SABRE-I: An End-to-End Hands-On CubeSat Experience for the Educate Utilizing CubeSat Experience Program

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EdUCE Program and Highlights

Rapid Prototyped CubeSat on Display at the National Mall for the 1st USA Science and Engineering Festival (Washington DC)

Undergraduate Team participates in NASA's Microgravity Flight for SwampSat Payload Verification (Houston, Texas)

SwampSat Engineering Model and Attitude Display

Gyrochair Experience

2nd USA Science and Engineering Festival – Gyro Chair Introduction (Washington DC)

SwampSat Unveiling

SwampSat Delivery and Launch supported by NASA's ElANA IV

5th Nano-satellite Symposium Presentation (Tokyo, Japan)

2015 ASEE Annual Conference & Exposition (Seattle, WA)

Weiss Middle School Visit SE Course (Gainesville, FL)

Weiss Middle School Visit Antenna Build (Gainesville, FL)

2010

Introduction to Space Seminar Course for High School Students (Gainesville, FL)

Student-led High Altitude Balloon Flights

Capturing Telemetry

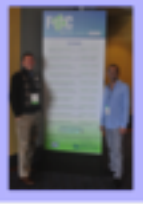
2011

Pilot CubeSat K-12 Teacher Training Workshop (Gainesville, FL)

CanSat Development Kits (In Collaboration with CPUT)

2012

TEDxYouth Event (Gainesville, FL)



2013

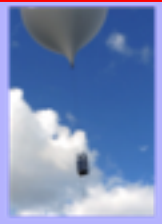
Small Satellite Conference Publication (Logan, Utah)

Florida Education Technology Conference Ticketed Workshop (Orlando, FL)

2014

3rd USA Science and Engineering Festival (Washington DC)

2015



SABRE-I Launch (Gainesville, FL)

SABRE-I for Capstone Design Course Fall 2015 (Gainesville, FL)

Future

Continue to advance EdUCE activities through NSF support and further participants worldwide

SABRE-I Project Life-Cycle

- The mission is to provide end-to-end hands-on experience through on-orbit/in-flight image and video capturing over Gainesville, FL on a CubeSat-class system

Need

Objective

- Need: To understand and learn the end-to-end process
- Approach: utilize SABRE-I to emulate an end-to-end space mission (i.e., conceptualize, design, fabricate, operate, and decommission)

Constraints

Programmatic

- Cost: $2,000
- Schedule: Complete within 1 year

Technical

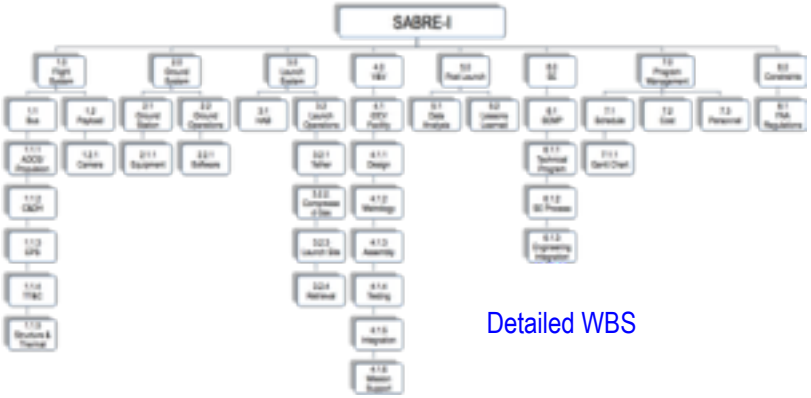
- Spacecraft: 3U-class or smaller
- Flight: Fly on high altitude balloon

- Mission definition
- Mission objectives
  - Primary
  - Secondary

- CONOPS
- WBS
- Tasks and responsibilities

Requirements

- Understand regulations
  - FAA regulation, U.S. CFR 14 Part 101 (MOORED BALLOONS, KITES, AMATEUR ROCKETS AND UNMANNED FREE BALLOONS)



Detailed WBS

- Developed requirements verification matrix for traceability

- Requirements flowdown and allocation
  - Detailed WBS

Number	Requirement	Verification Method					Verification Artifact	Status
		A	O	D	T	R		
1.1.3	EPS Subsystem							
1.1.3.1	The EPS subsystem shall include a rechargeable battery to provide sufficient power to all peripherals on SABRE-I			X		X	Design and Reference Document	
1.1.3.2	The EPS subsystem shall include a power distribution module that will deliver power to all peripherals on SABRE-I			X		X	Design and Reference Document	
1.1.3.3	The EPS subsystem shall include a power generation module to charge batteries			X		X	Design and Reference Document	

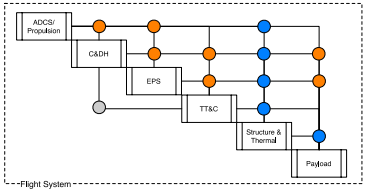
Requirements verification matrix

Design

	Volume	Mass	Power	Link	Altitude	Cost	Schedule
Initial budgets	3U-class	4 kg	TBD	TBD	152.4 m (500 ft.)	$ 2,000	< 1 year

- Performed trade studies on components
- Determined interfaces between all components
- Designed custom PCBs and structures
- Developed V&V plans

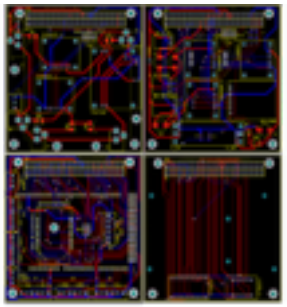
System architecture



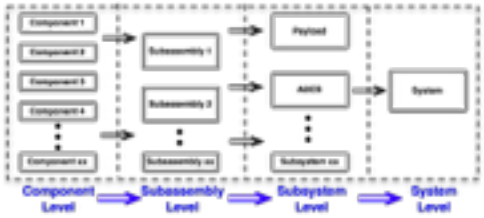
N2 diagram

Cameras			Option 1			Option 2		
Objective	Weighting Factor	Parameter	Mag.	Score	Value	Mag.	Score	Value
Price	0.10	$	69.99	7.0	0.7	49.04	10	1.0
Interface	0.40	Quality	Great	10	4.0	Poor	2	0.8
Compatibility	0.30	Quality	Great	10	3.0	Poor	2	0.6
Max Resolution	0.10	Pixels	1920000	10	1.0	307200	5	0.5
Min Resolution	0.10	Pixels	19200	8	0.8	19200	8	0.8
Overall value					4.7			1.8

Trade study



Custom PCBs

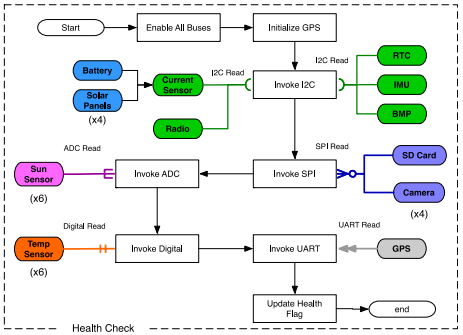


V&V plans

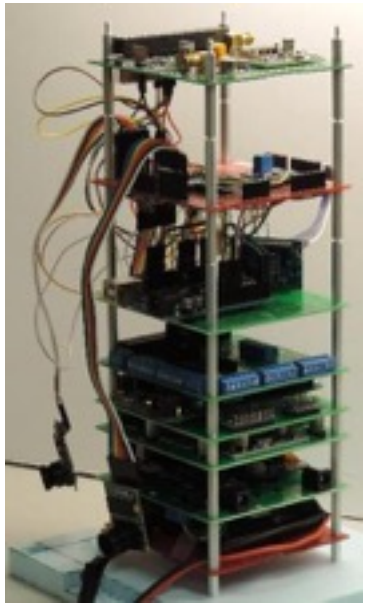
Development

Developed:

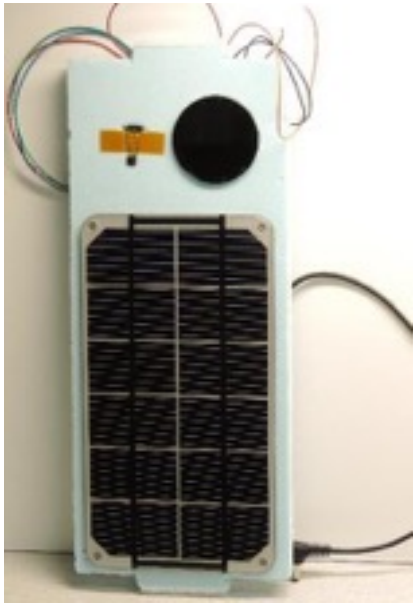
- PCB stack
- Structure (8020) & panels
- Flight software



Flight software



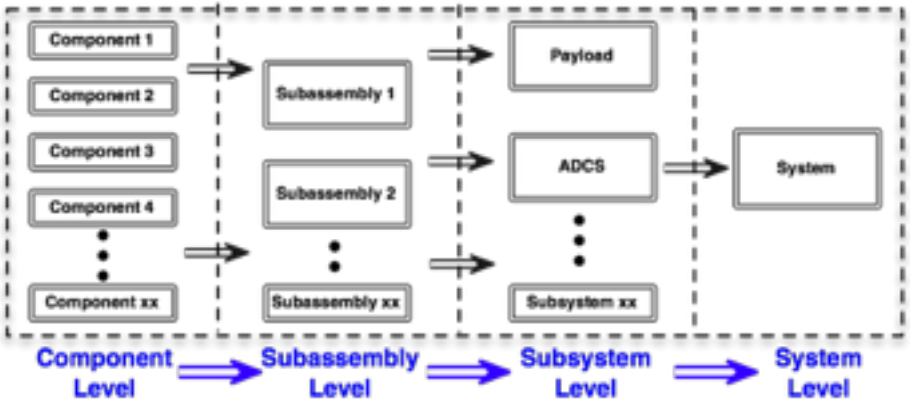
PCB stack



Custom panels

Verification and Validation

- Performed V&V tasks according to the plan developed earlier



- During V&V, completed final budgets (mass, power, cost, and link) and requirements verification matrix

Mass	1755.56 g	Power	< 2.5 W	Cost	$1,428.92
Volume	120x120x300 mm (3U-class)	Link	> 500 ft	Schedule	1.5 months

Test Launch

Design Iterations

First iteration to second iteration

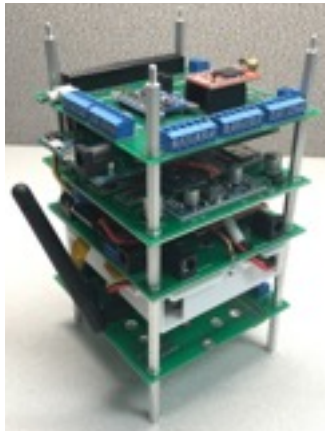
- Power on/off by connecting/disconnecting battery
- Camera has internal level shifter so no flight daughter board needed
- Optimize PCB stack design

Second iteration to third iteration

- Isolate voltage bus circuits
- Access ports on the panels are limited, thus, the RBF and charging ports were moved on the stack
- Optimize PCB stack design

Design iteration summary

Design 1	Design 2	Design 3
•Design •Development •V&V •Test launch	•Design •Development •V&V	•Design •Development •V&V •Launch

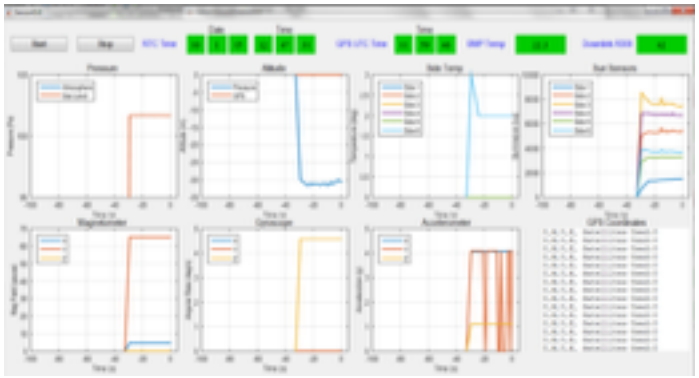


SABRE-I Specifications

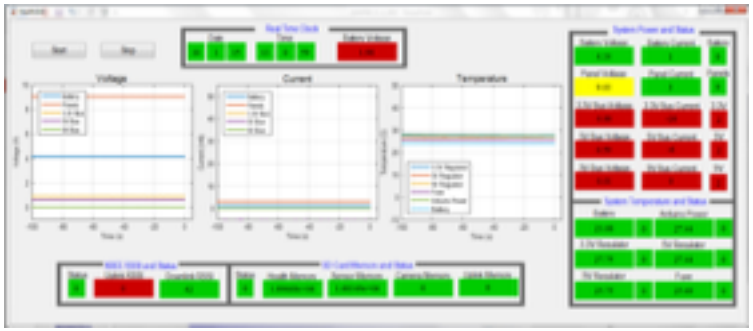
Mass	2215.82 g	Cost	< $1500
Power	~2 W (orbit average power)	Payload	4 cameras 4 camera temp sensors
Dimensions	3U CubeSat-class (12 x 12 x 32.5 cm)	CDH	Arduino DUE MicroSD card data storage RTC
TT&C	Xbee Pro 900 with duck antenna		5 current sensors 6 internal temp sensors 6 external temp sensors Pressure sensor with temp sensor
EPS	Solar cells on four sides	ADS	3-axis magnetometer 3-axis gyroscope 3-axis accelerometer GPS receiver 6 Sun sensors
	3.7V 10Ah Li-Po battery		
	3.3V, 5V, and 9V voltage buses (typical CubeSat voltages)	Structure	Custom side panels 80-20 structural frames
Launch	Balloon Tethers	Ground Support	Xbee Pro 900 with duck antenna Matlab GUIs

Utilization and Support

- Launched on a tethered balloon
- Flight Operations
  - Used set of uplink commands
  - Used GUIs to monitor real-time downlink



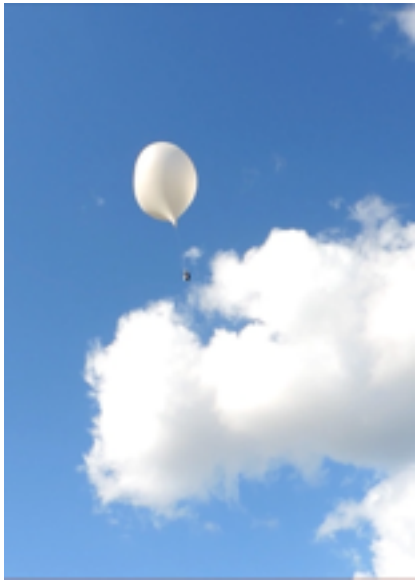
Sensor GUI

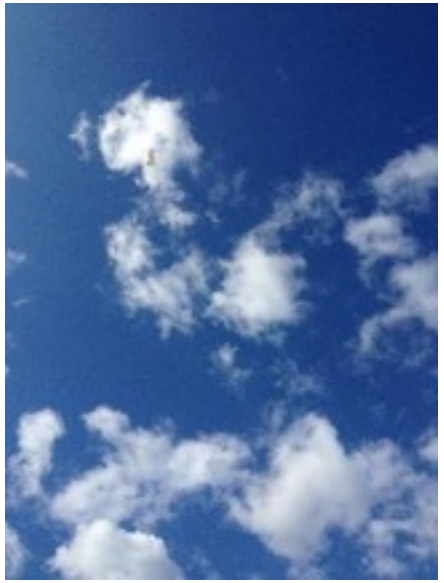


Health GUI

Command GUI

First Launch November 6, 2015



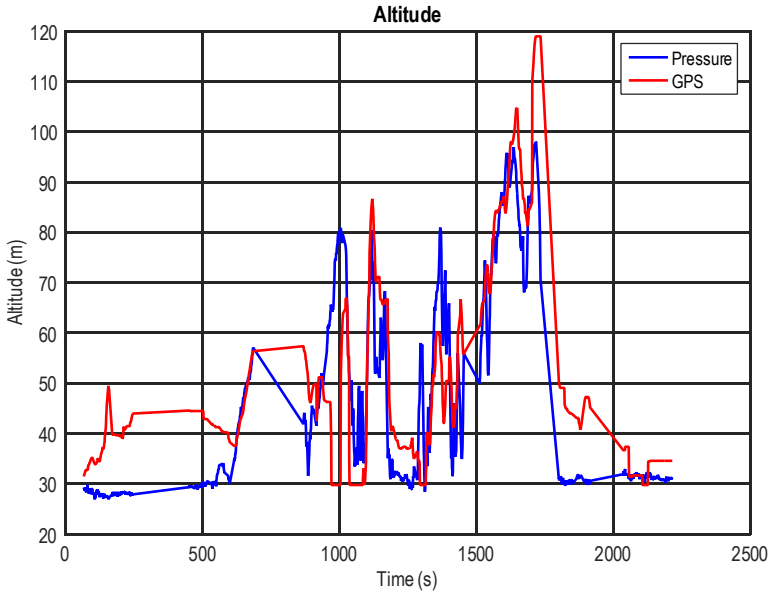


Second Launch December 2, 2015

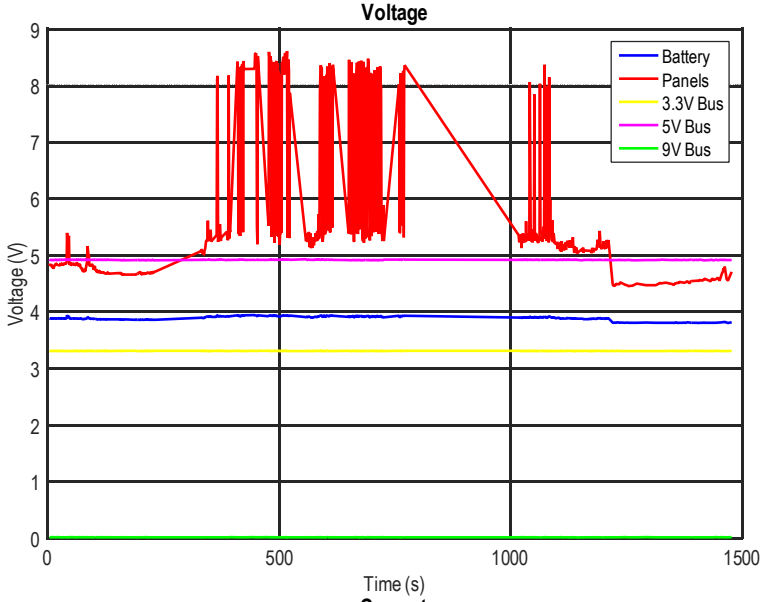
In-Flight Camera Data

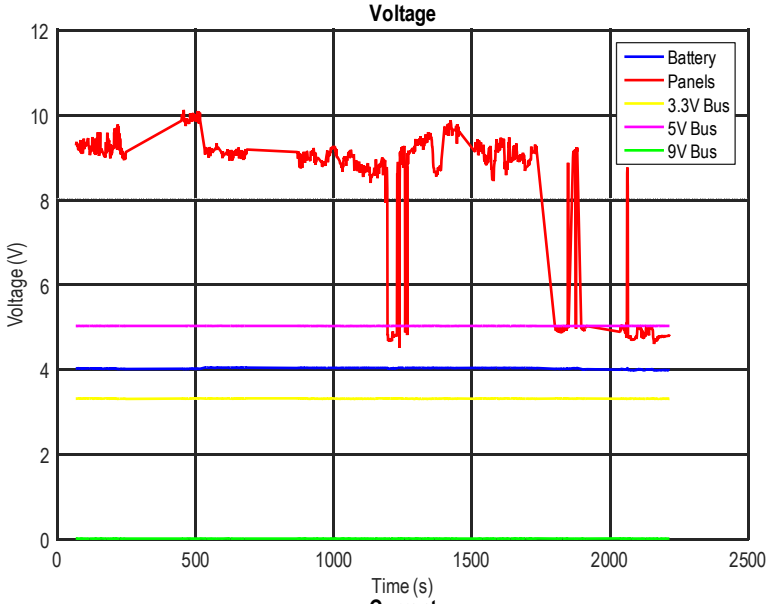
Retirement

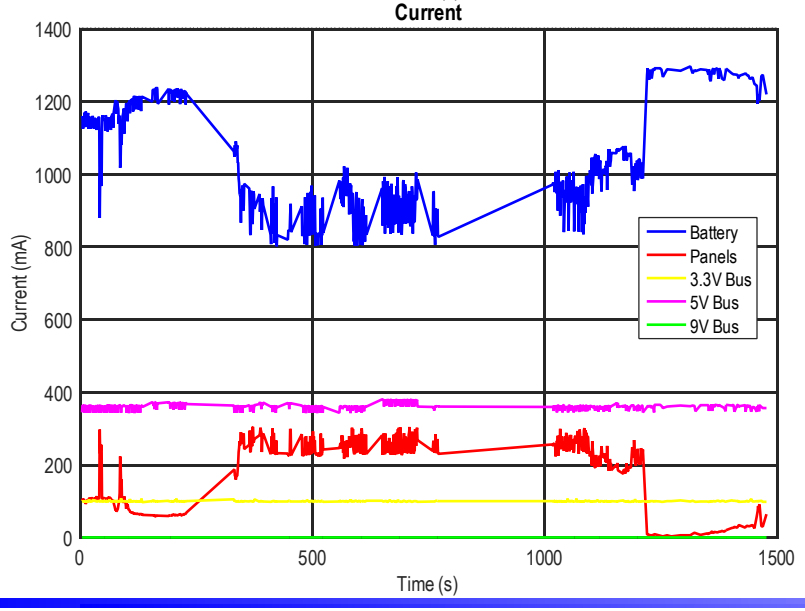
- Post-processed downlinked data
- Documented lessons learned

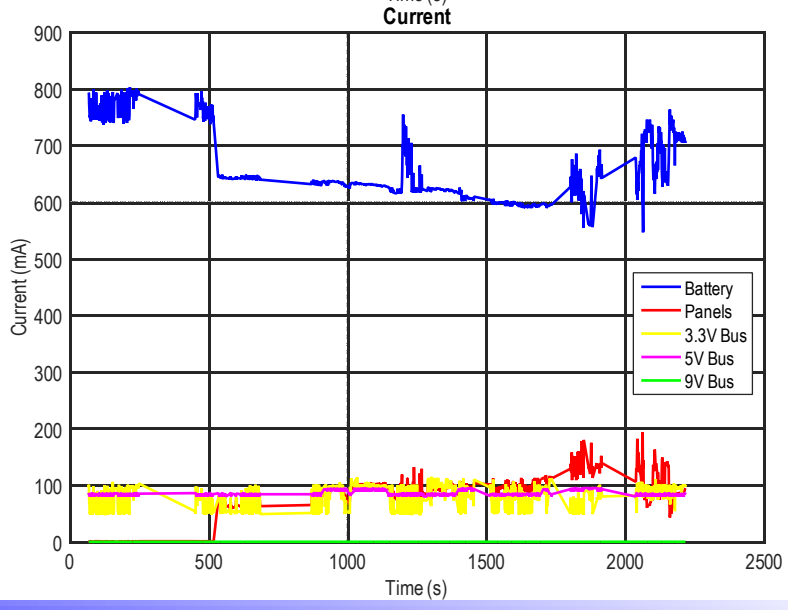


Flight Data: Voltages and Currents









Lessons Learned

Flight system

- Consider alternative payload and communication systems
- Use server to host code for multi-person coding
- Need alternative connectors on stack
- Use of CAD software and rapid prototyping to verify design
- Product verification after acquisition

Ground system

- Improve ground system (mainly software)

Launch system

- Written set of launch procedures
- Vital to check weather conditions prior to launch
- Improve on tether system

Lessons Learned

Comments

- Provides exposure to an end-to-end process
- Provides experience and knowledge for other projects and research
- Satisfied but wanted more experience with hardware and structure
- There are costs associated with shipping, taxes, etc.

- SABRE-I was utilized in a Capstone Design Course for college seniors in Fall 2015. All teams succeeded in obtaining flight data and gained valuable hands-on experiences.
- Elements of SABRE-I has been utilized to teach middle school students from The Weiss School (Palm Beach Gardens, FL).

Thank you!

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