TECHNICAL SESSION X: YEAR IN REVIEW

A review of missions that have been launched in the past 18 months with an emphasis on the technological advancements that significantly enhanced mission utility.

Session Chair: Catherine Tsairides, Wyle

8:00 AM
Small Demonstration Satellite-4 (SDS-4): Development, Flight Results, and Lessons Learned in JAXA’s Microsatellite Project
Yosuke Nakamura, Kunitoshi Nishijo, Naomi Murakami, Kazutaka Kawashima, Yuuta Horikawa, Kazuhide Yamamoto, Takashi Ohtani, Yasuyuki Takashashi - Japan Aerospace Exploration Agency (JAXA)

The Small Demonstration Satellite 4 (SDS-4) is the first zero momentum three-axis controlled 50kg class satellite from JAXA. It was launched on May 17, 2012 on H-IIA Launch Vehicle, and is now operating successfully. SDS-4 has four main demonstration missions: (1) Space-based automatic identification system experiment for tracking ships, (2) Flat-plate heat pipe on-orbit experiment, (3) Quartz crystal Microbalance for contamination environment monitoring, and (4) In-flight experiment of space materials using THERME, which is developed in the JAXA-CNES joint research program. The satellite has two deployable solar panels to the left and to the right, and two deployable AIS antennas in the front and in the back. In addition to the technology demonstration missions, SDS-4 has another important goal, namely to establish a 50 kg-class highly functional and precise three-axis controlled standard bus for future advanced missions. After a year of on-orbit experiments and evaluations, all missions are now deemed successful and excellent flight data has been obtained. We encountered several serious problems during operations. We investigated the reasons for those misbehaviors in a multi-step process using a methodical FTA approach, and managed finally to resolve all of the problems. This paper concludes with the lessons learned all of which contributed to the overall success of the SDS-4 project.
**8:15 AM**
**NASA’s GRAIL Spacecraft Formation Flight, End of Mission Results, and Small-Satellite Applications**
Christine Edwards-Stewart - Lockheed Martin Space Systems Company

The Gravity Recovery and Interior Laboratory (GRAIL) mission was composed of twin spacecraft tasked with precisely mapping the gravitational field of Earth’s Moon. GRAIL science collection required that the two spacecraft operate in the same orbit plane and with precise relative separation and pointing, which evolved through the primary and extended mission Science phases. Because of the relatively small size of the GRAIL spacecraft compared to other exploration missions, and the implementation of formation flight operations, lessons learned from this mission are applicable to future small-satellite missions. A description of the formation flight approach that was implemented on the GRAIL spacecraft will be accompanied by a presentation of flight results and discussion of small-satellite applications.

**8:30 AM**
**A Baptism of Fire: The STRaND-1 Nanosatellite**
C. Bridges - Surrey Space Centre; S. Kenyon - Surrey Satellite Technology Ltd.; P. Shaw, E. Simons, L. Visagie, T. Theodorou, B. Yeomans, J. Parsons - Surrey Space Centre

The CubeSat standard has inspired a new wave of engineers, researchers, and scientists – all aiming to utilise “commercial off-the-shelf” (COTS) subsystems to build nanosatellite systems. For this same reason, students and staff at Surrey have been designing a 3U CubeSat with the intention of providing low-level design, build and test experience for early career engineers, provide on-orbit demonstration of key technologies in attitude and orbit control systems (AOCS), and finally assess smart-phone components for future spacecraft applications. The modern smart-phone is the latest in a consumer driven and start-of-the-art electronics market which the STRaND-1 mission aims to exploit; assessing hardware components and exploring software towards new methods in designing and operating new satellites. The “Surrey Training, Research and Nanosatellite Demonstrator” is the first in a line of ambitious missions which aims to strengthen the ties between Surrey Space Centre (SSC) and Surrey Satellite Technology Ltd (SSTL). The project began in April 2010 where STRaND-1 was designed in the team’s free time but the major build work began in mid-October 2012. Launched on 25 February 2013, the assembly, integration and test (AIT) phase took approximately 4 months to complete. This paper discusses this phase and the typical CubeSat subsystems and non-PC/104 AOCS and computing payloads in a custom payload bay. In-orbit results of the new nanosatellite power, attitude and orbit control system are presented. With many new capabilities to demonstrate on STRaND-1 when in-orbit, exploiting the latest consumer electronics and software with real training and mission utility was disruptive. We evaluate the ground-based operational processes during commissioning.
Three satellites of the AeroCube-4 series built by The Aerospace Corporation were launched in September 2012 from Vandenberg Air Force Base. These satellites were each equipped with an on-board GPS receiver that provided position measurements with a precision of 20 meters and enabled the generation of ephemerides with meter-level accuracy. Each AeroCube was also equipped with two extendable wings that altered the satellite’s cross-sectional area by a factor of three. In conjunction with the GPS measurements, high-precision orbit determination detected deliberate changes in the AeroCube’s drag profile via wing manipulation. The AeroCube operations team succeeded in using this variable drag to re-order the satellites’ in-track configuration. A differential cross-section was created by closing the wings of one satellite while the others’ remained open, and the relative in-track motion between two AeroCubes was reversed. Over the course of several weeks, the satellites’ in-track configuration was re-ordered, demonstrating the feasibility of CubeSat formation flight via differential drag.

The Fast Affordable Science and Technology Satellite (FASTSAT) Mission
Mark Boudreaux, Steve Pearson, Joseph Casas - NASA Marshall Space Flight Center

The Fast Affordable Science and Technology Spacecraft (FASTSAT - HSV01) is a mini-satellite weighing less than 150 kg. FASTSAT was developed as a government-industry collaborative research and development flight project targeting rapid access to space to provide an alternative, low cost platform for a variety of scientific, research, and technology payloads. This initial spacecraft mission carried six instruments and was launched as a secondary “rideshare” payload. The design approach greatly reduced overall mission costs while maximizing the on-board payload accommodations. FASTSAT was designed from the ground up to meet a challenging short schedule using modular components with a flexible, configurable layout to enable a broad range of payloads at a lower cost and shorter timeline than scaling down a more complex spacecraft. The integrated spacecraft along with its payloads were readied for launch in 15 months from authority to proceed. As an Enhanced Expendable Launch Vehicle Secondary Payload Adaptor ESPA-class spacecraft, FASTSAT is compatible with a variety of launch vehicles. These vehicles offer an array of options for launch sites and provide for a variety of rideshare possibilities.
9:15 AM

**TacSat-4: Military Utility in a Small Communication Satellite**

Lieutenant Colonel Matthew Anderson - Operationally Responsive Space Office; Bill Raynor, Mike Hurley - Naval Research Laboratory

TacSat-4 is a Navy-led joint mission to augment existing Satellite Communication (SATCOM) capabilities and to advance the state of Operationally Responsive Space (ORS) capabilities. In September 2011 TacSat-4 launched from Kodiak Launch Complex in Alaska into a low Highly Elliptical Orbit (HEO). During the following 12 months, experimentation and formal utility assessment were performed. This operational testing allowed users from across the Department of Defense and other governmental agencies to use the capability. The spacecraft and operations were sponsored by the Office of Naval Research and Office of Secretary of Defense with Naval Research Lab leading the execution. The ORS Office funded launch and was tasked by the Commander of United States Strategic Command to conduct a Joint Military Utility Assessment (JMUA) to support a transition to operations decision as well as future acquisition decisions. This paper provides a description of the TacSat-4 system and a summary of the testing performed including the results.

A primary objective of the TacSat-4 JMUA was to assess the use of small satellites to provide UHF SATCOM to support disadvantaged users in the tactical community. The TacSat-4 experimentation and JMUA activities performed to-date have shown TacSat-4’s ability to provide SATCOM for a wide range of users and applications, using standard SATCOM equipment. Voice, chat, file transfers and other network applications were successfully performed. In addition to providing new SATCOM, the TacSat-4 program also advanced many elements of the ORS concept such as maturing the ORS bus standards, developing an enhanced Minotaur-IV+ launch vehicle capability, demonstrating the first long dwell orbit and mission for a small satellite, and developing highly automated command and control and mission planning systems.

9:30 AM

**Mission Results and Anomaly Investigation of HORYU-II**

Yuki Seri, Hirokazu Masui, Mengu Cho - Kyushu Institute of Technology

HORYU-II is a 30cm-cubic nano-satellite weighing 7.1kg developed by Kyushu Institute of Technology. HORYU-II was launched to 680km Sun-synchronous orbit as a piggy-back satellite onboard a H-IIA rocket of JAXA on May 18, 2012 (Japan standard time). Its main mission is to demonstrate high voltage photovoltaic power generation technology. HORYU-II succeeded in generating high voltage photovoltaic power, up to 350V, which is the world record as power generation voltage in orbit. The past record was 160V held by the International Space Station. HORYU-II also carried out other technology demonstration missions related to electrostatic discharge mitigation solar array designs, a spacecraft charging monitor, a passive spacecraft charging mitigation device, and a debris impact.
sensor. Three weeks after the launch, HOYRU-II suffered a serious anomaly for one month, and the satellite was not able to communicate with the ground station. Based on the anomaly investigation including various ground tests, the authors judged that a single event latch-up (SEL) due to radiation was the most probable cause. SEL occurred on two microprocessors. When the second SEL occurred, the battery was depleted due to the increased current consumption. The battery's depletion reset HORYU-II, and the satellite could be restored to its original condition. The lessons of HORYU-II suggest the needs of environmental testing standard to improve the satellite reliability, especially at the early phase of operation in orbit.