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Paper Session I-C - Overview of the USAF Space Structures Technology Program

Ken Qassim
Phillips Laboratory PL/VTS

Kevin Slimak
Phillips Laboratory PL/VTS

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Ken Qassim/Kevin Slimak[1]
Phillips Laboratory
PL/VTS
3550 Aberdeen Avenue SE
Kirtland AFB, NM, 87117-5776

1.0 ABSTRACT

As a pervasive technology, structures advancements will play a key role in enabling the lower cost, more responsive space systems for which US military planners and warfighters are currently defining requirements. This paper briefly summarizes on-going Air Force space structures technology programs from basic research to space flight demonstrations, briefly covering past successes and future directions/trends. On-going initiatives to change the future technology planning approach, emphasizing greater involvement from the private sector, will also be discussed.

2.0 BACKGROUND

Because every satellite and every launch vehicle has a structural subsystem, structures technology is generally classed as a pervasive technology rather than a program specific payload technology. This means that work in the structures area is often applicable to a wide range of missions and systems.

Under the auspices of the early 90's Tri-Service Project Reliance agreements, the Air Force has the DoD lead for the development of space structures and controls technology. Within the Air Force, the Phillips Laboratory has this mission. As a result, the Air Force program is a full spectrum program, running the gamut from basic research to the all-up, space experiments to do final proof of concept demonstration for technology transition to system applications. Work is conducted both in-house and via contracts, with over 80% of the annual funding (approximately $9M in FY96) being spent on contracts...mostly with private industry.

The Air Force structures & controls program has two primary technology sub-areas: Advanced Structural Components (ASC) and Structural Control & Vibration Damping (SCVD).

The objective of the Advanced Structural Components area is to reduce the weight and cost of spacecraft and launch vehicle system structures while improving their producibility and reliability. Work involves a wide range of materials (low outgassing graphite thermo-sets, graphite thermoplastics, carbon-carbon, metal matrix, etc.) for both satellites and launch vehicles applications. Space systems differ significantly from airborne and ground-based systems in that the major part of their life cycle cost is in design and production, not operations and maintenance due to both the end application and limited production quantities. Note that although basic material development is not included here, we do include work on the material/process/fabrication tailoring required to adapt advanced materials to the environmental requirements of the subject systems.

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[1] Mr. Kevin Slimak is the Division Chief for Space Vehicle Technologies Division at the Phillips Laboratory. Mr. Ken Qassim is a senior engineer in the Space Vehicle Technologies Division of the Phillips Laboratory.

The objective of the Structural Control & Vibration Damping area is to develop enabling technologies for space systems such as precision sensor platforms, space based radars, and space based interceptors. The type of effort includes basic research into the development of new structural control algorithms, new approaches for determining the characteristics of a space system on orbit, and the development of a new class of adaptive or smart structures which contain within them sensors and actuators which sense and suppress vibrations to meet mission requirements. In addition, new mechanism concepts, such as a non-pyrotechnic release device, are being developed.

3.0 USER NEEDS

Many Air Force Development Plans identify several structures technologies as critical to meeting Air Force Space Command Mission Area Plan deficiencies. These include:

SPACELIFT -	Low -Cost Structures/Tanks/Fairings; Lightweight, Operable Structures; Smart Structures, Conformal Tanks (RLV), Integral Tanks/Structure/Thermal Protection System; Launch Vehicle Isolation System; Lightweight Structures
MISSILE WARNING	-Lightweight Structure, Lightweight Antenna; Acquisition, Tracking and Pointing Development
NATIONAL MISSILE DEFENSE -	Beam Generator Isolation from Expansion and Pointing Optics
SATCOM -	Lightweight Antenna
NAVIGATION -	Lightweight Structures; Lightweight, Low Cost Arrays
INTELLIGENCE, SURVEILLANCE AND RECONNAISSANCE -	Lighter, Rigid, “Packable” Structures; Deployment Mechanisms

These mission area deficiencies and related technology needs give rise to our technology goals.

4.0 GOALS

The goals/time frame for each of the structures technology sub-areas appears below.
The baseline for our goals is the 1995 current state of the art:

ASC (Advanced Structural Components)

- For satellites, the structural subsystem averages 20% of mass and 13% of cost
- For launch vehicles, the structural subsystem averages less than 14% of the overall mass and 30% of cost

SCVD (Structural Control & Vibration Damping)

- Subsystems requiring precision pointing are hardmounted to satellites and must live with space craft disturbances as part of their error budget resulting in degraded performance. On a case by case basis, attempts have been made to passively isolate either the disturbance source or the payload
- For large space-based laser systems, the Phillips Lab has demonstrated 1000:1 disturbance attenuation using system level isolation between the telescope and the laser and 100:1 improvement in farfield line of sight using active structural control of the telescope
- Satellites launched on MLVs such as Delta II are subjected to pseudo-static loads $\pm$ 2.5 gs (axial) and dynamic loads of $\pm$ 3.0 gs (lateral) and $\pm$ 0.6 gs (axial) at the separation plane during launch and must be designed to survive these loads

Our near term goals for 2001 are:

ASC
- Reduce satellite structural mass by 40% and reduce cost by more than 10%
- Reduce launch vehicle structural subsystem cost by 25%

SCVD
- Decrease dynamic launch loads to which a satellite is subjected by a factor of 5
- Reduce pyrotechnic-shock to which satellites are subjected by more than two orders of magnitude
- Decrease on-orbit disturbances experienced by payloads by a factor of 10

The far term goals for 2011 are:

ASC
- Reduce satellite structural mass by 75% and reduce cost by more than 25%
- Reduce launch vehicle structural subsystem cost by a factor of 10

SCVD
- Decrease dynamic launch loads to which a satellite is subjected by a factor of 20
- Decrease on-orbit disturbances experienced by payloads by a factor of 100

What follows is a summary of our major programs.

5.0 Active Control Technology EXperiment I

In an ultra conservative environment like the spacecraft designers, it is almost impossible to have them implement new laboratory-proven technology in a new vehicle design. They always insist, and rightfully so, on space proven technology. The potential breakdown of a new design-in of a component in space is a gamble that they and their sponsors can ill afford in a multi-hundred million dollar unit-price tag space environment. A space heritage is a must for any new technology to be designed in, and the smart structures program of the Phillips Laboratory/BMDO is no different. The Air Force started looking for ways to validate smart structures in its native working space environment. In order to reap the advanced structures benefits, ground and on-orbit technology demonstrations were launched in the form of ACTEX I and II experiments.

5.1 ACTEX I objective

The objective of the ACTEX I experiment is to determine on-orbit performance of advanced structural controls hardware and algorithms, and to determine insensitivity of structural control hardware to the space environment. This objective addresses two key technical issues that have bogged this technology down. One is that smart structures/advanced structural control concepts have been ground tested and have no space heritage, and the other is on-orbit performance/reliability uncertainty data. The control system is expected to perform in a variety of orbits and environments over a long period of time. Once on orbit, this experiment if successful will abolish the notion that smart structures/advanced structural control concepts lack space heritage and customer acceptance would have been introduced. The anticipated functional life of this experiment is expected to be no less than 3 years.

5.2 ACTEX experiment description

ACTEX I has been designed to mitigate, actively, the space induced vibrations that are due to spacecraft equipment such as thrusters and reaction wheels etc. It uses embedded piezo ceramic as the active actuators. The active tripod itself consists of a top plate - representing the mass and inertia properties of a precision sensor - a bottom bracket/plate which interfaces to the host spacecraft, and the three composite legs with embedded piezo ceramic actuators (PZT actuators) and sensors. See Flight schematic in figure 1 that shows the tripod attached to the top plate and the mounting bracket along with the host deck and other components.

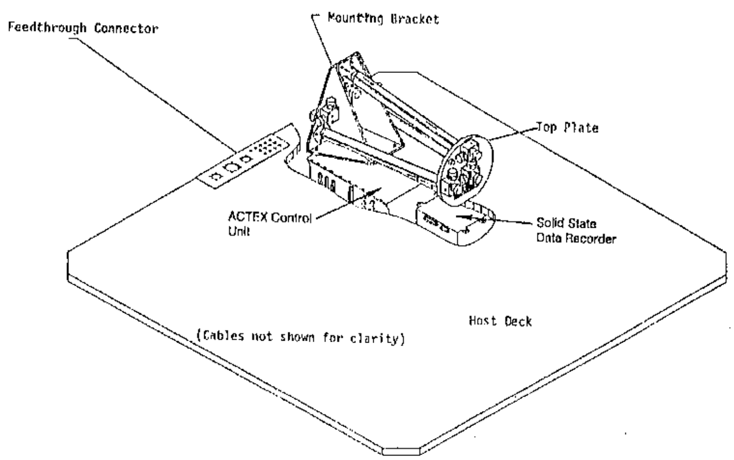

Figure 1 ACTEX Flight Experiment Schematic

The tripod structure measures approximately 0.6 meter by 0.3 meter by 0.25 meter including the mounting bracket. The tripod will be mounted to the host satellite payload deck externally and will thus be exposed to the harsh and unforgiving space environment. This arrangement will help evaluate the smart structures technology in its future native environment with no plans to shield or protect the tripod experiment.

The tripod experiment is equipped with a mechanism to change its dynamic behavior by means of stiffening a set of flexures. In addition to conducting the on-orbit structural characterization and vibrations suppression experiments, altering the dynamics of the tripod via the stiffening of the flexures, calls for the control system to adapt accordingly without any loss in performance. The stiffening of the flexures induces a 10% and 20% change in the first two system modes respectively, thereby changing the system behavior. See figure 2 which shows system behavior before and after system alteration. The system dynamic alteration, of the tripod will be used to demonstrate the ability of the on-board control system to adapt near real time. This adaptive control capability is a powerful technology tool in future deployment of large space DoD platforms. The experiment is well instrumented, as may be seen in figure 3, with accelerometers and thermistors t

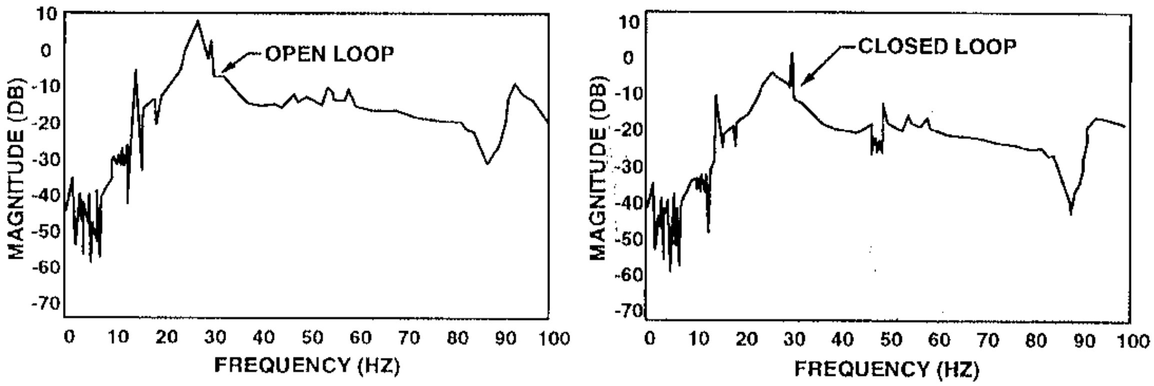

Figure 2: ACTEX I Open and Closed Loop Graphs

See table 1 that shows both open and closed loop data and the percent damping change. ACTEX was built by a division of TRW Incorporated and was delivered to the Naval Research Laboratory (NRL) that did the final integration.

After a couple of launch delays, due to higher priority programs, ACTEX I was launched during the second quarter of calendar year 1996. It is worth noting that in closed loop ground testing more than 22% damping was achieved.

Mode	Open Loop		Closed Loop	
	Frequency (Hz)	ζ(%)	Frequency (Hz)	ζ(%)
Lateral Bending	21.0	1.1	20.9	16.3
Lateral Bending	23.9	0.8	27.0	22.0
Torsion	77.0	0.5	75.0	6.7

Table 1: Ground Tested Damping Data

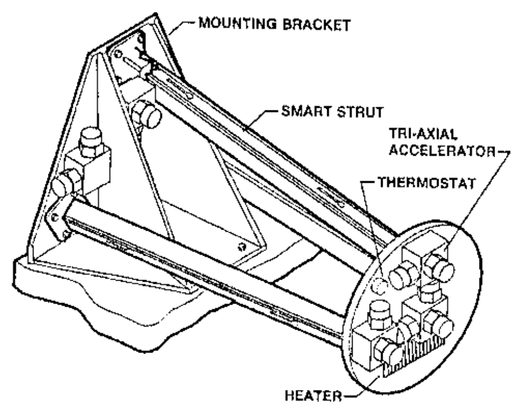

Fig 3: ACTEX Tripod Front View Showing Instrumentation location and bracket

6.0 Space Technology Research Vehicle 2 Program

6.1 Introduction:

The Space Technology Research Vehicle 2 (STRV-2) is an on-going collaborative effort between the Ballistic Missile Defense Organization (BMDO), NASA, the US Air Force/Phillips Laboratory, and the United Kingdom Ministry of Defence to provide critical space test data to enhance design and risk reduction efforts for space-based surveillance platform design. This project was initiated in the Spring of 1994 by BMDO and NASA/JPL was selected to perform systems engineering, integration, and test functions for the payload module.

6.2 Objective:

The objective of this program is to develop, deliver, integrate, and operate a set of space flight experiments that address the technology issues, risk mitigation, and data necessary to support development and long duration operation of Space Defense System (SDS) assets in the natural space environment.

6.3 Description:

Representing a multi-agency and multi-national collaboration in which the payload elements are funded and managed independently, the STRV-2 is comprised of a suite of synergistic experiments, see figure 8 which shows the different components of the experiment, to be developed that will: a) Obtain Medium Wave Infra Red (MWIR) background/clutter data from Space and Missile Tracking System (SMTS) (BE) mission altitudes over a mission duration of one year, providing seasonal variation information; b) Validate the effectiveness of advanced vibration isolation and suppression technology in reducing motion of the IR sensors that will improve image quality/pointing accuracy; c) Measure radiation levels occurring at SMTS (BE) mission altitudes and correlate these with degradation of IR sensors and microelectronic data processors and data storage components; d) Measure contamination resulting from outgassing of spacecraft components and correlate with performance of MWIR system; e) Demonstrate use of high stiffness, low weight all composite spacecraft structure; f) Obtain data on debris and micrometeorite fluence at SMTS (BE) mission altitudes; g) Demonstrate operation of a tactical cryocooler in space; h) Demonstrate high bandwidth space-to-ground data transmission using a low weight laser transmitter. For a brief glimpse into the STRV-2 innovations see figure 11. As can be seen from the scope and broad number of experiments comprising the STRV-2 program, it is an international cooperative effort that includes BMDO, UK Ministry of Defence, DoD International Programs Office, US Air Force Phillips Laboratory, and NASA

6.4 Payoff:

The payoff for this program will be in the form of data obtained that will have a positive impact on the design of future US SDS assets, and provide information on the performance of new technologies and materials in the space environment. Namely it will provide performance characteristics on: the Vibration Isolation and Suppression technology (VISS), the all composite bus, MWIR provided by the UK Ministry of Defence, broadband lasercomm from space, and environment degradation data for selected spacecraft materials and components.

7.0 Vibration Isolation and Suppression System (VISS)

7.1 Introduction:

A member of the STRV-2 experiment family, the MWIR, is being designed and fabricated by the UK Defence Research Agency (DRA), whose objective is to demonstrate its utility for detecting non-afterburning aircraft from space. Sensor jitter - see figure 8 - has always been a matter of serious concern for optical surveillance systems and the MWIR infrared sensor is no exception.

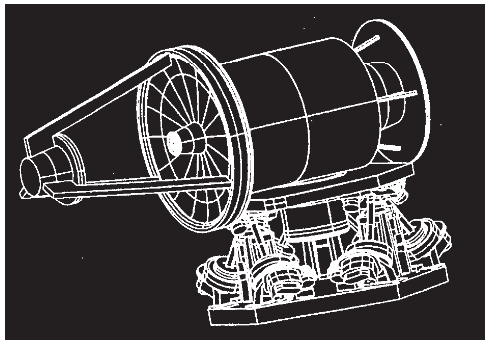

Figure 4: VISS Mounted MWIR

Usually , stirling cycle cryocoolers are used to cool the infrared space surveillance sensors and maintain them at their optimal operating temperatures. Unfortunately in many cases, one of the leading sources of jitter, given a quiescent spacecraft, is an operational cryocooler. In operation, a cryocooler generates vibrations which are transmitted to the MWIR sensor Focal Plane Array (FPA) via the cold figure which is in thermal contact with the FPA through a strap of copper. Furthermore, the common structure, to which both the cryocooler and the sensor are mounted to, may serve as an alternate path for the crycooler jitter to reach the MWIR sensor.

`The above mentioned DRA MWIR will be integrated and launched onto a TSX-5 noisy spoacecraft bus and hence requires some vibration isolation and suppression technology implementation to make it function optimally. VISS is a device currently under development to do just that - isolate the sensitive MWIR payload from other components and from satellite bus. See figure 4 that shows the MWIR attached to the VISS structure.

7.2 VISS objective:

VISS experiment has a three point objective. First, it is to provide vibration isolation between the spacecraft bus and the sensitive Infra Red (IR) sensor payload. The goal is to provide 20 dB reduction of vibration transmission over the range of 1Hz to 200 Hz. Second, it is to provide vibration suppression to the on-board generated jitter by the stirling cycle crycooler. It will provide a reduction in magnitude of the fundamental and first harmonic of the crycooler of about 20 dB. Third, it is to provide steering, in a sweeping mode of $\pm$ 0.3 degrees with a resolution of $\pm$0.002 degrees. The steering capability is non taxing considering that VISS steering has a six degrees of freedom capability to a magnitude of $\pm$ 1.0 degree with the same resolution.

7.3 VISS description:

The isolation capability of VISS is at least a broad 20 dB between 5 and 200 Hz band. The system is able to suppress the unwanted vibrational noise from the satellite bus or due to an operating cryocooler as well as payload steering/gimballing about its multiple axes. In its current configuration it opts to isolate the sensitive optical payload (MWIR) from the rest of the spacecraft versus distributed isolation techniques that tend to quiet a precision bus. The distributed technique attenuates the disturbance transmission path of the noisy device or component from the main spacecraft bus such as reaction wheel isolation; or attenuates the disturbance at the source such as solar panel damping and the ultra quiet cryocoolers. This distributed technique works well but at the expense of increased size, weight, and cost.   VISS utilizes both active and passive hybrid technology on all six isolation struts that are arranged in a hexapod configuration. See figure 6 which shows transmissibility curves versus frequency of purely rigid connection, purely passive damping application, and a hybrid of active and passive application.

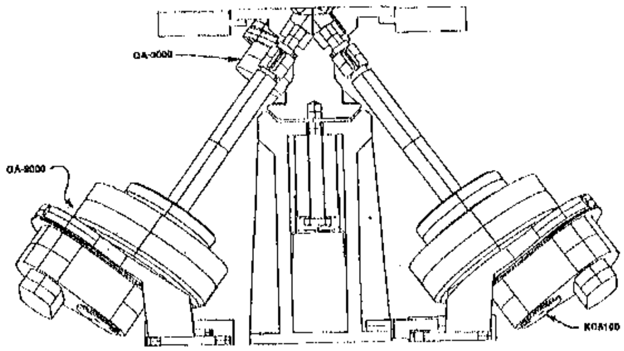

Figure 5: Sensor Location Schematic

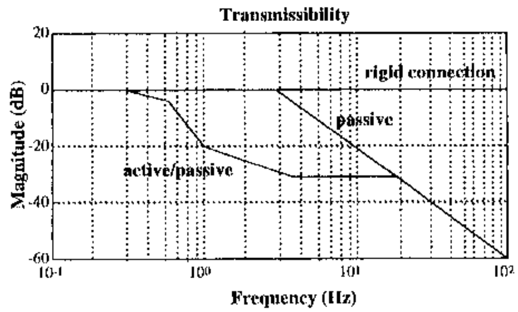

Figure 6: VISS Rigid, Passive, and Active Transmissibility Plots

The hybrid configuration is designed to satisfy most of the isolation requirement passively. The VISS configuration allows the passive damping treatment to provide isolation about 5 Hz and is supplemented by active control to achieve 20 dB total isolation for 5 Hz and above. The active portion is designed to enhance the low frequency isolation performance of the mount. To achieve this, active control techniques are employed to modify the passive system lower break frequency. High frequency isolation is provided by the passive system mount that takes over for the higher frequency region. Power requirements for the VISS are miserly and are further reduced by incorporating the passive damping versus a purely active mount for isolation.   VISS hybrid configuration retains the desired properties of an active system such as pointing and suppression and close to 40 dB/decade isolation roll off over the desired frequency range.

Should there be an active control system failure, the system leans onto the passive nature thereby degrading but not catastrophically. The graceful degradation is an insurance or peace of mind for the system and payload designers.   In addition to isolation and suppression abilities of the hybrid system it also steers the precision optical bench/payload. Precision steering allows multiple snapshots of the same area over time to detect target changes. Steering limits are ± 0.3 degrees in three axes and is done at 20 Hz rate.

VISS overall design and manufacture responsibility rests with Honeywell Satellite Systems Incorporated to include all mechanical, electrical, hardware, and software. The Air Force Phillips Laboratory is doing the integration, testing, and flight qualification testing, while the Jet Propulsion Laboratory is accountable for the system modeling, control system design, and overall integration of the STRV-2 satellite. VISS benefits include increased MWIR sensor performance, by allowing to go to a less costly MWIR sensor design, and decreased requirements on component vibration performance such as solar arrays and reaction wheels. The well instrumented VISS, see figure 5 for the sensor locations and type, is scheduled to fly in the fall of 1999.

8.0 Launch Vibration Isolation System (LVIS)

<u>8.1 Introduction</u>:

A big chunk of spacecraft development costs lie in trying to comply with the vibro-acoustic launch environment and with the launch-induced dynamic loads. These loads are usually the result of the launch vehicle structural dynamics being acted upon by a variety of systems including rocket engines, acoustics, pyrotechnics, and aerodynamic forces. The expense is derived from the fact that the payload and its associated attachments have to survive the harsh launch-induced forces through a very stiff customised payload attachment that do not attenuate these loadings. This translates to a beefier payload components and a lot more extensive testing to verify that the multimillion dollar payload will not fail after launch. Additionally it has been shown that nearly half of the spacecraft failures that occur soon after launch are attributable to vibration and acoustics according to a study done by the Aerospace Corp titled “Spacecraft Isolation Study” October 1991. See compiled table 2 from this study below which shows the various launch loads that spacecraft designers have to design to.

Launch Vehicle	Design Limit Loads Factors (g)				Frequency Reqmts (Hz)	
	@ Max. Axial		@ Max. Lateral			
	Axial	Lateral	Axial	Lateral	Axial	Lateral
Atlas G/ Centaur	+5.6	±0.5	+4.5	±2.0	>15	>10
Delta	+6.2	±0.1	+2.2/ -0.2	±2.5	>35	>15
Titan III	+2.5/ -7.0	±2.0	-3.0	±2.0	>26	>10
Titan IV	+2.5/ -6.5	±1.5	+3.2/ +0.2	±3.5	<5; 11-16; >25	>2.5

Table 2: Launch loads of various launch vehicles

<u>8.2 LVIS Objective:</u>

LVIS is a payload launch attenuator. LVIS objective is to design, fabricate, and test a flight-qualifiable hybrid LVIS that will provide a factor of five reduction in RMS acceleration while meeting all current payload adapter/attachment requirements while maintaining compatibility with the launch vehicle control system. LVIS will track and adapt to the varying acceleration loadings and natural frequencies of the launch vehicle to provide optimum isolation performance at all times during ascent.

<u>8.3 LVIS Payoff</u>:

When LVIS is successfully developed and made available to the commercial and military launchers, a less severe and harsh environment on the payload will translate into more affordable satellites. This translates into potentially lower cost spacecraft and lower cost launch systems due to the fabrication and testing to a less severe launch environment afforded by LVIS. While LVIS is not critically needed for old and new launch vehicles, it is definitely an enabling technology for a more competitive increasingly international launch community. A more competitive local launch community will directly benefit the Air Force by reducing their procurement costs. To summarize, LVIS will provide the technology that will enable mass and or cost reductions to occur while increasing payload reliability for payloads being designed for present and future launch vehicles.

LVIS is a two million dollar program that will last for three years. McDonnell Douglas Aerospace is the primary contractor with CSA Engineering and Loral as the subcontractors.

9. MULTIFUNCTIONAL STRUCTURES

9.1 Multifunctional Structures Objective:

Current spacecraft electrical systems involves thousands of feet of cables and numerous connectors to route the power, data transmissions, command, control and ground planes around the structure. These conventional systems are extremely heavy and are labor intensive to manufacture the spacecraft bus. The objective of this contract will be to design, fabricate, test, and evaluate sub-scaled integrated electronics structures and to fabricate and test a demonstration integrated electronic structure to validate the electrical and structural performance of the module. This integrated electronic structure is a load bearing element of the spacecraft and the electrical pathways will need to withstand the severe launch environment. These objectives will result in establishing a design philosophy for incorporating the ground and power planes, communication bus and data transmission lines into the spacecraft structure, thereby eliminating or reducing the need for cables and connectors.

9.2 TECHNOLOGY DESCRIPTION:

Modern spacecraft consist of two major systems: the payload, consisting of mission specific sensors or instruments; and spacecraft bus which supports the payload, providing all the housekeeping functions. These support and housekeeping functions are provided via a number of subsystems (such as Attitude Determination and Control, Command and Data Handling - (C&DH), Structure and Mechanisms, etc.) integrated to support the mission specific payload. In most spacecraft, C&DH is the principal interface between all the subsystems. It receives, validates, decodes, and distributes commands to other spacecraft systems and gathers, processes, and formats spacecraft housekeeping and mission data for down linking or use by an on-board computer. This role requires it to communicate with all parts of the spacecraft. In current state-of-the-art designs, communication is achieved using hundreds of cables and connectors which crisscross the entire internal volume of the spacecraft. The complexity of a C&DH subsystem is directly proportional to the complexity of the spacecraft. With the move towards complex yet light-weight, low-cost spacecraft, the current C&DH designs do not meet the system requirements.

9.3 PAYOFF:

It is estimated that for future spacecraft such as the Advanced Interceptor Technology (AIT) lifejacket, the avionics and its cabling and connectors constitute about 30% of the weight (compared with 10% for current spacecraft). This weight penalty of 20% is unacceptable to system designers. This program offers an innovative design solution by literally integrating the C&DH system into the spacecraft structure, thus reducing its weight to well under the 10% requirement. In this approach the cabling and interconnects are replaced by a multi-layer network deposited on the structural substrate, eliminating the need for cables and connectors. Each layer of the multilayer network performs a specific electronic function: power, ground, control and data transmission. This innovative approach also allows electronics components to be mounted directly on the spacecraft structure without the use of enclosures resulting in unparalleled weight savings. Typically, over 70% of the electronic component weight can be attributed to electronics enclosures and associated harness! This parasitic weight penalty will be virtually eliminated by this approach.

10.0 All Composite Bus

10.1 All Composite Bus Objective:

Another member of the STRV-2 experiment family, the objective of this program is to demonstrate advanced, high risk/high payoff manufacturing technologies for spacecraft structures. The approaches selected involve fabrication of simple, high stiffness, low cost, structural elements using advanced high thermal conductivity/high stiffness fibers and advanced joining techniques. Demonstration articles will be fabricated for BMDO and Phillips Laboratory space experiments missions. The ultimate goal is to simplify the design, lower cost, weight, and part count of structure with simpler fabrication processes.

10.2 Description:

For the current crop of satellite, the structural subsystem averages 20% of the satellite mass and 13% of its cost. This program will enable the development of advanced, higher performance, and lightweight spacecraft structures. The benefits to the commercial satellite manufacturers may be even greater than those to the military based on the scale of their operations and this is a good indication of the market size. Significant savings will be seen through a decrease in overall satellite mass due to higher stiffness to mass ratio that the composites inherently enjoy over the currently dominant all aluminum bus. Additionally, savings in the form of significantly reduced machinability and, whenever machinability is needed, it is a much reduced burden. An added benefit of an all composite bus is dimensional and thermal stability if the material is properly chosen. Dimensional/thermal stability increases pointing accuracy thus insuring high speed communications between satellites through the laser crosslink concept.

10.3 All Composite Bus Payoffs:

Numerically speaking, the immediate payoff of the all composite bus is to reduce the satellite cost by 10% and concurrently its weight by 40% thereby translating into a more capable higher weight payload or a reduced weight satellite. While the long range payoff expected is to reduce the satellite structural mass by 75% while concurrently reducing the cost by 25%.

11.0 Synergism In the Interaction of Atomic Oxygen, Electrons and Ultraviolet Radiation on Organic Polymers

11.1 BACKGROUND:

Spacecraft surfaces in low-earth orbit (LEO) are exposed to the simultaneous bombardment of atomic oxygen (AO), energetic charged particles (primarily electrons), solar radiation, and to hypervelocity impacts of micrometeorids and debris. Because of the simultaneity of the exposure, materials degrade by a synergistic interaction of all of the space environmental factors. Failure of researchers to correctly simulate the space environment has led to dramatically different results when space experiments are compared to ground simulation tests. For example, Los Alamos National Laboratory reports more than an order of magnitude increase in the oxidation rate of TEFLON compared to space experiments while their reported oxidation rate of epoxy resin is 1.5 times smaller than space experimental results. In the work to be discussed below, we seek to improve the understanding of the response of polymeric materials used in spacecraft to the simultaneous exposure to atomic oxygen (AO) and electrons. Preliminary experiments that we have done suggest that charging of the spacecraft surface can alter the total reaction rate of AO with the polymer.

11.2 Objectives:

Understanding the phenomenology of the interaction of the space environment with organic composite materials is important for the longevity of our space assets. This understanding has been made more critical by the recent suggested use of new organic composites whose lower weight and higher stiffness ratios will allow us to orbit larger payloads. However, the lack of corroboration between ground simulation degradation tests and actual space data clearly indicates that our understanding of the interaction between the space environment and composite spacecraft materials is poor. The specific objective of this research is to gain an understanding of the chemistry of the interaction between organic polymers, electrons and ultraviolet radiation in changing the oxidation rate produced by atomic oxygen.

11.3 Payoff

The Air Force, NASA, and other agencies are endeavoring to reduce the cost of launching satellites and to increase their useful lifetimes in orbit. Consequently, these agencies are depending, more and more, on the substitution of organic composite materials for metallic alloys used in spacecraft because of their more favorable strength to weight and stiffness ratios. Unfortunately, organic composite materials are attacked much more aggressively by atomic oxygen than metals. The application of this research work to the solution of the Air Force's spacecraft problem would be suggestions for hardening spacecraft materials against the space environment from our knowledge of the mechanisms by which atomic oxygen attacks spacecraft in the presence of electrons and ultraviolet radiation. Present day ground simulation testing does not reliably reproduce space degradation data from LDEF. This program is the first in the international community to simultaneously expose spacecraft composite materials to all of the significant space environmental variables and to yield damage results which duplicate those found on LDEF.

12.0 FUTURE TRENDS AND OPPORTUNITIES

On the socio-political side, as this is being written, the process by which we in DoD do our technology planning is undergoing change. Under the direction of the Undersecretary of Defense for Development, Research, & Engineering (DDR&E), a new process, the Technology Development Approach (TDA), is being implemented. Based on the approach used in the Integrated High Performance Turbine Engine Technology (IHPTET) program, the concept is for industry and government to jointly, formally set time-phased goals/objectives and anticipated technical and system-level payoffs for a technology area and identify the programs and resources (government and industry) necessary to achieve those goals. DDR&E then reviews the annual progress and adjusts budgets based on the progress made toward achieving the mutually agreed upon goals/objectives.

Currently, in the structures area, we government folks are putting together the first draft of the goals/objectives. (In fact, the goal/objectives in the front of this paper are those we are proposing as of when this paper is being written.) After review by DDR&E, and rewrites as directed/needed, the product was formally shared with industry during fourth quarter of 96. You will be hearing more from us, or directly from DDR&E, as the plans become more clearly defined.

Essentially, the TDA is a formalization of a method that we have always used in developing our space structures plan: actively involving you, in industry, in helping us identify what work we should fund. Hopefully, this process, plus the technical trend discussed below, will help us maintain the robust funding needed by the structures community.

On the technical side, we see a growing emphasis on greater subsystem integration, increasing the number of functions that any one component fulfills. Our own smart structures and multi-functional structures programs are just the beginning of this trend. Integration of energy storage and attitude control is already being examined in several programs. Additionally, the concept of integrating energy storage into our multifunctional structure is already being discussed.

13.0 CONCLUSIONS

Given the trends and programs discussed above, since the structure already integrates the rest of the subsystems in the physical sense, we see a bright future for structures and controls. As an indispensable component of any space vehicle, our challenge is to minimize the cost and weight of our subsystem to make future spacecraft both more capable and more affordable.

Working together, we will make it happen!

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