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14. ABSTRACT
The Air Force Research Laboratory (AFRL) Space Vehicles Directorate has developed the Demonstration and Science Experiments (DSX) mission to research technologies needed to significantly advance Department of Defense (DoD) capability to operate spacecraft in the harsh radiation environment of medium-earth orbits (MEO). The ability to operate effectively in the MEO environment significantly increases the DoD's capability to field space systems that provide persistent global targeting-grade space surveillance, high-speed satellite-based communication, lower-cost GPS navigation, and protection from space weather on a responsive satellite platform. The three DSX physics-based research areas are: 1. Wave Particle Interaction Experiment (WPIx): Researching the physics of very-low-frequency (VLF) transmissions in the magnetosphere and characterizing the feasibility of natural and man-made VLF waves to reduce space radiation; 2. Space Weather Experiment (SWx): Characterizing and modeling the space radiation environment in MEO, an orbital regime attractive for future DoD and commercial missions; 3. Space Environmental Effects (SFx): Researching and characterizing the space weather effects on spacecraft electronics and materials.
DSX uses a modular design that allows for launch either as a primary satellite on a conventional launcher, such as a Minotaur, or as a secondary payload on a larger rocket, such as the Evolved Expendable Launch Vehicle (EELV). Another key feature is the use of a dedicated payload computer, which unburdens the avionics of the need to conform to custom payload data interfaces, enabling the rapid procurement of a standard spacecraft bus. An overview of the DSX science experiments, payload design, spacecraft subsystems, and engineering approach will be described.

15. SUBJECT TERMS Demonstration and Science Experiments, DSX, MEO, Spacecraft, Wave Particle Interaction Experiment, WPIx, Very Low Frequency, VLF, Space Weather Experiment, SWx, Space Environmental Effects, SFx, Space Radiation, Space Weather, Payload, Spacecraft Subsystems

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Overview of the AFRL's Demonstration and Science Experiments (DSX) Program

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3. **Space Environmental Effects (SFx): Researching and characterizing the space weather effects on spacecraft electronics and materials.**

DSX uses a modular design that allows for launch either as a primary satellite on a conventional launcher, such as a Minotaur, or as a secondary payload on a larger rocket, such as the Evolved Expendable Launch Vehicle (EELV). Another key feature is the use of a dedicated payload computer, which unburdens the avionics of the need to conform to custom payload data interfaces, enabling the rapid procurement of a standard spacecraft bus. An overview of the DSX science experiments, payload design, spacecraft subsystems, and engineering approach will be described.

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I. Introduction

THE Demonstration and Science Experiments (DSX) flight program, is AFRL's fourth space science technology experiment (SSTE4). It was originally conceived by AFRL researchers in 2003 to conduct physics based experiments, and was selected as an AFRL mission in 2004. With primary funding from AFRL, DSX enjoys additional support from DARPA and NASA, and is comprised of elements provided by AFRL, NASA, academia, and many contractors.

The DSX spaceflight experiment comprises three major research areas, which together will pave the way for new DoD capabilities in space surveillance, small satellites with significant operational capabilities, and protection of space assets from natural and enhanced radiation environments. This mission will advance the warfighter's capabilities in communication, surveillance, and navigation. The DSX experiments include research in three major experiment categories.

The physics of Very Low Frequency (VLF, 3-50 kHz) electromagnetic wave injection from space and ground-based transmitters, propagation, and wave-particle interactions in the magnetosphere comprises the first category, *Wave Particle Interaction Experiments (WPIx)*. Equipment on DSX will transmit and receive VLF waves and quantify their effect on the trapped electron populations in the magnetosphere. Detailed measurement and mapping of high and low energy particle and plasma distributions; radiation dose rates, local magnetic fields and pitch angle distributions in the poorly characterized MEO environment and slot region make up the DSX *Space Weather Experiments (SWx)*. The third major experiment category, *Space Environmental Effects (SFx)*, involves characterization of the effects of space weather and the space environment on materials and electronics. SFx consists of NASA's Space Environment Testbed, as well as AFRL developed photometers and radiometers.

Coupling these experiments into a single platform provides a lower-cost opportunity for the AFRL due to their common requirements and goals. All three experiments need a 3-axis stabilized spacecraft bus, a suite of radiation sensors, and extended duration in a MEO orbit.

II. Flight Experiment Concept

The functional baseline configuration for the DSX flight experiment is shown in Figure 1. The core is the Evolved Expanded Launch Vehicle (EELV) Secondary Payload Adapter (ESPA) Ring [1,2], which is used to maximize launch opportunities on both Space Test Program (STP) and operational DoD launchers. ESPA was developed and designed by CSA Engineering. Every EELV launch is a potential ride for an ESPA ring, and thus also for DSX. The ESPA ring comprises the primary structure for DSX, and is upgraded to provide host spacecraft functions (avionics, TT&C, ADCS, C&DH, and power management and distribution) by the addition of components packaged on an *avionics module (AM)*. The DSX payloads (including deployable booms) are mounted on an identical structure, the *payload module (PM)*, attached to the ESPA ring opposite the avionics module. The AM and PM together comprise the DSX *Host Spacecraft Bus (HSB)*. The entire assembly is designed to be stowed within a 4-m diameter EELV fairing.
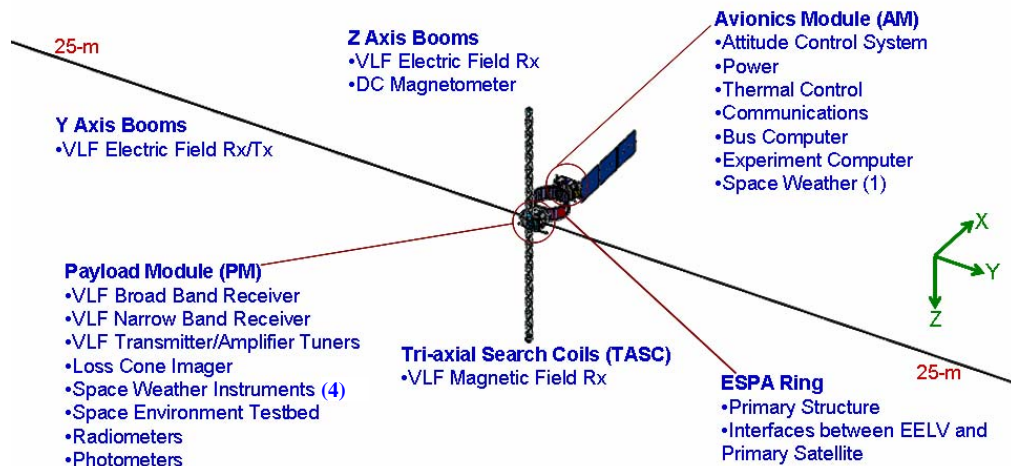

Figure 1: DSX baseline deployed configuration.

The design intent for the ESPA ring was for it to remain attached to the launch vehicle upper stage to facilitate deployment of up to six microsatellites. However, unlike the traditional ESPA approach, the DSX avionics and payload modules do not separate; they remain attached. After the primary satellite is deployed, the DSX ESPA separates from the EELV 2nd stage booster to become a free-flyer spacecraft. The ESPA ring serves as the DSX spacecraft's primary structure, with an upper separation interface to the primary payload adapter and a lower separation interface to the EELV upper stage adapter. Figure 2 shows DSX and identifies its major components in a stowed configuration. The experiment is baselined for flight in the radiation belts with a nominal orbit of 6,000 km x 12,000 km elliptical, mid-inclination, and 1-year of mission operations.
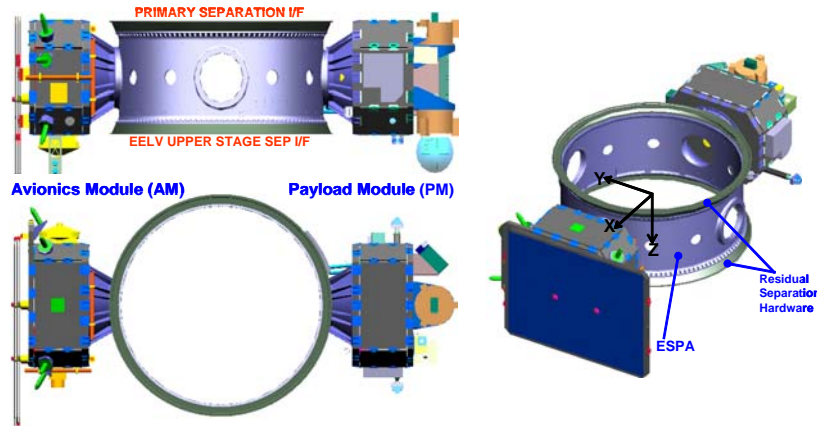

Figure 2: DSX baseline stowed configuration

Figure 3: DSX stacked configuration for dedicated launchers

From the earliest DSX conceptual planning, it was understood that the key to a successful program execution was maximizing DSX's compatibility with numerous launch vehicles. While the ESPA-based approach makes every EELV a potential ride, not all co-manifest opportunities possess sufficient excess launch vehicle performance needed to inject DSX into its MEO orbit. Therefore, flexibility in the design will be maintained for as long as possible to allow repackaging DSX for flight on dedicated launchers. Inherent in the modular approach shown in Figure 2 is the ability to separate the two modules from the ESPA ring, and directly stack them in a vertical assembly for a dedicated launcher. The stacked HSB configuration is shown in Figure 3, and fairing encapsulated views of DSX are shown for EELV, Minotaur IV/V, and Falcon 5 in Figure 4. This modular architecture not only makes DSX reconfigurable for various launch vehicles, but it also greatly simplifies payload integration.
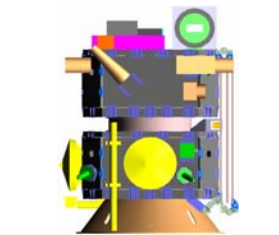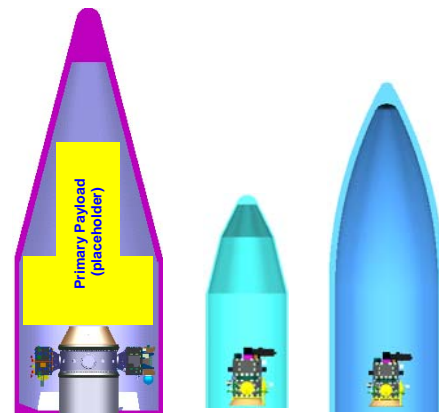

Figure 4: DSX Encapsulated

From left to right - Atlas V EELV (baseline ESPAsat), Minotaur IV/V, and Falcon 5

III. DSX Science Experiments

A. Wave-Particle Interaction Experiment (WPIx)

The Earth's radiation belts exhibit considerable dynamic behavior ranging from the creation and destruction of whole new belts in the outer zone (> 6,000 km) occurring on time scales of minutes to days and the slower diffusion of the innermost regions (< 6,000 km) occurring on timescales of months to years. A major cause of the energetic electron belt dynamics are wave-particle interactions driven by electromagnetic waves in the VLF range and below. Properly directed, this scattering will increase the electron velocity parallel to the local magnetic field by altering the "pitch-angle" (i.e. the angle between the particle's parallel and perpendicular velocity) and lower the altitude at which the electron magnetically reflects along the field line, an effect due to the conservation of magnetic moment (Figure 5). If the magnetic reflection is lowered to altitudes within the upper atmosphere, collisions with the plentiful neutral particles will lead to a depopulation of the radiation belt along that magnetic flux tube.
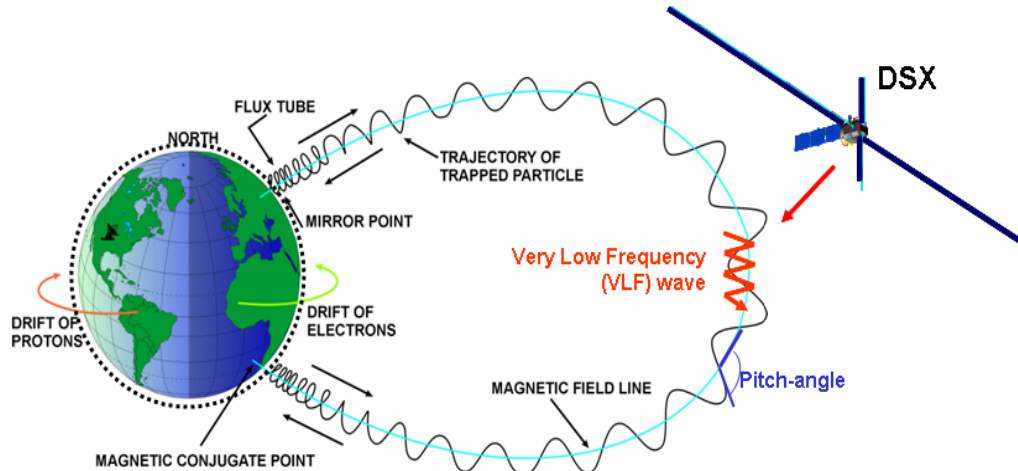
Figure 5: VLF wave particle interaction processes.

Natural sources of VLF in the magnetosphere include magnetospheric hiss generated by space weather processes and lightning-induced whistler waves propagating along field-aligned ducts through the magnetosphere. To match current models of radiation belt dynamics to the observed behavior of electrons, it is necessary to postulate that man-made VLF leaking into the magnetosphere from ground-based submarine communications systems is also a significant source. Direct measurements of VLF power have been sparse because scientific satellites with the required capability (e.g. the USAF CRRES [3] and NASA IMAGE [4] missions) have been in highly elliptic orbits with apogee > 6 Earth radii and consequently spend most of their time outside the inner belt and slot region. Placing a VLF receiver on the DSX satellite will allow for a quantitative determination of the current levels of natural and man-made VLF waves in the inner magnetosphere. Models of ground-based VLF injection and global magnetospheric propagation will also be validated in a controlled manner. The VLF transmitter on DSX will provide the capability to conduct active experiments to quantify space-based VLF wave-injection efficiency and determine the details of the wave-particle interactions. An electron loss cone detector on DSX will allow direct correlation of changes in energetic particle distributions with injected wave power. Accurate models of the VLF injection, propagation, and wave particle interaction processes will be developed and validated with DSX data. Such models are critical components of global radiation belt nowcast and forecast models required for space situational awareness and mission planning. The WPIx payloads consist of four major components, further described below.

1. Wave-induced Precipitation of Electron Radiation (WIPER) Broad-band Receiver (BBR)

The WIPER broadband receiver (BBR) is a passive receiver designed to measure the natural and man-made ELF, VLF and LF signals in the inner magnetosphere in the range 3-50 kHz. The BBR (shown in Figure 6) is electrically connected to all four deployed booms previously shown in Figure 1, with two channels of the BBR measuring electric fields via the y and z-axis VLF antennas, and three more channels measuring magnetic field about threes axes of the Triaxial Search Coil

Figure 6: WIPER BBR

Figure 7: TASC

Antennas (TASC). TASC (shown in Figure 7) is mounted on the tip of the +Z boom and the BBR is contained within the payload module. BBR measurements are also coordinated with high power transmissions resulting from the WIPER transmitter, transmissions from ground based facilities, as well as naturally occurring sources of magnetospheric VLF (i.e., lightening). The WIPER BBR is being developed by Stanford University.

2. WIPER Transmitter and Narrow-band Receiver Electronics

The WIPER transmitter electronics portion consists of the transmitter controller unit (TCU) with an integral narrow-band receiver (NBR) as well as two transmitter amplifier tuner units (TATU). Each TATU (shown in Figure 8) electrically connects to a pole of a center-fed dipole antenna supported by the ±Y booms shown in Figure 1. The transmitter electronics include dynamic tuning circuits, embedded within the TCU. The VLF transmission system will broadcast up to the kilowatt level in the range 1-50 kHz and at much smaller power levels from 50 kHz - 750 kHz by charging
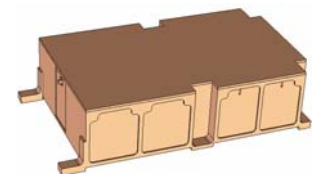

Figure 8: WIPER TATU

conductive antenna elements that run along the Y-axis booms to levels up to 10 kV. The TCU/NBR and both TATUs are housed within the payload module. The WIPER transmitter electronics are being developed by the University of Massachusetts-Lowell, benefiting from significant heritage resulting from work on a similar payload flown on NASA's IMAGE satellite.

3. Loss Cone Imager (LCI)

The Loss Cone Imager (LCI) is an electron loss-cone particle detector that will provide a measurement of three dimensional energetic particle distributions with emphasis on the measurement of the fluxes of energetic electrons along the direction parallel and anti-parallel to the local geomagnetic field vector. The LCI consists of two scanning heads, with $\pm180°$ motorized articulation capability, and each projected a 180° field of view fan, with each scan head position, so that together the full 4π unit sphere may be imaged. LCI depends on data from the DC Vector Magnetometer (VMAG) for its motor pointing control loop, and for later ground data correlation.

A separate Solid State Detector (SSD) telescope called the High Sensitivity Telescope (HST) will be mounted on the DSX in order to obtain fluxes of energetic electrons along the geomagnetic field vector direction. This telescope is designed to have a geometric factor of 0.1 cm^2 steradian with sufficient shielding to permit the detection of 100 particles/cm^2-sec-steradian in the loss cone. The LCI is under development by Boston University, and also benefits from heritage obtained in the development and flight of similar instruments such as the Imaging Electron Spectrometer (IES) on the ESA-NASA Cluster mission. The LCI scanning heads and HST are shown in Figure 9.
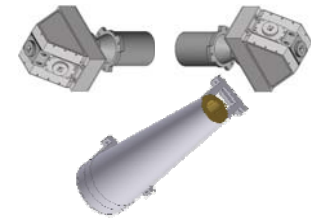

Figure 9: Loss Cone Imager

4. DC Vector Magnetometer (VMAG)

A DC fluxgate vector magnetometer (VMAG) will be used to determine the direction of the magnetic field to better than one degree at all points in the orbit. This performance will allow the mapping of locally measured particle distributions to global distributions. VMAG sensors will measure the DC B-field over a 100-10000 nT range with ±0.1 nT accuracy at 20 Hz. VMAG data is also used in real-time by the LCI, as previously discussed.
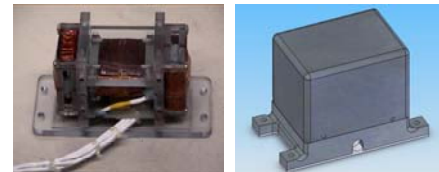

Figure 10: VMAG

VMAG will operate continuously to provide DC magnetic field and ULF wave environment data required by the SWx MEO space particle modeling experiment, thus it supports both WPIx and SWx experiment objectives.

The VMAG electronics will be mounted within the payload module and the fluxgate sensor will be deployed on the tip of the –Z boom, opposite TASC. VMAG is under development for DSX by UCLA, and is similar to other fluxgate magnetometers (shown in Figure 10) developed by UCLA and flown on several missions.

B. Space Weather Experiments (SWx)

With an orbit between 6,000-12,000 km, DSX will explore a large swath of the inner magnetosphere, in particular the outer region of the inner proton belt the "slot region", and inner regions of the outer electron belt. This domain has remained largely unexplored due to the understandable tendency of military, commercial, and scientific satellite systems to be located outside the intense regions of radiation, most often at LEO or GEO. However, increasing demands for uninterrupted coverage of the Earth from space are driving planners to consider putting satellite constellations in orbits spending significant time in the inner magnetosphere. Current standard space particle models (e.g. AE-8 and AP-8) can be off by as much as 50 times or more in estimating the time taken to reach hazardous dose levels in the MEO regime. It is imperative that measurements be made of the plasma and energetic particles so that adequate climatological, situational awareness, and forecast models can be developed to enable the successful design and operations of systems in these new and desirable orbit regimes. Accurate environment determination is important for DSX so that quantitative correlation with the performance of the spacecraft and its payloads over the course of the mission may be performed.

Deficiencies of current standard radiation belt models in the inner magnetosphere include the lack of (a) spectrally resolved, uncontaminated measurements of high energy protons (10-400 MeV) and electrons (1-30 MeV) and (b) accurate mid to low energy (< 1000 keV) measurements of the energetic particle and plasma environment. Not surprisingly, most of the space weather data to-date has been accumulated in the LEO and GEO regimes, as illustrated in Figure 11 with data from dosimeters aboard the TSX5 and DSP satellites in LEO and GEO, respectively. The Space Weather instruments onboard and the unique orbit of DSX will address these deficiencies.

Included will be electron and proton detectors measuring both the spectral content and angle of arrival of both species over broad energy ranges. An on-board magnetometer (VMAG, see section A.4) will allow for the transformation of angle-of-arrival measurements into estimates of the flux distribution with respect to the local pitch-angle (i.e. the angle between the particle velocity and magnetic field). Local pitch-angle distributions can then be used to estimate global particle distributions by mapping techniques using the well-known equations of motion and magnetic field models tagged to the local measurements. The nominal space weather sensor suite capabilities are described in detail in the following sub-sections.
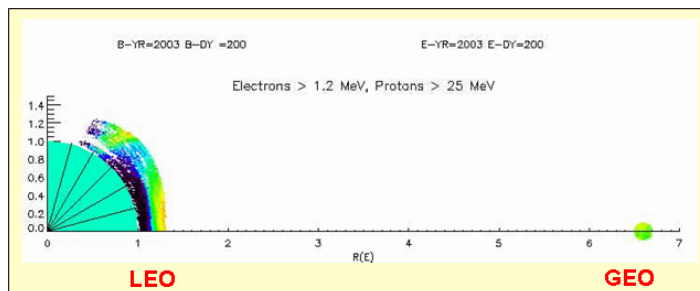

Figure 11: Space weather data from TSX and DSP shows lack of data in MEO.
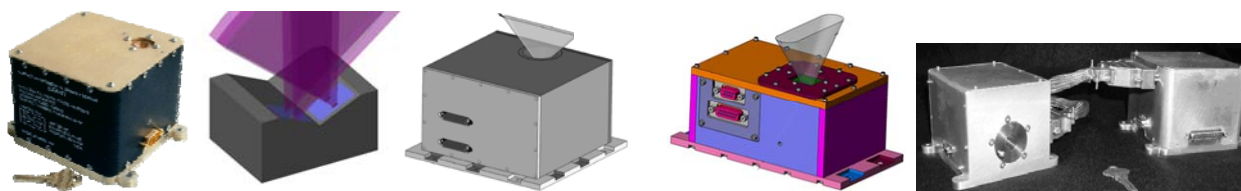

Figure 12: Space weather instruments CEASE, LEESA, HIPS, LIPS, and HEPS.

1. Compact Environment Anomaly Sensor (CEASE)

Composed of two dosimeters, two particle telescopes and a Single Event Effect detector, CEASE has the capability to monitor a broad range of space hazards from surface damage and charging (keV electrons) to Single Event Effects resulting from >100 MeV cosmic rays and solar protons [5,6]. The angular field-of-view for CEASE is relatively large and will not allow for pitch angle resolved measurements. CEASE will be mounted on an exterior panel of the payload module. One change for DSX is that CEASE will capture and downlink the full dose spectra from each dosimeter, whereas prior versions only captured six reduced data points (two for low LET data and four for high LET data). The CEASE instrument was developed by Amptek, Inc. and has already flown on several spacecraft. CEASE and the other SWx instruments are shown in Figure 12.

2. Low Energy Electrostatic Analyzer (LEESA)

LEESA will measure energy fluxes and energy spectra for low energy electrons and protons (100 eV to 50 keV). These low energy particles are responsible for surface electric charging and damage to thin films such as thin-film photovoltaics, conventional solar cell cover glasses, and coatings. LEESA will be mounted on an exterior panel of the payload module. It is under development for DSX by Amptek.

3. High Energy Imaging Particle Spectrometer (HIPS)

HIPS will measure electrons with energies between 1 and 10 MeV and protons with energies between 30 and 300 MeV. These high energy particles are responsible for microelectronics damage, displacement and total dose damage, SEEs, and deep dielectric charging. HIPS will be mounted on an exterior panel of the payload module. It is under development for DSX by Physical Sciences, Inc (PSI).

4. Low Energy Imaging Particle Spectrometer (LIPS)

LIPS is designed to measure the ring current particles that are important in the energy flow processes in the magnetosphere. This particle population plays an important role in spacecraft charging and surface damage due to sputtering. The instrument, built by Physical Sciences Inc, uses specially designed combinations of scintillator materials to detect electrons and protons with energies between 30 keV and 2 MeV. Eight 10 degree by 8 degree field-of-view windows will provide pitch angle resolution. LIPS will be mounted on an exterior panel of the payload module.

5. High Energy Particle Spectrometer (HEPS)

HEPS is a two box system that will measure protons with energies between 15 and 440 MeV and electrons with energies between 1.5 and 20 MeV. These high energy particles are responsible for microelectronics damage, displacement and total dose damage, SEEs, and deep dielectric charging. The HEPS sensor head will be mounted on the AM battery enable bracket and the electronics unit will mount below it to an exterior panel of the AM. It was developed for DSX by Amptek, Inc. and is currently being completed by Assurance Technology Corporation (ATC).

C. Space Environmental Effects

1. Space Environment Testbed (SET)

The SET carrier (shown in Figure 13), under development by NASA GSFC provides standard mechanical, electrical, & thermal interfaces for a collection of small flight investigations. The general areas of investigation of the instruments carried on SET fall in the following categories:

1. Characterization of the space environment;
2. Performance improvement for microelectronics used in space;
3. Accommodation and/or Mitigation of Space Environment Effects for detectors & sensors
4. Accommodation and/or mitigation of charging/discharging effects on spacecraft & spacecraft components;
5. Definition of mechanisms for materials' degradation and performance characterization of materials designed for shielding from ionizing radiation.
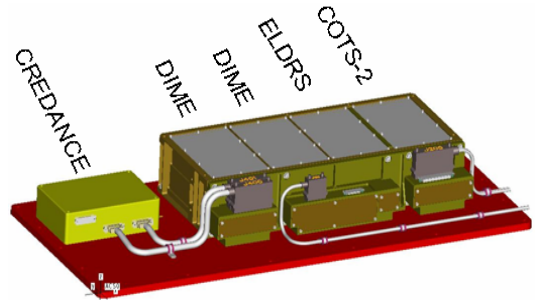

Figure 13: SET-1 (the red plate is non-flight).

The first SET mission, SET-1 consists of several specific investigations which are summarized on the following page.

Credance. Cosmic Ray Environment Dosimetery and Charging (Credance) measures the radiation environment (total dose), and the charging environment for normal background and during space weather events.   Credance specific measurements include:
1. Proton flux > 40 MeV per unit solid angle
2. Charge deposition in large silicon diodes arranged in telescopes. Pulse height analysis is used to obtain ion linear energy transfer (LET) spectra of heavy ions in the 100 MeV cm^2/g to 25000 MeV cm^2/g range
3. Threshold voltage shift as a function of time to measure total ionizing dose in silicon at two different shielding depths
4. Charging current at three different shielding depths which provides energetic electron flux measurements at three energies

Credance measurements overlap in part with the CEASE space weather instrument, and will provide for mutual validation and data correlation of both instruments. Credance has been developed by QinetiQ/UK.

DIME.   Dosimetry Intercomparison and Miniaturization (DIME) will measure space radiation environments which are detrimental to space system reliability using novel dosimetry techniques. DIME occupies two 3U card slots on the SET-1 carrier, and is being developed by Clemson University. Specific DIME measurements include:
1. Radiation-Sensing Field-Effect Transistor (RADFET) - threshold voltage shift as a function of time; converted to total ionizing dose.
2. Erasable Programmable Read-only Memory (EPROM) - threshold voltage shift as a function of time; converted to total ionizing dose. Also number of single event upsets as a function of time to measure rates as a function of radiation level.
3. Static Random Access Memory (SRAM) - hold devices at different voltages and measure single event upsets. Change in voltage at which an error occurs is converted to dose. Also number of single event upsets as a function of time to measure rates as a function of radiation level.
4. Linear Energy Transfer (LET) Spectrometer - pulse height spectra as function of time; converted to LET to measure ions including protons.
5. Optically Stimulated Luminescent (OSL) Films - visible emission spectrum as a function of time to measure micro-dose.

ELDRS.   Focused on characterization of Proton Effects and Enhanced Low Dose Rate Sensitivity (ELDRS) in Bipolar Junction Transistors (BJT), ELDRS measures space radiation induced total ionizing dose and displacement damage on linear devices sensitive to enhanced space low dose rate effects. ELDRS will measure base and collector currents for 24 commercial off-the-shelf (COTS) BJTs as functions of the emitter and gate voltages and time. ELDRS is being developed by Arizona State University.

COTS-2. COTS-2 measures particle induced single event effects on a single event effects mitigation platform in normal backgrounds and during solar storm events. COTS-2 will measure a single event effect (SEE) on COTS FPGAs, classify the event by event type, and determine if mitigation of the effect occurred without watchdog intervention. COTS-2 is being co-developed by NASA and CNES.

2. Photometers and Radiometers

DSX will fly several photometers and radiometers (see Figure 14), developed by AFRL's Propulsion Directorate (Edwards, AFB).   Together these will directly measure changes in optical transmission, thermal absorption and emission due to the MEO radiation environment.   Coupon level testing of specific developmental coatings intended for thin-film photovoltaics may also be performed using these sensors.
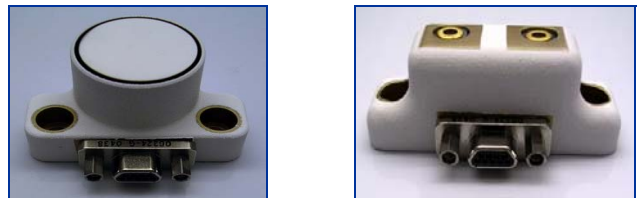

Figure 14: Radiometers (left) and Photometers (right).

IV. Enabling Technologies

Historically, spacecraft payloads have been produced via end-to-end development of the entire payload system as well as significant development of key satellite bus components with interfaces to the payload such as the flight computer and power management system. As part of this effort, a considerable fraction of the engineering development required to produce a working system is devoted to specifying, developing, and testing the components designed to perform payload functions that, in general, fall under the category of payload interface electronics for data acquisition and control. This approach is not conducive to rapid response missions because it depends on monolithic integration methods. Monolithic integration of a satellite involves assembly of many components simultaneously. This can present an integration and test nightmare, where debugging problems found in system level testing and routine maintenance of the vehicle can be very complex and costly to perform.

Modular integration on the other hand allows major subsystems and payload modules to be fully integrated and functionally tested separately. System level testing can be performed in a "FlatSat" configuration, pre-integration where the subsystems are wired together using test harnesses to verify connectivity as well as performing closed-loop performance tests. This allows for much faster isolation of problems and shorter integration spans.

DSX maximizes the benefits of modular integration via an architecture that requires that all devices adhere to a standard interface for control and communications (electrical, power, command & communications protocol). This is enabled by the use of dual-redundant network interface cards (NIC) in the Experiment Computer System (ECS) chassis that provide for command and data interface between the flight control computer and all payloads. Rather than a single on-board computer responsible for handling all spacecraft functions, DSX unburdens the main spacecraft computer with the payload related operations, by providing a dedicated payload interface computer, or Experiment Computer System, under development by Planning Systems, Inc. for DSX. This architecture decouples the requirements of the flight computer with the design of the payloads, allowing for a completely standardized spacecraft flight computer, almost independent of payload requirements. The highly capable ECS design is also generalized in nature, so that it can handle a wide range of payload types and classes simultaneously, with low data latency. An ECS block diagram is provided in Figure 15.

These modular avionics technologies complement the modular reconfigurable mechanical design, and together represent a possible path finder for future rapid-response spacecraft. With this approach, the DSX avionics module can be designed, integrated, and delivered before all the payloads have completed their development cycle, or even been selected. The next evolutionary step for this technology involves adding networking capabilities and enhancing the flight control computer so they are pre-programmed to self-configure spacecraft subsystems, components, devices, and payloads. This allows for rapid configuration and integration of off-the-shelf, modular spacecraft consisting of pre-defined building blocks "on the fly".
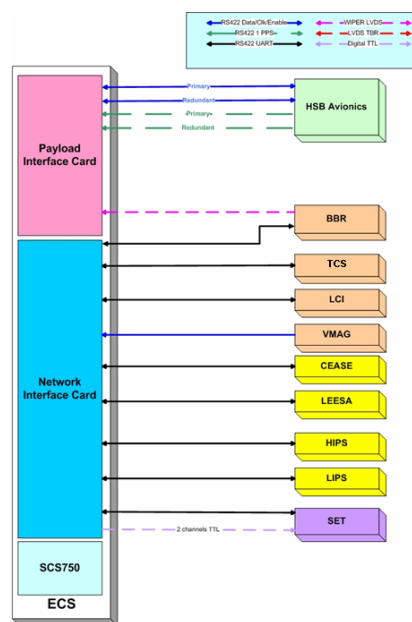

Figure 15: Experiment Computer

V. Concept of Operations (CONOPS)

The DSX mission starts with launch as a secondary payload on an EELV. During launch DSX is in a minimally powered state, so that it may detect a separation signal. Following separation of the primary payload from atop DSX, it is likely that the EELV upper-stage would need to be re-started in order to inject DSX into the correct orbit. At this point DSX then separates from the upper stage. Upon detection of the separation signal, DSX will undergo a series of autonomous scripted commands to initialize the bus. After acquisition of signal from the ground, and verification of nominal operation, the bus solar array deploys from the avionics module, and the attitude control system is activated in a sun-safe mode in order to orient the spacecraft into a power-positive attitude. Ground controllers will then perform various checks to verify the spacecraft state of health before initiating any boom deployments. Booms will be deployed in pairs: y-axis pair and z-axis pair, to minimize inertial imbalances. During

boom deployments the attitude control system is placed in a less responsive mode in consideration of the fact that during deployments the center of pressure and moments of inertia of the spacecraft will vary significantly. Upon completion of these deployments, additional in-orbit tests are performed before the spacecraft assumes an operational mode. The scheduling of the sequence of events from separation though entering the operational phase is being developed, but is expected to be accomplished in under one week.

Once the spacecraft is operational, routine commanding and data collection will be initiated as discussed in Section II-A (Ground Segment). Because spacecraft resources (namely power and data volume) are limited, and because certain experiments can only be operated at certain times, experimental payloads are duty cycled to fit within the capabilities of the spacecraft. In general, SWx instruments will operate continuously with only limited ground intervention, such as occasional commanding to adjust threshold and gain settings. They would only be turned off under low power conditions. The SET-1 payload will have two modes of operation, a low power mode where only Credance is powered and collecting data, and the normal, high power mode where all its experiment investigations are operating. While in normal mode measurements take place on a set interval, with some measurements triggered by the on-board orbit propagator, which will indicate to SET-1 the timing of ascending and descending node crossings. The most demanding constraints are associated with the WPIx measurements, since these consume the greatest power (during the high power Whistler transmission mode), and also generate the most data, as collected from the broadband receiver. For science reasons, the high power transmissions can be constrained to occur when the spacecraft is within ±20° latitude of equatorial, and because of power limitations the transmission durations will generally be limited to no more then 30 minutes per orbit. A detailed year-long mission timeline is being prepared to plan all DSX operations and coordinate ground resources.

VI. Summary

AFRL's DSX mission is well underway. The Spacecraft Systems Requirements (SRR) was completed in the fall of 2004. Avionics, spacecraft bus, and Experiment Computer System Critical Design Reviews (CDRs) were completed in 2005 and 2006, and all the science payloads have finished their Preliminary Design Reviews (PDRs) this year. The DSX team plans to have payload CDRs in the coming months with a goal of system CDR by the second quarter of 2007 With the fully integrated avionics module, depopulated payload module, and ESPA ring scheduled for delivery to AFRL by the end of the third quarter of 2007, and all flight payloads delivered for AI&T by August 2008, DSX is currently on track to be launch ready by late 2009.

The DSX mission will provide an important database from which future designers of space missions intended to operate in the MEO environment can rely.

- New climatology models for satellite design in MEO will be developed as a result of DSX

- Key wave-particle interaction components of global radiation belt space situational awareness and forecast models will be developed and validated from the DSX data

- New methods for rugedizing electronics for MEO will be tested

Beyond the value of the scientific experiments, DSX is also path-finding a new, responsive approach for integrating spacecraft. The ESPA platform ensures affordable and frequent opportunities for launch. The modular spacecraft design allows reconfiguration for multiple launch vehicles, as secondary or primary – this flexibility maximizes DSX's manifest opportunities. In addition, the combination of a dedicated payload/experiment computer and modular integration approach, allows a "standard" host spacecraft bus to be used, limiting the development risk to the experiments alone.

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