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**REPORT DOCUMENTATION PAGE**

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<b>13. SUPPLEMENTARY NOTES</b>					
<b>14. ABSTRACT</b> Undergraduate and graduate students at Washington University in St. Louis participated in the AFRL University Nanosat Program, designing, analyzing, integrating and testing protoflight hardware, ultimately earning 2 <sup>nd</sup> place in the Nanosat-5 competition. The two years' effort focused on mission assurance activities (functional and environmental tests), improved documentation/process control, and progress in structural and thermal modeling. Students also revised the Bandit flight electronics to reflect improvements in the capabilities of electronic components and (more importantly) our students' skill set since our previous versions in 2005. The period of performance spanned three academic years, involving more than four dozen undergraduates at Washington University. Although anecdotal, several aerospace recruiters cited the students' experience in UNP as a deciding factor in their hiring.					
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## **Objectives**

The objectives of the work completed differ significantly from the original proposal. In brief, it was agreed by our management team and the AFRL program office that the completion/flight certification of the Bandit/Akoya mission from the University Nanosat-4 Competition was sufficiently important (and sufficiently difficult). Therefore, the revised objectives under this work were:

- The primary mission, Bandit-C, is to demonstrate automated proximity operations, including docking using a 3-kg spacecraft. Specifically:
  - Successfully carry two Bandit-C vehicles into orbit inside the host vehicle.
  - Release one Bandit and recapture using the soft-dock mechanism
  - Recharge the Bandit and repeat the release & recapture process
  - Build up to remote operations of the Bandit free-flyer from distances of at least 1 meter
- The secondary mission of the 35-kg Akoya host vehicle is to demonstrate rapid integration technologies using a standardized wiring & data protocol.
  - Rapid integration will be demonstrated during the final integration & test process, defined as component-to-system integration of major elements in a matter of hours.
  - Mass, volume, power and data margin will be set aside for late-stage integration of an extra payload.
- These objectives are to be met using student-designed, student-built and student-tested spacecraft.

While the first two objectives occupied the bulk of the effort, those activities directly contributed to the third, which is the true contribution of this work. Participation in the University Nanosat Program (UNP) directed contributed to a large percentage of the WU engineering students choosing aerospace careers.

## **Review of Efforts**

Most flight-ready hardware was completed for the University Nanosat-4 competition in March 2007. After that competition, however, it was decided to redesign the Bandit electronics to take advantage of much more capable communications and on-board processing that exist now, compared to Bandit design freezes in 2004. The Akoya design remained frozen, except for modifications to the Akoya-Bandit electronic/data interfaces to make the system compatible with the new Bandit design. (The distributed command & data handling system and the standardized power/protocol interfaces made this upgrade seamless.) At present, the Akoya electronics are in flight-ready configuration, with a software rewrite in progress. Bandit electronics were provisionally completed by the end of the contract; however, they were not fully tested. Therefore, while we believe that this last revision of the electronics is fully functional that belief has not been verified.

We have also created a documentation team and a version-control archive, the improvement in student documentation is notable. Finally, we experienced an-expected-but-painful transition in May 2008, as almost all of the experienced student staff graduated. Summer 2008 involved training a new team of a dozen students. The lessons learned in handling significant staff turnover will be extremely useful for future Nanosat competitions.

Finally, WU students participated in all UNP-mandated activities: Expert Area Telecons, SHOT I and SHOT II Workshops, Fabrication Training, and all design reviews.

## **Accomplishments/Findings**

The main accomplishments of this work were the preparation and presentation of the Critical Design Review on 21 April 2008, the Prototype Qualification Review on 11 August 2008 and the Flight Competition Review on 20 January 2009. The presentation slides for all meetings have been archived with the AFRL UNP management team.

Since student training is an important objective of this work, it is worth noting that of the seven key students associated with the UNP project who graduated in 2008, five went to work for the aerospace

industry and two went on to graduate school in engineering. Of the ten key students to graduate in 2009, seven are now employed in the aerospace industry, two are enrolled in graduate engineering programs, and one went to work for Microsoft. Similarly, all of the supported/associated personnel listed below that did not graduate in 2009 secured summer employment with aerospace contractors,

### **Personnel Supported**

**Supported Personnel.** The following personnel received direct support from this contract:

- Dr. Michael Swartwout (PI) – 1 summer month, 2007 and 2008
- Forrest Rogers-Marcovitz (Electronics) – student intern
- Brian McDaniels (Bandit propulsion) – student intern
- Jeremiah Garrison (Bandit propulsion) – summer intern
- Doug Beattie (Bandit dock) – summer intern
- Elaine Bourne (Configuration Management) – summer intern
- Ryan Hacala (Electronics) – summer intern
- Brendan McCarthy (Bandit propulsion) – summer intern
- Brian O'Neal (Bandit propulsion) – summer intern
- Robert Pasque (Configuration Management) – summer intern
- Nathan Ritter (Akoya systems engineering) – summer intern
- Henry Schwartz (Electrical power) – summer intern
- Katlyn Sullivan (Program management) – summer intern
- Colin Towery (Propulsion) – summer intern

**Associated Personnel.** The following students were funded to participate in contract activities, with the funding coming from other programs:

- Stephen Forbes (Bandit Vehicle Lead, Department support)
- Katie Burlingame (Operations, University Research Scholarship)

**Key Students.** In addition to the students listed above, the following students made key contributions to the project, either through course work or volunteering in the summer: Rashied Amini, Erin Beck, Fiona Turett, Anne Schneider, Doug Beattie, Charles Gronek, Brad Kukurza, BettyLynn Ulrich, Justin Char, Erik Karulf and Lane Haury.

### **Publications**

M.A. Swartwout. The First One Hundred University-Class Spacecraft 1981-2008, *IEEE Aerospace and Electronic Systems Magazine*, 24(3), 2008.

### **Interactions/Transitions**

The PI and five students (Beck, Beattie, Gronek, Schneider, Kukurza) traveled to Space Systems/Loral in January 2008 to perform a dock verification test and structural vibration acceptance test.

Four students (Beattie, Bourne, Schwartz, McCarthy) attended the SHOT II workshop in Boulder, CO in June 2008.

Seven students (Sullivan, Garrison, Beck, Haury, Turett, Molly Stovel and Mary Mathias) participated in the NASA/JSC Microgravity University C-9 flight in June 2008. The students flight-tested the Bandit propulsion system in microgravity.

The PI and 12 students (including all supported students) attended the 22<sup>nd</sup> Annual AIAA/USU Conference on Small Satellites in August 2008. They presented the Akoya & Bandit prototypes as well as an early version of the 6DOF simulator as part of the Prototype Qualification Review. A significant fraction of the small satellite community attends this conference.

The PI and 12 students presented the project at the 2009 Nanosat-5 Flight Competition Review in front of a panel of industry experts.

Stephen Forbes (associated personnel) is expected to complete his PhD in aerospace engineering in December 2009; his thesis study is directly related to the University Nanosat activity.

#### **New discoveries**

No new discoveries were made during this reporting period.

#### **Honors/Awards**

Second Place, University Nanosat-5 Competition

Third Place (Beck) and Honorable Mention (Rogers-Marcovitz), 2007 Student Paper Competition at the Annual Conference on Small Satellites

Second Place (Amini) and Honorable Mention (Meyer), 2008 Student Paper Competition at the Annual Conference on Small Satellites