The Orbiting Astrophysical Observatory In Space (OASIS)

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***Abstract*. The Orbiting Astrophysical Observatory In Space (OASIS) is an Advanced Concept currently under study at NASA as a mission for the next decade. The goal of the OASIS mission is to identify a local site or sites where galactic cosmic rays (GCR) originate and are accelerated. The mission will also allow GCR data to be used to investigate how elements are made and distributed in the galaxy and to improve our understanding of supernovae and the nucleosynthesis of the heavy elements. OASIS consists of two instruments that provide complementary data on the location and nature of the source(s) through investigating the composition of ultra-heavy nuclei (Z ≥ 30) and the energy spectrum of electrons. In particular OASIS will measure the relative abundances in the actinide group ($90 \leq$ Z ≤ 96) to determine the age of the r-process material in GCRs. The presence of young r-process material would indicate that GCRs are a sample of the interstellar medium in OB associations. OASIS will measure the electron spectrum to $>$10 TeV. The energy where this spectrum ends will tell us the distance to the nearest GCR source(s). OASIS will look for spectral features and anisotropy in the high energy electron spectrum that are expected to appear when only a few of the nearest astrophysical sources can contribute to the electron flux. Spectral features may also suggest dark matter decay products. We anticipate that these measurements will lead to the identification of the nearest cosmic ray electron source and provide a crucial test of the OB association model for the origin of GCR nuclei.**

***Keywords*: cosmic rays, electrons, actinides**

I. Introduction

The Orbiting Astrophysical Observatory in Space (OASIS) is a mission to investigate Galactic Cosmic Rays (GCRs), a major feature of our galaxy. They affect the interstellar magnetic fields and the interstellar medium through which they move. OASIS will use measurements of GCRs to determine the cosmic ray source, where they are accelerated, to investigate local accelerators and to learn about the interstellar medium and the processes that occur in it.

It is believed that supernova explosions energize most GCRs, but the locations of the GCR sources are uncertain. As GCRs diffuse through the interstellar magnetic field the diffusion randomizes their directions so GCRs arriving at Earth do not point back to their sources. Instead, measurements of their composition, energy spectra, and possibly anisotropy in the arrival directions of TeV electrons must be used to learn about their origin.

OASIS will determine the astrophysical sources of both the material and acceleration of GCRs by measuring the abundances of the rare actinide nuclei and the spectrum and anisotropy of electrons up to energies of 10 TeV. The actinides have radioactive half-lives that span the ages of the GCRs; the presence of Pu and Cm would demonstrate GCR origin in regions of recent star formation. Because high-energy electrons lose energy rapidly, they must come from nearby sources; signatures of nearby sources would appear as peaks in the high-energy spectrum. The electrons in the peak from the nearest source may also show an anisotropic arrival distribution.

OASIS has two instruments. The Energetic Trans-Iron Composition Experiment [ENTICE, OG1.5] measures elemental composition. It resolves individual elements with atomic number $Z \geq 10$ and has a collecting power of 60 m^2-sr-yrs, >20 times larger than previous instruments, and with improved resolution. The sample of 10^{10} GCRs collected by ENTICE may include ≥100 well-resolved actinides. The High Energy Particle Calorimeter Telescope [HEPCaT, OG1.5] is an ionization calorimeter that will extend the electron spectrum to above the TeV region for the first time. It has 7.5 m^2-sr-yrs of collecting power. The HEPCaT will measure spectra of light nuclei from below 10^9 eV up to the knee region at 3×10^{15} eV. Figure 1 shows the ENTICE and HEPCaT modules integrated with the OASIS spacecraft. The HEPCaT looks toward the zenith with a full 120° field of view. ENTICE views cosmic rays entering either side from above the limb of the Earth. Details of the designs, performance and science objectives for each instrument are available in companion papers in these proceedings.

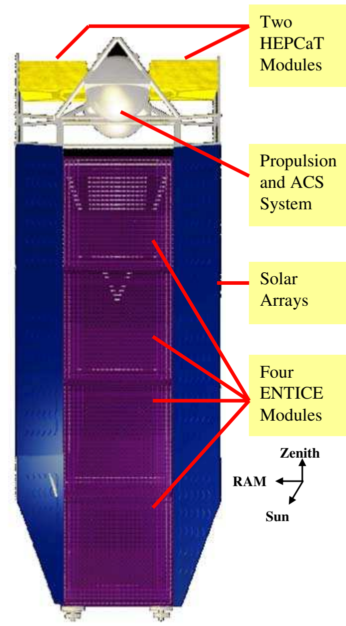

Fig. 1: The fully integrated OASIS spacecraft includes 4 ENTICE modules and 2 HEPCaT modules. The solar arrays extend nearly the full length of the spacecraft structure on either side of the ENTICE modules.

II. Mission and Spacecraft

OASIS will be launched into a 600 km circular sun-synchronous orbit on an Evolved Expendable Launch Vehicle (EELV). This orbit permits the use of a simple spacecraft with no moving parts (except valve motors) and passive attitude stabilization that satisfies the science requirements. The bus is designed for a nominal three-year mission with the potential for five years before drifting out of sun-synchronization and losing power. The OASIS spacecraft is launched with the heavy HEPCaT modules placed near the launch adapter on top of the upper stage of the launch vehicle (Figure 2). After achieving orbit, OASIS uses its hypergolic bipropellant propulsion and attitude control system (PACS) to re-orient the spacecraft so that the HEPCaT modules point toward the zenith and lie in the orbital plane. This is a stable orientation for the spacecraft. OASIS will remain in this gravity-gradient and orbital-gradient stabilized orientation for the entire mission. OASIS will have an average of 25.7 downlink opportunities per day (through Svalbard, Alaska, and Wallops), providing a large margin for data recovery. Because of its mass, OASIS is not allowed an uncontrolled re-entry. The PACS is needed at the end of the mission to execute a controlled reentry into the Pacific Ocean off the west coast of the Americas and far from any populated areas.

The OASIS spacecraft will be installed in a 5 m diameter Atlas−V long fairing (Figure 2). The large surface area of the spacecraft will interact with the acoustic environment during launch. A bowtie truss design is used to deflect acoustic loads and stiffen the long spacecraft structure. Finite Element Modeling (FEM) confirms the structure will withstand the axial, lateral and acoustic loads during launch. The planned launch vehicle adapter will connect to the outer frame of OASIS with 6 explosive bolts for quick and simple separation at orbit insertion.

OASIS maintains instrument temperatures between -10/+40 °C primarily by using passive means. Keep-alive heaters are used on the instruments when they are powered down and there are line heaters on the propellant tanks and feed lines. OASIS is protected from the micrometeoroid and orbital debris (MMOD) environment with armored multi-layer insulation (MLI). More impacts are expected on the leading edge of the bowtie truss which faces in the ram direction. The exposed propellant tanks are also at risk from MMOD and require armored MLI. The entire spacecraft will be kept within NASA risk guidelines.

The power subsystem uses 16.3 m^2 of body-mounted solar arrays and has sufficient battery storage capacity for initial start up, to sustain operations during eclipse periods and with sufficient reserve capacity for a 5 year mission. Some reduction in power generation efficiency is experienced because of the angle of the bowtie truss to the incoming solar illumination. This loss is accounted for in the power subsystem calculations and the design provides additional tolerance for yaw errors. After 5 years of operations power generation will gradually decrease with loss of synchronization to the Sun.

The Attitude Control Subsystem (ACS) uses horizon sensors, magnetometers and Global Positioning System (GPS) receivers to provide redundancy in determining orientation of the vehicle. During the mission it is used to satisfy the science requirement of 1° pointing knowledge which is not difficult to achieve. Analyses show that the passive orbit stabilization will be sufficient to null out perturbing torques. No ACS maneuvers are expected during nominal operation. But as a contingency, sufficient PACS propellant is available for reorienting the vehicle should that become necessary. The instrument

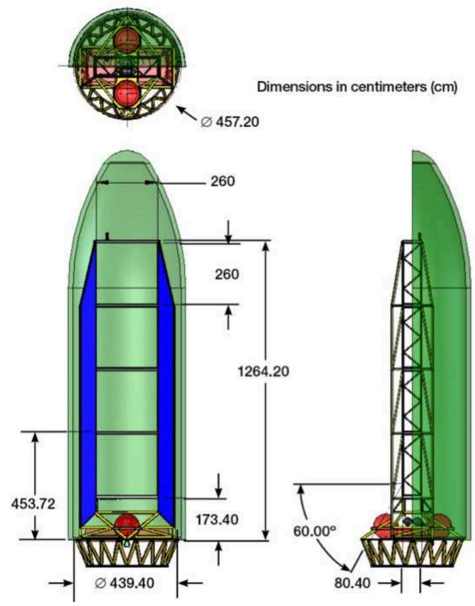

Fig. 2: Views of the OASIS spacecraft integrted in the Atlas−V fairing for launch. The spacecraft is attached to the launch vehicle adapter near the HEPCaT modules at the bottom of the figure.

	Mission		Instruments	
Category	Capability	Required	ENTICE	HEPCaT
Power (watts)	>3000	1920*	510	727
Mass (kgs)	13588	13424	2800	5200
Volume per module (m^3)			2.7×2.8×0.8	1.5×1.5×0.6
Field of View			120°	120°
Pointing (all axes) Requirement: Knowledge:	<5° <0.1°	±30° ±0.1°	±30° ±0.1°	±30° ±0.1°
Telemetry	1 Mbps 222min/day**	612 kbps 117min/day	40 kbps average	564 kbps average
Thermal	-10/+40°C	-20/+50°C	-30/+40°C	-30/+35°C

Table 1: Mission requirements and resource capabilities. *includes 30% contingency **using ground stations in Alaska, Svalbard, and Wallops, as well as others as available

resource requirements are given in Table 1 which also shows that the capabilities of the spacecraft exceed the required performance for the OASIS mission.

The PACS for OASIS is based on the configuration in the Solar Dynamics Observatory. This configuration is well understood and at a mature level of design. Helium pressurant tanks pressurize monomethyl hydrazine (MMH or CH_3NHNH_2) and Nitrogen tetroxide (N_2O_4) tanks which feed bi-propellant main and attitude control thrusters. All engines and tanks are standard and available COTS.

The launch vehicle chosen to meet the requirements for this mission is an Atlas−V 551. An upgrade to an Atlas−V 552 is possible if the OASIS mass grows beyond the allotted mass growth allowance of 30%. The long 5-m fairing was chosen to accommodate the OASIS spacecraft, fully deployed in the operational configuration, and avoiding the use of mechanisms. The initial design for the OASIS bus has been reviewed by an independent engineering team and several significant refinements have been incorporated. This process resulted in a robust design with high operational and programmatic reliability for the mission. The engineering teams have no design issues at this stage of the development.

The OASIS mission concept emphasizes use of well developed technologies, redundancy and minimizing high-risk operations. A major source of mission failure for any space endeavor has been deployment of booms, solar panels or instruments. These are all avoided in the OASIS mission. A sun-synchronous orbit minimizes power and thermal cycling experienced by the vehicle. The vehicle is designed for gravity and orbital gradient stabilization, requiring no active attitude control. The spacecraft is launched in the operational configuration.

III. Summary

OASIS is currently a NASA Advanced Mission Concept Study. The study has been completed and the final report submitted to NASA HQ for review. The science instruments use only proven technology; both are enlarged versions of instruments that have successfully flown in space and/or on high-altitude balloons. They are straightforward to build. The simple spacecraft bus relies only on previously flown systems. Together, these characteristics resulted in a Medium Mission classification for OASIS that uses mature technologies and has low risk with no new technology to be developed. OASIS is a candidate mission for early in the next decade and has been submitted to the ASTRO2010 Decadal Survey for recommendation to NASA.