DAMMPS APPROACH
  - DESIGN / ANALYZE, FABRICATE, AND TEST A DEMONSTRATION STRUCTURAL ARTICLE (DSA) THAT REQUIRES PASSIVE VIBRATION DAMPING (PVD) AND METAL MATRIX COMPOSITES (MMC)
  - DESIGN, FABRICATE AND TEST AN ALUMINUM BASELINE DSA
  - ASSESSMENT OF THE BENEFITS OF PVD AND MMC FOR FUTURE SPACECRAFT
  - EXPAND THE PVD DATABASE
  - PARTICIPATE IN INFORMATION TRANSFER AT TECHNICAL CONFERENCES AND WORKSHOPS

The goal is to have available at the end of the DAMMPS program a true demonstration of what passive damping and metal matrix materials can offer a satellite program, not as an afterthought to fix a design shortcoming, but as a developed design technology that is ready to be implemented at the conceptual design phase of any program. The DAMMPS Program objectives will result in a new maturity in the technology areas of passive damping and metal matrix materials for spacecraft applications.

The approach is to construct a component from an existing satellite program as a Demonstration Structural Article (DSA) and validate the design via a test. The DAMMPS program is divided into six technical tasks. The first three tasks are associated with the development of the DSA. Task 1 is Preliminary Design, Task 2 is the Detail Design Development and Task 3 is Fabrication of the DSA and an aluminum prototype. Both material coupon characterization tests and component tests are an integral part of these tasks.

The final three tasks are associated with the verification of the DSA design via testing, assessment of the design, analysis, fabrication, and applicability to future satellites and the final task is to distribute the findings to the technical community.



The Altitude Reference Module (ARM) of an on-going Air Force Satellite program which is currently in the hardware phase was selected because it provides the greatest design maturity and detailed knowledge of both the thermal and vibrational environments of interest. The configuration of the ARM is somewhat complex. A modified version of the ARM was selected to be the DSA with a few simplifications which preserved its salient features. The traceability of the DSA to the ARM is presented in this viewfoil.

The ARM is an aluminum structure designed to be stiff and to conduct heat away from the boxes/sensors mounted to it. These sensors are the source of all attitude knowledge for the spacecraft:

1. two horizon sensors (HSs),
2. two inertial reference units (IRUs), and
3. one set of accelerometers.

Since they frequently operate simultaneously, it is important that the sensors do not send contradictory information to the attitude control computer - a situation which could occur if the boxes became misaligned with respect to each other. From a flow-down of system-level requirements, tolerable alignment errors between the several sensors are known. The principal purpose of the ARM is to maintain relative alignment of the sensors while conducting heat from the sensors, especially the IRUs. This means that any structure functionally similar to the ARM should be *at least* as thermally conductive as the original aluminum structure. The modified version of the ARM referred to as the DSA possesses all of these qualities, whether fabricated of aluminum or metal matrix composites.

DAMMPS

DSA DESIGN

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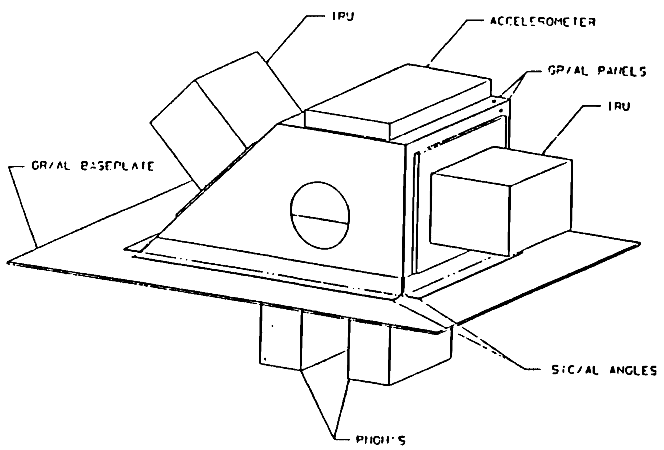

DESIGN FEATURES

BASEPLATE: Gr/Al
ISOTROPIC 80 mil PANEL

BOX: Gr/Al ISOTROPIC
60 mil PANEL

ANGLES: DISCONTINUOUS
SiC/Al 1x1x0.060

MASS SIMULATORS:
FULL WEIGHT
MATCH CG
ALUMINUM
FREQ. 150 Hz

JOINING: STRUCTURAL
BOND PERFERRED

Graphite aluminum was selected for the primary structural material because of its high stiffness to weight ratio, relatively low CTE, no outgassing, and high thermal conductivity. Specifically, P100 fiber in an aluminum matrix using a quasi-isotropic fiber orientation was selected because it is the lowest cost fiber which meets the requirements and P100/Al has a substantial experience database in the industry. Since this graphite aluminum cannot be formed, the DSA is made of flat plates. To accomplish the joints between the plates, discontinuously reinforced silicon carbide aluminum (SiC) angles are used. At a 0.25 volume fraction of SiC particulate for reinforcement, a stiffness similar to that of titanium is achieved at about the same weight as aluminum. This material is also readily extruded and can be applied to the DSA with little or no development.

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DAMPING REQUIREMENTS

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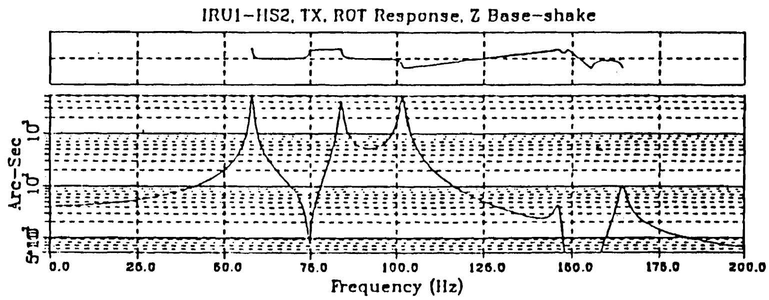
- 19 DYNAMIC RESPONSE QUANTITIES IN 3 INPUT DIRECTIONS = 57 EVALUATIONS
- REPRESENTATIVE TRANSFER FUNCTIONS OF RELATIVE ALIGNMENT DUE TO BASE SHAKE



- DAMPING REQUIREMENTS

MODE NO.	1	2	3	4
DAMPING(%)	4.0	3.5	4.0	1.2

The baseline DSA was designed to capture the same dynamics as the ARM. The mass simulators and various panels were sized to place the first four modes near those of the ARM as extracted from a system level modal test of the satellite.

The DSA FEM (Finite Element Model) was subjected to an appropriate base excitation to identify the most critical modes contributing to the response. The baseline modal damping level is assumed to be 0.5% of critical for this preliminary analysis. Transfer functions were determined relating base shake inputs in the x, y, and z directions to each of the pertinent response quantities (i.e., relative alignments, component base inputs). These transfer functions represent dynamic responses to a steady-state, unit-amplitude (in g's) base shake input at any given frequency. Data thus obtained were scaled to 0.004 g to determine the responses at the actual input levels.

As expected, several different analytical modes produce dominant responses. The modal damping requirements were determined from the peak responses in each of the transfer functions when compared to the appropriate requirement. A total of 19 response quantities with 3 input directions yielded 57 plots which were examined in this manner. The lowest four modes dominated each response. Their damping values were from mode 1 to mode 4, to be 4.0%, 3.5%, 4.0%, and 1.2%, assuming that the structure is forced by steady-state input and only damping is used to bring the responses to a level consistent with the requirements.

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DAMMPS SCHEDULE

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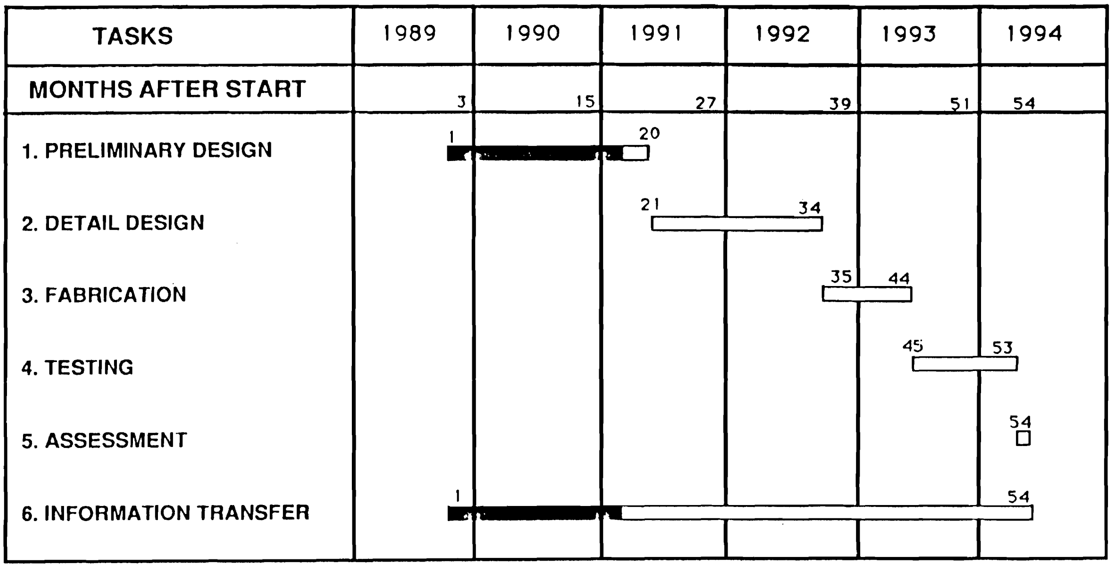

The DAMMPS Program schedule lists the tasks and shows the progress of each task for the four and half years program duration. The numbers appearing above the bars represent the months after the start of contract award. At the conclusion of the first year and a half the Preliminary Design task is nearing completion with material selection, sizing and coupon testing finalized. In addition the Information Transfer task is progressing on schedule with the generation of several documents, participation at two workshops and preparation of three technical papers. The contract is on schedule and with the anticipated continued funding will remain on schedule.

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PRELIMINARY DESIGN ACTIVITIES

- REQUIREMENTS
  - ALUMINUM (DAMPING/CTE/HEAT CONDUCTION)
  - MMC ONLY (DAMPING)
- DESIGN / ANALYSIS
  - ALUMINUM
  - MMC ONLY
  - DAMPED MMC
- MATERIAL SELECTION
  - METAL MATRIX COMPOSITE
  - DAMPING (FREQUENCY AND TEMPERATURE)
- MATERIAL TESTING
  - METAL MATRIX COMPOSITE (2 PANELS)
  - DAMPING (2 CANDIDATE VEMs)

REQUIREMENTS: In order to derive requirements a finite element model of the aluminum baseline DSA was constructed and subjected to the vibrational environment and the thermal temperature distribution. The relative alignment between the sensors was exceeded and the damping and CTE requirements were set by linearly scaling the Q factor and CTE to meet the specified requirements.

DESIGN/ANALYSIS: With the requirements set, several metal matrix designs were examined and evaluated trying to balance the constrained layer damping placement and metal matrix manufacturing limitations on fiber lay-up thickness to achieve isotropic properties which prevent distortions during the autoclave curing cycle.

MATERIAL SELECTION: While early trades were made to select the viscoelastic and GrAl material the feasibility of using each have to be based on test data which is not readily available. The layup design of composites couple with the selected manufacturing process and require test validation. Current viscoelastic characterization material data for space applications is very sparse and also must be generated before the viscoelastic material selection can be finalized.

MATERIAL TESTING: Two viscoelastic materials were characterized over a broad frequency and temperature range validating the material selection. A panel of GrAL was inspected via C-scan and mechanically tested to ensure the properties agree with the rule of mixture values. All test data was within acceptable bounds validating the panel material selection.

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PRELIMINARY DESIGN ACCOMPLISHMENTS

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ITEM	STATUS	DESCRIPTION
1	√	MASTER PLANNING AND CONTROL DOCUMENT
2	√	BASELINE DESIGN REQUIREMENTS
3	√	PRELIMINARY STRUCTURAL TEST PLAN
4	√	DAMPING MATERIAL TEST PROCEDURE
5	√	FIRST SEMI-ANNUAL TECHNICAL REPORT
6	√	SECOND SEMI-ANNUAL TECHNICAL REPORT
7	√	PRESENTED DAMMPS PAPER AT 61th SHOCK AND VIBRATION SYMPOSIUM

Note: √ means item is completed

All of the Preliminary Design activities have been documented and presented at Workshops and technical conferences. The above is a list of all the documents that have been generated to date. In addition there are two papers being presented at the Damping 91 Conference documenting the design trades leading to the current design and the results of the VEM characterization testing. These documents are available upon request from Mike Zeigler, FIBAA of WRDC.

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CONCLUSIONS
FUTURE PLANS

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- CONCLUSIONS
  - o CONCEPTUAL DESIGNS ARE COMPLETE
  - o MATERIAL SELECTION OPTIONS ARE UNDERSTOOD
  - o MMC AND VEM ARE A GOOD SOLUTION FOR HIGH PRECISION SENSOR PLATFORMS (WEIGHT, STIFFNESS, CTE, AND DAMPING)
  - o MATERIAL TESTING IS WELL UNDERWAY (VEM AND MMC)

- FUTURE PLANS - DETAIL DESIGN TASK
  - o INTEGRATED THERMAL/DYNAMIC MODEL FOR OPTIMIZED DESIGN
  - o FABRICATION TESTING - JOINTS AND INTEGRATED MMC/VEM
  - o COMPONENT TESTING - INTEGRATED MMC/VEM SAMPLES

Since the beginning of the contract significant progress has been made in accomplishing the goals of the Preliminary Design Task. Currently trade studies have been completed for both the aluminum and MMC DSAs. This includes material selection, damping treatment, and member sizing. Two candidate VEMs have been characterized and reported over the appropriate frequency and temperature ranges. A sample panel of the candidate graphite aluminum MMC has been tested to extract the mechanical properties validating the manufacturing process.

During the next phase our plan includes the testing of twelve additional VEM materials, integrated design optimization and component / fabrication testing. The integrated design optimization will include the simultaneous effects of MMC and VEM coupled together with the thermal and vibrational environments. The detailed finite element model accounts for the strain energy distribution and a thermal model accounts for the VEM altered thermal paths to calculate the thermal conductivity effects. These results will be presented to a formal design review prior to going into the fabrication phase.