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## Paper Session III-B - The Advanced Research and Global Observation Satellite (ARGOS) - Pioneering Advancements in Space

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# **The Advanced Research and Global Observation Satellite (ARGOS) - Pioneering Advancements in Space**

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## **Abstract**

The Advanced Research and Global Observation Satellite (ARGOS) is the largest (6000 lb.) Air Force Research and Development (R&D) satellite ever to fly. The mission responds to the periodic need to fly large, heavy, or high power R&D payloads. The Space Vehicle pioneers a number of innovations in advanced space systems, providing operational support for eight DoD experiments, which themselves are demonstrating a number of advancements in space hardware. ARGOS innovations include integration of low risk advanced features such as a radiation hardened flight computer, the first complete GPS receiver embedded within the flight computer for position determination and time reference, and an extremely accurate attitude determination and control system. In addition, ARGOS uses scaled up solid-state recorder, mass storage to provide 2.6 Gigabits of onboard data storage. This is the first space vehicle which combines such accurate positioning and pointing with abundant storage/retrieval capabilities for a suite of imaging sensors. Other ARGOS innovations include: four 15.5” high-angular-momentum reaction wheels - the largest to be flown to date; a next generation nickel hydrogen (NiH<sub>2</sub>) battery rated at 45 A-hr; advanced technology Ring Laser Gyros, 40°/0 the size of standard RLGs, and High Output Paraffin (HOP) thermal actuators for payload deployment- significantly reducing unique circuitry while satisfying stringent range safety requirements.

## **1. Background**

ARGOS is managed out of the Space Test Program (STP) based at Kirtland AFB, NM. STP is a Department of Defense (DoD) tri-service program under the executive management of the Air Force Space and Missile Systems Center (AF/SMC). STP's mission is to support the exploitation of Air and Space by providing World Class Space and Missile Research and Development, Test and Evaluation Services. All of the experiments which fly on STP missions are ranked first by the individual services and then by a Tri-Service DoD Space Experiments Review Board (SERB). The top DoD ranked experiments are then assembled into a viable mission complement by STP considering orbit, mission, and funding. STP then uses available budget, and searches for the most cost effective mechanisms to reach space. ARGOS is a 6000 lb class spacecraft which spans over 44 ft across the solar arrays. It will carry eight

experiments, two technology demonstrations and six payloads for global, celestial, and atmospheric phenomenology observations.

ARGOS is scheduled to launch from Vandenberg Air Force Base in the spring of 1997 on a Delta II 7920-10 launch vehicle. The final orbit is 450 nm circular, with an inclination of 98.7 deg. The intent is to be sun-synchronous with either a morning or afternoon ascending node to allow remote sensing of the entire earth each day while providing consistent observing conditions that permit scientists to study diurnal and seasonal changes more readily. The Integrated Space Vehicle (ISV) is being constructed by Rockwell International, Space Systems Division, Seal Beach, CA.

## **2. Payload Overview and Innovations**

ARGOS's eight primary experiments contain 31 sub-experiments valued at \$67M. These experiments are sponsored by Air Force, Navy, and Army customers. In addition to providing science data, a number of the experiments are also proving out technology never flown in space before and demonstrate significant technical advancements that will benefit a number of operational programs such as DMSP, DSCS, and Brilliant Eyes. Each of the primary experiments is summarized below with their science objectives and noteworthy technical innovations.

### **2.1- High Temperature Superconductivity Space Experiment (HTSSE II)**

High Temperature Superconductivity (HTS) has been selected as one of DoD's top 10 critical technologies. HTS is an important emerging technology with the potential for major breakthroughs in spacecraft operational capability. HTS digital technology offers more than 10 times higher speed than Si or GaAs. Factors of 100 to 1000 in power reduction and a 10 times reduction in weight are feasible. HTSSE II is a 290 lb experiment which will space qualify HTS digital and RF components, parts, and subsystems to demonstrate in space the capability of this new technology. HTSSE II results will enable DoD spacecraft designers to evaluate the benefits of HTS components and subsystems for future spacecraft. An advanced cryocooler (which could be used for focal plane arrays and cooled semiconductors as well as HTS devices) will be demonstrated. Space radiation effects and survivability of HTS devices will also be measured by the experiment. The operation of multiple semiconductor devices at high superconductivity temperature (77K) will be demonstrated. HTSSE II is sponsored by the Naval Research Laboratory/Naval Center for Space Technology; it was ranked #2 by the 1992 DoD SERB.

## **2.2- Unconventional Stellar Aspect (USA)**

USA will characterize astronomical X-ray sources for potential use as autonomous position, attitude and time keeping references for military space systems. USA will also perform the first X-ray tomographic survey of the earth's atmosphere. The experiment will track and measure X-ray sources on orbit, providing extremely precise timing resolution critical for autonomous navigation. USA combines the reflight of detectors flown successfully on the short-duration NASA Spartan-1 mission with state-of-the-art processor technology for data handling and time/position determination. USA will provide a platform for the first orbital test of three rad-hard 32-bit (RH32) space computers developed by BMDO for Brilliant Eyes and other applications. The computers will be space qualified on ARGOS by performing real-time navigation computations in a legitimate space radiation environment. The augmentation of a proven X-ray detector design with advanced computers will help to demonstrate the feasibility of autonomous satellite navigation. USA is sponsored by the Naval Research Laboratory/Space Science Division, it was ranked #22 by the 1990 DoD SERB; its weight is approximately 508 lb.

## **2.3- Electric Propulsion Space Experiment (ESEX)**

ESEX will prove high-power arcjet propulsion, a crucial technology needed to support cost effective access to space. ESEX weighs approximately 1038 lbs, and will demonstrate orbit transfer, circularization, and adjustment, verify compatibility with spacecraft subsystems, and space qualify the largest power system ever orbited (26 kW). ESEX will demonstrate reliable arcjet thruster operation in space without interfering with electrical, thermal, or contamination constraints of the host spacecraft. Electric propulsion will double the payload-to-orbit capability of an Atlas II and make it possible to use an Atlas or Delta instead of a Titan IV for many high orbit altitude payloads, reducing launch costs by a factor of ten. Electric propulsion also addresses the DoD spacelift and maneuvering requirements for global surveillance and communications orbits and the application of advanced technology in order to reduce life cycle costs. MILSATCOM has expressed interest in arc-jet thrusters for DSCS and other communication satellite systems. Tracking ESEX with ground radar and optical sites will allow characterization of the arcjet's electromagnetic and visual signature. ESEX is sponsored by the AF Phillips Laboratory Space Propulsion Branch; it was ranked #13 by the 1990 DoD SERB.

## **2.4- High Resolution Airglow and Auroral Spectrograph (HIRAAS)**

Extreme UV imaging of the ionosphere is required to improve a number of DoD systems that depend on radio and microwave propagation through the upper atmosphere and

ionosphere. Neutral density measurements will support standing NORAD operational requirements to improve satellite drag forecasting and the ability to predict orbital life and re-entry impact locations. The end product will be an improved environmental model for predicting effects of the ionosphere on communications and eventually a “weather” prediction of the upper atmosphere for operational use. HIRAAS is a 268 lb. multi-instrument experiment package containing three ultraviolet spectrographs to measure naturally occurring atmospheric emissions. One of the instruments (SSULI/LORAAS) is a demonstration/validation for a developmental DMSP operational sensor, and will provide proof of concept and early meteorological data three years before the DMSP sensor is launched. HIRAAS is sponsored by the Naval Research Laboratory/Upper Atmospheric Physics Branch; it was ranked #5 by the 1990 DoD SERB.

### **2.5- Extreme Ultraviolet Imaging Photometer (EUVIP)**

EUVIP will establish the behavior of the upper atmosphere and plasmasphere as needed for Army RF systems design, prediction of magnetic storms, and characterization of the aurora. This data will improve existing data bases of background intensity levels against which rocket plumes can be observed. EUVIP will observe the earth horizon and stellar environment to measure background radiation and provide information on variations in space and time for future sensor design. The end product will be an improved model for predicting effects of the upper atmosphere on communication systems. EUVIP is sponsored by the US Army Space and Strategic Defense Command and built by the University of California at Berkeley Extreme UV Astrophysics Laboratory, it was ranked #8 by the 1990 Tri-service SERB, its weight is approximately 156 lbs.

### **2.6- Global Imaging Monitor of the Ionosphere (GIMI)**

GIMI is a follow-on to the short duration, Shuttle-bay, far UV, film-based cameras which established the feasibility and utility of far UV imaging. GIMI will demonstrate operational Charged Coupled Device (CCD) sensor technology for environmental monitoring of upper atmospheric perturbation due to meteors, rocket exhausts, and aurora. Use of wide-field sensors in three separate wavelengths will enable GIMI to continuously image 350 square nm areas of the Earth’s limb. When integrated over the entire polar orbit, this will provide DoD users with an improved capability to obtain global ionospheric “weather” coverage. The significantly increased mission duration, wide-field coverage, and CCD technology will provide substantial improvements to our knowledge of the ionosphere, and aid in detecting unpredictable events such as rocket launches. GIMI is sponsored by the Naval Research

Laboratory/Space Science Division; it was ranked #19 by the 1990 DoD SERB, and its weight is approximately 289 lb.

### **2.7- Critical Ionization Velocity (CIV)**

CIV will release Xenon and CO<sub>2</sub> to study ionization processes caused by molecular collisions in the upper atmosphere. The results will be used to help identify plumes and atmospheric wakes of launch vehicles. This experiment improves on an existing CIV data base by using ground sensors to observe releases performed at a greater orbital velocity and with ten times the release volume of previous attempts. This also allows assessment of existing ground sensor performance, possibly eliminating the need to develop future sensors. CIV is sponsored by the AF Phillips Laboratory Spacecraft Environments Branch; it was ranked #9 by the 1990 DoD SERB, and its weight is approximately 402 lb.

### **2.8- Space Dust Experiment (SPADUS)**

SPADUS will provide definitive measurements of orbital debris in a highly populated DoD orbit. SPADUS responds to key operational needs for space survival set forth in the 1987 DoD Space Policy. SPADUS also supports the National Space Council's call for speed-up of work to characterize orbital debris. This effort will result in a 3-D survey map of the present dust distribution in low earth polar orbit and allow prediction of orbital debris "showers" which could affect DoD spacecraft, the Space Shuttle, and Space Station. SPADUS also includes ancillary diagnostics to measure the local radiation environment. Experiment results will help spacecraft shielding and electronics design; extending space vehicle lifetimes. SPADUS will also obtain early flight experience for sensors and electronics which are planned for Space Station Freedom and the Cassini mission to Saturn in 1998. SPADUS is sponsored by the Office of Naval Research/Electronics Division and built by the University of Chicago Enrico Fermi Institute/ Laboratory for Astrophysics and Space Research; it was ranked #33 by the 1990 DoD SERB, and its weight is approximately 51 lb.

## **3.0 Spacecraft Innovations**

In addition to the advancements mentioned above in the experiment overviews, the ARGOS spacecraft has a number of components which represent significant advancements in the state of the art for space systems. It was not the intent of this program to add additional risk by using previously unflown components; each component went through extensive development and acceptance testing at the vendor or at the Rockwell facility in the case that it was not subcontracted out. An overview of these components follows in the section below.

A 2.6 Gigabit Solid State Data Recorder (SSDR) by SEAKR Engineering, Torrance, CA is to be used for storage of payload image data. To date the largest known SSDR flown, was a 2.0 Gig capacity on Clementine. The ARGOS data storage system provides over 10.4 Gigabits per day of experiment data, and supports data transfer rates of up to 8 Megabits per second, data output is in NRZ-L format. It has a playback capability at 1.024, 4.096, or 5.0 MBPS for wideband downlink. Its bit error rate is less than or equal to 1 bit in 10 billion. It also provides redundant input/output interfaces, required command and measurement interfaces, state of the art error detection and correction (EDAC) and remap capabilities, and nominal data playback of stored data allows simultaneous record and playback. The recorder cost is minimized through the use of commercially available 4 Megabit dynamic RAM chips. These storage/retrieval capabilities combined with a suite of high data rate imaging sensors provides a unique opportunity for cost effective data return. Operational power is 20W max, and standby power is only 10W max. SSDR recording and playback times are summarized in the table below.

**Table 1.0- SSDR Recording and Playback Time**

Record Capability	Playback Capability
5.2 Hrs @ 128 KBPS	39 Min @ 1.024 MBPS
10.4 HrS @ 64 KBPS	9.8 Min @ 4.096 MBPS
16.7 Hrs @ 40 KBPS	8.0 Min @ 5.0 MBPS

The ARGOS GPS, a Rockwell Autonetics Electronics System Division (AESD) GPS receiver is the first space application of a complete GPS receiver to be implemented as a redundant embedded chipset within the flight computer. This provides on board correlation of science data to Universal Time Coordinated (UTC) to within 100 nanoseconds. Each second, a UTC time representation is broadcast to experiments across the MIL STD 1553 data bus. For more precise correlation, a one Hz synchronization pulse is provided to indicate when the broadcast time is valid. This provides an accurate reference to the flight computers for the individual experiments, to better facilitate post flight correlation of data between experiments of simultaneous observations. In addition to facilitating open loop pointing computations, GPS position and velocity are also broadcast to the experiments on the data bus. The ADACS software also utilizes this signal to update and check its position against that from the gyrocompasses.

The Attitude Determination and Control System (ADACS), a combination of both hardware and software, provides the spacecraft with the capability to maintain attitude control within 0.3 degrees, attitude knowledge within 0.05 degrees, jitter of only 0.017 degrees, drift plus jitter within 0.03 degrees over 100 sees, position knowledge within 15 meters SEP, velocity knowledge to within 0.08 meters/see accuracy and time to within 100 nanoseconds from the onboard GPS receiver. The hardware components of the ADAC system are the reaction wheels, electromagnets, horizon sensors, inertial reference units, and magnetometers.

ARGOS will utilize four (15.5" diam x 6.5") next-generation high angular momentum (45 ft-lb-sec @ 4775 RPM) Reaction Wheels (Type E) developed under Ithaco IR&D funding. The reaction wheels provide a vehicle slew rate capacity of up to two degrees/second in each axis. No-Load speed is 7000 RPM max, 6000 RPM minimum. coast down time is greater than 70 minutes and run-up time is less than 266 seconds. The reaction wheels have a lifetime expectancy of greater than 3 years.

The ARGOS Inertial Reference Units (IRU) is another significant step forward, it will consist of 3 of Honeywell's new Ring Laser Gyros (RLG), which are only 40% the size of standard gyros, in addition to the Inertial Attitude Electronics to provide electronic processing. The IRU system's angle rate range is  $\pm 5$  deg/sec, with a bias repeatability  $\leq 0.02$  deg/hr ( $1 \sigma$ ). Random walk is not to exceed 0.005 deg/hr ( $1 \sigma$ ), while magnetic sensitivity is  $\leq 0.02$  deg/hr/Gauss. Noise equivalent angles are  $\leq 18$  arc-see (1 hr) and  $\leq 3$  arc-see (100 see). The IRU system is accurate to a 0.04 deg/hr drift rate.

Two next generation nickel hydrogen (NiH<sub>2</sub>) batteries rated at 45 A-hr, developed by Eagle Picher, Joplin, MO are used to provide power during eclipse or during any period where load requirements exceed solar array power. Each battery contains 22 independent pressure vessel cells connected in series. The two batteries are integrated into one assembly with a common radiator. Each cell is installed in an electrically insulated mounting sleeve. The aluminum mounting sleeve provides the primary heat flow path from the cells to the SV radiator. The batteries also have real-time pressure transducer telemetry to aid the operators in determination of state charge.

The ARGOS will feature a Rockwell RI-1750AB processor. This is a high performance, (~4MIPS at 20 Mhz), radiation hard, 16 bit processor that implements the MIL STD 1750 architectures. It features 1.25 micron CMOS/Silicon on Sapphire technology to provide a latchup immune processor capable of withstanding upwards of 1 Mrad (Si) total dose.

High Output Paraffin (HOP) Thermal Actuators built by Starsys Research Corp., Boulder, CO, will be used by a number of the experiments as payload deployment devices. Paraffin actuators utilize the volumetric expansion of paraffin that occurs during solid to liquid

phase change to drive an actuator. These actuators replace the more conventional pyres and greatly reduce range safety compliance costs. Pyro circuits require significant more redundancy and checkout prior to arrival at the range.

Another innovative item of note is the ARGOS philosophy of factory to pad. ARGOS is undergoing 27 weeks of comprehensive integrated space vehicle testing at the Rockwell facility. This testing will include integrated system, functional, environmental, RF compatibility, and a total end-to-end test. Once ARGOS successfully completes this extensive testing sequence, it will be packed and shipped to the launch pad at Vandenberg AFB. After arrival at the pad the testing required will be minimal, only 4 weeks for integration and check out with the Delta II launch vehicle. This is in contrast to the normal sequence where the ISV is tested at the factory and then shipped to the launch pad for another whole sequence functional testing followed by integrated testing in conjunction with the launch vehicle.

#### **4.0 Conclusion**

All of these innovations do not come without cost. Advancing the state-of-the-art is always a complex iterative process both in the laboratory and on the manufacturing floor. We have experienced a number of technical hurdles and subsequent cost growth throughout the 5 year development process, but none of these have not been overcome by an exemplary teaming of Rockwell International, the Air Force, and Aerospace Corp., our support contractor. Once we achieve our orbit and begin supplying science data a number of DoD programs will begin benefiting from the advances we have made in the development of the ARGOS spacecraft and its experiment compliment.

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