

## Development of a NASA 6-U Satellite

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### ABSTRACT

NASA/Wallops Flight Facility has focused on the development of new technologies for the advancement of 6 Unit (6U) small satellites. From the design of the structure and instrument support hardware to improvements in the deployer, NASA is concentrating on maximizing the potential of small satellites for the benefit of science. The telemetry system provides much higher data rates than typical 1U UHF system. 6U provides up to several hundred kilobits per second and utilizes the existing NASA Ground Network for data reception. The guidance, navigation and control system keeps the satellite pointed within  $\pm 10^\circ$  of the sun and has knowledge of the sun vector within  $1^\circ$ . The 6U power design increased the options for different voltages and power switching capabilities and is capable of supporting instruments with higher power requirements. The Command & Data Handling (C&DH) system includes a low-power 520 MHz flight processor which provides more processing capability than existing 1U processor technologies. These optimized technologies will offer the science community a greater opportunity for flying more sophisticated and complex instruments.

### INTRODUCTION

In 2009, a Congressional appropriation was assigned to NASA Wallops Flight Facility (WFF) for the advancement of Unmanned Aerial Systems (UAS) and Small Satellite (SSAT) technologies. Part of this effort was to focus on developing a brassboard 6U small satellite with advanced capabilities.

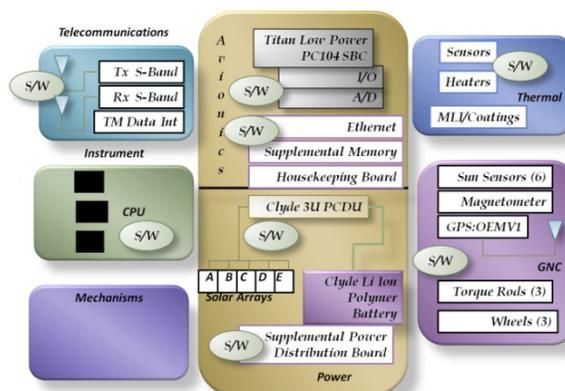
The first step the Wallops 6U Project Team performed in 2009 was to assess what hardware was currently available for small satellites. Based on the assessment of those capabilities, a decision was made as to what small satellite support subsystems needed enhancements. The focus was to optimize processing capabilities, data downlinks and maximize available volume while providing flexibility in the support systems and instruments layout.

Development of an architecture that would maximize optimization for science was the focus of the 6U design project team. These satellites can be used as a technology development test bed for advanced science instrumentation which will support the objectives of the various NASA science programs.

To further develop this technology, in 2010 Congress directed another appropriation to Wallops. The direction of this appropriation was to take the 6U brassboard design to a flight ready small satellite with a Technology Readiness Level (TRL) of 6 or higher.

This effort will be completed by September 2011. The following sections provide a summary of the various 6U support system elements.

Figure 1 shows the functional block diagram of the 6U small satellite.



**Figure 1: 6U Functional Block Diagram**

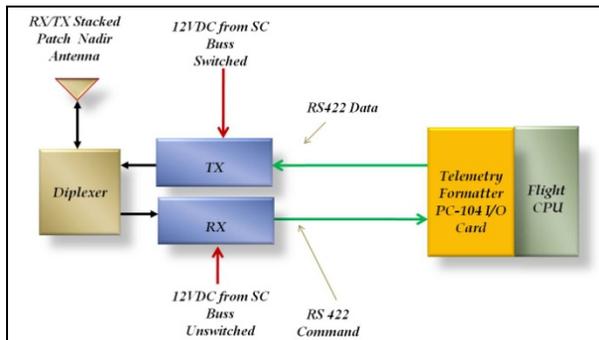
### TELEMETRY SYSTEM

The telemetry system was one of the key focus areas for change. Based on the desire to take advantage of the

available NASA Ground Network, 6U meets the following requirements.

1. Provide S-Band Telemetry and Command using NASA's Ground Network.
2. Design for a single S-Band Antenna (Nadir Pointing)
3. Design for a command rate of ~50Kbps
4. Design for downlink of at least 500 Kbps

Based on these requirements, the telemetry and the volume/power constraints of the small satellite are as shown in Figure 2.



**Figure 2: Telemetry Block Diagram**

The nadir pointing Receiver/Transmitter patch antenna normally is a standard 4" x 4" stacked patch antenna but was cut down to fit into the allowable space. It is now 3.5" (89mm) x 3.5" (89mm) x .216" (5.5mm). Figure 3 shows the pattern after the reduction in size.

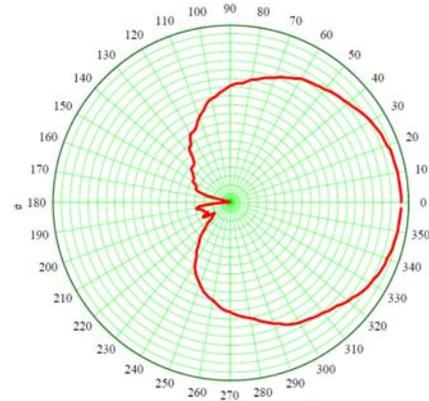
The diplexer is a small 0.40" H x 1.025" W x 2.95" L module. The custom made receiver is from Microwave Innovations. It is a single S-Band command receiver that supports FM/FSK and a command rate of 50Kbps. It measures 2.5" x 3.5" x .85" at 12 ounces while using less than 2 watts of total power.

The transmitter is an Emhiser model EDT. It uses 1 W of power at a 500 Kbps transmit rate. At 2 ounces and 2.5" H x 3.5" L x .85" D, it is a good fit for small satellites needing higher data rates.

The custom designed Telemetry Formatter card is a PC104 size footprint and is less than 3W. This board has four selectable data rates, 1Msps, 500Ksps, 250Ksps, and 10Ksps.

The Command data rate is 50Kbps. Return telemetry incorporates Reed-Solomon encoding and conforms to Consultative Committee for Space Data System (CCSDS) requirements.

The forward (command) link conforms to CCSDS supporting bit synchronized data and error detection.



Maximum on the plot is 8 dBic. 2 dB per division. Dual frequency patch antenna.

**Figure 3: Antenna Pattern**

Both the receiver and transmitter operate in the S-Band spectrum, making them compatible with the NASA Ground Network (Figure 4). This telemetry capability will broaden the opportunity for scientists to collect larger amounts of data on a more frequent basis.

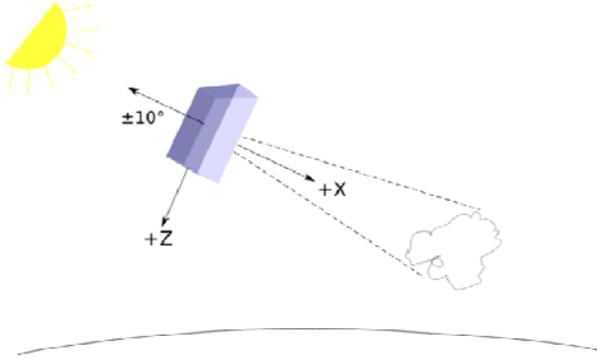


**Figure 4: NASA Ground Network**

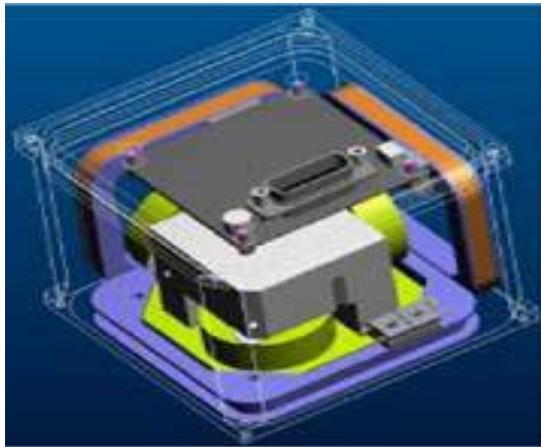
## GUIDANCE, NAVIGATION AND CONTROL (GNC) SYSTEMS

The NASA 6U meets the following requirements:

1. Point the observatory –X axis towards the sun within  $\pm 10$ degrees, Figure 5
2. Perform the initial target acquisition with initial body rates of 3 deg/s
3. Provide pointing knowledge of 1 degree (3 sigma) ECEF frame in the X, Y, and Z axes
4. Knowledge of the s/c position in EDI within 500m.



**Figure 5: Pointing Orientation**



**Figure 6: Attitude Control System**

The IMI-100 by Intellitech Microsystems (Figure 6) has 3 RWA (Reaction Wheel Assemblies) and MTBs (Magnetic Torque Bars) and a flight processor. As part of the package a TAM (three axes Magnetometer) is included. Each RWA stores up to 1mNm and has a maximum torque of 0.635 mNm. The MTB has a capability of 0.1 A-m<sup>3</sup>. Both of these capabilities meet the actuator sizing. The fine sun sensor is a 2-axis sensor developed by the University of Maryland Baltimore County. It will be used to provide high accuracy sun vector measurements. The 5 other sun sensors are LiCor LI-200 pyranometers. They will help in estimating the sun vector during acquisition of the sun. The last components of the GNC subsystem is a Novatel OEMV-1 GPS receiver and a 1.2" square patch antenna with a built-in LNA from Antcom.

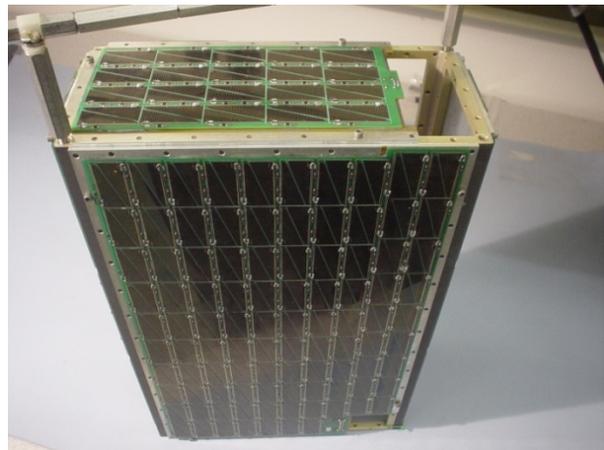
### POWER SYSTEM

The core design of the power system uses Clyde Space hardware. This hardware has been flown in many 3U

spacecrafts. To meet the additional requirements, some custom boards were designed and built, to include:

1. Provide operating voltages of 3.3V, 5V and 12V, regulated  $\pm 1\%$
2. Provide switching capability for the individual subsystems
3. Provide switched peak power during eclipse of 2.0W at 3.V3 and 12W at 5V
4. Provide switched peak power during sunlight of 2.0W at 3.3V, 12W at 5V and 55W at 12V.

One custom developed board, is the Auxiliary Power Board (APB). This board interfaces to the Clyde Space power system and to the remote batteries. Its primary purpose is to provide 12V to the payload. It provides some power switching and housekeeping via I<sup>2</sup>C. The other custom board provides power switching to all major systems in the payload. This switching is performed through I<sup>2</sup>C. The solar cells are mounted on 5 of the 6 sides. Figure 7 shows the solar cells mounted on the +X and -Z sides. The only side not containing cells are on the +Z side where the patch antenna is mounted.



**Figure 7: Photo of Structure with Solar Panels**

### COMMAND & DATA HANDLING

The Command & Data Handling meets the following requirements:

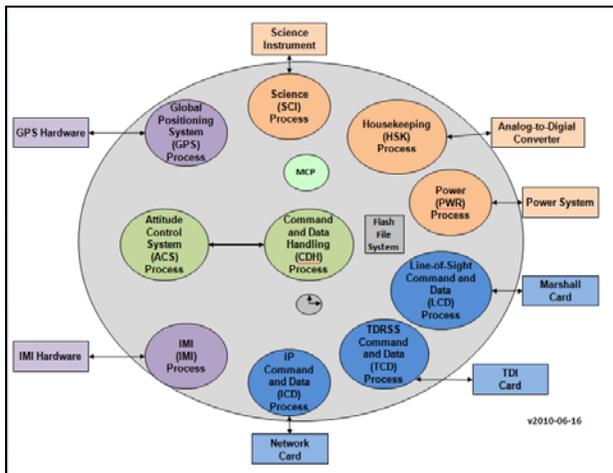
1. Require less than 2W of power
2. Run an operating system (OS) that supports the Wallops' Generic Reusable Aerospace Software Platform (GRASP) software
3. Contain a watchdog timer and Ethernet port

The selected flight computer shown in Figure 8 is the Eurotech TITAN SBC. This 520MHz computer uses 1.5 watts has four serial ports, supports I<sup>2</sup>C and has 2Gb of onboard data storage.



**Figure 8: Flight Computer**

The flight software, GRASP is a modular, customize software package development in-house. This real-time software can turn-on or turn-off processes as needed. It performs data management, e.g. collection, time stamping, logging, and distribution. GRASP also performs health monitoring such as normal and critical, threads and process heartbeats. This software has been used on other missions and at least 80% was applicable for use on small satellite.



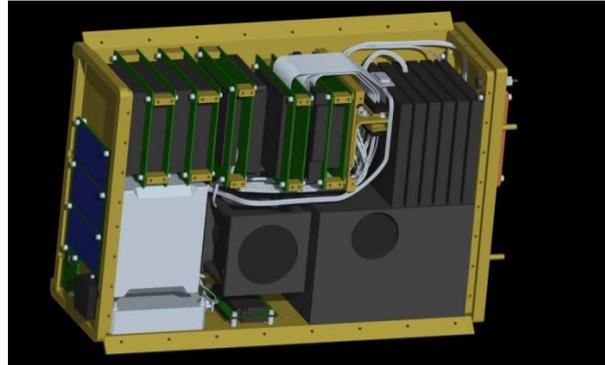
**Figure 9: Software Illustration**

**MECHANICAL STRUCTURE**

The primary focus of the structure design was to maximize volume and flexibility of arranging both the support systems and the instrument within the space. The 3U cubesats structure consisted of 3 10cm x 10cm x 10cm cubes stacked together. Our goal was to remove those constraints in our development of a 6U structure.

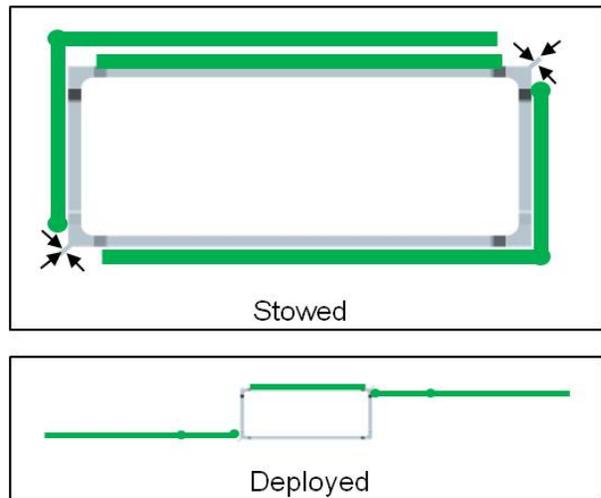
The mechanical team developed a single “Open Book” design to accommodate both the instrument and support systems. Each half could sit next to the other while mounting hardware inside. Figure 10 shows one-half of

this “Open Book” design. Given the two halves in addition to the end plates, this simple 4 piece structure allows the flexibility to optimize an instrument layout and mount the support systems around the instrument to minimize any dead space. This design also allows the instrument design to be more creative in their layout to potentially improve their science



**Figure 10: Populated Structure**

The other advantages of this design is that it does not use longerons, thus allowing for greater internal volume capacity. The two-guide rail design allows for the future development of a wrap around solar panel design. Figure 11 provides a view of the wrap around solar panel design. It also provides an increased outer volume capability if surface mounted solar cells are desired.



**Figure 11: View of Wrap Around Solar Panel**

This 3.3kg structure provides 7,700cm<sup>3</sup> of internal volume and 2,265 cm<sup>2</sup> of external surface area. Table 2 provides the overall dimensions<sup>2</sup> of the structure.

**Table 1: Overall Dimensions of Structure**

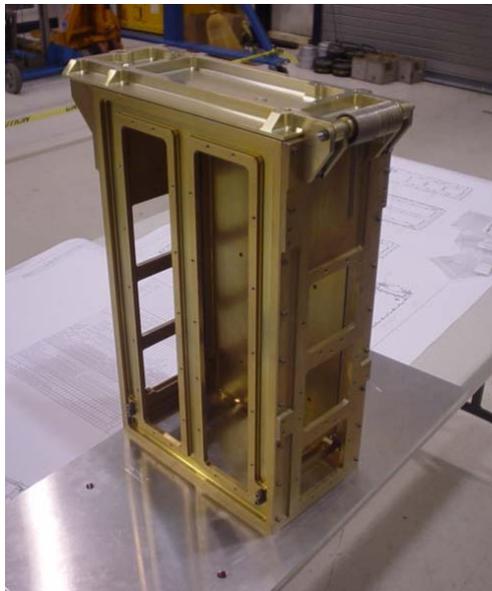
	External	Internal
Height	15" (38.1 cm)	12.99" (33.0 cm)
Width	10.24" (26.0 cm)	9.02" (22.9 cm)
Depth	5.24" (13.3 cm)	4.02" (10.2 cm)

**DEPLOYER**

The deployer was designed to carry the 6U structure. The key requirements are:

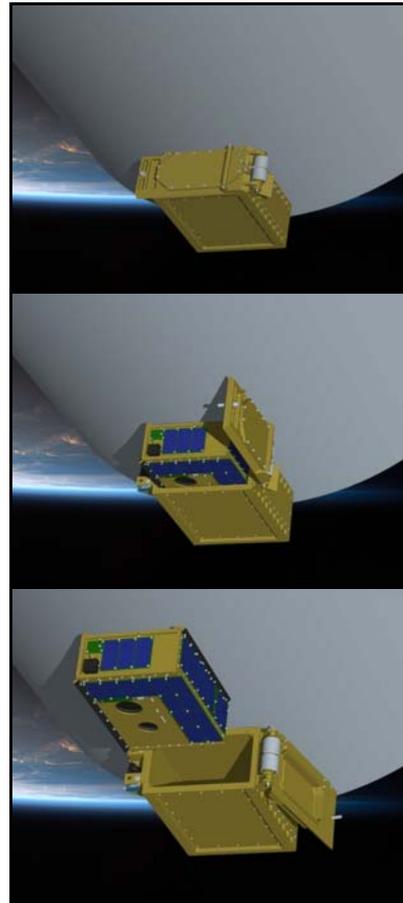
1. Deployer mass not to exceed 12kg
2. Design for a 12kg payload.
3. Design for a deployment velocity of 1 – 1.8 m/s

The deployer’s key design is based on using a pusher plate constraint and preloading. With this design with the satellite preloaded, it prevents rattling. Figure 12 shows the deployer.



**Figure 12: Photo of Deployer**

Figure 13 shows the sequence of the small satellite deploying. The deployment is initiated by a non-explosive actuator at which time the door bolt is released. Kick-off and torsion springs rotate the deployment door ahead of the satellite. These kick-off springs help initial door acceleration. The satellite is ejected by the linear spring which stops pushing the satellite midway, allowing the rails to guide the satellite the rest of the way. The energy absorbing plate reduces impact and door bounce-back ensuring no interference with the ejection of the satellite.



**Figure 13: Illustration of 6U Deploying**

**CONTROL CENTER**

The control center is customized to provide operators with all housekeeping and status data to assess the health of the payload. The multiple screens address the flight computer status and error checks, all aspects of the power system from the individual boards to the solar panels, sensors to the GNC system. These commands and data screens are created using LabView. A small control center has been permanently set up at Wallops Flight Facility to support missions.

Figure 14 shows some sample control center screens. The screen with the gauges is the power system. It shows the APB power board, battery, solar cells and power switching board status. The two smaller screens are the flight computer errors and status. The remaining screen displays the LiCor sun sensor status.

Each status in addition to the instrument has their command and status screens.



Figure 14: Samples of Control Center Screens

### Acknowledgments

The author would like to acknowledge her team, Joel Simpson, System Engineer, David Stuchlik, Integration and Test Manager, John Hudeck, Mechanical Lead, Luis Santos, Deployer Designer, Bob Stancil, C&DH Lead, Scott Heatwole, GNC Lead, Brian Corbin, Telemetry Lead, Larry Lutz, Power Lead (Phase 1), Tony Baldwin, Control Center Designer and Greg Waters, Lead Technician.