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

Ronald Fevig, Ph.D.

Department of Space Studies,
University of North Dakota

2011 June 23

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

<u>Outline</u>

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

Space Studies Department

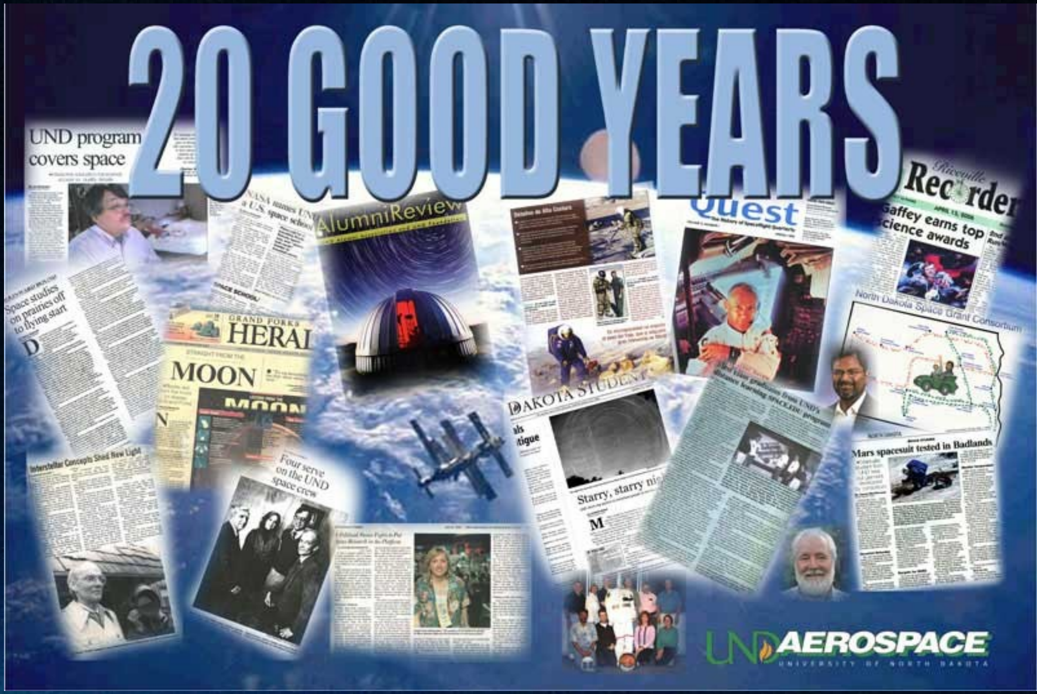
John D. Odegard School of Aerospace Sciences

University of North Dakota

Grand Forks, North Dakota

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

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 Design[1] (SMAD)
    - Understanding Space: An Introduction to Astronautics[2]

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

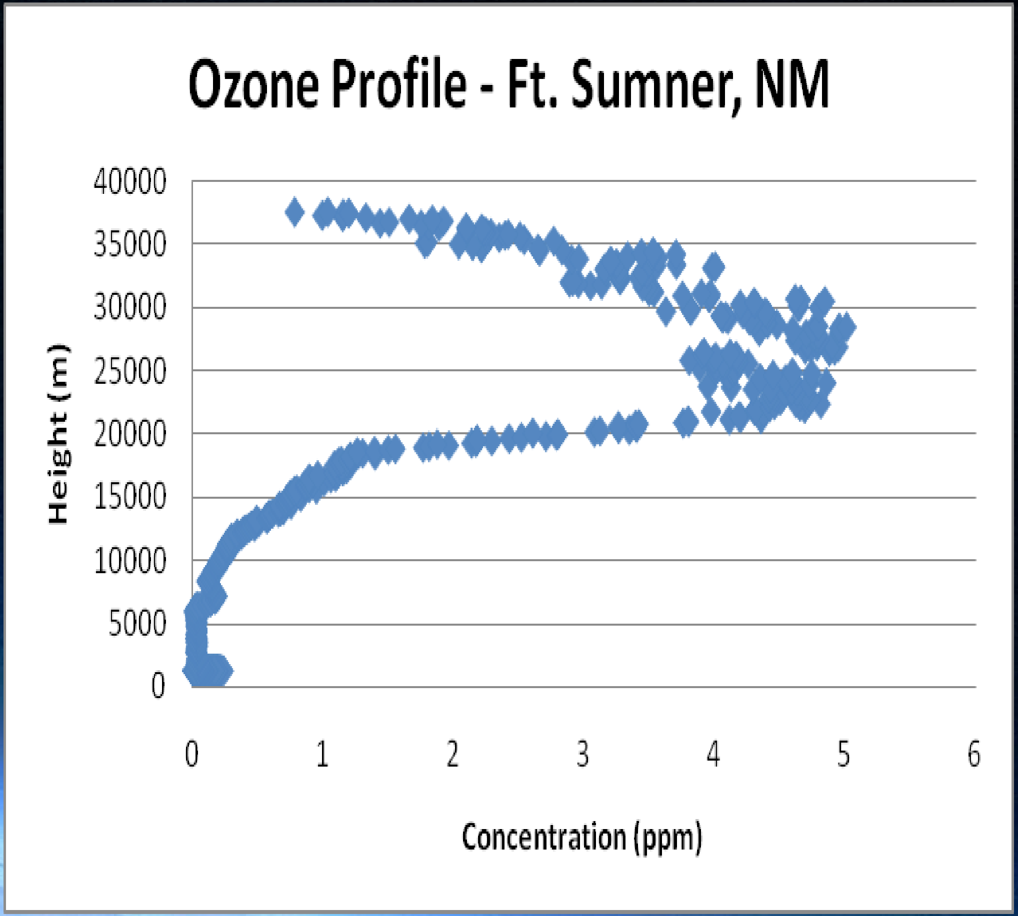
F

UND HAB Coordinators

John Nordlie

Ron Fevig

UND/UNF HASP 2008 - 2011

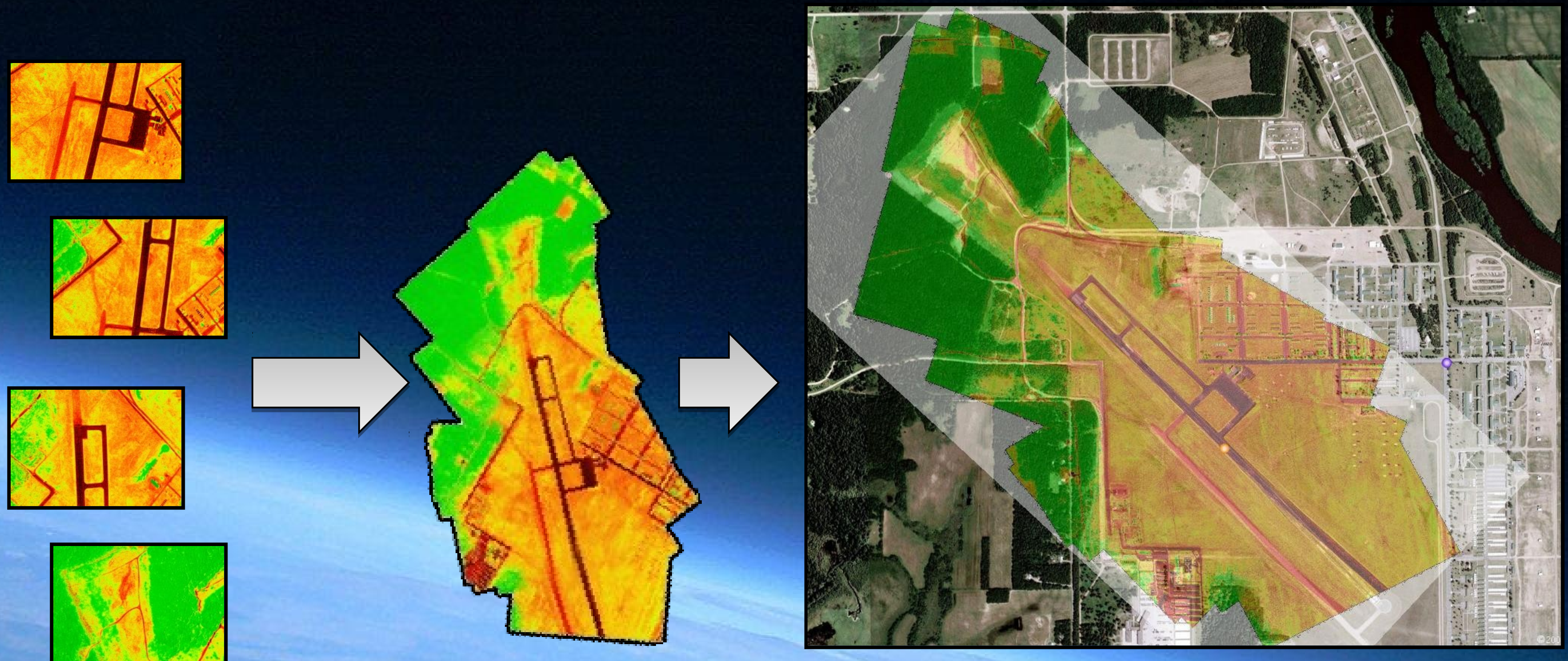


Airborne Real-Time Embedded Mosaicking Imaging System (ARTEMIS)

- 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

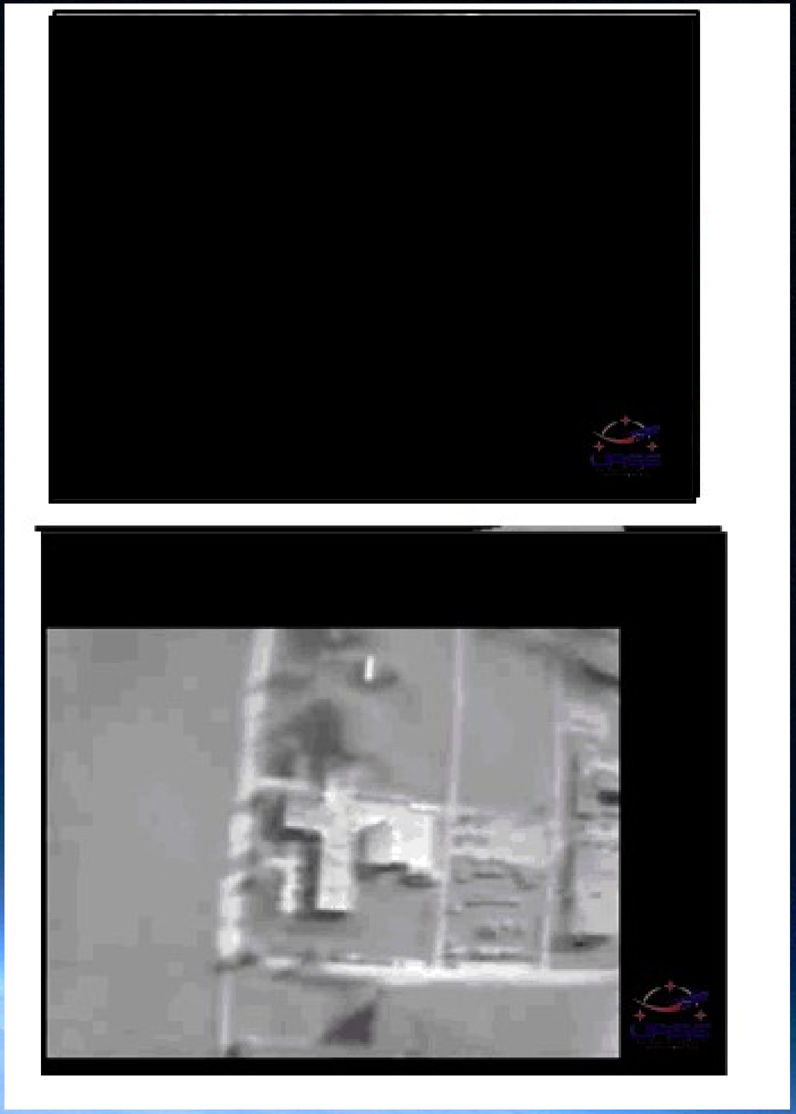
- Feature detection
- Correlation between frames
- Motion estimation
- Image transformation

Size comparison:

Video: 2.78MB (4sec AVI, 15fps)

Image: 25.2 KB (380x290 JPEG)

* Still image is over **100x** smaller *

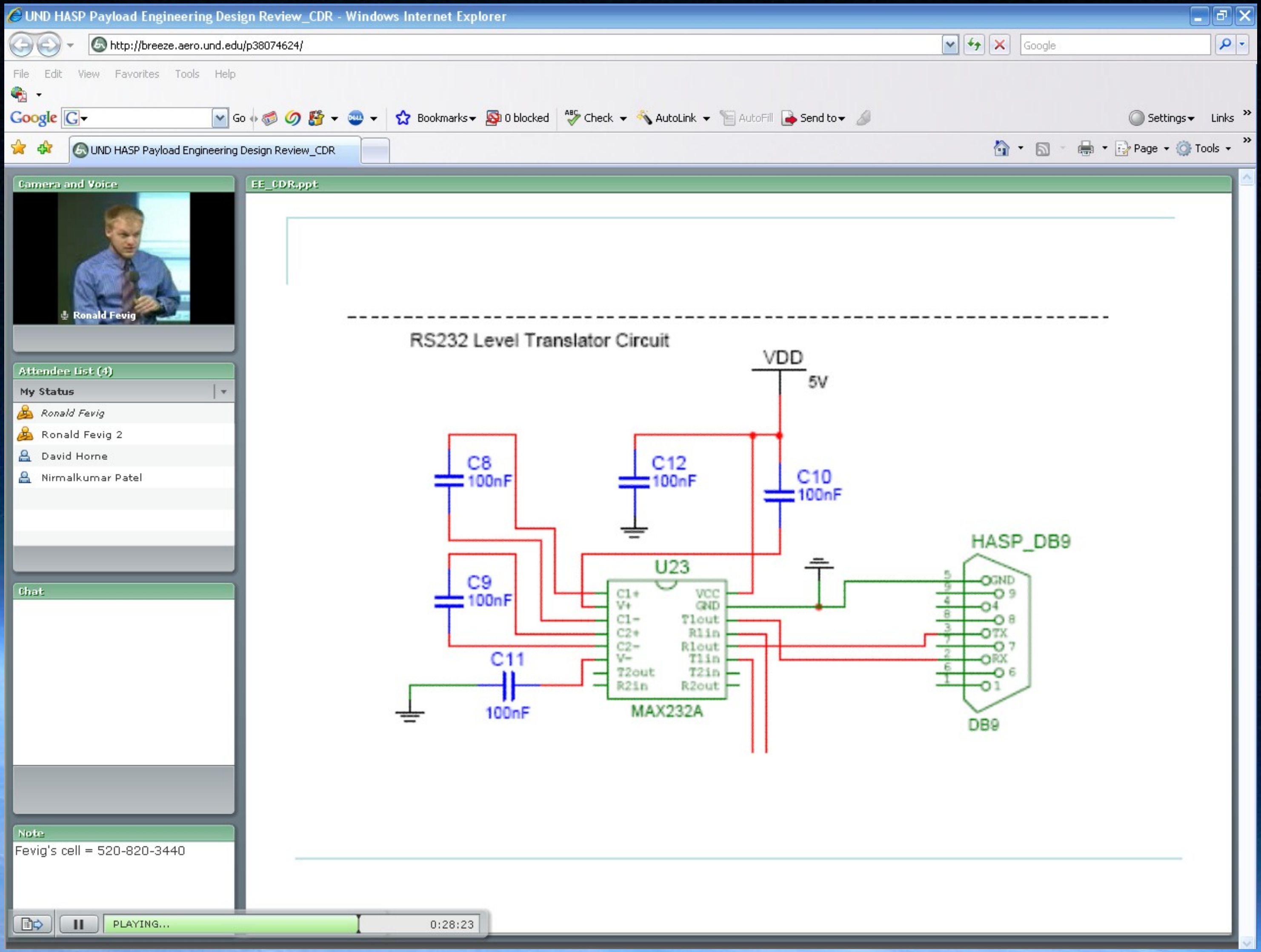


Online conferencing

- 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

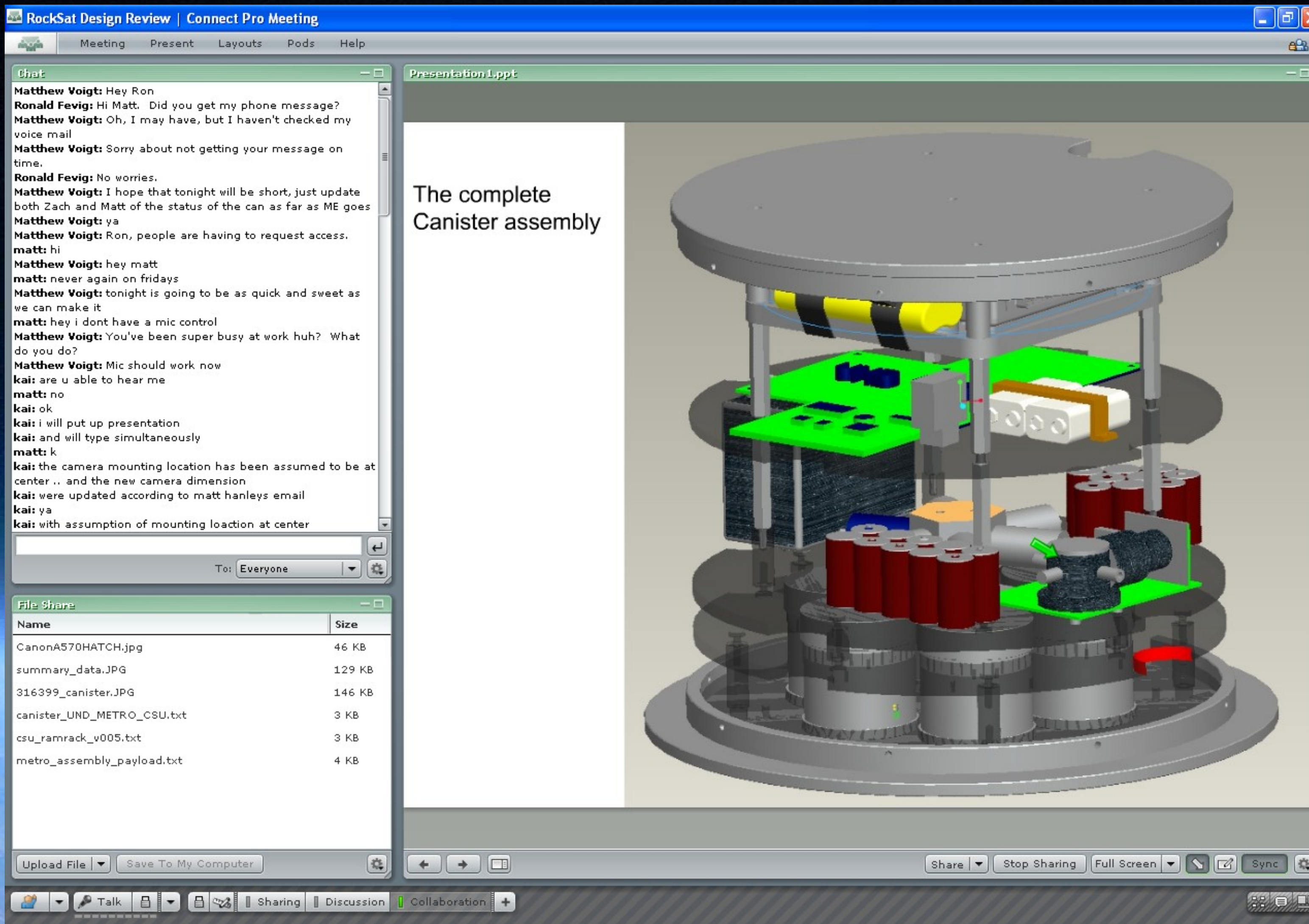
Virtual Engineering Teams

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

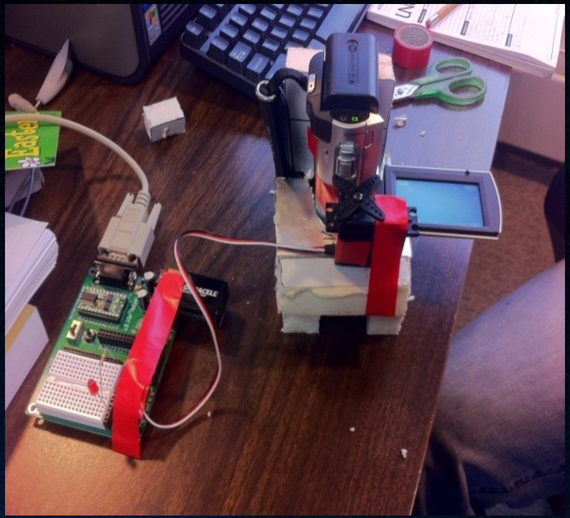
Focal length - 1.8 mm to 180 mm

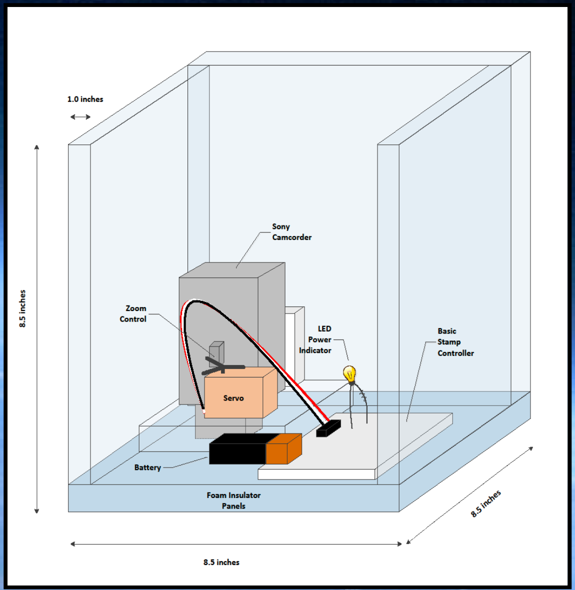
DCR-SX40 picture from Sony Website at: http://www.sonystyle.com/

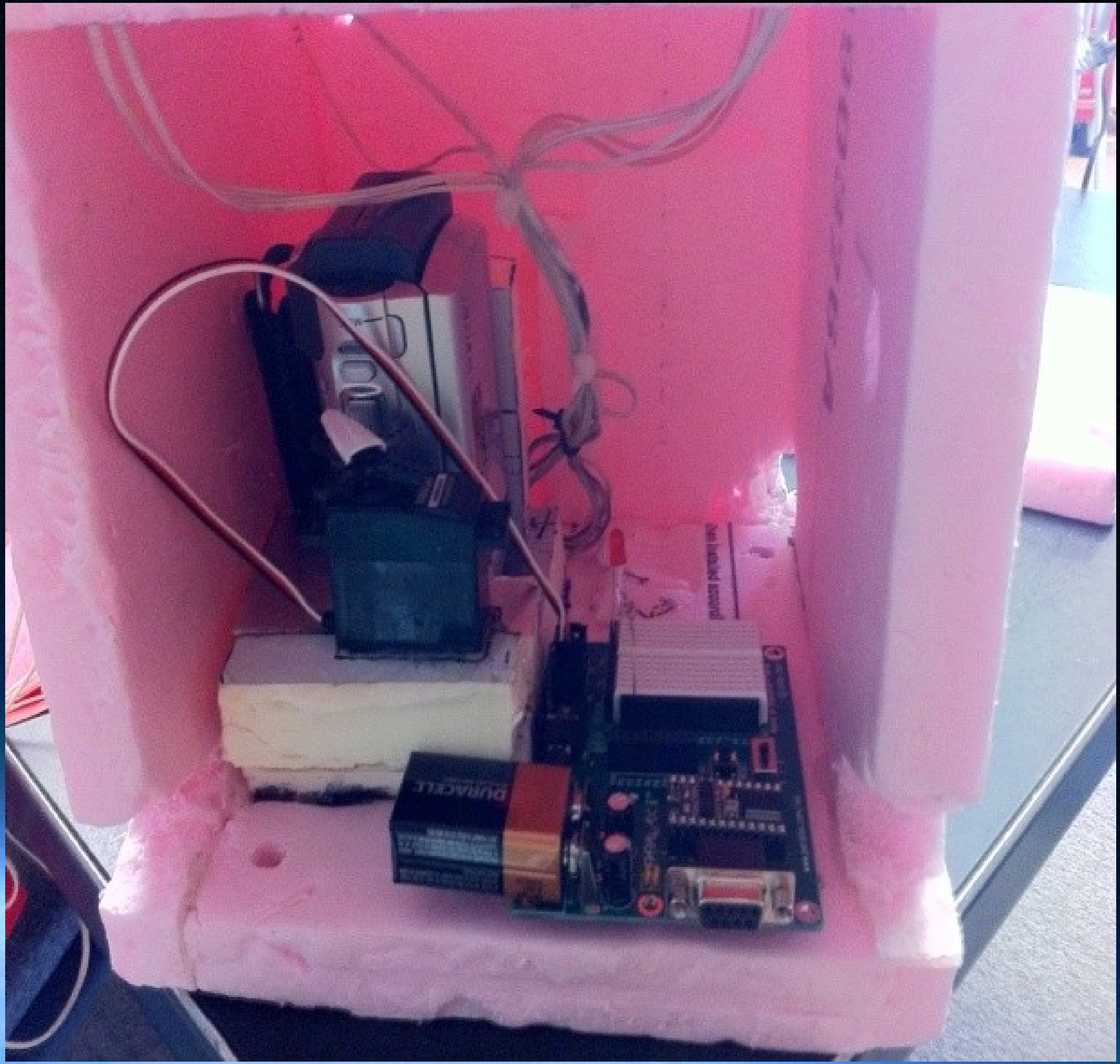
HAB Imaging Payload

- 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

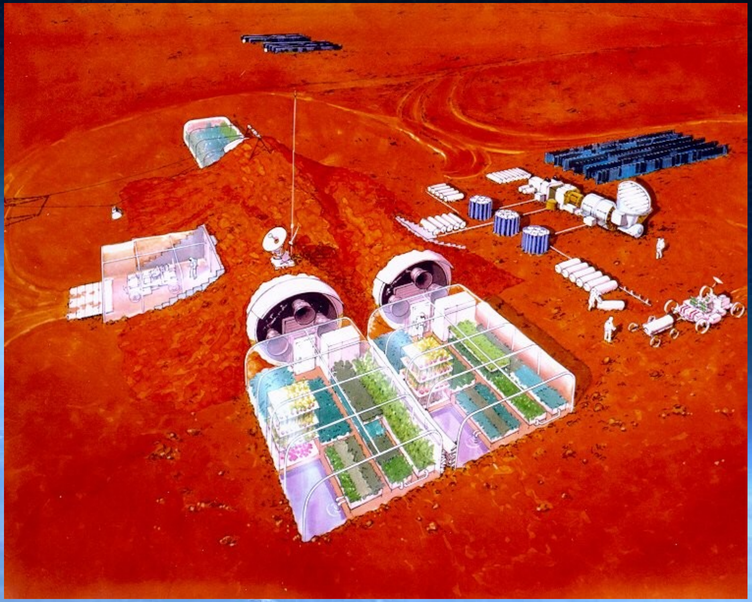


Image courtesy of NASA

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."

SpSt 405 - Student Feedback

- Some written comments (cont.)

  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

- North Dakota Space Grant Consortium
  - Course development for SpSt 405 through the 2010 Summer Faculty Fellowship
  - Funds for HAB hardware

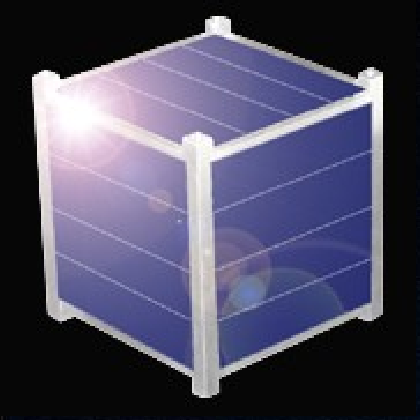
References

[1] Wertz, James R., and Wiley J. Larson, Space Mission Analysis and Design (Third Ed.), Microcosm Press, 1999.

[2] Sellers, Jerry Jon, Understanding Space: An Introduction to Astronautics (Third Ed.), McGraw-Hill, 2007.

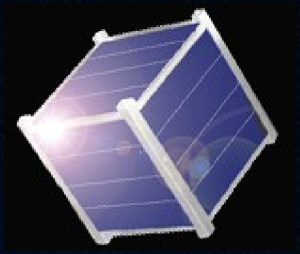
Questions?

Ron Fevig
rfevig@space.edu
(701)777-6790
www.space.edu



University of Arizona CubeSat Program

- The CubeSat program secures launch
- The University of Arizona designed, built
- Size = 10 X 10 X 10 cm
- Mass ≤ 1 kg
- Target orbit → 650km, sun-synchronous



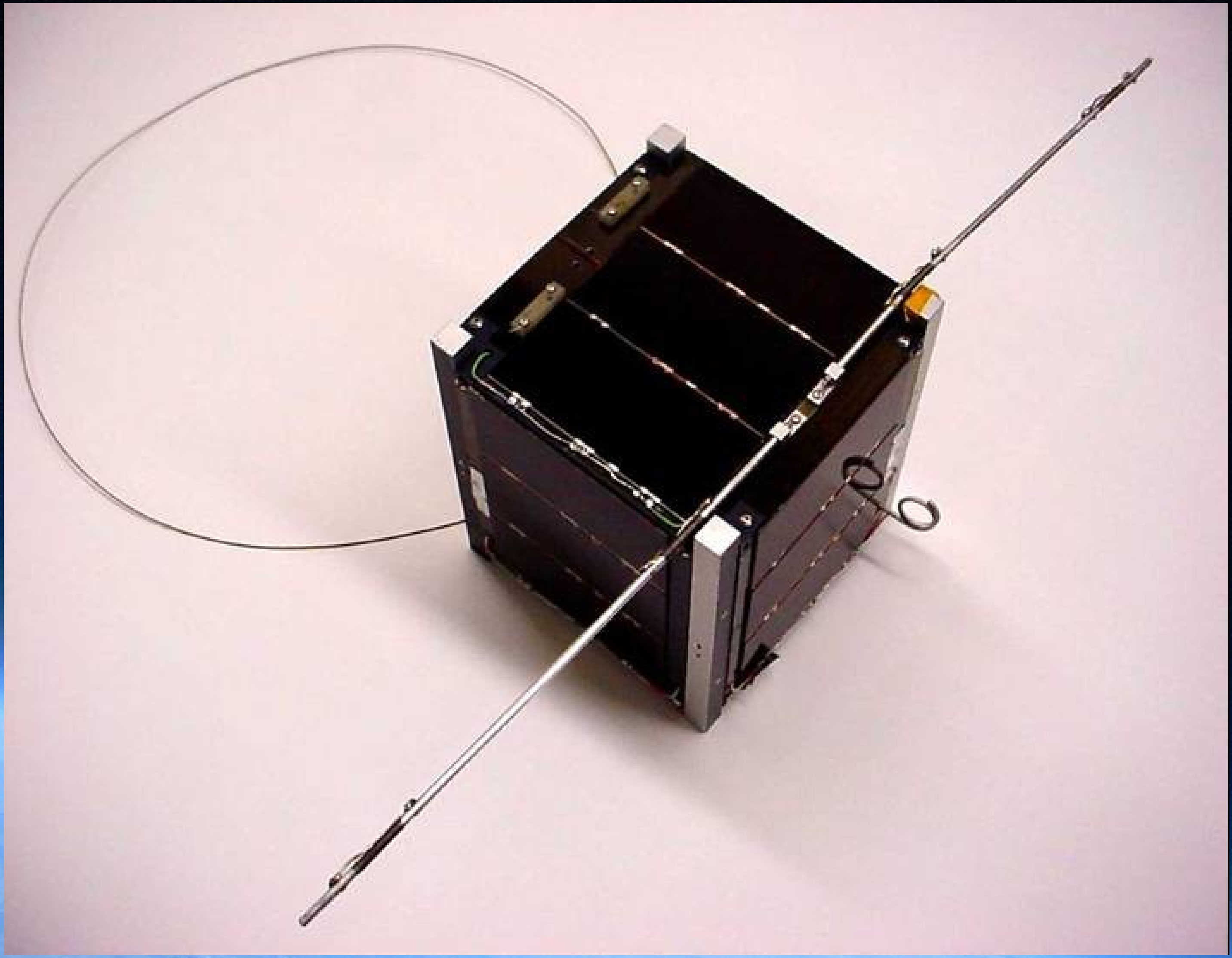
DEPARTMENT OF PLANETARY SCIENCES
LUNAR AND PLANETARY LABORATORY
The University of Arizona · Tucson, Arizona 85721

ALCATEL RESEARCH PARTNER

RINCON RESEARCH CORPORATION

ARIZONA SPACE GRANT CONSORTIUM

UA Rincon Cubesat



Scope of the UA CubeSat Project

- 56 students (20 extremely dedicated)

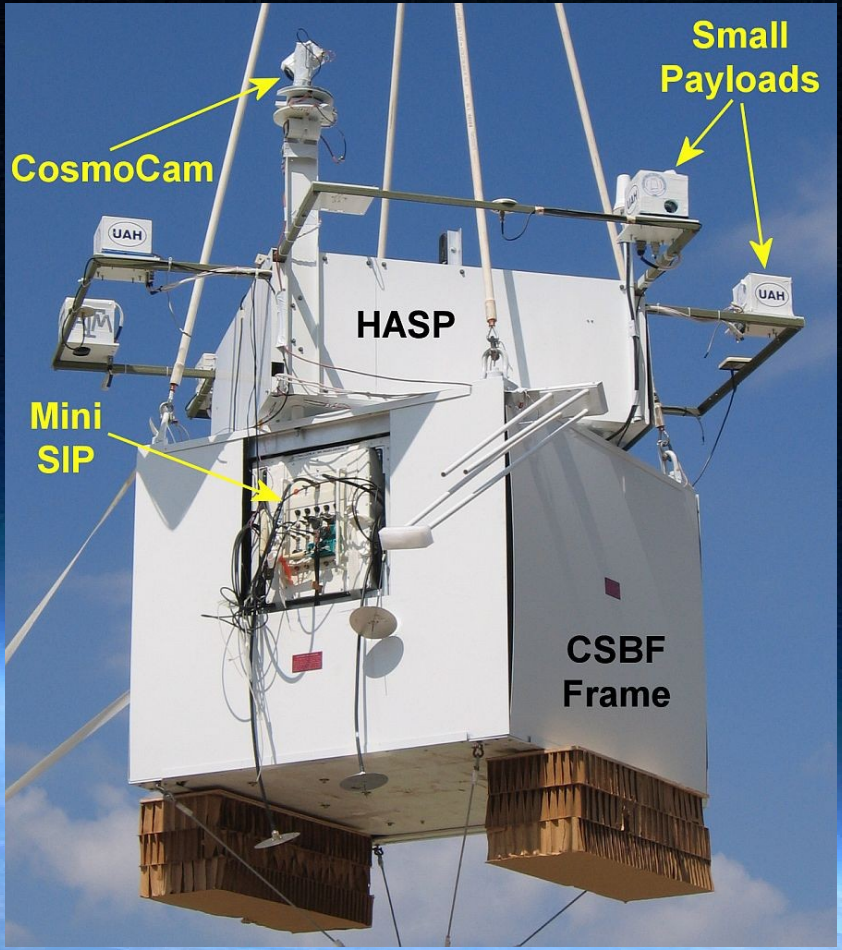
  Majors from EE, ME, CS, Physics, Planetary Sciences, Optical Engineering, Systems Engineering
- 25 faculty mentors
- 36 sponsors
- Cost/satellite ≈ $250,000 (?)

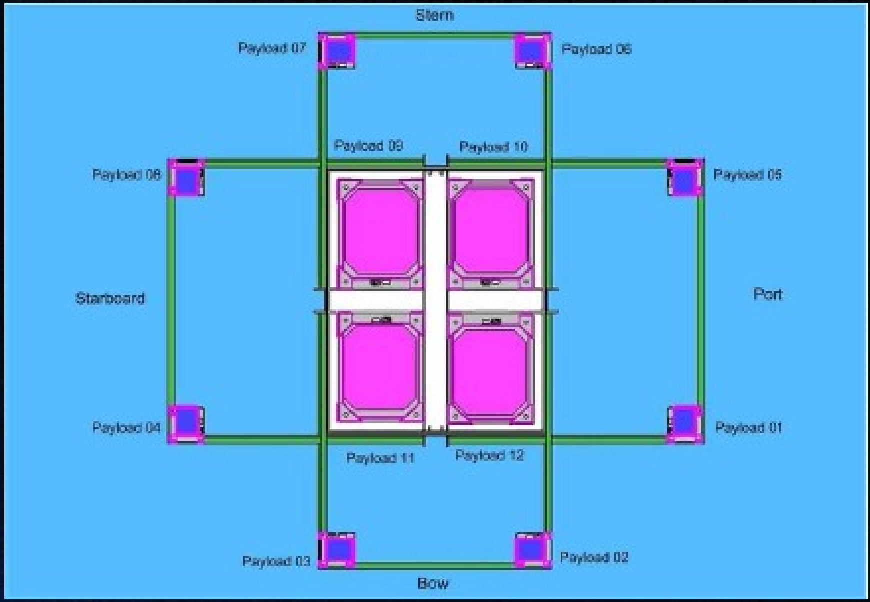
UND HASP
(High Altitude Student Platform)

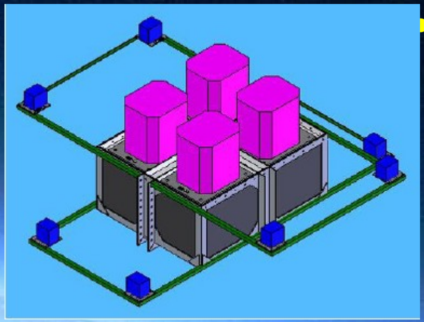
- HASP provides flights for student-
- HASP provides power and a data
- Altitude ≈ 36 km
- Duration = 15 - 20 hours
- UND DSS applied for and was

LSU SPACE SCIENCES GROUP
Department of Physics and Astronomy

HASP & Gondola





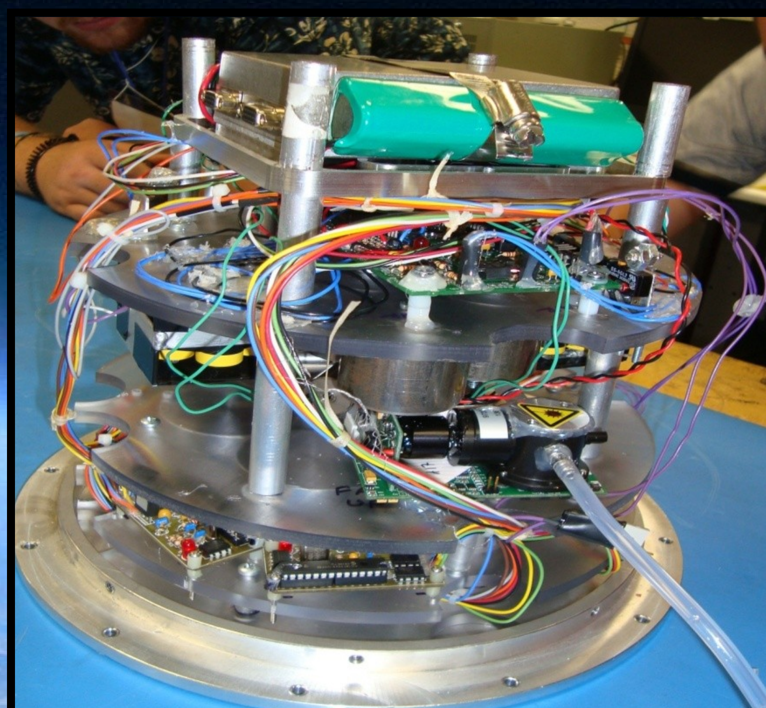


(HASP Manual, 2008)

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

T

•Spin Stabilized!

Time Line

41.083/Koehler

Weight: 581.6 lb.   QE: 84.0 deg.   AZ: 120.0 deg., ARC, WFF

11/3/2008

	Time (sec)	Altitude (Km)	Range (Km)	Velocity (mps)	Mach No.	Q (psf)	Fl. El. (deg)
Rail Release	0.4	0	0	47.7	0.1	29.1	84
Terrier Burnout	5.2	2	0.2	739.9	2.2	5779	83.1
Imp. Orion Ignition	15	8	1	522.9	1.7	1521.3	82
Imp. Orion Burnout	40.4	36.8	5.6	1413.9	4.4	140.8	80.2
Payload Separation	125	120.3	25.2	629.4	1.6	0	68.6
Apogee	187.5	138.6	39.1	227	0.6	0	0
300 kFt Downleg	287.9	91.4	61.7	971.6	3.7	0	-76.1
Ballistic Impact	361.4	0	78.4	1134.1	3.3	16451.7	-81.7
Chute Deploy	533.3	6.3	78.4	127.4	0.4	108.8	-44.5
Payload Impact	1012.4	0	78.4	31.9	0.03	1.2	-90

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

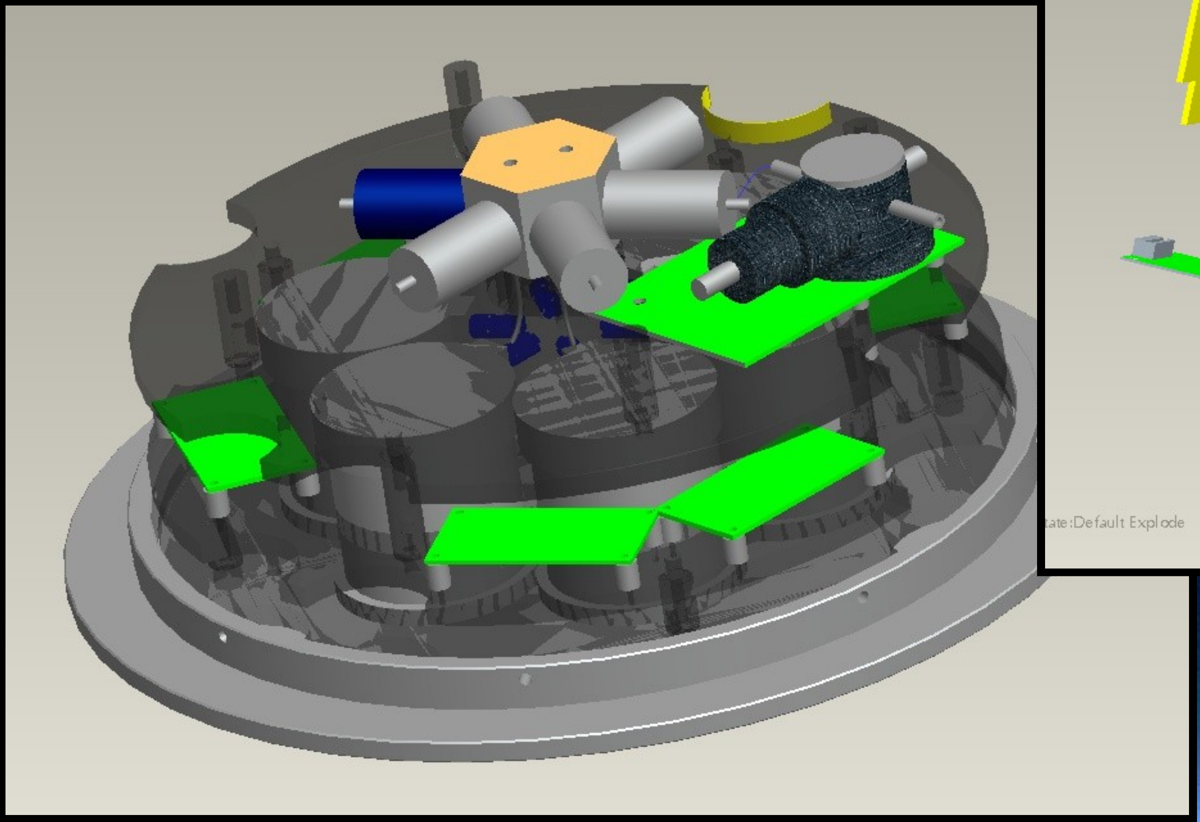
Wallops Flight Facility
Goddard Space Flight Center

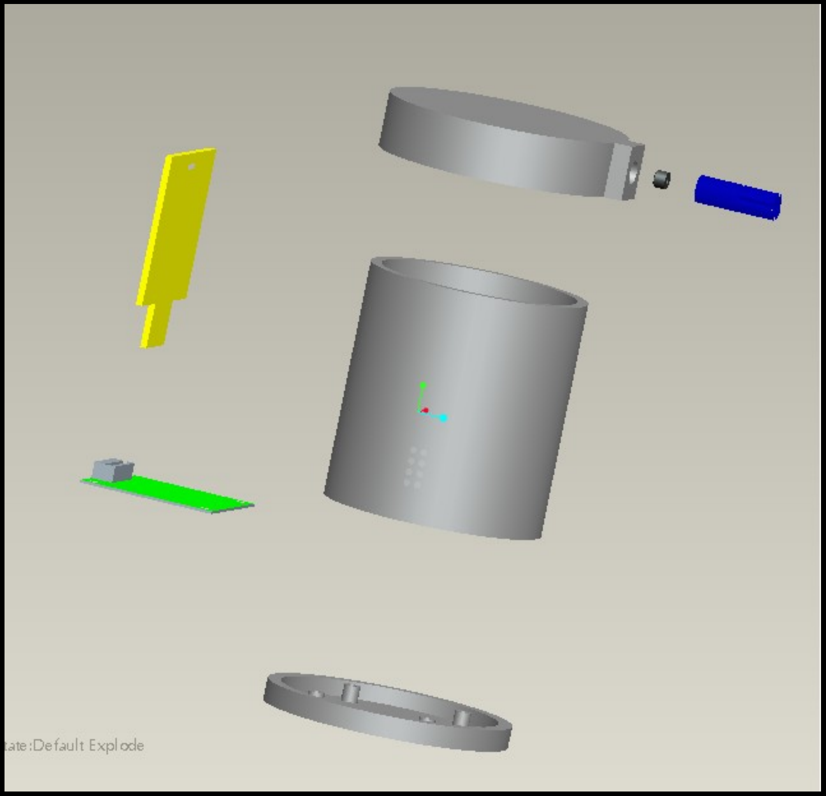
The **Mission Objective**

- **To study the Mesosphere between 50 km and 90 km**
- **Demonstrate the capability of in-situ atmospheric**
- **To measure:**

Payload Design

Pro Engineer used for design phase



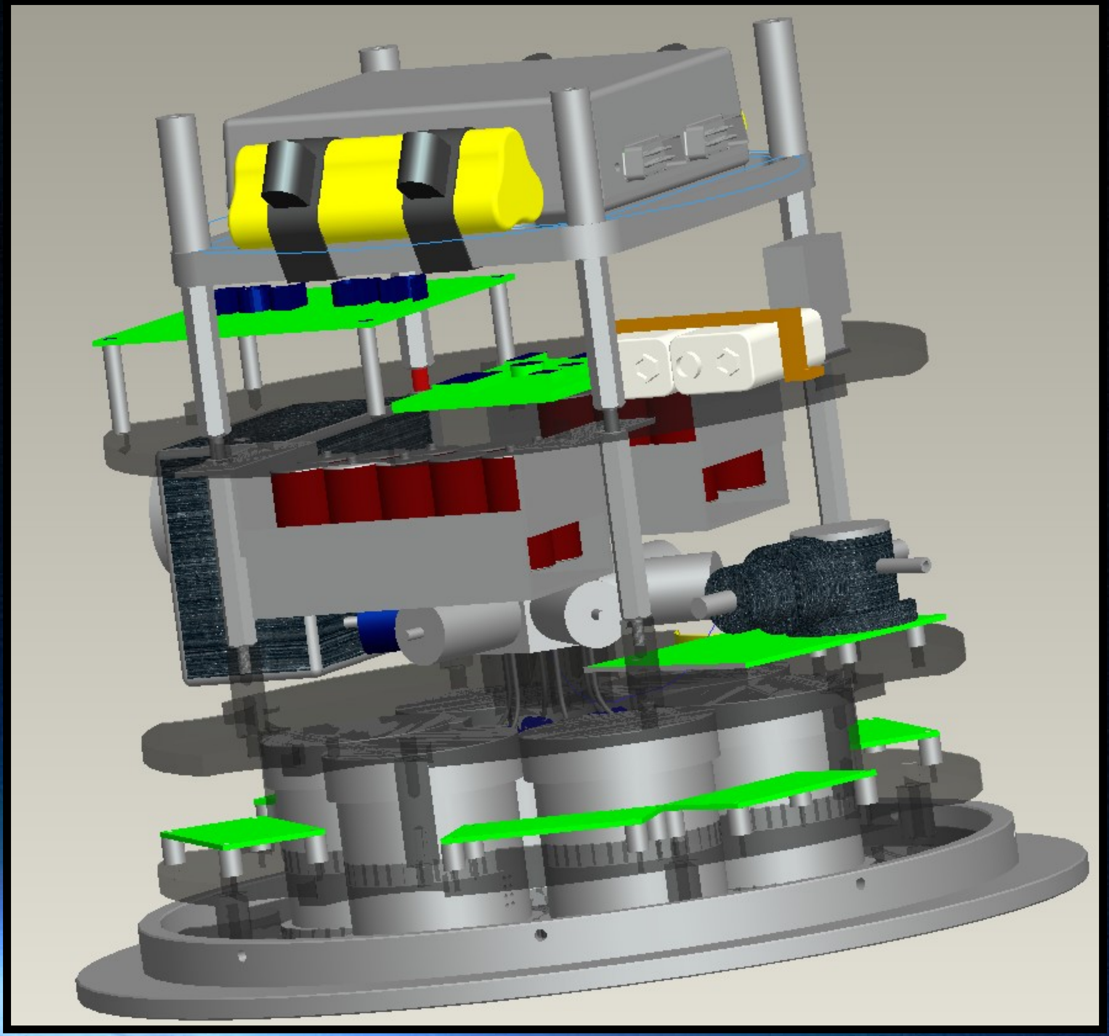


Payload Design

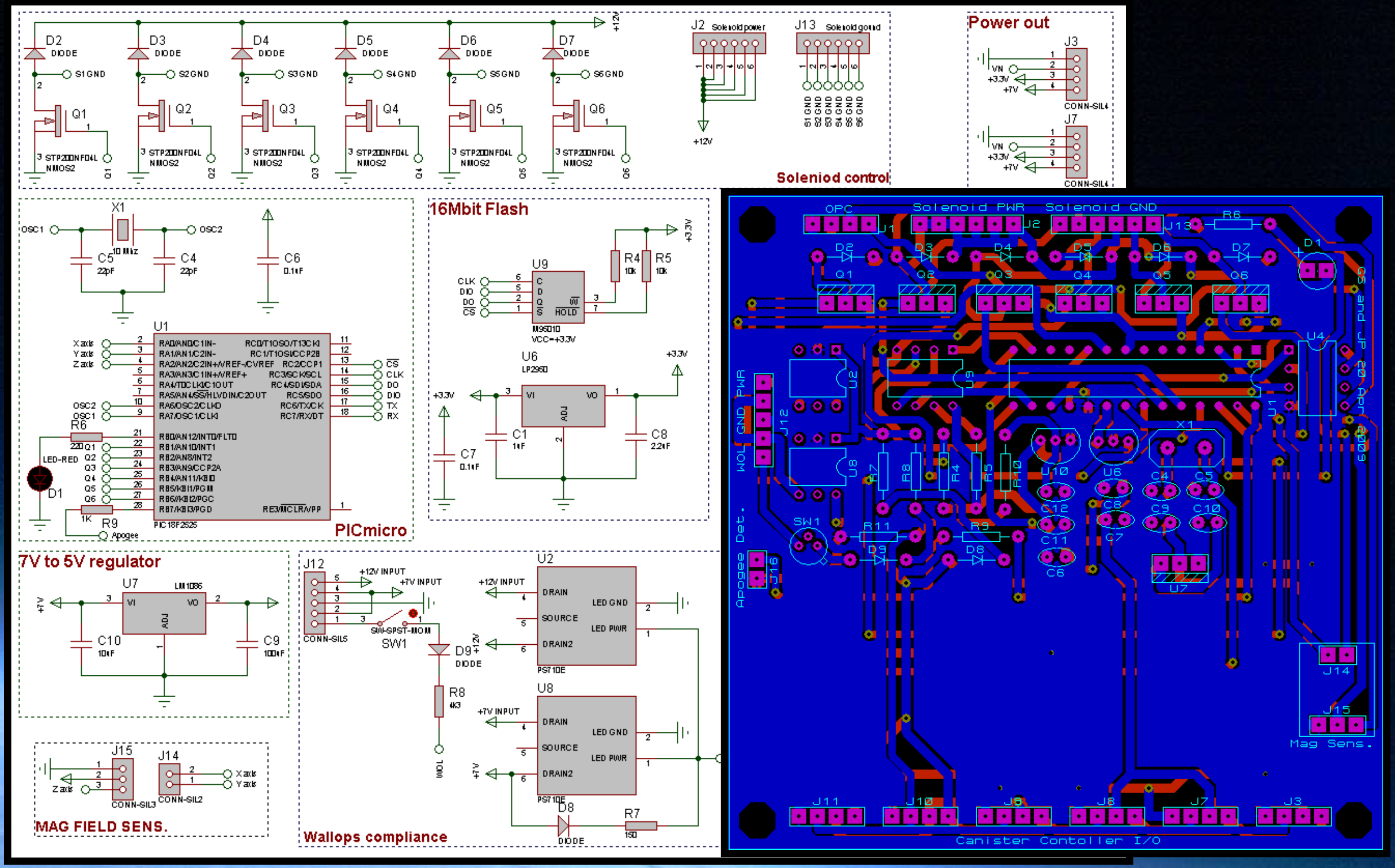
- Allowed for accurate

- CG (1 cubic inch)
- Weight (20 lbs. +/-

- Spatial restrictions



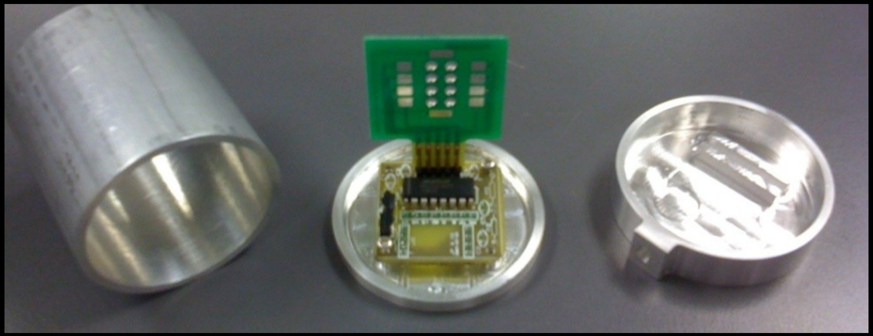
Electrical Design

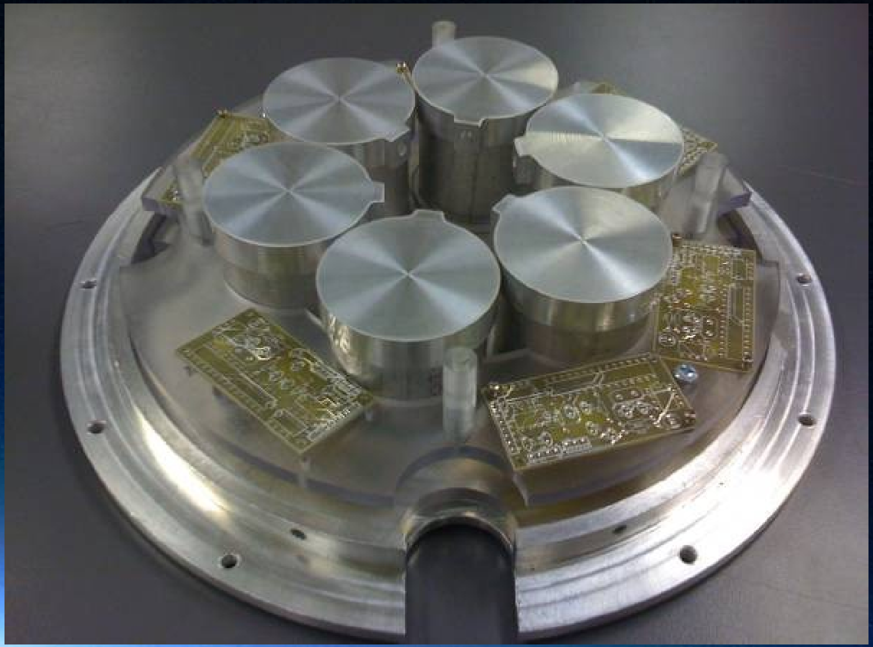


Wallops Flight Facility
Goddard Space Flight Center

Payload Construction

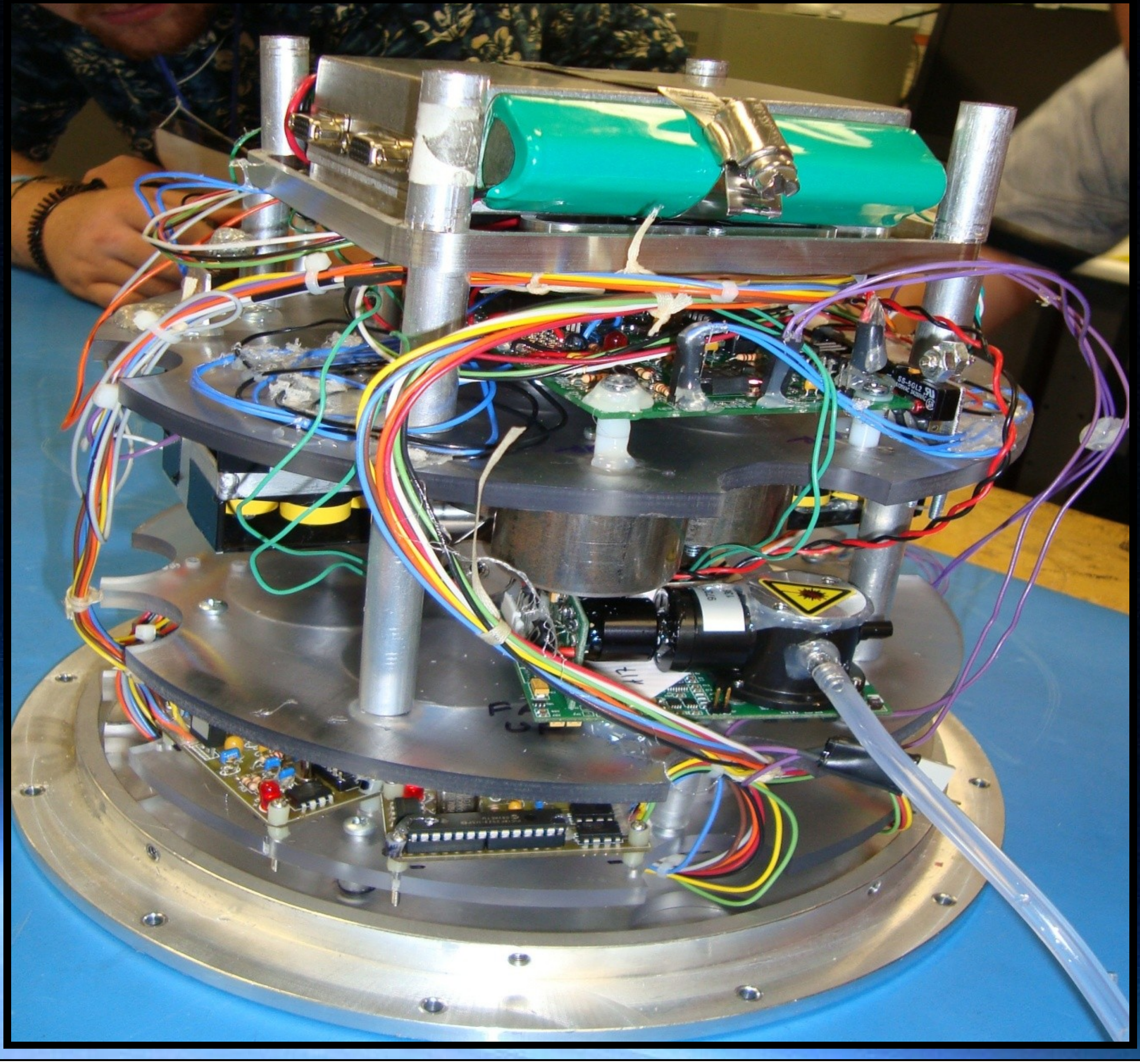
All the structural components were manufactured in-house.





Be Prepared!

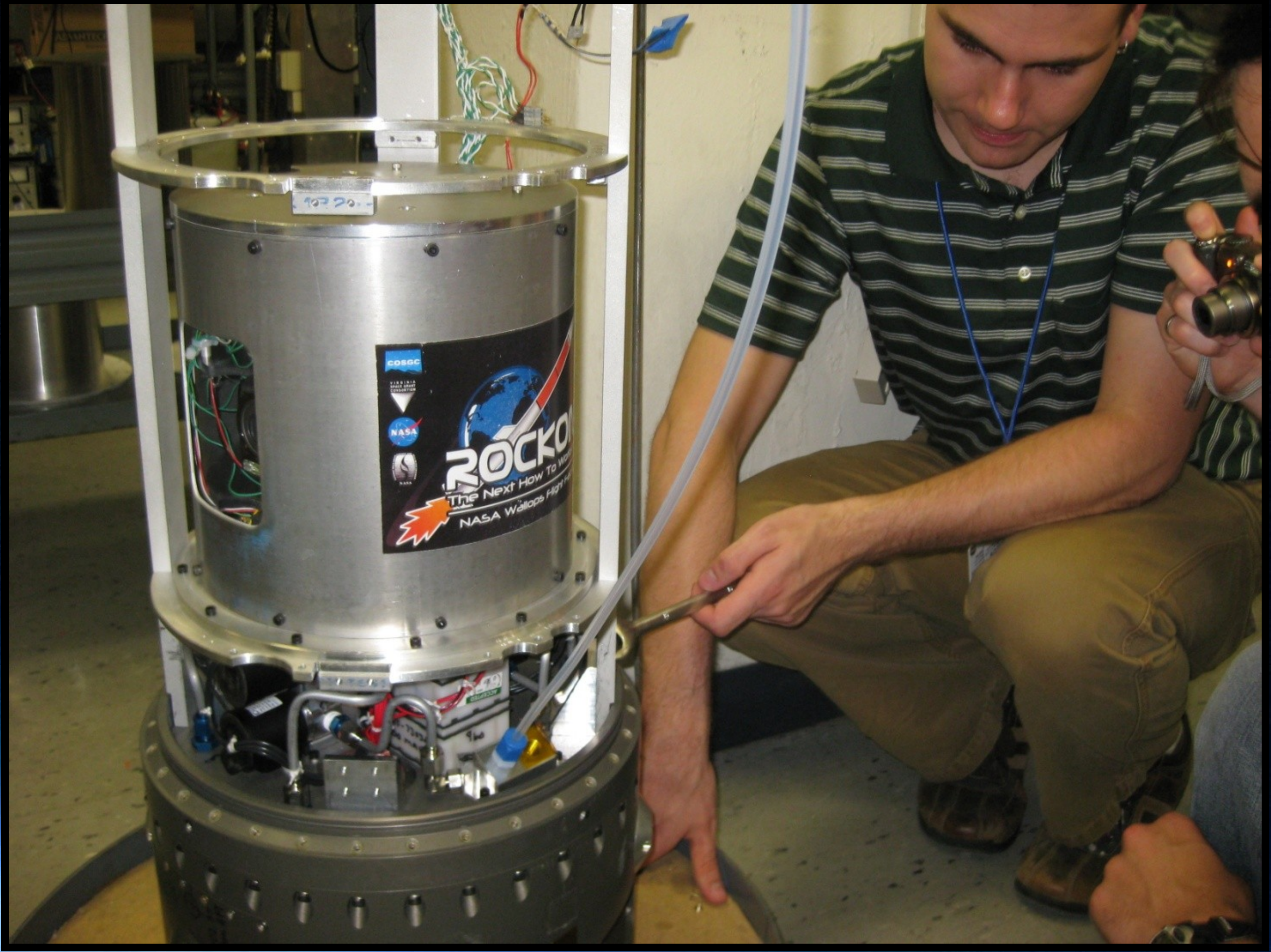
The Completed Payload



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

CUBESAT

The Future of ARTEMIS

T