EdUCE, Educate Utilizing CubeSat Experience: a Pragmatic Approach to Shatter Barriers to Space

Dante Buckley, Vivek Shrivante, Kunal Patankar, Scott Harden, Paul Muri, Norman Fitz-Coy
University of Florida
Gainesville, FL 32611-6250; (407) 716-4305
dante35@ufl.edu

ABSTRACT

The Educate Utilizing CubeSat Experience (EdUCE) project uses CubeSats to further develop and incorporate an innovative STEM approach to enhance scientific knowledge of K-12 students and teachers. Space technology is an advanced form of engineering that combines aspects of aerospace, mechanical, electrical, and computer engineering. In brief, EdUCE's multidisciplinary science teachings provide a foundation to the early education of students. Through practical hands-on experiences into the design of complex engineering systems, the student understands applications and relationships for each discipline and their impact in engineering. Small satellites are used as the mechanism to deliver STEM concepts. At the University of Florida (UF), the Advanced Space Technologies Research and Engineering Center (ASTREC), a National Science Foundation Center, has been coordinating this activity fulfilling a charter goal to promote this approach among local K-12 schools and like-minded community organizations.

This paper discusses the methodology, the activities, the systems developed, the practices, and the future actions based on past lessons to increase awareness of space technology and, in general, the human capacity development process through space system engineering outreach programs to engage K-12 students and teachers. To improve global awareness, associations with universities in other countries have been established and their role is also detailed.

INTRODUCTION

The program has been building and sustaining engineering practices with guided educational material to lay down a foundation to train educators and motivate students. Several programs have been initiated over the years with different target audiences of educators and students. EdUCE debuted an exhibit as an informal science education project at the first USA Science and Engineering Festival in Washington DC and later piloted a weeklong teacher training opportunity at UF. A selected handful of middle and high school teachers were chosen to participate in the inaugural program. These EdUCE teachers became ambassadors at their respective schools and with their districts upon completion of the workshop. During the weeklong workshop, the teachers were mentored by ASTREC personnel and were involved with hands on action plans in satellite subsystem engineering and curriculum planning. As part of the workshop, CanSat kits, which included a microcontroller, standard input/output module, and communication transceivers in a wireless sensor network environment, were utilized to promote hands-on learning experience for a tethered balloon experiment. This approach exposes the K-12 educators to multidisciplinary research such as aerospace/mechanical, electrical, and computer engineering fields with a satellite system design perspective. The EdUCE program will be installed as an annual summer activity at UF.

Additionally in partnership with UF's Student Science Training Program (SSTP), rising high school students participate in a rigorous eight-week summer residential research program. This unique and intensive learning environment challenges and inspires student interest in STEM fields. ASTREC personnel acted as associates of SSTP for an accredited "Introduction to Space Systems" seminar course. The culmination of the seminar course was highlighted by a high altitude balloon flight conducted by the students. Furthermore, activities are presented to provide a perspective of the various outcomes of the interaction to grow the STEM community.

INNOVATIVE SATELLITE SYSTEMS

ASTREC serves the space industry through fundamental and applied research that result in innovative technologies for the space industry and an active program of technology transfer[1]. Through member sponsored research and technology transfer activities, the center provides a global research, educational, and training resource for the space industry by developing innovative materials, processes, and systems that sustain and improve the economic well being of the industry. The focus of this paper is on the inclusion of K-12 educational prospects.

Human Capacity Development

Human Capacity Development (HCD) enhances multidisciplinary science teachings that strengthen the foundation of students' applicable skill set in a manner that provides tangible value to future employers. In addition, ASTREC projects enhance the quality of STEM education for K-12 students and educators. Through practical hands-on experiences into the design of complex engineering systems, students use the small satellite platform with scientific fundamentals to explore applications and relationships in various engineering disciplines, increasing the likelihood they enter STEM fields in the future. Figure 1 envisions the development from concept to the end user.

Figure 1: Delivering from concept to end user

SwampSat

The State of Florida's Lt. Governor, Jennifer Carroll, unveiled SwampSat on April 6, 2012 seen in Figure 2. SwampSat[2] is a 1U CubeSat for on-orbit demonstration of a compact three axis-attitude control system developed to effect rapid retargeting and precision pointing (R2P2) of PNsats (pico/nano-satellites). SwampSat seen in Figure 3 is representative of the types of innovation which drives the activities in the Integrated Design, Engineering, & Verification (iDEV) facility.

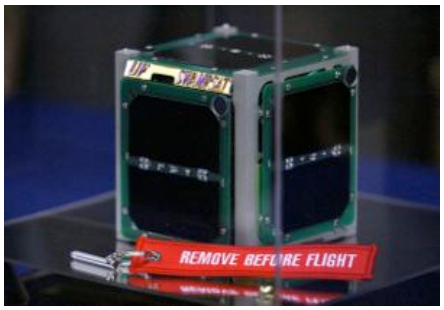

Figure 2: Unveiled SwampSat developed by the Space Systems Group in the Department of Mechanical & Aerospace Engineering at UF

(Photo courtesy: Gainesville Sun)

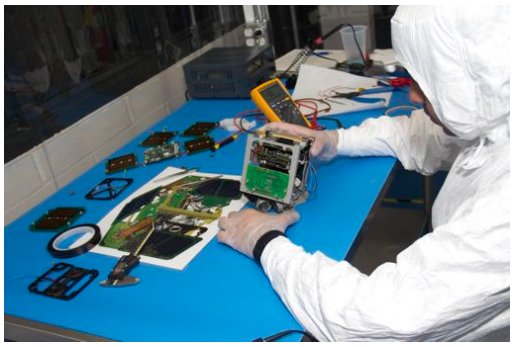

Figure 3: SwampSat Assembly inside iDEV facility

SwampSat team members have gained valuable hands-on experiences and have derived lessons learned from conceptual work to the assembly integration and testing phases. SwampSat received its seed funding from the Florida University Satellite Design (FUNSAT) competition[3] sponsored by the Florida Space Grant Consortium and Space Florida and is projected for launch in 2013 as part of NASA's Educational Launch of Nano-satellites (ELaNa) program.

EDUCE MISSION

EdUCE aims to "change the game" in STEM education by making spacecraft concepts accessible and realizable to K-12 students. In EdUCE (meaning to bring out), we bring aerospace to individuals with similar interests.

EDUCE PROJECT DESIGN

The project design takes a two-fold approach to informal STEM learning that we believe will increase the awareness of the value of STEM pursuits in the US and will increase connections in science and engineering programs at the college level. EdUCE delivers STEM experiences to the public through innovative and varying hands-on space systems such as

CubeSat, CanSat, high altitude balloon, and microgravity projects.

1) Pursue a hypothesis of "personal spacecraft" in which individual, local, and distributed teams engage in the creation of a viable self-contained spacecraft in an informal classroom environment

2) Utilizes the spacecraft components as tools to teach STEM ideas ranging from, but not limited to electricity, digital logic, engineering mechanics, and energy conversion/storage

This approach utilizes a process and system to bring together the key parts of spacecraft and space mission development in a form accessible to students and instructors. The key elements in the design were presented to a select group of middle and high school teachers for their evaluation and action plans.

PILOT TEACHER CUBESAT WORKSHOP

A Teacher's Engineering Experience through CubeSat Interactions, a Prelude to EdUCE at UF is a critical step in establishing relationships with interested K-12 educators. Table 1 indicates the topics presented during day one: the information session. The primary objectives of the workshop are:

- Provide a Teacher Training Workshop
- Introduce the merit of CubeSats to current educational portfolios
- Focus primarily on high school (and middle school) for initial implementation

Content for the teacher training exercises provided a comprehensive teacher workshop manual and a unique hands-on CubeSat experience with current pedagogy model exemplifying SwampSat. A prototype of hands on kit for a high school classroom was also presented. Project-based learning techniques with an emphasis on "engineering" in STEM were highlighted. EdUCE pilot teachers collaborated on group discussions and worked individually to provide feedback to refine the EdUCE activities to be more engaging. Each teacher developed an action plan identifying effective approaches to STEM, which are consistent with EdUCE. Table 1 showcases the information session. Figure 4 shows the EdUCE teachers on the iDEV facility.

Figure 4: EdUCE teachers in the iDEV facility

Table 1: Pilot Workshop Agenda: Day 1

Information Session Agenda
Workshop Objectives & Expectations
Overview of Space Activities
Introduction to Space Mission Engineering
The CubeSat Program / iDEV Facility Tour
Approach & Concept of STEM: Introduce Hands-on Kit
Day 1: Summary and Feedback Forms

Table 2 details the first teacher training session agenda. Teachers toured W4DFU, the amateur radio ground station for SwampSat, and learned about communication, space inter-networking, and general terrestrial internet concepts such as AX.25, delay tolerant networking, and TCP/IP from the Wireless and Mobile Systems Laboratory. Teachers also gained hands-on experience using programmable flatsat kits. Flatsats are similar to a spacecraft; however, it is used for development and proving mission concepts. The flatsat prototype kit developed consisted of three major components: (1) sensor suites (2) microcontroller (3) communication antenna seen in Figure 5.

Figure 5: EdUCE workshop prototype kit

Table 2: Pilot Workshop Agenda: Day 2

Teacher Training Session #1 Agenda
Hands-on Build Kit
Visit and Tour of W4DFU Radio Station
Hands-on Build Kit
Wireless Networking Applications
Systems Engineering
Current UF Research Outreach Initiative
Brainstorm Presentation Ideas / Project Clarifications
EdUCE Architecture
Day 2: Summary and Feedback

Table 3: Pilot Workshop Agenda: Day 3

Teacher Training Session #2 Agenda
Hands-on Build Kit (breakout session)
Transforming Research for Public Educators
Applying Science with an Engineering Approach
Catalyzing STEM Education through Innovation
Hands-on Kit
Day 3: Summary and Feedback

Tables 3 and 4 indicate the teacher training sessions #2 and #3. Training session #3 gave a final opportunity to complete their application on their kit. The teachers were exposed to Web 2.0 (online tools and resources) applications to streamline their CubeSat work. The broader impacts presentation enlightened the teachers about informal and formal science education. A realization of the teachers to inquire about the Direct Research K-12 approach with current teaching benchmarks in their respective programs resulted rather than the Informal Science Education approach. The teachers strengthened this feedback through their action plans.

Table 4: Pilot Workshop Agenda: Day 4

Teacher Training Session #3 Agenda
Hands-on Build Kit
Engagement through Education Technology
Hands-on Build Kit
Understanding your Value within Broader Impacts
UF Involvement and Overview of ELaNa Program
Roundtable Discussions with Professor Fitz-Coy
Presentation Preparation
Day 2: Summary and Feedback

Table 5 indicates a teacher presentation and collaboration session in which each teacher put together a slideshow and submitted their action plans for the review. In addition, STEM project experience germane to EdUCE was presented and further detailed in the following sections such as high altitude balloon flights, microgravity flights, and research outreach.

Table 5: Pilot Workshop Agenda: Day 5

Presentation / Collaboration Session Agenda
STEM Projects / Challenges
Action Plan Guidelines
Assessing Hands-on Projects: Lessons Learned
Teacher Presentations
Action Plan Review
Closing Remarks
Day 5: Summary and Feedback

Table 6 shows action plans developed by Andrew Moon, a Mathematics teacher at Bronson High School and summer instructor at Upward Bound at Santa Fe College. Mr. Moon has paired several EdUCE topics with his lessons. Curriculum mapping is an effective method for implementing standards such as Common Core Standards. Common Core Curriculum has fewer yet rigorous standards for students and is currently being implemented.

Table 6: Innovative Curriculum Mapping

Benchmark	Course	Description
Topic: Global Positioning System		
MA.912.T.2.3	Precalculus	Apply the laws of sines and cosines to solve real-world problems using technology
MA.912.T.3.4	Precalculus	Solve trigonometric equations and real-world applications involving applications of trig equations using technology when appropriate
MA.912.T.4.1	Precalculus	Define polar coordinates and relate polar coordinates to Cartesian coordinates with and without the use of technology
Topic: Financial Benefits of Secondary Payloads		
MA.912.A.3.15	Adv. Algebra w/ Financial Applications	Create a graph to represent a real-world situation
MA.912.A.2.2	Adv. Algebra w/ Financial Applications	Interpret a graph representing a real-world situation
MA.912.A.3.55	Adv. Algebra w/ Financial Applications	Symbolically represent and solve multi-step and real-world applications that involve linear equations and inequalities
MA.912.A.3.15	Adv. Algebra w/ Financial Applications	Solve real-world problems involving systems of linear equations and inequalities in two and three variables

Topic: Voltage Passing through a Circuit		
MA.912.T.1.6	Algebra II	Identify the real and imaginary parts of complex numbers and perform basic operations
MA.912.A.4.7	Algebra II	Write a polynomial equation for a given set of real and/or complex roots
MA.912.A.7.5	Algebra II	Solve quadratic equations over the complex number system
Topic: Reaching Microgravity in Parabolic Motion		
MA.912.T.7.6	Algebra II	Identify the axis of symmetry, vertex, domain, range, and intercept(s) for a given parabola
MA.912.A.4.10	Algebra II	Use polynomial equations to solve real-world problems
MA.912.A.4.9	Algebra II	Use graphing technology to find approximate solutions for polynomial equations

The standards are internationally benchmarked to ensure that K-12 students compete globally. [1] Students are expected to have thorough, concentrated learning experiences on more difficult skills. The EdUCE lessons are aimed to be cross-curricular according to the pilot teachers where writing requirements are paired with the technical studies.

STUDENT SCIENCE TRAINING PROGRAM

The Student Science Training Program (SSTP) is a rigorous summer residential program since its inception in 1959. ASTREC personnel initiated an accredited college seminar course, *Introduction to Space Systems*, in 2009. High school students were introduced to systems engineering and developed high altitude balloon experiments for college credit within the 18-hour contact time. Figure 6 showcases the first SSTP class at the Kennedy Space Center where they launched their project. A homebrewed transmitter was developed for this launch with a Morse code beacon – the signal results are in Figure 7.[4] A similar balloon launch experiment was conducted in 2011, this time with a camera and GPS unit as a payload. Figure 8 shows picture taken from the height of 5000 feet by this balloon. The GPS log of the flight was later processed to generate a trajectory using Google Earth as shown in Figure 9.

Figure 6: 1st SSTP Team

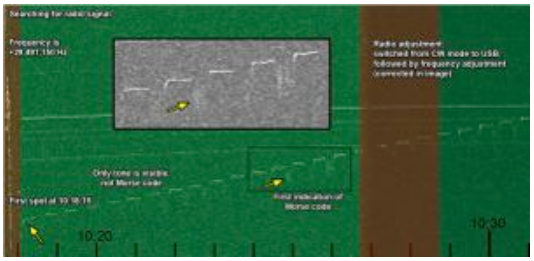

Figure 7: Trace of the Transmitter at W4DFU

Figure 8: Curvature of the Earth Photo

Figure 9: Google Earth plot from the KMZ files recovered from the GPS data

USA SCIENCE & ENGINEERING FESTIVALS

EdUCE had the privilege to be introduced at the Gators in Space: from Telescopes to Satellites exhibit as part of the 1st USA Science and Engineering Festival at the National Mall in Washington DC on Oct 23rd-24th 2010 seen in Figure 10.

Figure 10: Kathryn Cason holding a SwampSat rapid prototype

The festival returned to Washington DC on April 28th-29th 2012 at the Walter Washington Convention Center. The Gators in Space exhibit in Figure 11-13 showcases the gyrochair concept, design, and operation.

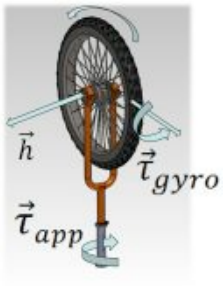

Figure 11: The applied torque ($\vec{\tau}_{app}$) rotates the wheel and causes a gyroscopic torque ($\vec{\tau}_{gyro}$) to conserve the angular momentum ($\vec{h}$)

Figure 12: When the handle indicated by the arrow to the right is pulled left, which direction does the chair rotate? Does this make sense to you?

Figure 13: The gyrochair in motion at the exhibit

The gyrochair allows participants to experience the gyroscopic effects while the control box in Figure 14 shows the same principle applied to the SwampSat mission. The CMG control box display is setup to test the various operational modes for visual inspection and Hardware-in-the-Loop implementation.

Figure 14: The CMG Operational Control Box

MICROGRAVITY FLIGHT

Small Satellite Design Club members participated in NASA's Microgravity University program June 2011 at the Johnson Space Center to demonstrate SwampSat technology.[5] This microgravity opportunity provided the chance to perform science onboard a research aircraft that simulates zero gravity environments in space. Figures 15 and 16 show the team and CubeSat hardware. The EdUCE teachers were offered the opportunity to partner with university researchers to participate in the K-12 Microgravity teacher flights.

Figure 15: UF's Microgravity Team presenting their CubeSat hardware built inside the iDEV facility

Figure 16: UF's CMG Microgravity Team

ENHANCING GLOBAL AWARENESS

ASTREC at the University of Florida has partnered with the French South African Institute of Technology (F'SATI) at the Cape Peninsula University of Technology (CPUT) led by Professor Robert Van Zyl. In addition, the EdUCE pilot teachers were shown the F'SATI CanSat camera and GPS units at the conclusion of the workshop.

Acknowledgments

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