# Blending research and teaching through high-altitude balloon projects

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2011 June 24

# The Problem

- Teaching students concepts involved in designing, constructing, launching, and operating spacecraft and space systems
  - Mechanical
  - Electrical
  - Thermal
  - Power generation
  - Stabilization
  - Software

# Access to space

- Mission design
- Spacecraft design, construction, and testing
- Launch cost
- Ground control cost
- Timeline vs. student availability

# Access to space

- Regularity of access
  - Annual/semester courses

For many institutions, access to space is too costly to be practical

# “Paper spacecraft”

- Design-only approach: spacecraft never leaves the drawing board
  - Good for high-level concepts, overall system design, overall mission design
  - First step to provide framework within which to carry the concept further
  - Very low cost

# “Paper spacecraft”

- Considered ‘too academic’ by some
- No exposure to real-world problems like
  - Debugging
  - Unexpected systems interactions
  - Assembly problems
  - Thermal control
  - Component behavior vs. specs

With “paper spacecraft” students don’t get some of the most valuable real-world experience that would teach them what to expect when they start building real spacecraft.

# Simulated spacecraft

- Two basic types
  - Software-only simulations
    - Spacecraft attitude control, thermal control, power generation, communications
    - Teaches a very important lesson: writing good software is a non-trivial task
    - Inexpensive: requires only general purpose computers

# Simulated spacecraft

– Drawbacks to the software-only approach
  - Similar to “paper spacecraft”, level of abstraction is high
  - May seem overly technical and/or arbitrary to students
  - Does not expose students to mechanical and electrical design and construction issues and interactions

# Simulated spacecraft

- Hardware-based
  - Actually constructing a spacecraft bus
  - Exposes students to designing, building, wiring, programming, and running a spacecraft
  - Optionally exposing the spacecraft to simulated elements of the space environment
    - Vacuum
    - Temperature

# Simulated spacecraft

- Hardware-based pros
  - Cheaper than launching
  - Exposure to real-world systems performance
  - Less "launch pressure"
- Cons
  - Not space
  - Limited science payload applicability

# The near-space alternative

- High altitude unmanned balloons
  - – Many similarities to space
    - Partial Vacuum
    - Cold temps
    - Ionizing radiation
    - Solar insolation

# Near-space

- Inexpensive access compared to rocketry or high-altitude aircraft
- Provides an environment where actual scientific studies may be performed
  - Upper-air chemistry
  - Dust collection
  - Radiation measurements
  - Radio propagation

# UND High Altitude Balloon Project

- Started in 1998
  - John Graham and John Nordlie, Space Studies Department
  - Pilot project
    - Self-funded
    - No experience
    - AMSAT balloon work
    - Edge Of Space Sciences (EOSS) – invaluable!

# UND HABP

- Student volunteers
  - Physics, EE, ME, Space Studies, etc.
  - First experience with high-altitude balloons, electronics, radio communications, tracking, weather, and federal regulations
    - FAR 101: what do they mean!?

# UND HABP

- Radio amateurs
  - Strong interest from local hams
  - Invaluable experience and advice
  - Extensive ‘fox-hunting’ experience

# First Launch

- "Baby steps": realistic mission objectives
  - Build, launch and track payload
  - Radio transmitter
  - Flight computer
    - Send tracking signal on radio
    - Trigger camera
    - Run dust collector experiment
  - Power
  - Parachute

- Successful launch and tracking
  - GSE and procedures
- Ran out of battery power before burst
  - Power system design flaw
  - Insufficient testing
- Never recovered
- Considered valid proof-of-concept
  - Additional funding and student interest

# Additional launches

- 1999 – 2011: 40+ flights, 90%+ recovery
- Switch to APRS tracking
- Refined filling and launch techniques
- Payloads:
  - Film cameras
  - Radio propagation and repeating
  - Video camera

- – Air samplers
- – Plant seeds
- – Plantlets
- – Unexposed film
- – Dust collectors
- – Aerogel micrometeorite collector
- – Model rocket

# Student involvement

- Student-designed systems:
  - Temperature logging
  - Ionizing radiation logging
  - Cut-down mechanisms
  - Flight computers

# Student involvement

- Student-designed spacecraft
  - Microsatellite bus, UND School of Engineering and Mines

# Faculty research

- Atomic mercury traps (gold coated sand and air pump)
  - Blaise Mibeck, UND EERC
- Biological payloads (plants)
  - Dr. Vadim Rygalov, UND Space Studies

# Transition

- Sure it's fun and all, but what are we trying to accomplish?
- Launch service provider, or learning environment?
- Roles of faculty, staff, and students

# Recent work

- Mission design concept rethink
  - Formal systems engineering approach
  - Inclusion in student Senior Project curriculum
  - More meetings, milestones, deliverables, fixed dates
  - Less chaos and frustration, more directed work and better progress

- Role of faculty now seen more as mentors
  - Students learn more, and are more responsible for mission directives, planning, and execution

# Challenges

- Keeping a core group with skills and experience
- Funding
- Launch schedules and opportunities
  - ND Climate
  - Weather
  - Summer student availability
  - Launch site availability

# Challenges

- Liability insurance
  - How much is enough?
  - What are the risks?

# Future work

- Blending Unmanned Aerial Vehicle and ballooning technologies
  - Launch site return
  - Obstacle avoidance
    - Lakes, forests, populated areas
    - ADS-B
- Modular bus system
  - Simplify integration
  - Standard tracking, communication, and control

# Questions?

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