Augmenting a space mission design course with high-altitude balloon projects

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Outline
1. Introduction
2. Background
3. High-Altitude Balloon Team Projects
   A. Imaging Payload
   B. Other Team Projects
4. Conclusion
UND Space Studies

- Established in 1987
- Space Studies
  - goal/mission: provide broadly-based, interdisciplinary space studies education
  - ~15-20 students on campus
  - ~75 distance students
  - ~650 alumni working in commercial space industry, NASA, military, and other organizations
UND Space Studies combines:

1. Space physical & life science
2. Space engineering
3. Space policy and law
4. Space business and management
5. Space history
What We Offer

- M.S. in Space Studies (in both campus and distance mode)
- Undergraduate minor in Space Studies (campus only)
- Research opportunities at MS level
- Ph.D. is under consideration
Space Studies 405 (SpSt 405) - Space Mission Design -

• **Course objective**
  - Foster an understanding of the space mission design process, including knowledge of payloads and subsystems and the interaction of major mission elements

• **Team projects**
  - One-third of the student effort
  - Engineering design projects assigned throughout the second-half of the semester
Space Studies 405 (SpSt 405)
- Space Mission Design -

• Students
  – On-campus and distance
  – Undergraduate and graduate
  – Technical and non-technical backgrounds

• Can be taken for graduate credit
SpSt 405 - Space Mission Design

• Course content
  – Recently modified to incorporate more experiential learning
  – Exposure to many aspects of a typical space mission through near-space missions
  – Textbooks
    • Space Mission Analysis and Design¹ (SMAD)
    • Understanding Space: An Introduction to Astronautics²
UND student-driven aerospace engineering projects

• Prominent aerospace engineering projects
• Unmanned aircraft system (UAS)
  – Motivation SpSt 405 Imaging Payload
• High-altitude balloon (HAB)
• Sounding rocket payload
• Small spacecraft development
• Support for these projects that involve geographically dispersed participants
UND High Altitude Balloon (HAB) Project

UND HAB Coordinators
John Nordlie
Ron Fevig
UND/UNF HASP 2008 - 2011

Ozone Profile - Ft. Sumner, NM

Height (m)

Concentration (ppm)
Airborne Real-Time Embedded Mosaicking Imaging System (ARTEMIS)

- Collaborative effort between the Departments of Electrical Engineering and Space Studies
- Imaging system is currently being developed for UAS
- May be implemented on balloon-borne and space-borne platforms
Image Mosaicking

- Multiple images transformed into a single image
- Feature detection used to determine overlap
- Mosaicking traditionally involves post processing

*Images courtesy of David Dvorak, Dr. Jeremiah Neubert*
Mosaicking from Video

- Feature detection
- Correlation between frames
- Motion estimation
- Image transformation

Size comparison:
Video: 2.78MB (4sec AVI, 15fps)
Image: 25.2 KB (380x290 JPEG)

* Still image is over
100x smaller *
Online conferencing

• Adobe Connect Pro® used for distance instruction within the Department of Space Studies
  – Audio, video, chat, whiteboard, share (presentations and screen), file sharing
  – Chat sessions
  – Distance student classroom presentations
  – Regular communications with independent study and thesis-track students

• “Virtual Engineering Teams” for geographically dispersed participants
Virtual Engineering Teams
Preliminary Design Review for HASP 2008
Virtual Engineering Teams
Coordinating with our RockSat canister partners in CO
SpSt 405 - Space Mission Design

Team Projects

• Grading
  – Examinations = 60%
  – Team project(s) = 30%
  – Participation = 10%
    • Split between instructor and peer evaluations

• If taken for graduate credit, student must serve as a team lead, or serve on two teams.
SpSt 405 – Team Projects

• Culminated in either a
  – Mission concept review (MCR)
  – Preliminary design review (PDR)
  – Critical design review (CDR)
  – Flight readiness review (FRR)
  – Operational readiness review (ORR)

• Four deliverables:
  1. Team member biographical sketches
  2. Team status report
  3. Initial design review
  4. Final design review
SpSt 405 – Team Projects

• Focus on HAB Imaging Payload
• Primary objective
  – Acquire video with varying levels of ground resolution from a high-altitude balloon to test with ARTEMIS software

Camcorder: DCR-SX40
Aspect Ratio - 16:9 (movie)
Resolution - 720x480 pixels
zoom - 60x (optical)
CCD - 1/8" Advanced HAD
F stop - 1.8 to 6.0
Focal length - 1.8 mm to 180 mm

DCR-SX40 picture from Sony Website at: http://www.sonystyle.com/
HAB Imaging Payload

• Mission requirements and constraints were derived

• Design tasks included
  – Field-of-view and theoretical resolution calculations
  – Simple thermal modeling
  – Mass and power budgets
  – Mechanical drawings
  – Software development
  – Rudimentary engineering prototype
  – Flight model was built, fully tested, passed the FRR, and now awaits launch
HAB Imaging Payload
SpSt 405 – Team Projects

• Six projects in total
  - HAB Biological Payload – CDR
  - HAB Imaging Payload – FRR
  - HAB Launch and Tracking – ORR
  - Superpressure Balloon Mission – MCR
  - Satellite Ground Station – PDR
  - Small Satellite Mission – MCR
HAB Biological Payload Team

Mcnutt, Marty (Lead)
Booth, David
Borzych, Todd
Howell, Elizabeth
Perks, Theresa

Image courtesy of NASA
HAB Imaging Payload Team

Holland, Timothy (Lead)
Doby, John
Howell, Elizabeth
Spencer, Earl

Image taken from a locally-flown, UND high-altitude balloon at about 85,000 ft.
HAB Launch and Tracking Operations Team

Shallbetter, Wyatt (Lead)
Fitzgerald, Nicole
Haag, Lauren
Ray, Ron
Woida, Matthew
Superpressure Balloon
Mission Architecture Team

Meeks, Denise (Lead)
Booth, David
Borzych, Todd
Boyce, Patrick
Doby, John
Perrin, Thomas
Wilkins, Mary

Image courtesy of NASA
Satellite Ground Station Team

La France, Kayla (Lead)
Spencer, Earl
Anderson, Travis
Dusterhoft, Zachary
Small Satellite Mission
Architecture Team

Lilko, Randall (Lead)
Anderson, Travis
Boyce, Patrick
Perks, Theresa
Perrin, Thomas
Wilkins, Mary

Image courtesy of JAXA
SpSt 405 - Student Feedback

• Very high marks in all categories of the students’ evaluation (4.7/5.0)
  – Connection of assignments to course goals (4.8/5.0)
  – Connection to real world situations (4.8/5.0)

• Some written comments
  – “Fantastic way to teach us both the book process for Space Mission Design while actually having us participate in two teams and track the other teams at the same time.”
  – “I would recommend this as a great practical way to begin a hands-on way to learn the Space Mission Design process.”
Q: “Describe some aspects of this course that promoted your learning.”
A: “Real world projects to work through mission design process.”

Q: “If a student asked whether you would recommend this course from this instructor, what would you recommend and why?”
A: “Yes, because of the team project.”
Conclusion

Concluding remarks and directions for future work:

High-altitude balloon missions provide practical exposure to the major phases of space mission design. Such projects provide a low-cost, short-timeline solution to otherwise costly and lengthy spacecraft development projects.

SpSt 405 high-altitude balloon projects are an incremental step toward a self-sustaining, student-led high-altitude balloon program at the University of North Dakota.
Conclusion

• Concluding remarks and directions for future work (cont.):

  Collaboration with those who have experience with assessment plans that tests the effectiveness of this type of project-based learning in a space mission design course is more than welcome.

  We invite collaborative efforts involving virtual design teams for payload development efforts and coordinated launches.
Acknowledgments

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  • Funds for HAB hardware
References

Questions?

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The CubeSat program secures launch opportunities for nanosatellites.

The University of Arizona designed, built and delivered two Cubesats.

Size = 10 X 10 X 10 cm

Mass ≤ 1 kg

Target orbit → 650km, sun-synchronous
UA Rincon Cubesat
Scope of the UA CubeSat Project

- 56 students (20 extremely dedicated)
  Majors from EE, ME, CS, Physics, Planetary Sciences, Optical Engineering, Systems Engineering

- 25 faculty mentors

- 36 sponsors

- Cost/satellite ≈ $250,000 (?)
UND HASP  
(High Altitude Student Platform)

- HASP provides flights for student-built payloads on NASA zero-pressure balloons.
- HASP provides power and a data link for these payloads.
- Altitude ≈ 36 km
- Duration = 15 - 20 hours
- UND DSS applied for and was awarded a flight.
HASP & Gondola

(HASP Manual, 2008)
2009 RockSat

“The Next Step in Low Cost Student Access to Space”

- UND’s payload sampled gases in the mesosphere
- Launch date = June 26, 2009
RockSat Timeline

- 08-18-2008  RockSat Payload User’s Guide Released
- 09-22-2008  Submit Intent to Fly Form
- 09-29-2008  Initial Down Selections Made
- 10-27-2008  Earnest Payment of $1,000 Due
- 10-28-2008  Conceptual Design Review (CoDR) Due
- 10-28-2008  Online Progress Report 2 Due
- 11-14-2008  Preliminary Design Review (PDR) Due
- 11-28-2008  Online Progress Report 3 Due
- 12-12-2008  Critical Design Review (CDR) Due
- 12-19-2008  Final Down Select—Flights Awarded
- 01-23-2009  First Installment Due
- 01-30-2009  RockSat Payload Canisters Sent to Customers
- 01-30-2009  Online Progress Report 4 Due
- 02-20-2009  Individual Subsystem Testing Reports Due
- 02-27-2009  Online Progress Report 5 Due
- 03-27-2009  Payload Subsystem Integration and Testing Report Due
- 04-10-2009  Final Installment Due
- 04-17-2009  First Full Mission Simulation Test Report Due
- 04-30-2009  Online Progress Report 6 Due
- 05-22-2009  Second Full Mission Simulation Test Report Due
- 05-29-2009  Online Progress Report 7 Due
- 06-10-2009  Launch Readiness Review (LRR) Teleconference
- 06-(22-24)-2009  MOI and Vibration Testing at WFF
- 06-24-2009  RockSat Payload Canister Integration with WFF
- 06-26-2009  Launch Day!
The Ride

- Terrier booster for ~5 seconds (Navy)
- Orion sustaining for ~25 seconds (Army)

Spin Stabilized!

Time Line
41.083/Koehler

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The Mission Objective

• To study the Mesosphere between 50 km and 90 km

• Demonstrate the capability of in-situ atmospheric measurements on sounding rockets.

• To measure:
  - $H_2$, $C_4H_4$, $O_2$, $N_2O$, gases in the mesosphere.
Payload Design

Pro Engineer used for design phase
Payload Design

- Allowed for accurate
- CG (1 cubic inch)
- Weight (20 lbs. +/-)
- Spatial restrictions
Electrical Design
Payload Construction

All the structural components were manufactured in-house.
Be Prepared!
The Completed Payload
Vibration Testing

• Vibration testing in x, y

• If our payload broke, we
  – Everything held but the boards were still not working and the ‘replacement’ payload was not integrated yet
Final Integration
Launch: June 26th, 2009 at 5:30am EDT

Recovered and returned to NASA WFF by 9:30am EDT
2009 RockSat Launch
Lessons Learned

Be Prepared
- Debugging at the hotel is not fun.

Freeze Design Early
- Freeze your payload design before it’s too late.

Communication
- Early and often
- Adobe “Connect Pro” for online conferencing
NSF CubeSat Program

• CubeSat-based science missions for space weather and atmospheric research
• NSF expects to launch two to four P-PODS per year in pursuit of achieving these scientific research goals
• Proposal deadline March 10th of each year
• Funding level up to $300,000/year for up to 3 years
The Future of ARTEMIS