University of Colorado
Aerospace Engineering Sciences
ASEN 4018
Project Definition Document
Baffling Buffs

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Approvals

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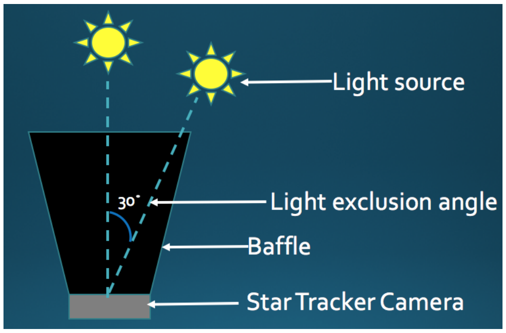
I. Problem or Need

Light from the Sun and Earth poses problems for optical sensors on satellites in space. In this case, the optical sensor is a star tracker, meant to use the stars in its view, compare them to a known database, and from that, determine the attitude of the satellite. However, compared to the sun, the observed stars are much dimmer. There are two metrics for measuring the brightness of a star. Apparent brightness (apparent magnitude) details how bright the star appears to an observer on Earth and does not account for the distance to the star. Absolute brightness takes into account the star's brightness and it's distance from the observer. The sun appears the brightest to the satellite with an apparent magnitude of -26.72, while Sirrus, the next closest (and next brightest) star, has an apparent magnitude of -1.46. This is because the sun is 93 million miles from the Earth, and Sirrus is 8.6 light years away. In order for the star tracker to observe these dim stars, the light from the sun must be blocked, thus a star tracker baffle is required[1].

With the onset of microsatellite technology, reductions in the mass and volume of satellite components are of increasing importance. Baffles take up precious volume and surface area on a spacecraft. By making a baffle deployable, the volume is greatly reduced for the times in which the baffle is not being used[2]. The goal of this project is to design, build, and test a deployable star tracker baffle prototype for a small spacecraft. The baffle mass shall be 300 grams or less with a stowed volume constrained to 125 mm x 125 mm x 50 mm. The success of this project depends on the ability to remotely deploy the baffle via an electronic process such that it creates a 30 degree half-angle light source exclusion zone, as measured from the boresight of the optical sensor. In simpler terms, this angle is shown in Figure 1 and is defined as the angle between the light source (in this case the sun) and the star tracker camera's normal axis, where a zero degree light exclusion angle is defined when the light source is located directly over the sensor. Success also includes creating a test methodology and instrumentation suite to confirm that the baffle meets these requirements and perform these tests accordingly.

Figure 1. Light Exclusion Angle



Baffles that are currently in use are neither small nor deployable. Designing a deployable baffle is challenging because there currently are not any but the need is growing as microsatellite popularity is growing. Deployable space structures of many different shapes and sizes have been developed and tested. The challenge for this project is to design a smaller baffle than is currently being used by Surrey Satellite Technology, and to make that baffle deployable. Because this baffle must be deployable, instead of the widely used rigid cone, it is likely that the baffle will not attenuate the stray light in exactly the same manner as their rigid counterparts. This also poses a challenge to designing a deployable baffle. Due to the fact that this has never been done before, this project will serve as a proof of concept that a small deployable baffle can be made. As such, the baffle produced by this project need not be space grade. Also, because the optics involved with a star tracker baffle requires high accuracy, for this project the deployable baffle is required to only sense light to determine the light exclusion angle and does not need to recognize star constellations.

II. Previous Work

The novelty of this project is the fact that the baffle will be deployable and ideally be used on a microsatellite. The use of a star tracker, and thus a baffle, on a microsatellite has been rare due to the fact that star trackers are extremely expensive (due to the amount of calibration needed for their high accuracy) and usually outside the budget of these types of missions. The size of the sensor and baffle are also difficult to accommodate on the microsatellite. However, the use of this type of attitude determination is becoming more commonplace among more advanced missions.[3]

Since baffles are typically not deployable, and the fact that small satellite star trackers have only been available for the past several years[2], it was difficult to find literature that directly related to our project since this is a new concept. One applicable source talked about designing deployables for small satellites using rollable high strain composite structures. Benefits from this technology include simpler mechanical design, increased structural integrity, and reduced volume of the deployment system, which is a critical goal of this project.[4] Another option of deployment commonly used on spacecraft is the use of EIMS (Electrostatically Inflated Membrane Structure). Though this deployment method has not directly been used for a baffle application, it provides an alternative to typical mechanical systems which contain more mass and thus increase launch costs. The source also suggests that EIMS would allow for lightweight membrane structural shape stability while also reducing mass and decreasing power usage (assuming an electrostatic deployment).[5]

III. Specific Objectives

In order for this project to satisfy the goal outlined by Surrey Satellite Technology, different tiers will be used as benchmarks for success. The design focus, development, and fabrication of this project will include meeting requirements and creating tests to accurately calibrate sensors and hardware and software systems. The first tier, referenced as Tier 1, designates the objectives that must be completed for the most basic level of success for this project. There are two tiers total for this project. The second tier level in each category describes a goal explicitly prescribed by the customer in the project description.

Tiers of success for project requirements

	TIER 1	**TIER 2**
DEPLOY BAFFLE	Manual deployment	Electronic deployment with a wired connection
BAFFLE LIGHT EXCLUSION	40 degree light exclusion angle	30 degree light exclusion angle
BAFFLE MASS	<500 g	<300 g
STOWED BAFFLE VOLUME	Constrained by: 175 mm width 175 mm length 50 mm height	Constrained by: 125 mm width 125 mm length 50 mm height

Deployment requirements are based on the fact that the baffle designed must be able to deploy. The first tier is based on any deployment mechanism that doesn't have to be done electronically, e.g. a lever that can be physically flipped on the device itself and the baffle will deploy. The second tier requires that the deployment be electronic. This implies electronic triggering, e.g. a human presses a button and the mechanism performs the deployment itself. In order to be used in space, the baffle must be able to deploy from a ground station, a person will not be up there to deploy it.

The baffle light exclusion angles were provided by the customer. The basic 40 degree exclusion angle would be easier to achieve within the given mass and volume constraints because the baffle would not need to be as tall in order to shield the sensor from light coming from the Earth and the Sun. This exclusion angle is also the same as an exclusion angle currently used by some of Surrey Satellite Technology's baffles. Trigonometry dictates that the 30 degree exclusion angle, though providing a more narrow field of view, would be more difficult to achieve because of the added height requirement and more effective at blocking stray light from the Sun and the Earth.

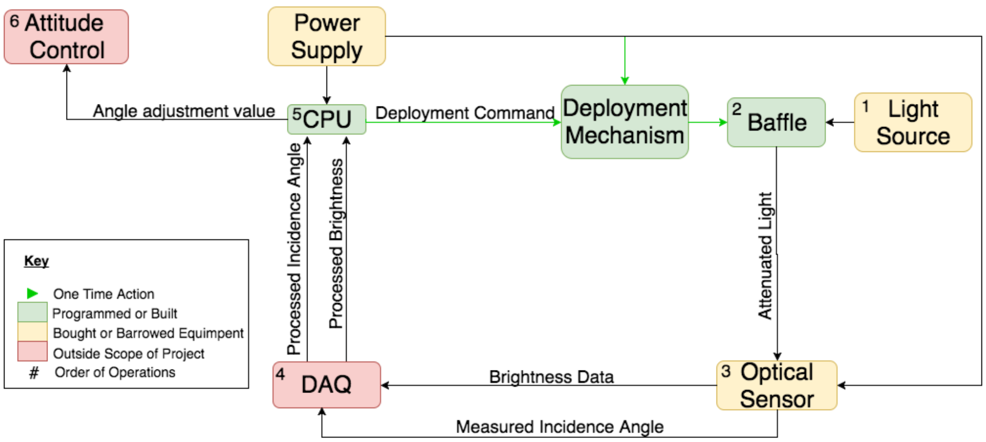
The mass requirements of the baffle are based off the masses of current baffles being utilized by Surrey Satellite Technologies. Their smallest baffle has a mass of 0.5kg, which is designated as Tier 1. This project is designed to make a baffle lighter than any currently used and therefore the Tier 2 requirement is how light the customer would like the baffle to be.

The volume requirements for the baffle are also based of the volumes of current baffles in use by Surrey Satellite Technologies. The Tier 2 volume dimensions were specifically given in the project description and do not conform to standard cube sat dimensions.

IV. Functional Requirements

A. Functional Block Diagram

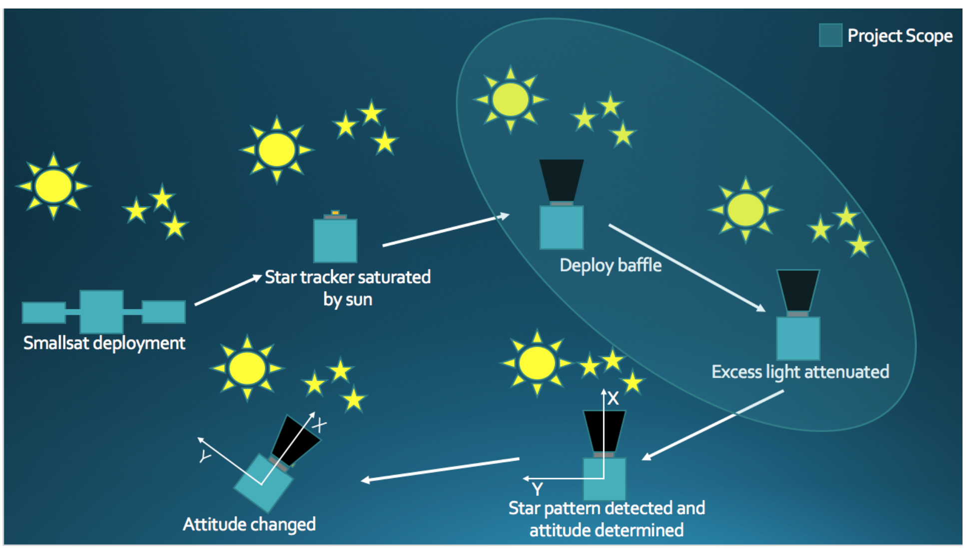
Figure 2. Functional Block Diagram



The functional block diagram, depicted in Figure 2, details the system interactions necessary to test and verify the baffle prototype. A central processing unit will send the deployment command to the mechanism that will deploy the baffle. Light from an external source will be attenuated by the baffle and sent to the optical sensor. The resulting optical data will be sent to a DAQ module for processing and sent back to the central processing unit. The star tracker unit will be powered by the Smallsat's available on board power supply which is limited to 12 Volts.

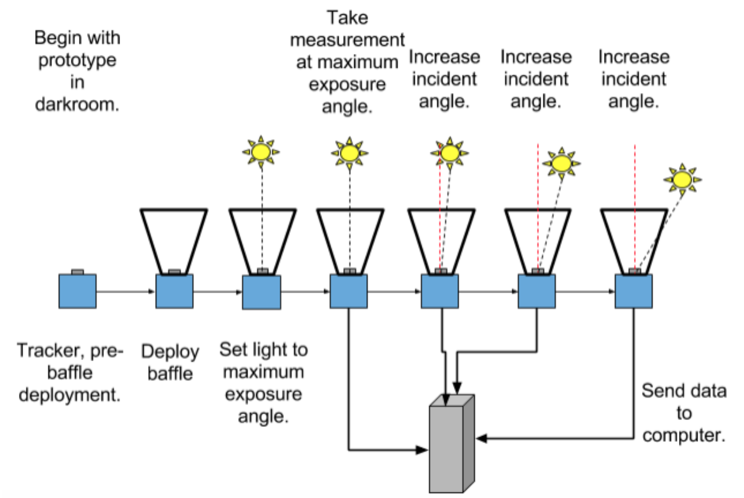
B. CONOPS Diagrams

Figure 3. Mission CONOPS diagram



The mission concept of operations (CONOPS) in Figure 3 depicts a baffle deployed on a small satellite platform. The purpose of the baffle is to prevent the optical star tracker sensor from being saturated by stray light. The baffle will be deployed after the small satellite is released. The baffle will then attenuate optical noise, which will allow for the optical sensor to recognize star patterns. After star patterns are recognized the small satellite will determine its attitude and maneuver if necessary, using the star tracker data as a reference point.

Figure 4. Operational testing CONOPS.



The CONOPS diagram in Figure 4 shows the stray light testing process. This test uses a light source and optical sensor to initially take measurements at the maximum exposure angle of the baffle. The incidence angle of the light source is then increased incrementally to a desired maximum exclusion angle. Once the maximum exclusion angle is reached, a small light source is placed in front of the baffle to simulate a star and testing is done to determine if the sensor can detect the small light with the large light source being filtered out by the baffle.

V. Critical Project Elements

Optics Expertise - Optics is going to be a large part of this project in both the design and testing phase. In order for the optics to be successful, the team must find someone to advise them on the optics behind light exclusion testing, as well as the optical ramifications of baffles on the sensor.

Material Selection - It is imperative to select a material for the baffle that simultaneously satisfies the appropriate optical requirements, meets the customer's stowed volume and mass constraints, and does not require a burdensome financial investment. The baffle is the central component of this project and the material used shall adhere to the $5,000 budget.

Deployment - The star tracker baffle is required to deploy once the spacecraft is in position for the star trackers to be operated. Therefore, it must not only deploy when remotely commanded, but also deploy fully and effectively.

Testing - In order for the project to become a success, testing is considered a critical aspect in terms of light exclusion and deployability. The light exclusion aspect will include both a testing methodology and testing apparatus that will be able to measure light noise entering the baffle. Simulating an on-orbit light environment, vibrational testing, thermal testing, and vacuum testing may also be included in this part of the project. Deployability testing will include demonstrations of both the software and hardware functioning correctly.

Manufacturing - This project must be fully built by the team within the time requirements. The manufacturing has the possibility to be complicated and take a lot of time to accomplish.

VI. Team Skills and Interests

Critical Project Element	Team Interests and Skills
Optics Expertise	**Interested Team Members:** Sierra, Lindsay, Aspen, Anthony, Mary, Emmett
Material Selection	**Interested Team Members:** Steven, Anthony, Elizabeth
Deployment	**Experienced Team Members:** Nicholaus - Electronics and soldering Sierra - Software and microcontrollers Zachary - Microcontrollers **Interested Team Members:** Aspen, Lindsay, Mary
Testing	**Experienced Team Members:** Nicholaus - Electronics testing and test procedures Steven - Hardware testing Sierra - Hardware and software testing **Interested Team Members:** Aspen, Mary, Zachary, Anthony
Manufacturing	**Experienced Team Members:** Anthony - Machine shop certification Lindsay - Steel welding and manufacturing Elizabeth - Various manufacturing techniques **Interested Team Members:** Aspen, Nicholaus, Emmett, Zachary

VII. Resources

Critical Project Element	Resource
Optics Expertise	Dr. Chu, Webster Cash All have worked with space optics and may be able to advise the team on how the optics of a baffle work, they will also be able to help the team design proper testing procedures.
Material Selection	Dr. Maute Dr.Maute has worked with materials that are used in space and will be able to provide insight on what is possible with space grade materials.
Deployment	Dr, Maute, Dr. Fillipa: Both professors have worked with deployable space structures and can provide insight and expertise on how structures deploy in space
Testing	Matt Rhode: Darkroom at CU Boulder (existing on campus) Trudy Schwartz: testing aparatus and procedure expertise, Darkroom: Surrey Facilities in Denver
Manufacturing	Matt Rhode: Machine Shop expertise, will be able to assist in design that is feasable to machine as well as the manufacturing of the design Bobby Hodgkinson can help with design manufacturability and manufacturing CAD software: Solidworks will be used to create the design 3D models will also be used if Computer Aided Manufacturing is needed

References

[1]Howell, E., ”Brightest Stars: Luminoscity and Magnitude,” 19 June 2016 [http://www.space.com/21640-star-luminosity-and-magnitude.html, Accessed on 20 Sep 2016.]

[2]Marciniak, M., Enright, J., Sinclair, D., Dzamba, T., ”Microsatellite Star Tracker Baffles: Validation and Testing,” AIAA/USU, [http://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=2930context=smallsat. Accessed on 29 Aug 2016.]

[3]Breukelen, E. v., ”Facet Nano, A Modular Star Tracker Concept for Highly Miniaturized Spacecraft”, 60^{th} International Astronautical Congress 2009,12 October 2009 [http://www.lr.tudelft.nl/fileadmin/Faculteit/LR/Organisatie/Afdelingen_en_Leerstoelen/Afdeling_SpE/Space_Systems_Eng./Publications/2009/doc/IAC2009_Facet_Nano_paper4_HANS.pdf, Accessed on 20 September 2016]

[4]Davis, B., Francis, W., Goff, J., Cross, M., Copel, D., ”Big Deployales in Small Satellites,” AIAA/USU, [http://www.altius-space.com/wp-content/uploads/2014/08/Roccor_SmallSat_Paper_Final_2014-06-20.pdf. Accessed on 29 Aug 2016.]

[5]Stiles, L., ”Electrostatically inflated gossamer space structure voltage requirements due to orbital perturbations,” Acta astronautica, 01 March 2013, [goo.gl/Qa7PEQ, Accessed on 29 Aug 2016.]