SwampSat - eoPortal Directory - Satellite Missions

SwampSat

SwampSat is a 1U student-developed CubeSat mission of the University of Florida (UFL) in Gainesville, FL, USA. The goal of the project is to advance the TRL (Technology Readiness Level) of **CMGs** (Control Moment Gyroscopes) appropriate for smallsats, as a means of increasing the capabilities, and hence the utility of CubeSats. The intend is to demonstrate on-orbit precision three axes attitude control using a pyramidal configuration of CMGs. The satellite is designed around the CubeSat form factor and the architecture is subsystem based. [1] [2] [3] [4] [5]

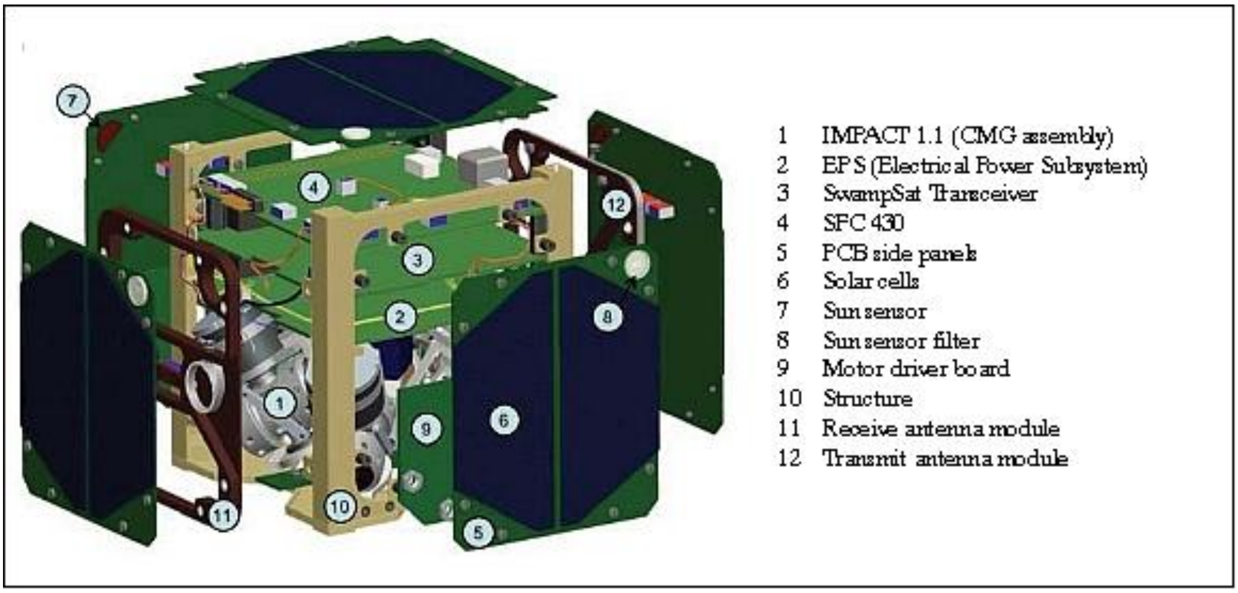

Figure 1: Exploded view of the SwampSat assembly (image credit: UFL)

Spacecraft:

The spacecraft conforms to the CubeSat standard in size 100 mm x 100 mm 110 mm; the mass is 1.2 kg. The design employs COTS

(Commercial-off-the-Shelf) components where appropriate. The electrical power and transceiver circuit boards are COTS components. The flight computer is a custom design for the SwampSat mission requirements. The three boards are connected with a 104 pin stack through connector, occupying the top half of the available volume.

<u>ADCS (Attitude Determination and Control Subsystem)</u>. The CMG based ADCS is designed to occupy the bottom half and the electrical power system, transceiver and flight computer occupy the top half of SwampSat. An aluminum frame and the solar panels structurally support SwampSat and isolate the CMG based ADCS and other satellite components from solar radiation. Note: The CMG assembly is also known as IMPACT 1.1.

The ADCS consists of four single gimballed CMGs in a pyramidal configuration as shown Figure 2. The pyramid is designed to fit within 1/2U of a standard CubeSat using custom built hardware. The IMPACT mass is less than 0.5 kg and its estimated maximum torque output is 0.8 mNm. The on board electronics use a quaternion feedback regulator with a generalized singularity robust (GSR) steering logic algorithm, programmed on a 32 bit DSC (Digital Signal Controller) of Texas Instruments (TI).

A start up sequence for powering up the flywheels and (as well as shutting them down) is included in the program, and is required to minimize changes to the angular velocity of the satellite before beginning a maneuver. Absolute encoders are used to determine gimbal position. To minimize friction and prevent outgassing from lubricants, silicon nitride bearings are used in the flywheel housing and gimbal frame. Capton tape is used to protect the flywheel housing from contaminants.

Figure 2: Illustration of a single CMG (left) and of the CMG pyramid at right (image credit: UFL)

Figure 3: Photo of a single CMG (image credit: UFL)

Mass of CMG	500 g
Maximum torque output	0.8 mNm
Momentum envelope	0.8 mNms
Power consumption	3 W (peak)
Flywheel speed	4500 rpm
Gimbal rates	1 rad/s (max)
Volume of instrument	100 mm x 100 mm x 50 mm

Table 1: Specification of the CMG assembly

The ADCS utilizes a magnetometer and sun sensors to obtain vector measurements, and an extended Kalman filter in conjunction with the QUEST algorithm. The sun sensors are based on analog transducers. An optical filter consisting of spectralon and mylar is used to prevent the sensors from saturating. The low resolution of the sun sensors (~5º) combined with the uncertainty in the magnetic and orbital propagation models, as well as Earth albedo effects restricts the ADCS to one of coarse resolution, preventing SwampSat from validating precision pointing. The data obtained from maneuvers will be post processed at mission control to verify rapid retargeting capabilities, while the pointing accuracy will be quantified with respect to the attitude determination system.

The main goal of the SwampSat mission is to validate on-orbit a compact, three-axis attitude actuator, capable of rapid retargeting and precision pointing (R2P2) on board a 1U CubeSat. The following attitude maneuvers are planned:

- slew to point the -Z axis (top face) at the sun

- settle -Z axis at the sun within 2 minutes

- dwell (track) -Z axis on the sun for 10 minutes

- slew 180° to point the face normal to +Z axis at the sun

- slew 180° to point the face normal to -Z axis at the sun

- settle -Z axis at the sun within 2 minutes

- dwell (track) -Z axis on the sun for 10 minutes

- point -Z towards the sun continuously over an orbit (during sunlit time of orbit).

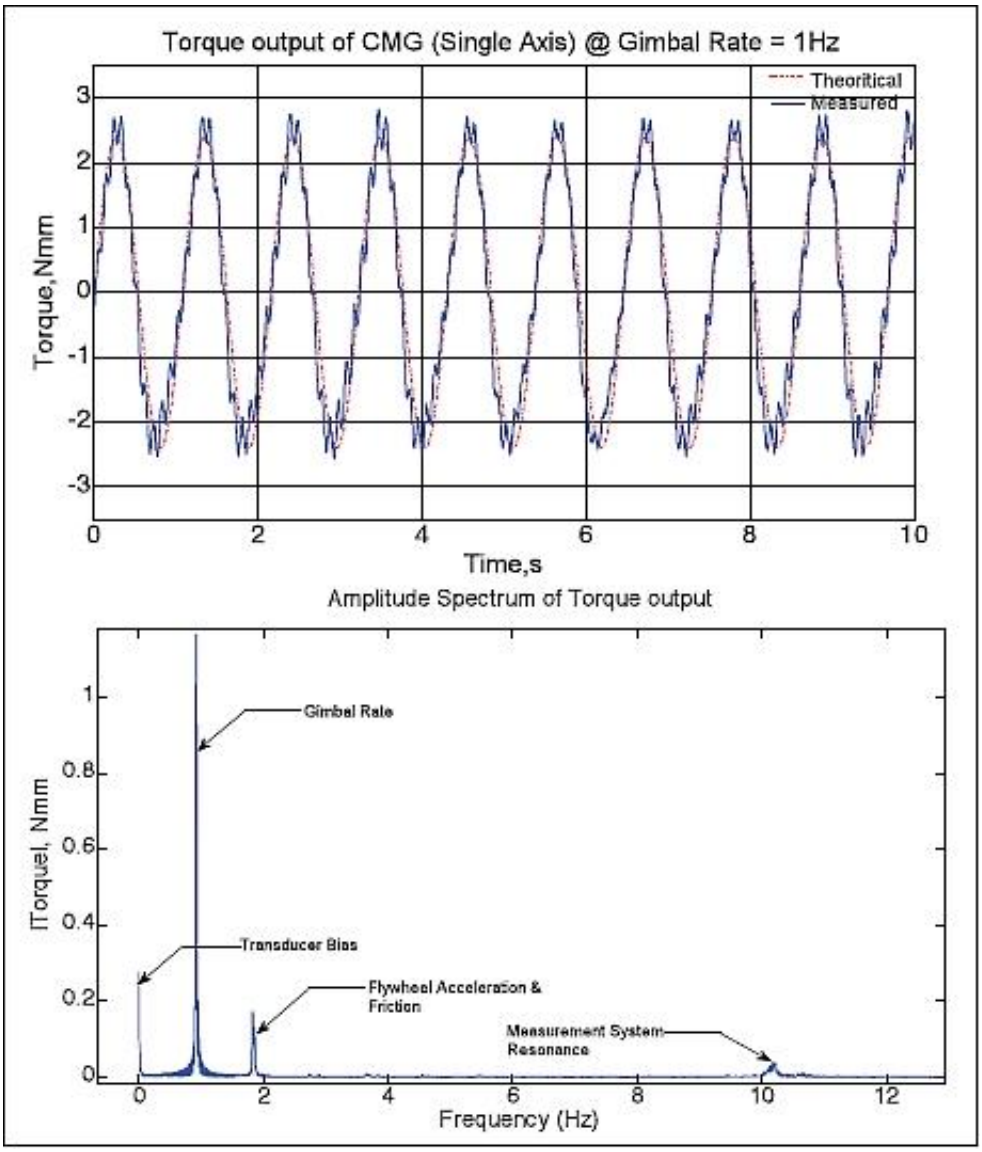

Figure 4: CMG torque test results (image credit: UFL)

The C&DH (Command & Data Handling) subsystem is controlled by the SwampSat Flight Computer (SFC430) which utilizes the msp430 microcontroller of TI. The SFC430 is in-house developed and manages the I^2C bus, data storage, telemetry strings, sensors, and the magnetorquer coils. The I^2C bus is used to connect the SFC430 with the external A/D converters, real time clock, storage memory, transceiver, electrical power supply board, and the CMG processor. The four types of telemetry strings (real time, ADCS, detumbling, and maneuver data) are managed by the flight computer.

EPS (Electrical Power Subsystem): EPS consists of a power management board and lithium polymer batteries manufactured by ClydeSpace, and solar cells manufactured by Spectrolab. Solar cells cover five sides of the satellite, producing an estimated on orbit average power of 1.5 W. The solar cells are bonded to custom PCBs (Printed Circuit Boards) which form the sides of five faces of SwampSat.

Figure 5: The EPS battery pack (left) and a PCB side panel of solar cells (right), image credit: UFL

RF communications: Use of the UHF/VHF amateur bands (437.385 MHz) in downlink and uplink, respectively. Two half wavelength dipoles couple the transceiver to the channel. The antennas are held in a stowed configuration during launch and deploy into their operational state when commanded by the SFC430. The antennas are mounted to a custom delrin plate which supports the deployment mechanism. The transceiver is configured using the I^2C bus and communicated with using a serial connection.

Figure 6: Photo of the transceiver board (image credit: UFL)

The CubeSat structure consists of a custom base plate and frame rails machined from T-6061 aluminum which supports the CMG pyramid and provides compatibility with the CubeSat specifications for frame rails and the P-POD (Poly-Picosatellite Orbital Deployer). The structure is augmented with custom delrin antenna plates to provide structural support to the aluminum chassis, in conjunction with the PCB side panels.

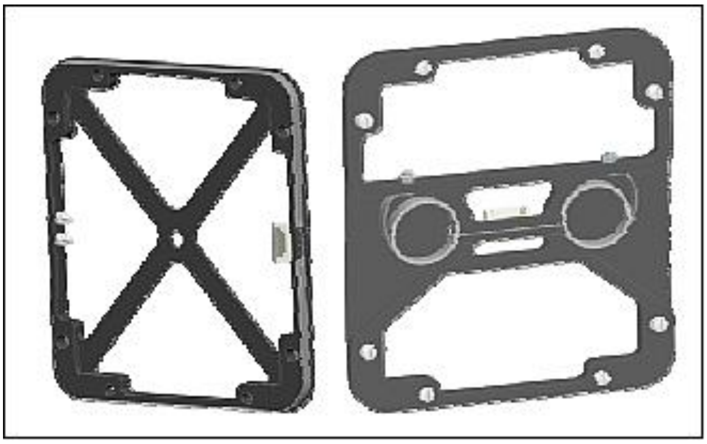

Figure 7: Illustration of the delrin antenna plates (image credit: UFL)

Spacecraft mass, power	1.22 kg, ~1.5 W on-orbit average power
Size	Standard 1U CubeSat of 10 cm x 10 cm x 10 cm
ADS (Attitude Determination Subsystem)	6 sun sensors 3-axis magnetometer IMU (Inertial Measurement Unit) QUEST, Kalman Filtering
ACS (Attitude Control Subsystem)	CMG assembly (referred to as IMPACT 1.1) 3 magnetic coils QFR (Quaternion Feedback Regulator) GSR Inverse Steering Logic
EPS (Electrical Power Subsystem)	~ 2 W solar cells on each PCB panel ~ 10 Whr Li-Po battery

C&DH (Command & Data Handling)	MSP430 based flight computer
TT&C (Telemetry Tracking & Command)	437.385 MHz, AX.25 protocol, AFSK modulation, data rate = 9600 baud
Ground support	GNES (Gator Nation Earth Station), distributed telemetry collection

Table 2: Overview of SwampSat parameters

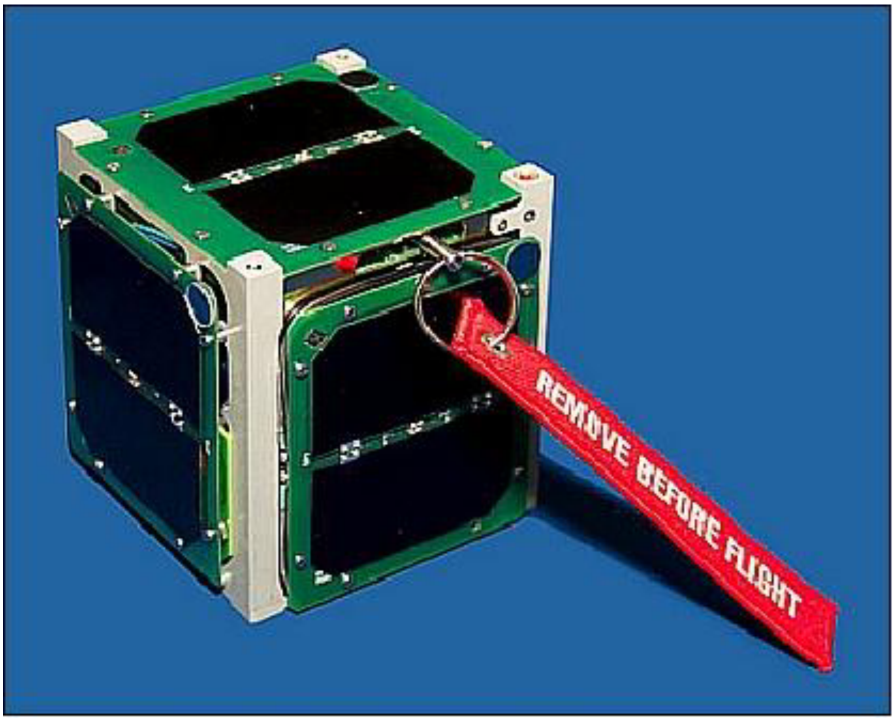

Figure 8: Photo of the SwampSat CubeSat (image credit: UFL)

Launch: On Nov. 20, 2013, the SwampSat CubeSat was launched as a secondary payload on the **ORS-3** (Operationally Responsive Space-3) mission, a joint initiative of several agencies within DoD (Department of Defense). The ORS Office at Kirtland AFB is the manager of the ORS program. The launch site was MARS (Mid-Atlantic Regional Spaceport), located at NASA's Wallops Flight Facility,Wallops Island, VA. The launch vehicle was a Minotaur-1 of OSC (Orbital Sciences Corporation). The primary payload on this ORS-3 flight was STPSat-3. [6) 7)]

Note: The ELaNa-4 CubeSats were originally manifested on the Falcon-9 CRS-2 flight (launch of CRS-2 on March 1, 2013). However, when NASA received word that the P-PODs on CRS-2 needed to be de-manifested, NASA's LSP (Launch Services Program) immediately started looking for other opportunities to launch this complement of CubeSats as soon as possible. [8] [9] [10]

Orbit: Near-circular orbit, altitude of 500 km, inclination = 40.5º.

Secondary Payloads: The secondary technology payloads on this flight consist of 26 experiments comprised of free-flying systems and non-separating components (2 experiments). ORS-3 will employ CubeSat wafer adapters, which enable secondary payloads to take advantage of excess lift capacity unavailable to the primary trial. [11] [12]

NASA's LSP (Launch Services Program) ELaNa-4 (Educational Launch of Nanosatellite-4) will launch eight more educational CubeSat missions. The ELaNa-4 CubeSats were originally manifest on the Falcon-9 CRS-2 flight. When NASA received word that the P-PODs on CRS-2 needed to be de-manifested, LSP immediately started looking for other opportunities to launch this complement of CubeSats as soon as possible. [13]

Spacecraft	ORS-3 mission sponsor	Spacecraft provider	No of CubeSat Units
ORS-1 ORSES (ORS Enabler Satellite)	ORS	ORS	3
ORS-2 ORS Tech 1	ORS	ORS	3
ORS-3 ORS Tech 2	ORS	ORS	3

Prometheus-1	SOCOM (Special Operations Command)	LANL (Los Alamos National Laboratory)	1 x 3
Prometheus-2	SOCOM	LANL	1 x 3
Prometheus-3	SOCOM	LANL	1 x 3
Prometheus-4	SOCOM	LANL	1 x 3
SENSE-A	STP (Space Test Program)	SMC/XR	3
SENSE-B	STP	SMC/XR	3
Firefly	NASA/NRO	NSF (National Science Foundation)	3
STARE-B (HORUS)	NRO (National Reconnaissance Office)	Lawrence Livermore National Laboratory	3
Black Knight-1	NASA LSP/STP	US Military Academy, West Point, NY	1
TetherSat	NASA LSP/STP	US Naval Academy, Annapolis, MD	3
NPS-SCAT	NASA LSP/STP	Naval Postgraduate School, Monterey, CA	1
Ho'ponopono	NASA LSP/STP	University of Hawaii, Manoa, HI	3
COPPER	NASA LSP/STP	St Louis University, St. Louis, MO	1
ChargerSat-1	NASA LSP/STP	University of Alabama, Huntsville	1
SPA?1 Trailblazer	NASA LSP/STP	COSMIAC, University of New Mexico	1
Vermont Lunar CubeSat	NASA LSP/STP	Vermont Technical College, Burlington, VT	1
SwampSat	NASA LSP/STP	University of Florida, Gainsville, FL	1

CAPE-2	NASA LSP/STP	University of Louisiana, Lafayette, LA	1
DragonSat-1	NASA LSP/STP	Drexel University, Philadelpia, PA	1
KYSat-2	NASA LSP/STP	Kentucky Space, University of Kentucky	1
PhoneSat-2.4	NASA LSP/STP	NASA/ARC, Moffett Field, CA	1
TJ^{3}Sat (CubeSat)	NASA LSP/STP	Thomas Jefferson High School, Alexandria, VA	1

Table 3: ORS-3 manifested CubeSats & Experiments (Ref. 10)

ORS and CubeStack: [14)]

• ORS (Operationally Responsive Space) partnered with NASA/ARC and AFRL to develop & produce the CubeStack

• Multi CubeSat adapter provides "Low Maintenance" tertiary canisterized ride capability

• ORS-3 Mission: Will fly 2 CubeStacks in August 2013. This represents the largest multi-mission launch using a Minotaur I launch vehicle (26 free flyers, 2 experiments).

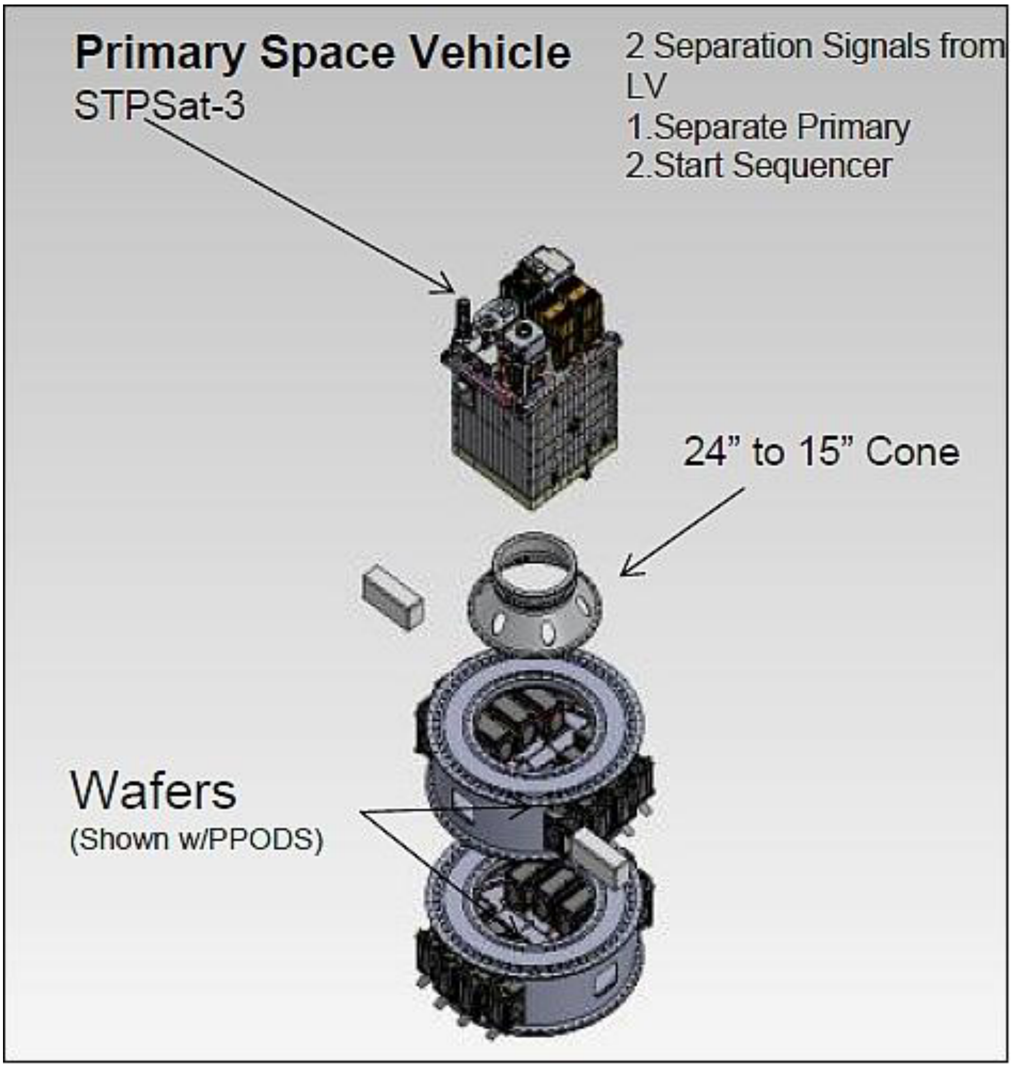

Figure 9: Illustration of the CubeStack, (consisting of wafers) configuration (image credit: ORS, Ref. 10)

The CubeStack adapter structure is a design by LoadPath and Moog CSA Engineering. [15)]

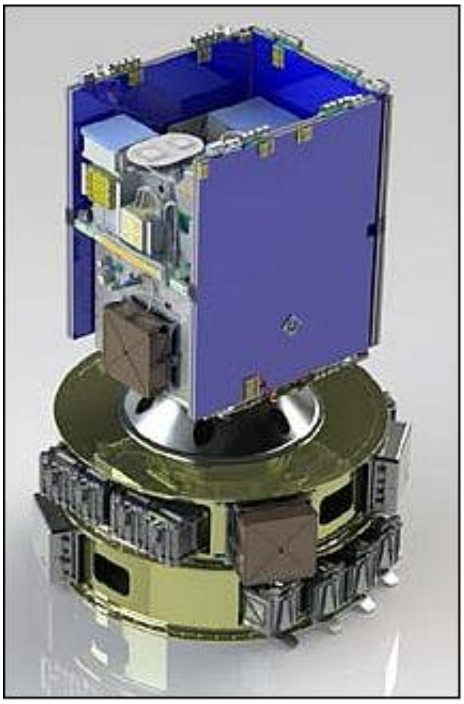

Figure 10: Photo of the ORS-3 launch configuration with STPSat-3 on top and the integrated payload stack at the bottom (image credit: AFRL)

Mission status:

• The SPTSat-3 spacecraft was deployed ~12 minutes after lift-off at an altitude of about 500 km. The Minotaur's upper stage then executed a pre-planned collision avoidance maneuver before starting deployment of 28 CubeSats sponsored by the ORS office, the U.S. Air Force SMC's (Space and Missile Systems Center) Space Test Program, and NASA's Educational Launch of Nanosatellites (ELaNa) program (Ref. 6).

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7) Patrick Blau, “Minotaur I successfully launches STPSat-3 & record load of 28 CubeSats,” Spaceflight 101, Nov. 20, 2013, URL:

http://www.spaceflight101.com/minotaur-i-ors-3-launch-updates.html

8) Garrett Lee Skrobot, Roland Coelho, "ELaNa – Educational Launch of Nanosatellite Providing Routine RideShare Opportunities," Proceedings of the 26th Annual AIAA/USU Conference on Small Satellites, Logan, Utah, USA, August 13-16, 2012, paper: SSC12-V-5

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10) Peter Wegner, "ORS Program Status," Reinventing Space Conference, El Segundo, CA, USA, May 7-10, 2012, URL: http://www.responsivespace.com/.../Dr.%20Peter%20Wegner.pdf

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The information compiled and edited in this article was provided by Herbert J. Kramer from his documentation of: "Observation of the Earth and Its Environment: Survey of Missions and Sensors" (Springer Verlag) as well as many other sources after the publication of the 4th edition in 2002. - Comments and corrections to this article are always welcome for further updates.