UKSEDS-SSPI 2019-20 Chapter Competition

Cubesat Astronomy

Robert Bell, Executive Director, Society of Satellite Professionals International
Prahalad Kuthethoor, Vice Chair, UKSEDS

According to the magazine *Nature Astronomy*, we are on the verge of an astronomy cubesat revolution. Cubesats, of course, are small satellites built inexpensively in standard sizes and form factors. They offer the opportunity to monitor sources for weeks or months, while NASA orbital telescopes are constantly re-tasked from mission to mission. They are effective for studying wavelengths that are not accessible from the ground, including ultraviolet, far-infrared and low-frequency radio. Advances in precision-pointing, compact sensitive decors and miniaturization of propulsion systems are providing new capabilities.

Project Specifications

Research and identify an astronomy opportunity or requirement for which cubesat technology offers a high-quality solution and provide a high-level design for one or more cubesats capable of carrying out that mission and transmitting observational data to Earth. Your submission should address as many of the following topics as possible:

- Identification of an astronomical opportunity or requirement that can be effectively met by small satellites in Earth orbit, with the most likely candidate being ultraviolet astronomy, infrared astronomy or low-frequency radio astronomy.
- Establishment of mission goals and system requirements to meet them.
- Engineering design and technology requirements for the spacecraft and communications network required to support them.
- Technology sourcing from existing technologies as well as technology innovation required to accomplish the mission.
- Manufacturing, launch and orbital insertion of the spacecraft.
- Cost estimates to develop the spacecraft and place it into orbit, and running costs for the mission.

The submissions will be judged first on the quality, depth and rigor of the work presented and secondly by the breadth of the work in terms of topics covered.

Team Specifications

Teams must be comprised entirely of students at one university. Teams will be limited to one per university, and team candidacy must be submitted through that university's UKSEDS chapter. We recommend between 3 and 10 members per team, but we encourage team leadership to include as many interested chapter members as possible. Individual team members must maintain student status at the university naming the team and may only contribute to one project at a time.

Since this is a student project, SSPI and UKSEDS expect student team members to do the vast majority of the work. Mentors are assigned to assist teams with overcoming the learning curve, but should not do substantial work on the project, except when necessity dictates (driven by, e.g., proprietary software). All contributing team members should be credited on the team roster, which is submitted with the project.

Recommended Reading

We recommend a book titled *Space Mission Engineering: The New SMAD* edited by James R Wertz for guidance in mission design beginning with a blank sheet of paper and creating a cost-effective space mission. It may be available from your university bookstore or can be purchased from Amazon.com.

Background Information

The following offer a starting point for research:

- https://www.nature.com/articles/s41550-018-0438-8
- https://www.universetoday.com/115626/making-cubesats-do-astronomy/
- https://www.popularmechanics.com/space/satellites/a14392639/nasa-to-test-cubesat-telescope-for-measuring-the-brightness-of-stars/

Ultraviolet astronomy. The success of the International Ultraviolet Explorer (IUE) observatory and successor instruments such as the GHRS and STIS spectrographs on-board the Hubble Space Telescope (HST) demonstrate the major impact that observations in the far ultraviolet wavelength range, from ~100 to 300 nm, have had on modern astronomy. Of particular importance has been access to high-resolution R ~ 40,000 – 100,000 échelle spectra providing an ability to study the dynamics of hot plasma and separate multiple galactic, stellar or interstellar spectral lines. Since 1978 astronomers have enjoyed continuous access to the far-UV. Observing time on HST remains heavily oversubscribed in total (a factor ~6 in 2004), with far-UV observations taking a large share. However, in August this year, the Space Telescope Imaging Spectrograph (STIS) failed, leaving HST without its UV spectroscopic capacity.[1]

Infrared astronomy. Like all other forms of electromagnetic radiation, infrared is utilized by astronomers to study the universe. Indeed, infrared measurements taken by the 2MASS and WISE astronomical surveys have been particularly effective at unveiling previously undiscovered star clusters.[9][10] Examples of such embedded star clusters are FSR 1424, FSR 1432, Camargo 394, Camargo 399, Majaess 30, and Majaess 99.[11][12] Infrared telescopes, which includes most major optical telescopes as well as a few dedicated infrared telescopes, need to be chilled with liquid nitrogen and shielded from warm objects. The reason for this is that objects with temperatures of a few hundred kelvins emit most of their thermal energy at infrared wavelengths. If infrared detectors were not kept cooled, the radiation from the detector itself would contribute noise that would dwarf the radiation from any celestial source. This is particularly important in the mid-infrared and far-infrared regions of the spectrum.

The principal limitation on infrared sensitivity from ground-based telescopes is the Earth's atmosphere. Water vapor absorbs a significant amount of infrared radiation, and the atmosphere itself emits at infrared wavelengths. As is the case for visible light telescopes, space is the ideal place for infrared telescopes. In space, images from infrared telescopes

[1] "Does Ultraviolet Astronomy Have a Future?" Martin Barstow, Abstract in A&G, Oxford University, https://academic.oup.com/astrogeo/article/45/5/5.10/210049

can achieve higher resolution, as they do not suffer from blurring caused by the Earth's atmosphere, and are also free from absorption caused by the Earth's atmosphere. Current infrared telescopes in space include the Herschel Space Observatory, the Spitzer Space Telescope, and the Wide-field Infrared Survey Explorer. [2]

Low-frequency radio astronomy. The opening of a new spectral window for astronomical investigations has always resulted in major discoveries, significant insights into astrophysical processes, and an enrichment of our understanding of the universe. Interferometric space or lunar-based arrays for imaging the entire sky below 30 MHz will cover a frequency range which is totally inaccessible or extremely difficult to observe from the ground due to ionospheric absorption and scattering. This is a region of the electromagnetic spectrum which is essentially unexplored by astronomy but which, at ~10^6 Hz, is likely to display phenomena as different from those at centimeter radio wavelengths (~10^9 Hz) as centimeter radio phenomena are from infrared (~10^{12} Hz), infrared are from the ultraviolet (~10^{15} Hz), or ultraviolet are from the X-ray (~10^{18} Hz).

Also, this low frequency window from ~30 kHz (just above the local plasma frequency of the interplanetary medium) to ~30 MHz (where high resolution observations from the ground become possible most of the time) spans three orders of magnitude in frequency, wider than the infrared window opened by IRAS and ISO or the ultraviolet window opened by IUE and EUVE. It is the last region of the electromagnetic spectrum which is still largely unexplored.

Because of this large gap in our knowledge, the likelihood of discovering new processes and objects is great, even though many worthwhile projects can already be defined for a new instrument. Jansky sensitivity and subarcminute resolution would be as much of an advance for the field as was the Einstein satellite for X-ray astronomy or the IRAS for infrared astronomy.

High resolution (less than 1'), very low frequency (less than 30 MHz) observations cannot be done from the ground. The ionosphere is too severe a restriction. (Kassim et al. 1993) have shown that by using dual frequency observations at 327 MHz and 74 MHz with the VLA, ionospheric phase corrections can be introduced. However, they estimate that these techniques will begin to fail below ~30 MHz due to ionospheric scintillation. At these frequencies ionospheric phase and amplitude fluctuations become so large that even the strongest calibration sources become decorrelated and selfcal techniques fail.[3]

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[2] Infrared Astronomy, Wikipedia, https://en.wikipedia.org/wiki/Infrared_astronomy

[3] Low Frequency Radio Astronomy from Space, US Naval Research Laboratory, Remote Sensing Division https://www.nrl.navy.mil/rsd/7210/7213/lfra-from-space

Timeline for Submissions

Discussions with UKSEDS leadership have yielded the following schedule for the project.

Activity	Responsible	Target Date
ANNOUNCEMENT AND DECISION		
First project announcement to chapters	UKSEDS	12 November 2018
Second project announcement to chapters	UKSEDS	26 November
Teams indicate interest in participating	UKSEDS	7 December
Conference call/hangout to review requirements	Teams, SEDS	11 December
PROJECT START		
Final deadline for team commitment to project	Teams	16 December
Mentor assignment deadline	SSPI	31 January 2019
First online meeting with mentor	Teams	1 March
Complete outline and project plan	Teams	8 March
PROJECT WORK AND SUBMISSION		
First conference call on progress & problems	Teams, SEDS	24 March
Second conference call on progress & problems	Teams, SEDS	31 May
Reports due to UKSEDS and SSPI for review	Teams	30 July
Completion of judging, announcement of awards	SSPI	31 October
Presentation of awards	UKSEDS, SSPI	March 2020

Submission Details

Teams are expected to thoroughly document their progress through their project:

First Meeting

Team leadership should meet with their assigned mentor and submit brief documentation by the deadlines above. The documentation should include the following:

- Project overview (round-number estimates of basic engineering goals)
- Team roster
- How you will address each bullet point under "Project Specifications" (above), which you expect to be expect to be most challenging (and why), and a couple of scope reduction options.
- Brief timeline for project completion
- "Wish List" from SSPI/UKSEDS

These items should all be discussed among team leadership before the mentor meeting.

Final Submission

The final submission should address each bullet point under "Project Specifications" (above), including brief descriptions where appropriate of why items were not treated in the project as a whole. Your submission should "tell a story," more or less. The overall submission should be built around a Project Overview document, which should reference documents like:

- Technical Drawings
- Case-studies

- Orbit scenarios
- Launch simulations

Final submission should reference modern scientific literature, much like a research paper. Additionally, the project must include a team roster, preferably with each team member credited with general areas of contribution. Teams are encouraged to assist and seek assistance from one another during that session.

How to Structure the Report

Use the following outline as a template for your report. You need not follow this exact order or include every item, but an effective report will use this outline as a guideline.

1. The mission
   a. Description of astronomical research opportunity
   b. Explanation of why one or more smallsats are appropriate for the mission
   c. Mission goals and systems requirements
   d. Required timeline from specifications through operation
2. Review of current research and market developments
   a. Current findings on your selected research opportunity
   b. Rationale for selecting your research opportunity
   c. Existing technology for study of research opportunity
3. Design and technology requirements, sourcing
   a. Engineering design and technology requirements for the spacecraft including power and communications network
   b. High-level design for the spacecraft
4. Manufacturing, launch and operations
   a. Sourcing of technology (existing and proposed new) and spacecraft manufacturing
   b. Identification of appropriate launch provider
   c. Cost analysis for spacecraft development, launch and annual running costs for in-orbit operation
5. Conclusions

Awards

SSPI is making available up to three cash prizes payable to the top-scoring teams in the competition. The first prize is £500, second prize is £350 and third prize is £200.