EAS4700-0075(12255) – AEROSPACE DESIGN 1 (3 credits) - FALL 2020 online
*** Syllabus (a.k.a. our contract for the semester) ***

COURSE INSTRUCTOR: Dr. Riccardo Bevilacqua, MAE-A 308, bevilr@ufl.edu, 352-392-6230. Office hours: zoom meetings scheduled as needed with teams/individual students (**online until directed otherwise**). Official zoom open session to interact with the instructor is Thursday 10am-12pm.

The instructor will provide feedback within 48 hrs. and students will have an opportunity to respond.

CLASS WEBSITE: on canvas https://ufl.instructure.com/courses/404091

CLASS MEETS: M, W, periods 9-10 (4:05pm-6:00pm), FLG 230 (**online until directed otherwise**). This class is offered in synchronous form. The synchronous meetings will focus on instruction and meeting one team at a time.

IMPORTANT NOTE ON ONLINE CLASSES: Our class sessions may be audio visually recorded for students in the class to refer back and for enrolled students who are unable to attend live. Students who participate with their camera engaged or utilize a profile image are agreeing to have their video or image recorded. If you are unwilling to consent to have your profile or video image recorded, be sure to keep your camera off and do not use a profile image. Likewise, students who un-mute during class and participate orally are agreeing to have their voices recorded. If you are not willing to consent to have your voice recorded during class, you will need to keep your mute button activated and communicate exclusively using the "chat" feature, which allows students to type questions and comments live. The chat will not be recorded or shared. As in all courses, unauthorized recording and unauthorized sharing of recorded materials is prohibited.

TEACHING ASSISTANT/S: Byczkowski, Cale A., cale.byczkowski@ufl.edu (see zoom meetings on Canvas for his office hours).

PRE-REQUISITES: EAS4510 and EML4312 with at least D grade, STRICTLY ENFORCED, NO MATTER IF YOU HAVE BEEN ABLE TO REGISTER FOR THE CLASS. Working knowledge of MATLAB, Simulink, STK and a CAD program is required. Student will have to learn tools as they go.

COURSE OBJECTIVES: By the end of this course, you should be able to do the following:

1. Prepare technical documents in aerospace industry.
2. Give technical presentations, develop communication skills.
3. Work in team and lead a team.
4. Seek, find, and assimilate the knowledge you need to solve new problems.

COURSE ASSESSMENT MEASURES FOR ABET:

The following shows the ABET Student Outcomes and Student Learning Outcomes (SLO)

ABET Information – Criterion 3 – Student Outcomes

Criterion 3. Student Outcomes: (1-7) The program must have documented student outcomes that support the program educational objectives. Attainment of these outcomes prepares graduates to enter the professional practice of engineering. Student outcomes are outcomes (1) through (7), plus any additional outcomes that may be articulated by the program.
1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
3. an ability to communicate effectively with a range of audiences
4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

Aerospace Engineering UF Student Learning Outcomes:
(SLO 1) Apply knowledge of mathematics, science, and engineering principles to aerospace engineering problems (ABET Outcome (1))
(SLO 2) Design and conduct aerospace engineering experiments and analyze and interpret the data (ABET Outcome (6))
(SLO 3) Design an aerospace engineering system, component or process to meet desired needs within realistic economic, environmental, social, political, ethical, health and safety, manufacturability and sustainability constraints (ABET Outcome (2))
(SLO 4) Communicate technical data and design information effectively in speech and in writing to other aerospace engineers (ABET Outcome (3))

The following tables shows how SLOs and ABET criterions are supported in this class and the mapping with assignments.

ASE Specific Courses	**1 SLO1**	**2 SLO3**	**3 SLO4**	**4**	**5**	**6 SLO2**	**7**
EAS4700 Aerospace Design 1	H	H - A	H	H - A	H – A	M	L

Legend: H = outcome stongly supported, M = moderately supported, L minimally supported; A = outcome assessed;
1-7 = ABET outcomes; SLO = UF Student Learning Outcome

Assessment	**Student Learning Outcomes**
Final Report	SLO1, 2, and 3 – ABET criterions 4 and 7
Presentations	SLO4 – ABET criterion 5
Peer grading	SLO4 – ABET criterion 5
STK Certification	SLO1

COURSE DESCRIPTION: This course introduces all elements of the spacecraft design process. Students are organized into design teams and associated with different subsystems and tasks, to develop a solution to a space vehicle system's problem of practical interest, by drawing on their background in aerospace engineering science, machine design, and manufacturing methods. Topics include problem definition and requirement analysis, design specifications, concept development, reliability, consideration of alternative solutions, materials considerations, engineering prototyping, mission analysis, costs, and presentation skills. This is a communication-intensive and writing-intensive course.

For this semester, a set of design requirements for a spacecraft removing another CubeSat are provided. Mr. Larry Fineberg, NASA retired, will serve as customer. See document at the end of the syllabus. The table below provides a tentative schedule for this course. Each week the topic leaders shall provide an update to the instructor. The teams will meet around 30 times, and most of the meetings will be design work time.

TOPIC	NOTES	Week #	Points
Project, relevant documents, STK (Mr. Kennedy from ADAMUS), Matlab/Simulink (Dr. Bevilacqua)	During the first 6 weeks teams will decide the size of the ROAO (how many U's) and its initial CAD design. A thermal desktop model should be also incrementally populated and updated to monitor for issues.	1	--
Thermal Desktop (Ms. Martin from ADAMUS), finite elements (Mr. Itkin from ADAMUS). **MODULE 1**: Teams decide the method of capture.		2	1
MODULE 2: Orbital calculations: OAO state end of mission, deployment of ROAO, maneuvers calculations, decay surface required to obtain goal.		3	2
MODULE 3: Attitude requirements calculations: detumble, maneuver to OAO orientation, requirements during and after capture.		4	2
MODULE 4: Choice of thruster/s, ADCS, and deorbit subsystems. Power budget and choice of EPS & solar panels.		5	2
MODULE 5: How does ROAO know where OAO is? Relative navigation subsystem choice (performance required to reach OAO and capture correctly drive the choice).		6	1
Preliminary Design Review (PDR) presentation & **MODULE 6**: choice of onboard computer, potential GPS, and decision on the data to be sent/received to/from the ground. Radio choice and link budget calculations.		**Week of Oct 12 (7)**	**20+2**
Midterm survey due	During these weeks, risks	**Oct 16**	**Extra 5**
Midterm peer-feedback opportunity		**Oct 16**	**--**

Address PDR comments in writing.	and their management must be addressed	8	--
MODULE 7: Electrical/power/data schematics (Mr. MacFarlane will assist).		9	2
MODULE 8: finite element analysis to verify compatibility with launchers. If deployables are present, their modes of vibration must be compared against control inputs (force/torque).		10	2
MODULE 9: Thermal desktop analysis and potential design changes outcomes.		11	2
MODULE 10: High fidelity simulations of capture and deorbit.		12	1
High fidelity simulations of capture and deorbit.		13	1
Refinements on entire design.		14	--
Final presentation & report & STK & peer grade		**Dec 9**	**20+22+20+extras**

<u>TEXTBOOK/SOFTWARE</u>:

Text No. 1	Title: **ELEMENTS OF SPACECRAFT DESIGN** ISBN: **1563475243** Cover: **N/A**	Publisher: **AIAA** Edition: **2ND**	Author: **CHARLES D. BROWN** Copyright: This text is **recommended**
Text No. 2	Title: **SPACE MISSION ANALYSIS AND DESIGN, 3RD EDITION** ISBN: **1881883108** Cover: **N/A**	Publisher: **MICROCOSM** Edition: **3RD**	Author: **JAMES WERTZ** Copyright: This text is **required**
Text No. 3	Title: **EMERGENCE OF PICO & NANOSATELLITES** ISBN: **9781600867682** Cover: **N/A**	Publisher: **AIAA** Edition:	Author: **THAKKER** Copyright: This text is **recommended**
			(End of Adoption No. 222566)

You must have access to MATLAB and a CAD program. You must have STK installed on individual machines, with running license. More requirements may arise during the semester.

<u>WEEKLY TASKS (CANVAS MODULES)</u>: a few points are assigned for the completion of the weekly activities, required to obtain satisfactory designs. The deadlines for those tasks will be kept flexible, but students must keep in mind that accumulating pending tasks will greatly affect their performance for the most important milestones.

<u>PRESENTATIONS AND REPORT</u>: Midterm (**Week of Oct. 12 2020, scheduled as needed**) and final (**Week of Dec. 7, 2020, scheduled as needed**) presentations will be given to the instructor and customer, **20% each**. A final report, in the format of a student competition conference paper for the small satellite conference will be due **Dec. 9, 2020, 22%** (conference website: https://www.smallsat.org/ , paper template: https://smallsat.org/downloads/paper-template.pdf).

Each member of each team will evaluate his/her peers. **This peer evaluation is 20% of the grade**. This is a semester long update-able grade (everyone is given a chance to correct performance till the end).

MIDTERM SURVEY: A voluntary mid-term survey will be provided, **due Oct 16**. To incentivize your participation, the survey will be valued as 5% **bonus**.

STK OPTIONAL CERTIFICATIONS: The instructor will provide instructions to access AGI's Systems Tool Kit and to get certified in its use, at the beginning of the semester. Those interested will have the opportunity to receive 5% **bonus** for the first level certification, 10% **bonus** for the second level. **The bonuses are NOT cumulative, i.e. 5% for first level, an additional 5% for second level. No credit for level 3**. THIS IS NOT REQUIRED AND COMPLETELY OPTIONAL, BUT VERY MUCH ENCOURAGED. **THE DEADLINE TO TURN IN PROOF OF CERTIFICATION/S (EMAIL FROM AGI) IS DECEMBER 9, 2020**

STK LICENSE INSTRUCTIONS:

1. Go to www.agi.com and create an account (needed for certification later, etc.).
2. Download and install STK from http://agi.com/resources
3. Go on http://agi.com/about/partners/educational-alliance-program and click on "collect licenses", go to on-demand license, and use code **Z{m3/8X**
4. Choose "program" and then "students training - research" on dropdown menus.
5. Agree and generate license.
6. Follow steps on email you have received.

Thermal desktop licenses for educational use are also available and direction will be provided when needed. In the meantime, those using it must have AutoCAD and Intel Parallel Studio.

GRADING POLICY: The grading scale is as follows:

A: 94 to 100

A-: 90 to 93.99

B+: 85 to 89.99

B: 80 to 84.99

B-: 75 to 79.99

C+: 70 to 74.99

C: 65 to 69.99

C-: 60 to 64.99

D+: 55 to 59.99

D: 50 to 54.99

D-: 45 to 49.99

E: Less Than 45

CLASS ATTENDANCE AND MAKE UP POLICY: Students are expected to attend all meetings. There will be no early/late exams. Please make your travel arrangements according to the exam dates specified in the syllabus. The general rule is no make-up exams and no rescheduling of exams to other times.

Requirements for class attendance and make-up exams, assignments, and other work in this course are consistent with university policies that can be found at: https://catalog.ufl.edu/ugrad/current/regulations/info/attendance.aspx.

The students remain completely responsible for timely communications with the instructor.

Students Requiring Accommodations

Students with disabilities who experience learning barriers and would like to request academic accommodations should connect with the disability Resource Center by visiting https://disability.ufl.edu/students/get-started/. It is important for students to share their accommodation letter with their instructor and discuss their access needs, as early as possible in the semester.

Course Evaluation

Students are expected to provide professional and respectful feedback on the quality of instruction in this course by completing course evaluations online via GatorEvals. Guidance on how to give feedback in a professional and respectful manner is available at https://gatorevals.aa.ufl.edu/students/. Students will be notified when the evaluation period opens, and can complete evaluations through the email they receive from GatorEvals, in their Canvas course menu under GatorEvals, or via https://ufl.bluera.com/ufl/. Summaries of course evaluation results are available to students at https://gatorevals.aa.ufl.edu/public-results/.

University Honesty Policy

UF students are bound by The Honor Pledge which states, "We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honor and integrity by abiding by the Honor Code. On all work submitted for credit by students at the University of Florida, the following pledge is either required or implied: "On my honor, I have neither given nor received unauthorized aid in doing this assignment." The Honor Code (https://sccr.dso.ufl.edu/policies/student-honor-code-student-conduct-code/) specifies a number of behaviors that are in violation of this code and the possible sanctions. Furthermore, you are obligated to report any condition that facilitates academic misconduct to appropriate personnel. If you have any questions or concerns, please consult with the instructor or TAs in this class.

Commitment to a Safe and Inclusive Learning Environment

The Herbert Wertheim College of Engineering values broad diversity within our community and is committed to individual and group empowerment, inclusion, and the elimination of discrimination. It is expected that every person in this class will treat one another with dignity and respect regardless of gender, sexuality, disability, age, socioeconomic status, ethnicity, race, and culture.

If you feel like your performance in class is being impacted by discrimination or harassment of any kind, please contact your instructor or any of the following:

- Your academic advisor or Graduate Program Coordinator
- Robin Bielling, Director of Human Resources, 352-392-0903, rbielling@eng.ufl.edu
- Curtis Taylor, Associate Dean of Student Affairs, 352-392-2177, taylor@eng.ufl.edu
- Toshikazu Nishida, Associate Dean of Academic Affairs, 352-392-0943, nishida@eng.ufl.edu

Software Use

All faculty, staff, and students of the University are required and expected to obey the laws and legal agreements governing software use. Failure to do so can lead to monetary damages and/or criminal penalties for the individual violator. Because such violations are also against University policies and rules, disciplinary action will be taken as appropriate.

We, the members of the University of Florida community, pledge to uphold ourselves and our peers to the highest standards of honesty and integrity.

Student Privacy

There are federal laws protecting your privacy with regards to grades earned in courses and on individual assignments. For more information, please see: https://registrar.ufl.edu/ferpa.html

Campus Resources:

Health and Wellness

U Matter, We Care:
Your well-being is important to the University of Florida. The U Matter, We Care initiative is committed to creating a culture of care on our campus by encouraging members of our community to look out for one another and to reach out for help if a member of our community is in need. If you or a friend is in distress, please contact umatter@ufl.edu so that the U Matter, We Care Team can reach out to the student in distress. A nighttime and weekend crisis counselor is available by phone at 352-392-1575. The U Matter, We Care Team can help connect students to the many other helping resources available including, but not limited to, Victim Advocates, Housing staff, and the Counseling and Wellness Center. Please remember that asking for help is a sign of strength. In case of emergency, call 9-1-1.

Counseling and Wellness Center: http://www.counseling.ufl.edu/cwc, and 392-1575; and the University Police Department: 392-1111 or 9-1-1 for emergencies.

Sexual Discrimination, Harassment, Assault, or Violence
If you or a friend has been subjected to sexual discrimination, sexual harassment, sexual assault, or violence contact the Office of Title IX Compliance, located at Yon Hall Room 427, 1908 Stadium Road, (352) 273-1094, title-ix@ufl.edu

Sexual Assault Recovery Services (SARS)
Student Health Care Center, 392-1161.

University Police Department at 392-1111 (or 9-1-1 for emergencies), or http://www.police.ufl.edu/.

Academic Resources

E-learning technical support, 352-392-4357 (select option 2) or e-mail to Learning-support@ufl.edu. https://lss.at.ufl.edu/help.shtml.

Career Resource Center, Reitz Union, 392-1601. Career assistance and counseling. https://www.crc.ufl.edu/.

Library Support, http://cms.uflib.ufl.edu/ask. Various ways to receive assistance with respect to using the libraries or finding resources.

Teaching Center, Broward Hall, 392-2010 or 392-6420. General study skills and tutoring. https://teachingcenter.ufl.edu/.

Writing Studio, 302 Tigert Hall, 846-1138. Help brainstorming, formatting, and writing papers. https://writing.ufl.edu/writing-studio/.

Student Complaints Campus: https://care.dso.ufl.edu.

On-Line Students Complaints: http://www.distance.ufl.edu/student-complaint-process.

Design Requirements for University of Florida's Aerospace Design I class (EAS4700), Fall 2020 semester

Introduction

In the fall of 2016, the UF's Aerospace Design 1 class was tasked with the design of a CubeSat hosting the APS sensor (details of the sensor and requirements in the last pages). The mission was named Orbiting Aerosol Observatory (OAO). One team stood out and competed at the small satellite student paper competition in 2017 (https://smallsat.org/students/previous-winners), being awarded the 3rd prize (paper: http://www.riccardobevilacqua.com/Rutherford_Jenson_Wilson_Paper.pdf).

Given the altitude for the OAO (700km), orbital decay may violate the 25-year rule for LEO spacecraft. Removal of defunct satellites has been a hot topic for many years, as the population of space debris has grown rapidly. Examples of the community's engagement on this matter can be seen at the International Academy of Astronautics Conference on Space Situational Awareness (ICSSA), held twice (2012, 2020). Several system have been proposed to remove satellites at the end of life: propulsive, drag enhancement, magnetic, etc.. The UF's Advanced Autonomous Multiple Spacecraft (ADAMUS) laboratory has developed the Drag De-orbit Device (D3): http://www.riccardobevilacqua.com/JSR_D3.pdf

This year's design will require the development of a 6U (max) CubeSat, deploying from the ISS using the NanoRacks system at the end of mission of OAO, rendezvousing with OAO, capturing it with means chosen by the students, and augmenting its drag to the point of cutting in half its original decay time. Students will name their mission. For the time being we will call it ROAO (Removing-OAO).

The requirements listed below are often similar to those of OAO (same orbit, for example), but are not identical. Please, pay attention to the requirements for this year's design.

Compliance Documents

The ROAO shall adhere to the following compliance documents:

a. CubeSat Design Specification: https://www.cubesat.org/resources
b. NanoRacks IDD https://nanoracks.com/wp-content/uploads/NanoRacks-CubeSat-Deployer-NRCSD-Interface-Definition-Document.pdf
c. NASA CubeSat 101: https://www.nasa.gov/sites/default/files/atoms/files/nasa_csli_cubesat_101_508.pdf
d. https://www.nasa.gov/sites/default/files/atoms/files/soa2018_final_doc-6.pdf

Additional resources include:

a. GSFC-STD-7000A
b. MIL-P-27401 (Revision F), Military Standard, Performance Specification, Propellant Pressurizing Agent, Nitrogen

c. MIL-STD-1246 (Revision C), Military Standard, Product Cleanliness Levels and Contamination Control Program
d. FED-STD-209E, Clean Room and Work Station Requirements, Controlled Environments
e. NASA-STD-6016, Revision dated 07-11-2008, Section 4.2, Standard Materials and Processes Requirements for Spacecraft
f. NASA Reference Pub. 1124, Outgassing Data for Selected Spacecraft Materials

Assumption: the ROAO is assumed manifested and launcher choice is not required by the teams. The vibration analysis will have to cover a series of possible vehicles.

ROAO Requirements

1. **Debris**: the ROAO cannot create additional debris, i.e., its own orbital decay once deployed, in the event of total failure, should be less than 25 years. Additionally, decay calculations should be performed at the OAO altitude as well, in the event of drag system not functioning.

2. **Orbital decay:** The new orbital decay lifetime after capture by the ROAO must be at least half of the OAO orbital decay pre-capture.

3. **Data**: the ROAO shall transmit its state, relative state w.r.t. OAO, health data, and drag system state every 5 minutes. It shall also be able to receive software updates and commands to override onboard algorithms (thruster commands, drag system commands, attitude control commands, etc.).

4. SC Coordinate System

The SC coordinate system shall be as defined in the compliance documents.

1. Not-To-Exceed mass

The ROAO Not-To-Exceed (NTE) mass is 26.5 lbs (12 kg). The NTE mass does not include any Launch Vehicle hardware that could be attached to the ROAO.

2. Center of Gravity

The ROAO Center-of-Gravity (CG) shall be in accordance with the compliance documents. The uncertainties in the CG location are an estimate based on knowledge of the component specification values, as-measured parts, the modeled values of the components.

3. Moments and Products of Inertia

a. The Moments and Products of Inertia shall be calculated in both the pre and post deployment configuration of the ROAO.
b. Pre-deployment is defined as the ROAO configuration when stowed for launch. Post-deployment is defined as the ROAO's configuration while in its mission mode.

4. Orbit Requirements

Parameters for the desired injection orbit state for OAO are provided in the table below. The state is given in osculating orbital elements referenced to the True

Equator of Date coordinate system. The epoch for the state is defined at the first ascending node closest to spacecraft separation from the launch vehicle. The one target value for the Mean Local Time (MLT) of the Ascending Node (AN) is provided and is valid for each day in a 30-day launch period. Epoch of orbital injection from PPOD for the OAO is 1 January 2020 12:00:00 GMT.

Teams shall calculate the epoch and state at the end of mission for OAO, and time the ejection of ROAO from the ISS accordingly. Starting from the orbital elements below and propagating with a high-fidelity model for the duration of the mission, the teams will be able to obtain the new state. The OAO will be still in its original orbit once ROAO deploys.

Orbit Requirements for OAO [1]

Osculating Elements			
Parameter	**Injection Orbit**	**Operational Orbit**	**Tolerance [2]**
Altitude	700 km	700 km	N/A
Semi-Major Axis	7071 km	7071 km	± 10 km
Eccentricity	0.00125	0.00125	± 0.0005 [3]
Inclination	98°	98°	± 0.05°
MLTAN [4]	15:00	11 minutes after Aqua spacecraft MLTAN	± 1 minutes
Argument of Perigee	69	69	±30°

Notes:

1 The coordinate system for all elements is Earth-centered inertial Earth True Equator of Date

2 Tolerances are the probabilities equivalent to a 3-sigma probability of a normal distribution

3 The eccentricity and argument of perigee tolerances combine to negate the need for an apogee requirement

4 Mean Local Time of Ascending Node

5. **Launch Environments**

For analysis and/or test of structural and mechanical environments, it is at the project's discretion to utilize either full qualification or protoflight qualification environments (the team shall decide whether there is budget for a protoflight unit or not - From the GEVS document: Section 1.8, see Design Qualification Tests and also Hardware item b1 for a better explanation.).

a. Structural Loads

The ROAO shall be qualified for Structural Loads per GEVS section 2.4.1

b. Vibration and Acoustic

The ROAO shall be qualified for Vibroacoustics per GEVS section 2.4.2. As a screen for design and workmanship defects, components/units shall be subjected to a random vibration test along each of three mutually perpendicular axes per GEVS section 2.4.2.5 and Tables 2.4-3 and 2.4-4.

c. Shock

All subsystems, including instruments, shall be qualified per GEVS section 2.4.4 for the mechanical shock environment. Shock testing is not required when the following conditions are met:

1. The qualification random vibration test spectrum when converted to an equivalent shock response spectrum (3-sigma response for Q=10) exceeds the qualification shock spectrum requirement at all frequencies below 2000 Hz.
2. The maximum expected shock spectrum above 2000 Hz does not exceed (g) values equal to 0.8 times the frequency in Hz at all frequencies above 2000 Hz, corresponding to the velocity of (50 inches/second).

d. Thermal

The ROAO shall be qualified per GEVS section 2.6.

e. Temperature Range

TBD by the team.

f. Relative Humidity

TBD by the team.

g. Maximum Pressure Decay Rate

During launch, the ROAO shall be capable of withstanding a pressure decay rate of ≤ 0.8 psi/sec.

6. **End to End testing**

A plan shall be developed for ROAO end to end testing. It is recommended to use GEVS section 2.8 as a guideline.

7. **ROAO Logo**

A graphic shall be created which represents the purpose of the mission. The graphic shall be in a PANTONE format. The graphic size and location on the

ROAO shall be large enough to be visually seen from 1 meter, with the unaided eye, prior to encapsulation into the CubeSat deployed.

8. Mission Operations

a. A mission plan shall be developed to show the ROAO design is capable of rendezvous with OAO

b. Attitude requirements are to be identified by the team, depending on the chosen capture and deorbit approaches.

9. Budget

The total amount of money that can be provided ("Total Cost Cap") to the project shall be no greater than $12 million US Dollars (USD). Within this total cost, the following amounts cannot be exceeded:

- Maximum cost to build a "launch-ready" ROAO: $5 million USD
- Maximum launch cost: $3 million

The budget report shall show costs comprised of both labor and hardware costs. If the Total Cost Cap is exceeded, then the mission will be canceled.

Cost reduction bonus: As an incentive to reduce the actual total cost of the mission, the project will receive a 10% cash bonus for every USD below the Total Cost Cap. By way of example, if the total project budgeted cost equals $10 million USD then there is a resultant mission project savings of $2 million USD. As a result of this savings, a total of $200,000 USD would be returned to the project as cash, with no restrictions as to how that cash would be spent.

The budget report should indicate profit margins as well.

Design Requirements for University of Florida's Aerospace Design I class (EAS4700), Fall 2016 semester

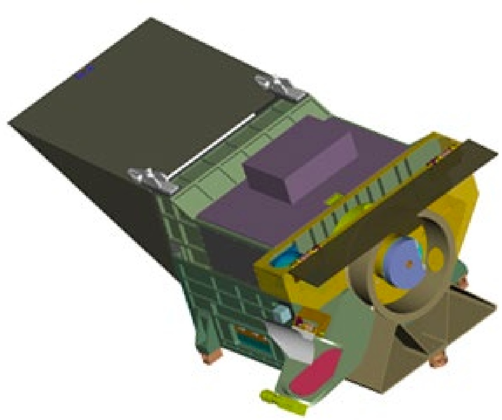
The spacecraft, hereafter referred to as the "Observatory", will improve the understanding of aerosol contributions to global climate change and help maintain a record of total solar irradiance. Data provided by the mission will enhance global climate modeling and help reduce uncertainties associated with the causes and consequences of global climate change.

The Primary Instrument on the Observatory is called the Aerosol Polarimetry Sensor (APS) and it will collect information about atmospheric aerosols, such as the shape, composition, and reflectivity of different types of aerosol particles.

This Observatory will join a fleet of Earth observing satellites known as the Afternoon Constellation, or "A-Train", which together offer a more cohesive and detailed picture of the Earth's biosphere and climate.

The Observatory's mission, designed to improve NASA's understanding of Earth's climate system, is to be launched from Vandenberg Air Force Base (VAFB), CA. The launch vehicle has not yet been assigned.

The Observatory's primary science goal will be to fly a miniaturized Aerosol Polarimetry Sensor (mAPS) that was planned to fly on the NASA GLORY mission. The mAPS is an order of magnitude smaller in size, power usage, and mass from the APS planned for the NASA mission GLORY.



miniaturized Aerosol Polarimetry Sensor (mAPS) – credit http://glory.gsfc.nasa.gov/overview-aps.html

Additional details of the original APS can be found on publically available sources such as Reference j and Reference k.

Compliance Documents

The Observatory shall adhere to the following compliance documents:

g. 6U CubeSat Design Specification (6U-CDS), Revision Provisional, The CubeSat Program, Cal Poly SLO (http://www.cubesat.org)
h. GSFC-STD-7000A, Revision dated 4/22/2013, General Environmental Verification Standard (GEVS) For GSFC Flight Programs and Projects
i. MIL-P-27401 (Revision F), Military Standard, Performance Specification, Propellant Pressurizing Agent, Nitrogen
j. MIL-STD-1246 (Revision C), Military Standard, Product Cleanliness Levels and Contamination Control Program
k. FED-STD-209E, Clean Room and Work Station Requirements, Controlled Environments
l. NASA-STD-6016, Revision dated 07-11-2008, Section 4.2, Standard Materials and Processes Requirements for Spacecraft
m. NASA Reference Pub. 1124, Outgassing Data for Selected Spacecraft Materials
n. Peralta, R.J., C. Nardell, B. Cairns, E. E. Russel, L. D. Travis, M. I. Mishchenko, and R. J. Hooker 2007: Aerosol Polarimetry Sensor for the Glory Mission. *Proc SPIE* 6786, 67865L. http://glory.giss.nasa.gov/aps/docs/SPIE_6786_67865L.pdf
o. Glory Project Aerosol Polarimetry Sensor Calibration, Aug 2010, GSFC 421.7-70-03, Section 3.6.1 Lunar Calibration Maneuver. http://glory.giss.nasa.gov/aps/docs/APS_ATBD_CALIBRATE_CCB.pdf
p. GLORY Observability Meeting April 2010, http://icap.atmos.und.edu/ObservabilityMeeting/MeetingPDFs/Day-2/5_Glory-Maring.pdf
q. Aerosol Polarimetry Sensor for the Glory Mission, Petalta, Richard. Raytheon Santa Barbara Remote Sensing, http://glory.giss.nasa.gov/aps/docs/SPIE_6786_67865L.pdf

Observatory Requirements

Where conflicts arise between the Compliance Documents and the Observatory Requirements, the Observatory Requirements shall take precedence.

5. SC Coordinate System

The SC coordinate system shall be as defined in the 6U-CDS.

10. Not-To-Exceed mass

The Observatory Not-To-Exceed (NTE) mass is 26.5 lbs (12 kg). The NTE mass does not include any Launch Vehicle hardware that could be attached to the Observatory.

11. Center of Gravity

The Observatory Center-of-Gravity (CG) shall be in accordance with the 6U-CDS section 3.2.10. The uncertainties in the CG location are an estimate based on knowledge of the component specification values, as-measured parts, the modeled values of the components.

12. Moments and Products of Inertia

c. The Moments and Products of Inertia shall be calculated in both the pre and post deployment configuration of the Observatory.

d. Pre-deployment is defined as the Observatory configuration when stowed for launch. Post-deployment is defined as the Observatory's configuration while in its mission science mode.

13. Orbit Requirements

Parameters for the desired injection orbit state are provided in the table below. The state is given in osculating orbital elements referenced to the True Equator of Date coordinate system. The epoch for the state is defined at the first ascending node closest to spacecraft separation from the launch vehicle. The one target value for the Mean Local Time (MLT) of the Ascending Node (AN) is provided and is valid for each day in a 30-day launch period. Epoch of orbital injection from PPOD is1 January 2020 12:00:00 GMT - this provides an epoch for the sun and moon calculations needed for phasing and attitude point design needed for mAPS calibration and science.

Orbit Requirements (1)

Osculating Elements			
Parameter	Injection Orbit	Operational Orbit	Tolerance (2)
Altitude	700 km	700 km	N/A
Semi-Major Axis	7071 km	7071 km	± 10 km
Eccentricity	0.00125	0.00125	± 0.0005 (3)
Inclination	98°	98°	± 0.05°
MLTAN (4)	15:00	11 minutes after Aqua spacecraft MLTAN	± 1 minutes
Argument of Perigee	69	69	±30°

Notes:

1 The coordinate system for all elements is Earth-centered inertial Earth True Equator of Date

2 Tolerances are the probabilities equivalent to a 3-sigma probability of a normal distribution

3 The eccentricity and argument of perigee tolerances combine to negate the need for an apogee requirement

4 Mean Local Time of Ascending Node

14. Launch Environments

For analysis and/or test of structural and mechanical environments, it is at the project's discretion to utilize either full qualification or protoflight qualification environments (the team shall decide whether there is budget for a protoflight unit or not - From the GEVS document: Section 1.8, see Design Qualification Tests and also Hardware item b1 for a better explanation).

h. Structural Loads

The Observatory shall be qualified for Structural Loads per GEVS section 2.4.1

i. Vibration and Acoustic

The Observatory shall be qualified for Vibroacoustics per GEVS section 2.4.2. As a screen for design and workmanship defects, components/units shall be subjected to a random vibration test along each of three mutually perpendicular axes per GEVS section 2.4.2.5 and Tables 2.4-3 and 2.4-4.

j. Shock

All subsystems, including instruments, shall be qualified per GEVS section 2.4.4 for the mechanical shock environment. Shock testing is not required when the following conditions are met:

1. The qualification random vibration test spectrum when converted to an equivalent shock response spectrum (3-sigma response for Q=10) exceeds the qualification shock spectrum requirement at all frequencies below 2000 Hz.
2. The maximum expected shock spectrum above 2000 Hz does not exceed (g) values equal to 0.8 times the frequency in Hz at all frequencies above 2000 Hz, corresponding to the velocity of (50 inches/second).

k. Thermal

The Observatory shall be qualified per GEVS section 2.6.

l. Temperature Range

On the ground and while encapsulated in the launch vehicle, the Observatory shall be capable of withstanding a temperature range from 13 to 23 C.

m. Relative Humidity

On the ground and while encapsulated in the launch vehicle, the Observatory shall be capable of withstanding a Relative Humidity (RH) range between 30% RH to 70% RH.

n. Condensation Prevention

The Observatory shall be maintained such that condensation on the instrument does not occur.

o. Maximum Pressure Decay Rate

During launch, the Observatory shall be capable of withstanding a pressure decay rate of ≤ 0.8 psi/sec.

15. Contamination Control

In order to function properly during the on-orbit science phase of the mission, the Primary Instrument must be maintained in an inert, clean environment during manufacturing, assembly, test, and storage.

a. Surface Cleanliness: All Observatory surfaces shall be cleaned and maintained to a surface cleanliness Level 750A per MIL-STD-1246C
b. Purge Requirements
    i. The Observatory instrument requires a continuous gaseous nitrogen (GN2) purge starting with installation into the Observatory and ending with Observatory encapsulation inside the CubeSat deployer. Interruptions of the purge gas flow are allowed as long as the total cumulative time without purge does not exceed 30 minutes.
    ii. GN2 purge gas supplied to the instrument shall be Grade B per MIL-P-27401, Revision F.
    iii. GN2 purge shall flow at a rate of 1.0 ± 25% standard cubic feet per hour (SCFH).
    iv. Purge system components/line shall be cleaned to MIL-STD-1246C, Level 100A prior to first use and maintained clean thereafter.
c. Materials: Materials used on Observatory shall comply with NASA-STD-6016.

16. End to End testing

A plan shall be developed for Observatory end to end testing. It is recommended to use GEVS section 2.8 as a guideline.

17. Observatory Logo

A graphic shall be created which represents the purpose of the mission. The graphic shall be in a PANTONE format. The graphic size and location on the Observatory shall be large enough to be visually seen from 1 meter, with the unaided eye, prior to encapsulation into the CubeSat deployed.

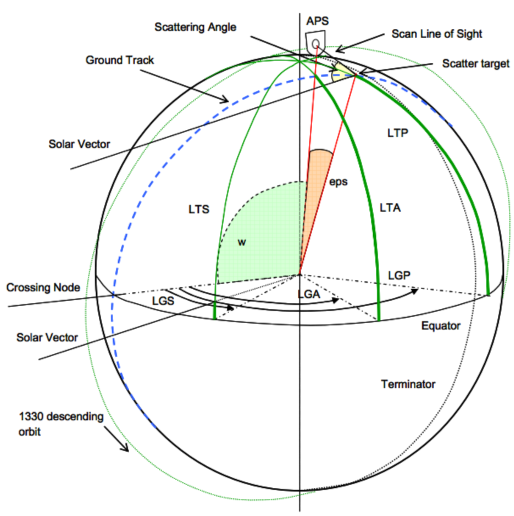
18. Mission Operations

c. A mission plan shall be developed to show the Observatory design is capable of meeting mAPS calibration maneuver requirements as identified in Reference i.
    i. Calibration maneuvers are to occur between 1 January 2020 12:00:00 GMT and 10 January 2020 12:00:00 GMT.
d. The entire mission shall be designed for two years of operational life. The on-orbit mission plan shall include a sample operational plan for collecting data, storing data, and transmission of data over a one-week duration (Jan 10, 2020 to Jan 17 2020.
    i. Sample operations should show the total number of scientific measurement opportunities over the sample week, as well as scientific measurements made given systems power, data storage, and communications capabilities.
    ii. Science measurement opportunities exist when the mAPS has line of sight with the solar glint off the earth surface. (Reference h Section 2.1 System Optimization)
e. Sun Angle Constraints
    iii. As the mAPS is an optical instrument it is sensitive to direct solar exposure. Any time in the sample mission plan or calibration maneuver sequence the mAPS receives direct solar exposure the sensor must be entered into SAFE mode to prevent sensor damage. The mission plan shall identify all incidences where the mAPS must be commanded to SAFE mode.

f. Attitude requirements are identified during the instrument check out and for the science gathering phase.

Instrument check out procedure is identified in Ref I: Section 3.6.1.Lunar Calibration Maneuver. This is a pretty specific section of attitude requirements needed for calibrating the mAPS, sweeping the mAPS instrument across the moon in a tight scanning pattern.

Science gathering attitude requirements are in ref H: section 2.1 System Optimization and Figure 5 (also copied below).
The APS acquires data over a large range angles to characterize the scatter target which directly leads to the sensor scan angle requirement of +/– 50° plus a near limb view of 60° to one side, or a full angular field of view of 110°. The relationship of the APS line of sight and the incident solar radiation is the central geometry of the system. In simple terms, the APS collects scatter data of a target where the sun is the source of illumination and the APS is the detector. It is planned that periodically throughout the mission, the APS will be maneuvered about the velocity axis to directly view the solar glint and get an improved measurement of the aerosol absorption.



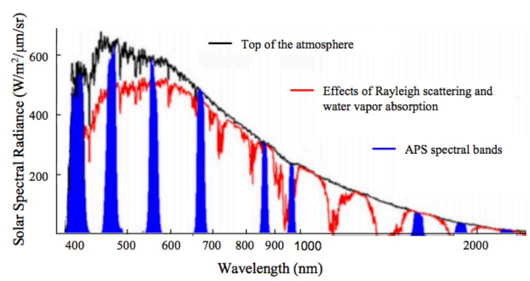
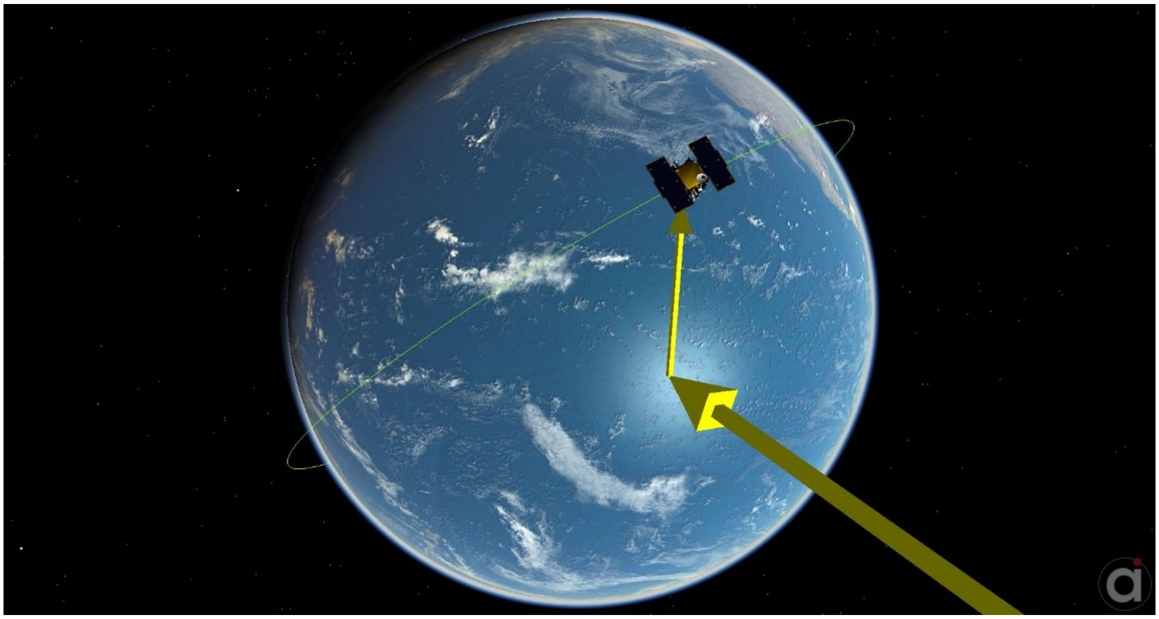


Figure 6. APS spectral bands (normalized to TOA) and scene dynamic range.

Figure 5 (left). Geometric relationship of the APS, incident solar vector, and scatter target.

Legend: LTP = latitude of scatter point
LTA = latitude of APS
LTS = latitude of solar vector
LGP = longitude of scatter point
LGA = longitude of APS
LGS = longitude of solar vector
w = APS position relative to equator crossing
eps = angle between APS and scatter target

The "scatter target" that the sensor has to point at is the incident solar vector. This requires to know the SC to scatter target vector, while the scatter target is the reflection of the sun off the earth. NASA designed the GLORY mission according to this requirement too. See image below.



The similar version would be to design the attitude during science gathering to point the mAPS nadir while on the sun lit side of the planet.

19. Budget

The total amount of money that can be provided ("Total Cost Cap") to the project shall be no greater than $12 million US Dollars (USD). Within this total cost, the following amounts cannot be exceeded:

- Maximum cost to build a "launch-ready" Observatory: $5 million USD
- Maximum cost of the mAPS instrument: $2 million USD
- Maximum launch cost: $3 million
- The maximum Mission Science Operations cost during the two-year designated mission life is $2 million USD

The budget report shall show costs comprised of both labor and hardware costs. If the Total Cost Cap is exceeded, then the mission will be canceled.

Cost reduction bonus: As an incentive to reduce the actual total cost of the mission, the project will receive a 10% cash bonus for every USD below the Total Cost Cap. By way of example, if the total project budgeted cost equals $10 million USD then there is a resultant mission project savings of $2 million USD. As a result of this savings, a total of $200,000 USD would be returned to the project as cash, with no restrictions as to how that cash would be spent.
The budget report should indicate profit margins as well.