TJ³Sat – The First Satellite Developed and Operated by High School Students

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• **Key to Success** – Do not simply start a spacecraft program; Create a curriculum around the concept

• TJHSST established a system engineering course aimed at Sophomores, Juniors, Seniors
  ➢ Introduce the art of engineering to the students
  ➢ Bring the students together in a collaborative team environment
  ➢ Center efforts around a large scale project (build a satellite!!!)

• Focus the curriculum on both technique and process
  ➢ Formulate potential missions and justify their validity
  ➢ Bring in industry experts to provide insight and answer questions
  ➢ Follow proper system engineering techniques – establish requirements, create budgets, decompose functionality into subsystems

"We want students getting their feet wet and muddy doing fun things with science in a vigorous way“ – Principal Evan Glazer
The First Satellite Developed and Operated by High School Students

TJ³Sat
Project Team

- Project team structure was developed by students with guidance from advisor and industry mentors
- The advisor/teacher serves as the program director
- The technical student lead is the systems engineer
- Subsystem leaders have been on project 2-3 years and mentor first year students

- Subsystem breakdown established by students to fit their working style and expertise
  - Subsystem teams are not the traditional teams seen on most student projects
  - Telecom – RF Communications
  - C&DH – Development of software (both ground and flight)
  - Power – power regulation, solar panels, batteries
  - Sensors & Instrumentation – spacecraft telemetry
  - Integration, Test, and Launch
  - Publicity – web site and outreach
TJ³Sat Mission

- Create resources to promote the aerospace industry within K-12
  - All effort has been documented and will be published online
  - Hardware design and software code to be released open source

- Allow public, especially students to interact with TJ³Sat primary payload
  - Elementary student sends “happy birthday” to classmates
  - High school teams receive an out-of-this-world cheer
  - Students use the satellite to deliver messages around the world

- Web site will also publish all TJ3Sat telemetry (temperatures, voltages, currents)
  - Can be used in Math and Physics classes to create real-world simulations of physical systems

- *Primary Payload* – TTL-03 Voice Synthesizer
TJ³Sat Concept of Operations

- Simple command and telemetry system
- Remote operation of voice synthesizer through the internet
- Voice recordings can be picked up using a handheld amateur radio
Communications & Data Handling

- Based on the Pumpkin Cubesat Kit FM430 flight module
- Texas Instruments MSP430 primary processor
- All software, including OS, custom-written from scratch
- Primary emphasis of software on telemetry collection and control of voice synthesizer payload

Sensors and Instrumentation

- Collects spacecraft state-of-health telemetry
- All telemetry collected using 1-Wire® interface
  - DS2438 – Smart Battery Monitor
  - DS2406 – Switch with output sensor for antenna deployment
  - DS18b20 – Temperature Sensor
- Telemetry collection rate can be varied for different purposes
  - i.e. use solar panel current for attitude determination
Telecom

● Stensat Transceiver
  ➢ Radio flight heritage on KatySat but custom-designed for TJ³Sat.
    – Students took active role on design of flight hardware
  ➢ Receiver operates via AFSK AX.25 1200 baud
  ➢ Transmitter operates via AFSK AX.25 1200 baud and FSK AX.25 9600 baud
  ➢ 1 Watt power output
  ➢ 4 Nitinol antennas deploy via heated resistor and nylon wire (UV will deteriorate wire if necessary)

● Groundstation (constructed primarily via donations from AMSAT)
  ➢ Kenwood TM-D700A radio
  ➢ Receiver and antennas located on school grounds
  ➢ Custom dual side band antennas with polarity switching

● Frequency Allocation
  ➢ Downlink: 437.320 MHz
  ➢ Uplink: 145.980 MHz
Power

- Topology based on schematic design supplied by Stensat, LLC
- Component selection carried out by students based on research and mentor recommendation
- All boards designed in-house and prototyped in-house using LPKF s42 PCB mil
- Prototypes tested and design meets all requirements

- Solar Panels – Six panels each with 18 Spectrolab TASC cells
  - Simple, low component design
  - Shunt regulator design to reduce excess power

- Battery Board – Four 1.2V NIMH cells supply 4.8v to bus
Integration, Test, and Launch

- Engineering model completed for initial testing
- All testing to be compliant with CalPoly requirements
  - Recently received TestPod and testing will begin this fall
- Preliminary testing to be conducted at TJ campus
  - Testing equipment includes $10^{-4}$ tor Thermal Vac, Vibration table, Oscilloscopes and reflow soldering capability
- Flight testing to be conducted at Orbital campus
  - Construction of flight ready hardware and circuitry
  - Testing of flight ready hardware
Learning Lessons Early in a Career

When asked about the important lessons they have learned, the students working TJ³Sat are particularly insightful:

- The importance of the engineering design process, including design reviews
- Good communication skills are critical. Standing in front of an audience of mentors and peers is daunting
- Mistakes are the most powerful and effective learning tool
- Electrostatic discharge can kill a solar panel
- Problem solving abilities are essential to any good system engineer
- Program continuity and transition between school years is a challenge

A “learn by doing” class like this has proven its worth over time and has taught students new skills and concepts that could not have been taught by a teacher.
Can my High School do a Cubesat?

- Can my High School design and build their own satellite rather than simply be involved as a recipient of an “outreach” program?

**Conventional wisdom:** NO

- Lacking knowledge base
- Insufficient resources
- Unqualified faculty

**Visionary Response:** YES

- Provide a lab-based curriculum that accommodates design projects
- Allow students to take the “same” class multiple years
- Create a structured program that focuses on the design process
- Use existing standards and COTS components
- Simplify the process
- Provide solid mentoring
Bringing It All Together

● Building a satellite is a great catalyst to instill students with a sense of discipline, teamwork, and accomplishment

● Systems Engineering is not just a discipline, it is also process, coordination, and continuous learning

● The students are learning important lessons in the most formative years of their future careers

SmallSat 2009 – Stay tuned for an update of TJ³Sat’s orbital operations!
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