EAS 4700 – AEROSPACE DESIGN 1 (3 credits) - FALL 2016
*** 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: Tuesdays 3-6pm, from August 22nd, 2016 to Dec 6th, 2016.

CLASS WEBSITE: canvas and http://www.riccardobevilacqua.com/teaching.html

CLASS MEETS: M, W, periods 9-10 (4:05pm-6:00pm), PUGH 170.

TEACHING ASSISTANT/S: Sanny Omar <sanny.omar@ufl.edu> MAE-A 211
10-11:30am on Mondays & 9-10:30am on Wednesdays.

PRE-REQUISITES: EAS4510 and EML4312 with at least D grade. Working knowledge of MATLAB and a CAD program is required.

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 table shows which ABET Student Learning Outcomes (SLO) are targeted by this course.

	Students Learning Outcomes											
Course #	**Course Name**	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**
EAS4700	Aerospace Design 1			P	P		P	OP	P			P

A	B	C	D	E	F
P	P	P	P	P	P

Legend

a	An ability to apply knowledge of mathematics, science, and engineering
b	An ability to design and conduct experiments, as well as to analyze and interpret data
c	An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
d	An ability to function on multi-disciplinary teams
e	An Ability to identify, formulate and solve engineering problems
f	An understanding of professional and ethical responsibility
g	An ability to communicate effectively
h	The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental and societal context
i	A recognition of the need for, and an ability to engage in lifelong learning
j	Knowledge of contemporary issues
k	An ability to use techniques, skills, and modern engineering tools necessary for engineering practice
A	A knowledge of aerodynamics
B	A knowledge of aerospace materials
C	A knowledge of structures
D	A knowledge of propulsion
E	A knowledge of flight mechanics
F	A knowledge of stability and control

E	Direct measure - Focused ***E***xam or assignment problem and grade		Essential aspect of course - Direct measure
P	Direct measure - Focused ***P***roject section write up and grade		Essential aspect of course - Indirect measure
L	Direct measure - Focused ***L***aboratory (section) write up and grade		Essential aspect of course - not measured
OP	Direct measure - focused **O**ral **P**resentation, and write up grade.		Important aspect of course - not measured
QI	Indirect measure - Survey ***Q***uestion "***I***"		Covered, but not major aspect - no data collected
CG	Indirect measure - ***C***ourse ***G***rade		Not covered
CR	Indirect measure - **C**oop **R**eports		

The following table maps assignments to SLOs. It shows how each SLO is assessed.

Assessment	Student Learning Outcomes
Final Report	c, d, f, h, A, B, C, D, E, F
Presentations	g
Peer grading	d
STK Certification	k

COURSE DESCRIPTION: This course introduces all elements of the spacecraft design process. Students are organized into design teams (6 people each) 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, Kennedy Space Center provided a set of design requirements for a specific mission. See document at the end of the syllabus.

The table below provides a tentative schedule for this course, highlighting only some events. The teams will meet 30 times, and most of the meetings will be design work time.

TOPIC	**Meeting # or date**
Intro, syllabus, teams (6 people each), action items list	1
Systems engineering, risk examples, STK examples	2
Simulink/Matlab examples	3
Reviewing applicable docs – kick off design work	4
SYSTEMS ENGINEERING 1 -- Recognize the need for new system, often a customer requires it. A market analysis often happens outside of Systems Engineering.	12
Midterm presentation	**Oct 13**
Midterm survey due	**Oct 18**
SYSTEMS ENGINEERING 2 -- Collecting requirements and selecting which ones are stringent. Define Functions of the system. Iterations with customer to understand needs and balance them. Often this will clarify the customer's ideas. Identify constraints on cost, weight, volume, reliability, etc. … .	16
SYSTEMS ENGINEERING 3 -- Translate the problem definition into quantities, measurable inputs/outputs that the engineer can use. Performances definition. DESIGN OBJECTIVES: framework to compare against, when design alternatives are developed.	21

SYSTEMS ENGINEERING 4 & 5 -- Formulation of several system models (concepts) meeting the design objectives. / Selection of the best model, or combination of models. Analytical tools used to evaluate performances. First evaluation of costs can be done.	25
Final presentation & report & STK & peer grade	**Dec 2**

<u>TEXTBOOK/SOFTWARE</u>: The documentation needed for the specified design is available publicly. Additional suggestions (optional) are:

Required or recommended texts:

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 **optional**
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 **optional**
Text No. 3	Title: EMERGENCE OF PICO & NANOSATELLITES ISBN: 9781600867682 Cover: N/A	Publisher: AIAA Edition:	Author: THAKKER Copyright:	This text is **optional**

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>PRESENTATIONS AND REPORT</u>: Midterm (**Oct. 13, 2016, MAE-A 211, scheduled as needed**) and final (**Dec. 2, 2016, MAE-A 211, 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. 2, 2016, 40%** (paper template: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=4&ved=0ahUKEwifoZ6AkdXNAhUFbSYKHWCYBrwQFggxMAM&url=http%3A%2F%2Fwww.smallsat.org%2Fstudents%2Fcompetition-paper-template.doc&usg=AFQjCNHZphaZVOka2f_i8SmNmhtiAEvDuw&sig2=21arXUNjskPs07trV7BgZg&cad=rja). Each member of each team will evaluate his/her peers. **This peer evaluation is 20% of the grade**.

<u>MIDTERM SURVEY</u>: A voluntary mid-term survey will be provided, **due Oct 18**. To incentivize your participation, the survey will be valued as 5% **bonus**.

<u>STK OPTIONAL CERTIFICATIONS</u>: 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 (http://downloads.agi.com/u/downloads/products/STK-Certification-Flyer.pdf).
Those interested will have the opportunity to receive 10% **bonus** for the first level certification, 20% **bonus** for the second level. **The bonuses are NOT cumulative, i.e. 10% for first level, an additional 10% for second level.** 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 2, 2016 (DAY OF FINAL PRESENTATION)

GRADING POLICY: The grading scale is as follows, and it is not flexible:

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 WITH DISABILITIES: Students with disabilities requesting accommodations should first register with the Disability Resource Center (352-392-8565, www.dso.ufl.edu/drc/) by providing appropriate documentation. Once registered, students will receive an accommodation letter which must be presented to the instructor when requesting accommodation. **Students with disabilities should follow this procedure as early as possible in the semester. In other words: immediately at the beginning.**

CHEATING POLICY: absolutely zero tolerance. Your examinations must be completed completely independently. If anyone is caught having worked together on an exam or having used an unauthorized source, the penalty is an automatic failure of the course.

Cheating breaks the mutual trust between instructor and student. Cheating will invariably result in an automatic “E” grade and the incident will be reported to the University.

Familiarize with the concept of plagiarism as well – plagiarized work is cheating.

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 (http://www.dso.ufl.edu/sccr/process/student-conduct-honor-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.

Students should also familiarize with the Code of Ethics for Engineers: http://www.nspe.org/resources/ethics/code-ethics

ONLINE STUDENTS COURSE EVALUATION: Students are expected to provide feedback on the quality of instruction in this course by completing online evaluations at https://evaluations.ufl.edu. Evaluations are typically open during the last two or three weeks of the semester, but students will be given specific times when they are open. Summary results of these assessments are available to students at https://evaluations.ufl.edu/results/.

The instructor will also provide a midterm evaluation form to the students, to monitor the development of the class, and make necessary adjustments, when possible. I value your input, and that is why I am giving you an incentive to complete this optional survey at mid-semester. See also grading policy for points assigned to this survey.

CLASS DEMEANOR EXPECTED BY THE INSTRUCTOR: I have little tolerance for students who are repeatedly late to class, cell phone ringing, text messages beeps, and any behavior that may be distracting both students and instructor. Offenders will be asked to leave the classroom, and the lecture will not resume until they comply. If they do not comply, the lecture will be given for granted and the instructor will move on.

Also, I will not be eating while teaching (obviously!), and I expect you not to eat in class.

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

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

Introduction

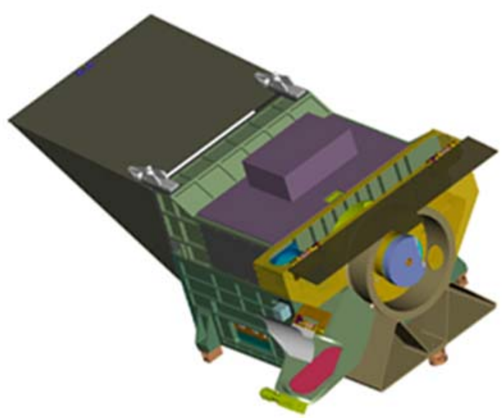
The spacecraft, hereafter referred to as the "Observatory", will improve the understanding of aerosol contributions to global climate change and help maintain a record of total solar irradiance. Data provided by the mission will enhance global climate modeling and help reduce uncertainties associated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

a. 6U CubeSat Design Specification (6U-CDS), Revision Provisional, The CubeSat Program, Cal Poly SLO (http://www.cubesat.org)

b. GSFC-STD-7000A, Revision dated 4/22/2013, General Environmental Verification Standard (GEVS) For GSFC Flight Programs and Projects
c. MIL-P-27401 (Revision F), Military Standard, Performance Specification, Propellant Pressurizing Agent, Nitrogen
d. MIL-STD-1246 (Revision C), Military Standard, Product Cleanliness Levels and Contamination Control Program
e. FED-STD-209E, Clean Room and Work Station Requirements, Controlled Environments
f. NASA-STD-6016, Revision dated 07-11-2008, Section 4.2, Standard Materials and Processes Requirements for Spacecraft
g. NASA Reference Pub. 1124, Outgassing Data for Selected Spacecraft Materials
h. 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
i. 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
j. GLORY Observability Meeting April 2010, http://icap.atmos.und.edu/ObservabilityMeeting/MeetingPDFs/Day-2/5_Glory-Maring.pdf
k. 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.

1. **SC Coordinate System**
   The SC coordinate system shall be as defined in the 6U-CDS.
1. **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.
2. **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.
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 Observatory.
   b. 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.

4. 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

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 Observatory shall be qualified for Structural Loads per GEVS section 2.4.1

b. 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.

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 Observatory shall be qualified per GEVS section 2.6.

e. 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.

f. 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.

g. Condensation Prevention

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

h. Maximum Pressure Decay Rate

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

6. 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.

7. 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.

8. 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.

9. Mission Operations

a. 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.

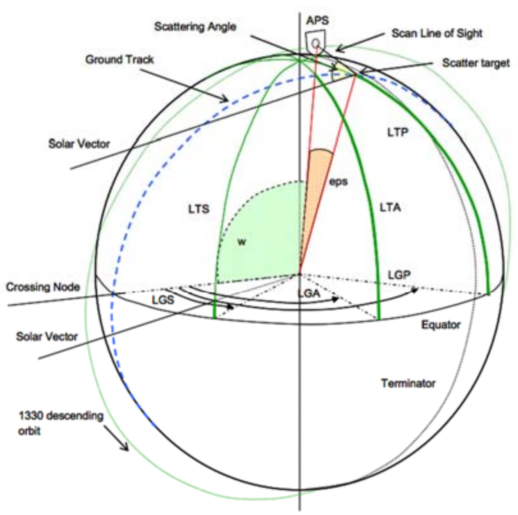
b. The entire mission shall be designed for two years of operational life. The on-orbit mission plan shall include a sample operational plan for collecting data, storing data, and transmission of data over a one-week duration (Jan 10, 2020 to Jan 17 2020.
   i. Sample operations should show the total 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)

c. 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.

d. 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.



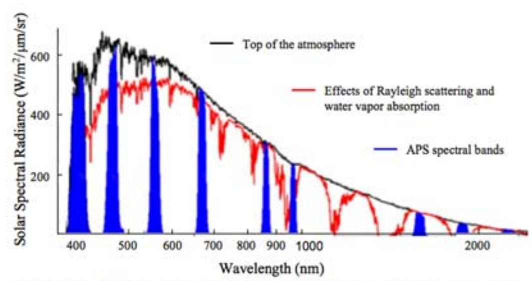
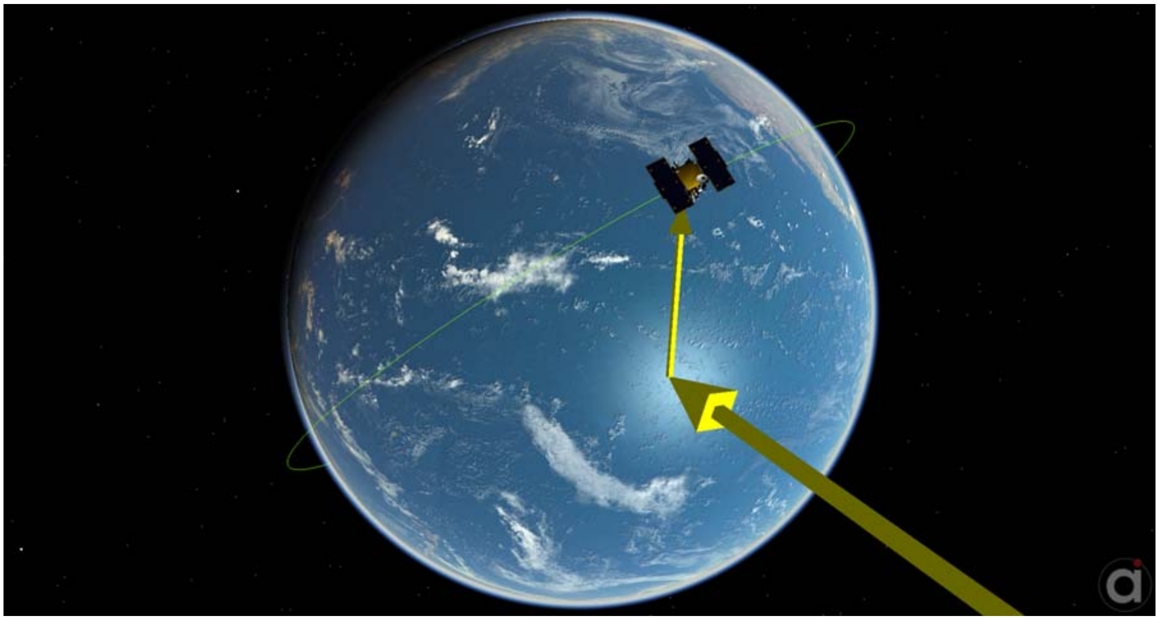


Figure 6. APS spectral bands (normalized to TOA) and scene dynamic range.

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.

10. 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.