Space Station Integrated Kinetic Launcher for Orbital Payload Systems (SSIKLOPS) – Cyclops

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ABSTRACT

Access to space for satellites in the 50-100 kg (110-220 lb) class is a challenge for the small satellite community. Rideshare opportunities are limited and costly, and the small satellite must adhere to the primary payloads schedule and launch needs. Launching as an auxiliary payload on an Expendable Launch Vehicle presents many technical, environmental, and logistical challenges to the small satellite community. To assist the community in mitigating these challenges, and in order to provide the community with greater access to space for 50-100 kg satellites, the NASA Johnson Space Center's (JSC) International Space Station (ISS) and Engineering communities in collaboration with the Department of Defense (DoD) Space Test Program (STP) is developing a dedicated 50-100 kg class ISS small satellite deployment system. The system, known as Cyclops, will utilize NASA's ISS resupply vehicles to launch small sats to the ISS in a controlled pressurized environment in soft stow bags. The satellites will then be processed through the ISS pressurized environment by the astronaut crew allowing satellite system diagnostics prior to orbit insertion. Orbit insertion is achieved through use of the Japan Aerospace Exploration Agency's Experiment Module Robotic Airlock (JEM Airlock), and one of the ISS Robotic Arms. Cyclops' initial satellite deployment demonstration of DoD STP's SpinSat and Texas A&M University (TAMU)/University of Texas at Austin (UT)'s LONESTAR-2 (Low earth Orbiting Navigation Experiment for Spacecraft Testing Autonomous Rendezvous and docking) satellites will likely be the summer of 2014. Cyclops will be housed on-board the ISS and used throughout its lifetime. The anatomy of Cyclops, its concept of operations for satellite deployment, and its satellite interfaces and requirements will be addressed further in this paper.

INTRODUCTION

Access to space for satellites in the 50-100 kg class is a challenge for the small satellite community. Rideshare opportunities are limited and costly, and the small sat must adhere to the primary payloads schedule and launch needs. Launching as an auxiliary payload on an Expendable Launch Vehicle presents many technical, environmental, and logistical challenges to the small satellite community. To assist the community in mitigating these challenges and in order to provide the community with greater access to space for 50-100 kg satellites, the NASA Johnson Space Center's (JSC) International Space Station (ISS) and Engineering communities in collaboration with the Department of Defense (DoD) Space Test Program (STP) is developing a dedicated 50-100 kg (110-220 lb) class ISS small satellite deployment system known as Cyclops.

Cyclops' anatomy and concept of operations for satellite deployment will be addressed as well as an outline of its demonstration mission. Upon successfully demonstration of Cyclops it will be stowed on-board the ISS as a payload facility for future deployments of satellites. Preliminary satellite requirements and satellite interfaces with Cyclops are also introduced.

CYCLOPS' ANATOMY

Cyclops' Anatomy is shown in figure 1. Cyclops interfaces with the JEM Airlock (AL) Slide Table, the ISS Robotic Arms, and the deployable satellites. It is being designed to be able to be utilized for the duration of the ISS mission for deployments of satellites. It is roughly a 127 cm L x 61 cm W x 7.6 cm H (50" L x 24" W x 3" H) platform capable of deploying satellites of any geometry up to 100 kg (220 lb) in size contingent upon the satellites meeting all Cyclops and ISS safety requirements. These requirements are under development and will be available from the ISS Program when completed. Preliminary discussion of these requirements is provided later in this publication.

Figure 1: Cyclops Anatomy

CONCEPT OF OPERATIONS

Cyclops, will be launched onboard one of NASA's ISS resupply vehicles in a controlled pressurized, soft stowed environment. It will then be removed from its launch configuration by the astronaut crew and placed in its stowed location until needed.

Once a satellite deployment has been scheduled, Cyclops will be removed from its on-orbit stowage bag and placed on the JEM Airlock Slide Table. The deployable satellite will be placed on Cyclops. Cyclops and its attached satellite will be processed through the JEM Airlock to the ISS external environment. Upon completion of JEM Airlock operations Cyclops and its attached satellite will be grasped by either the ISS robotic arm or the JEM robotic arm and transported to its predetermined deployment position. Cyclops will then deploy the satellite away from the ISS. After successful deployment of the satellite Cyclops will be maneuvered back to the JEM Airlock and secured on the JEM Airlock Slide Table. JEM Airlock operations will be conducted bringing Cyclops back inside the ISS where it will be removed from the JEM Airlock Slide Table and placed in its on-orbit stowage bag. This concept of operations is illustrated below in figure 2.

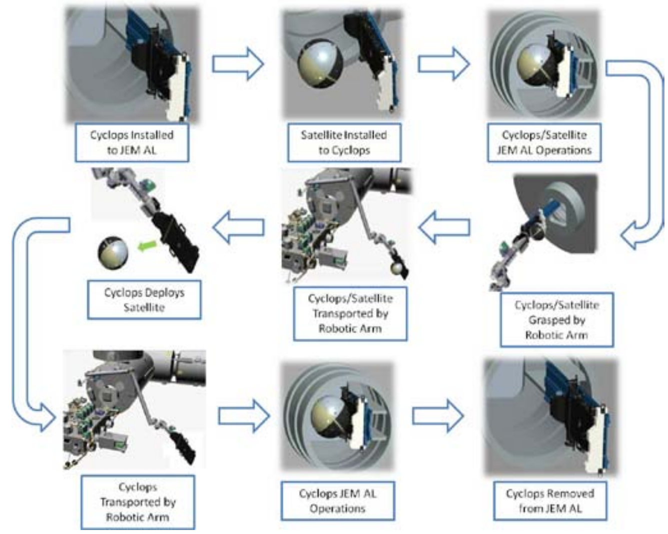

Figure 2: Cyclops' Concept of Operations

DEMONSTRATION MISSION

Cyclops is currently manifested on SpX-4 with its two demonstration mission satellites. SpX-4 is planned for April 2014 which would likely place deployment of these satellites in the late spring, summer timeframe. Cyclops' two demonstration mission satellites are the LONESTAR-2 and SpinSat satellites.

LONESTAR-2 is a combined TAMU/UT effort. It is 66 cm x 76.2 cm x 30.5 cm (26" x 30" x 12") and 56 kg (123 lb) in size. NASA JSC's LONESTAR program is a series of four missions in which two satellites will ultimately demonstrate autonomous rendezvous and docking capabilities. Each mission consists of a pair of satellites, one each built by TAMU and UT, demonstrating key technologies for development toward the final mission. The current mission, LONESTAR-2, consists of AggieSat4 with partner satellite Bevo-2 contained inside. The two satellites will be launched and deployed together from the ISS via the Cyclops. After deployment from the ISS, AggieSat4 will release Bevo-2 and conduct on-orbit operations, including taking photographs of one another, as well as other mission events, operating the on-board GPS, called Dragon, developed by the NASA JSC, stabilization and pointing control, and crosslink communicating between the satellites, sharing data for calculating relative navigation solutions.

SpinSat is a 55.9 cm (22") diameter, 57 kg (126 lb) DoD STP satellite. Built by the Naval Research Laboratory, SpinSat has three goals. The first goal is to characterize the performance of the Electronically-controlled Solid Propellant thrusters on orbit. The second goal is to test, stress, and assess the Space Surveillance Network's ability to observe and characterize state changes induced by the ESD firings. The final goal of the mission is to provide a calibrated drag experiment at higher solar activity than the Atmospheric Neutral Density Experiment Risk Reduction (ANDERR) and Atmospheric Neutral Density Experiment (ANDE) missions.

These satellites are preliminarily depicted in figure 3.

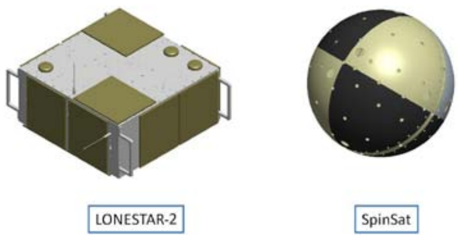

Figure 3: LONESTAR-2 and SpinSat Satellites

The satellites will be launched as pressurized cargo in the SpaceX Dragon vehicle, but could be launched as pressurized cargo in the ATV, HTV, or the Cygnus. Contained within foam padded soft stow cargo bags, the spacecraft only needs to meet the less stringent launch loads of soft-stow items. Multiple launch opportunities are available based on the readiness date of the satellites and the resupply vehicle manifest. To prepare for deployment, the crew removes the spacecraft from its stowage bag and attaches it to the Cyclops. The crew verifies the inhibit states and performs other actions such as removing handling fixtures, attaching antennas, or verifying the health of the spacecraft. After deployment, the spacecraft's transmitters will be inhibited on-board until it reaches a safe distance from the ISS. Deployment is expected to occur at approximately 400km in the retrograde direction.

PAYLOAD FACILITY

As mentioned previously Cyclops is being designed to operate for the duration of the ISS mission. Upon successful completion of its initial demonstration deployments Cyclops will be stowed on-board the ISS for future satellite deployments. To accomplish this Cyclops will be transferred from being a demonstration mission to being an ISS Payload Facility. As a payload facility it will be available for the duration of the ISS mission to accommodate satellite deployments approved by the ISS Program.

SATELLITE INTERFACES/REQUIREMENTS

The interface between Cyclops and the satellite is shown in figure 4. It attaches to the satellite via 3 bolts. It has a mass of approximately 0.11 kg (0.25 lb).

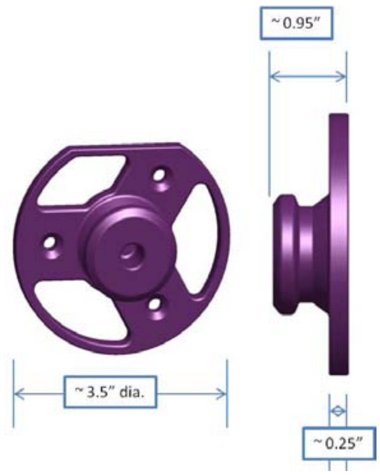

Figure 4: Experiment Attachment Interface between Cyclops and the Satellite.

The fixture attaches to the bottom of the satellite and interfaces with the Cyclops grapple system as shown in figures 5 and 6. It remains with the satellite at deployment.

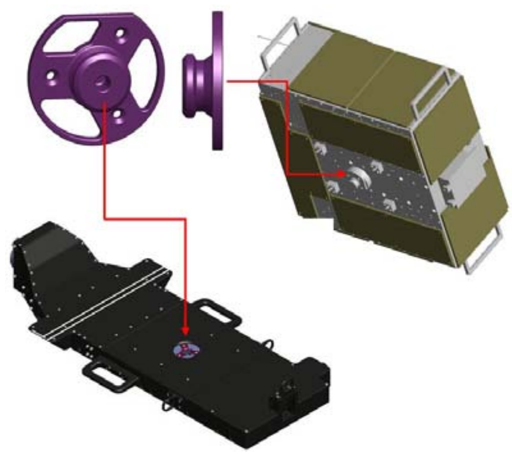

Figure 5: LONESTAR-2 to Cyclops Interface.

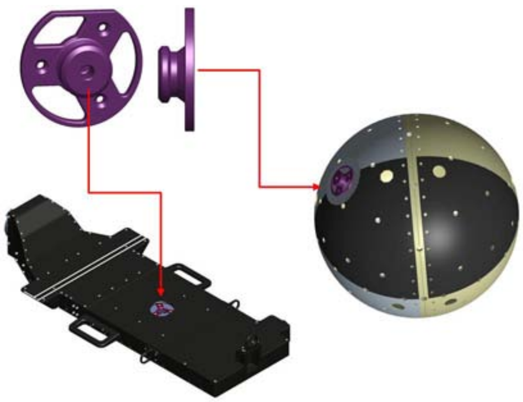

Figure 6: SpinSat to Cyclops Interface

Preliminary satellite requirements are listed in Table 1. Cyclops is working with the ISS Program to define the requirements that will be levied on the satellite users. These requirements will be published in the Cyclops to ISS Interface Control Document (ICD) and will be available to the satellites from the ISS Program.

Table 1: Preliminary Satellite Requirements for Cyclops' Deployment

REQUIREMENT	DESCRIPTION
Ballistic Number (BN)	Satellite shall have a ballistic number of 100 kg/m^2 or less. BN = Mass / (Frontal Area * Cd) where Cd=2.0
Center of Gravity (CG)	Satellite shall meet the defined Cyclops' defined CG corridor (TBD).
Deployment Force	The satellite shall be able to withstand the maximum force (TBD) applied from Cyclops at the deployment interface during deployment.
Electrical Bonding	The satellite shall provide a Class S electrical bonding path to Cyclops.
Impact	The satellite shall meet the ISS robotic arm potential transfer impact loads without creating debris.
Inhibit Switch Contact Surfaces	The satellite shall maintain keep out zones with its inhibit switch locations and contact surfaces.
Mass	Satellite shall meet the mass of 100kg or less (includes the mass of the experiment attachment fixture).
Safety	The satellite shall meet all ISS Payload Safety requirements.
Structural/Mechanical Interface	The satellite mounting interface to the experiment attachment fixture shall meet the Cyclops specified requirements (TBD)
Survivability	The satellite shall be capable of functioning after exposure to the external environment for no less than 10 hours unpowered.
Volume	The satellite shall meet the defined allowable envelope (figure 7).

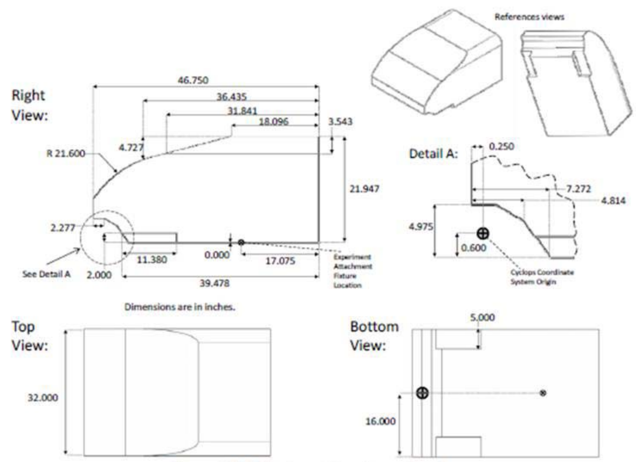

Figure 7: Cyclops' Allowable Satellite Envelope

Figures showing both the LONESTAR-2 and SpinSat satellites attached to Cyclops on the JEM AL Slide Table in the Cyclops satellite envelope are shown respectively in figures 8 and 9.

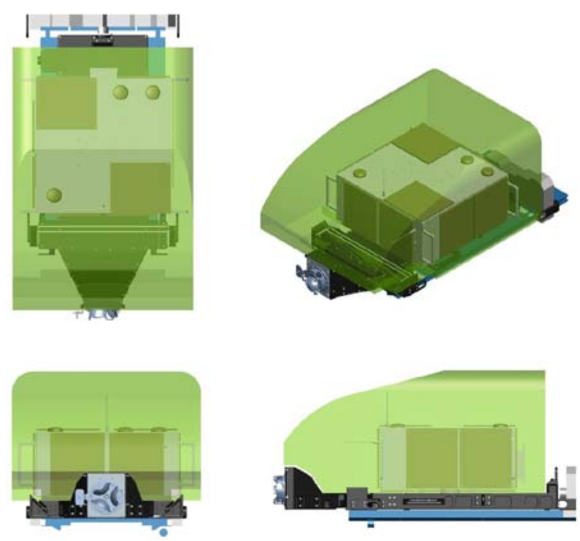

Figure 8: LONESTAR-2 Cyclops' Satellite Envelope

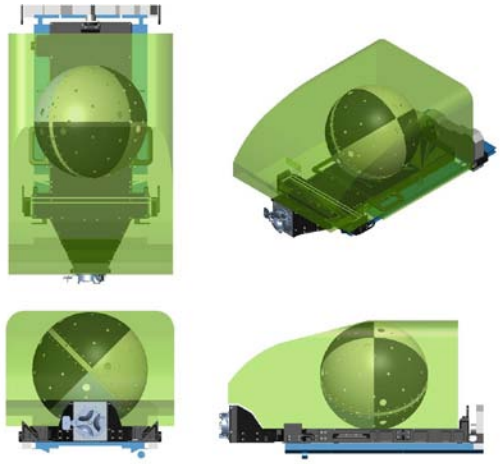

Figure 9: SpinSat in Cyclops' Satellite Envelope

CONCLUSION

NASA JSC's ISS and Engineering communities in collaboration with DoD STP is developing a dedicated 50-100 kg (110-220 lb) class ISS small satellite deployment system to provide the small satellite community another means for small satellite insertion. This system, known as Cyclops, will provide demonstration of its capability with the deployment of the LONESTAR-2 and SpinSat satellites likely in the summer of 2014. Once demonstration is completed it will remain on-board the ISS as a Payload Facility to be utilized by the ISS Program and small satellite community. Satellite interface requirements with Cyclops and the ISS are in development and will be available from the ISS Program upon completion.

ACKNOWLEDGEMENTS

Special thanks to the ISS Program, the DoD STP, and the NASA JSC Structural Engineering Division for their financial, resource, technical, integration, and safety support in the development and eventual successful operation of the Cyclops ISS satellite deployment system. Gratitude is also extended to the LONESTAR-2 and SpinSat teams for not only providing valuable data for this publication, but also patiently assisting in the development of a satellite deployment system that accommodates their needs as well as those of future satellite users.