The "BEST" Program

HKU ACADEMY-LSR-OASA Partnership: A High School CubeSat STEM Initiative

Finding solutions to 21st Century Problems

BEST Program Parameters:
Provide a STEM-based, hands-on, education program for talented secondary (mainly science) students in Hong Kong. It is based on using a CubeSat Prototype Mission Design & Build Competition with a strong entrepreneurial edge and implemented under the name "BEST" – Business Economy for Space Technology.

Schedule:
During Academic Year 2021-2022 across two Semesters (September to April 2022).

Structure & Delivery (across 2 school semesters and ~13 hours of taught materials)
Two 2-hour and one 2hr20min webinar-based taught workshops in September & October 2021 (6 hours 20mins) in Semester one. Then three 2-hour taught workshops in January & February 2022 (6 hours) and then one further hour of recap materials presented in Semester 2. This gives a total of 13 hours and 20mins of scheduled materials in total. This will of course be supplemented by support from a dedicated team of mentors from HKU and OASA and as much additional teamwork effort and application as each School team decides to invest to deliver their contribution. Effort is open-ended but should be set within an overall reasonable envelope of extra-curricular activity as decided by the Teacher and team. After the final taught segments on Friday February 18th 2021 there will be two months where teams can work on putting all what they have learnt and already accomplished into their final concepts and incorporated into a CubeSat proto-type teams can build. Teams will then present their work at a special celebration, judging and prize-giving event at HKU on Thursday April 14th just before Easter.

Focus and program split:
There is a ~75% focus on STEM (~9.5hrs) and a ~25% focus on Entrepreneurship and related matters (~3.5hrs). The BEST program consists of a total of 5x2 hour taught "episodes" plus one episode of 2hrs20min and one hour of review materials. There is then 3 hours for school team project presentations at the end of the program in April followed by judging and awards. Schools and teams can invest as much time, energy and effort as they want over the course of the program.

DRAFT PROPOSED TEACHING PROGRAM

SEMESTER 1

FRIDAY SEPTEMBER 24th 4:30-6:40pm EPISODE 1: AN INTRODUCTION TO SPACE
New frontiers in Science, Technology and Commerce – defining teams

Hour 1+: 1x10min intro; 3x20min segments
This is the foundational introductory material for this program

Introduction: what is the HKU academy, the LSR & OASA? (BL/QAP/GL) (5-10)
A brief introduction to introduce each partner's motivations and contributions to the BEST initiative.

Segment 1: Space Science – at the frontiers of science (QAP) (20)

Human curiosity and a desire to know how the universe works motivated mankind for millennia. This led to the development of the "Scientific Method" that underpins how modern science functions. In this first segment we will briefly explore how the needs and interests of astrophysicists, scientists, engineers and technologists have come together in interdisciplinary endeavors to deliver remarkable achievements in space at the very frontiers of science.

Segment 2: Space Engineering – cutting edge technologies & challenges (RP) (20)

Large Space missions have become more sophisticated and more complex, often costing billions of dollars. CubeSats are an alternative tool used to address single targeted science questions and increasingly commercial opportunities in a rapid, and affordable, manner. In this segment we will show some of the challenges Space Missions represent according to size and costs. We will mention policy problems such us orbital debris, spectrum-frequency challenges, and difficulties in obtaining affordable access to space. It is essential that students understand the importance of such factors before planning their mission.

Segment 3: Space Astropreneurship – imagination and opportunities (GL) (20)

The era of entrepreneurs leading space initiatives, so-called "astropreneurship", has arrived with private funding of new space ventures. This segment introduces new space businesses like reusable rockets and miniature satellites, including CubeSats, and the opportunities their founders are seeking to develop through Venture Capital and the marketplace.

Hour 2: 3x20min segments

Segment 4: What is a CubeSat? (RP) (20)

CubeSats are miniature satellites for space research and increasingly now also for commercial exploitation that follow a standardised cubic form 1U (10x10x10cm). Several cubes or Units (U) can be combined together as 2U, 3U, 6U etc. though each unit should have a mass of no more than 1.33 kilograms. They are typically constructed using commercial off-the-shelf (COTS) components for their electronics, on-board computer and basic structure, though the payload is usually "bespoke"

Segment 5: Team selection – issues to consider when forming teams (QAP) (20)

A team is the fundamental unit of co-operative human endeavor. In this program teams of students will work together to a common goal – to conceive, design and test a concept for a viable CubeSat mission. But how can we construct a good team that can deliver? In this segment team roles and responsibilities will be discussed with an emphasis on interdisciplinarity combining together to create impact.

Segment 6: Project Management and project team roles (PL) (20)

Once teams are selected everything then depends on how the team works together and how well each team member can fulfill their assigned roles. This does not mean they work independently in these roles - the process is managed and activities need to be integrated. In this segment we will look at good practices in team management, leadership and collective responsibility and how this can lead to meaningful and impactful outcomes. One key aspect of the BEST program is that all teams are expected to be interdisciplinary in nature.

Important note:

All school teams should be in place BEFORE Episode 2.
Episode 2 commences FRIDAY OCTOBER 8th 2021

FRIDAY OCTOBER 8th 4:30-6:30pm EPISODE 2:
MOTIVATIONS, MENTORING, DEFINING MISSIONS

Hour 1: 3x20min segments

Segment 7: Motivations: Why use a CubeSat? (QAP) (20)

CubeSats have been used exclusively in Low Earth Orbit (LEO) for more that 15 years but this changing and they are now also being used in deep space for interplanetary missions. In LEO they were typically used for remote sensing or communications but their breadth of operation has recently been growing. They are used because they are cheap, effectively disposable and increasingly useful for science and commerce. Constellations of hundreds or even thousands of CubeSats are being planned or considered.

Segment 8: Can School teams compete to really build a CubeSat? (CTK) (20)

Since 1999 when CubeSats were first developed, well over a thousand CubeSats have launched into orbit, many by universities, high schools and even elementary schools. This segment introduces some student CubeSat projects from around the world, and how they are increasingly being used for STEM education, commercial and scientific research purposes.

Segment 9: Mentoring support to work on Team problems (PL) 20mins

Teams are not alone. The project consortium will provide keen student mentors from HKU and OASA who will be specially assigned to work with each team. Additional support from senior consortium academics and specialists will also be available as required. Here we will outline how this mentorship program is intended to work in practice and what school teams can expert from this service. Effective collaboration and how to work as a high performance team is also covered.

Hour 2: 3x20min segments

Segment 10: How can CubeSats solve Problems on earth & In Space? (GL) (20)

Satellites have become an essential element in everyday life, from television and telecommunications to weather monitoring, geolocation and navigation. Satellites account for the largest part of the global space economy, yet most people are unaware of their presence and functions. This segment introduces some of the important use cases of CubeSats as solutions to problems facing the world such the United Nations 17 Sustainable Development Goals (SDGs) and the dangers of space debris.

Segment 11: CubeSat typical mission structure – technical (RP) (20)

The mission steps and profile for a CubeSat program basically follows that for much larger satellites by say NASA or ESA but on a drastically reduced timescale and with a curtailed set of processes and elements. In this segment we will explore the differences and similarities between traditional large space missions and their CubeSat counterparts. We focus on the key project steps in a CubeSat mission and their sequential and in some cases, parallel interdependence.

Segment 12: Typical mission timetable from inception to launch (RP) (20)

A CubeSat development timeline typically takes from 18-24 months from concept to launch. Here, we compare a typical CubeSat mission timetable with its more traditional counterparts and explore what this means for this 1 year program in terms of what is achievable over two semesters.

FRIDAY OCTOBER 22nd 4:30-6:30pm EPISODE 3:
SELECTING & FUNDING MISSIONS, PROJECT MANAGEMENT & REQUIREMENTS

Hour 1: 3x20min segments

Segment 13: How to formulate/select a CubeSat mission (QAP) (20)

Here we explore the issues and challenges surrounding the development of a viable concept for a CubeSat mission. We will then examine how decisions are made on whether to proceed from CubeSat concept to mission selection and then to build and deployment. Is it economics, potential scientific or commercial value, motivation or the dedication and insistence of a team that is more important?

Segment 14: Costing a mission – depends on mission scope (RP) (20)

COTS components guarantee standard costs for all main CubeSat subsystems, but the payload itself depends on the mission. Here, we consider three main missions:
i) Downstream missions oriented to services and applications for institutional and/or commercial users; ii) Scientific missions to pursue knowledge and understanding of natural phenomena etc and iii) Technology demonstration missions for new architectures and concepts for use of in orbit. This may include innovative technologies. Strategies for time and cost reductions are also examined. This process is compared to the qualification for new mission concepts and payloads for bigger missions (where a CubeSat may be a pathfinder for such a larger mission).

Segment 15: Funding a mission – challenges and solutions (JC and/or GL) (20)

The costs of designing, building and launching a CubeSat mission typically runs into the hundreds of thousands of dollars (US). This segment introduces how CubeSat missions are usually funded and describes strategies for how a school team can raise funds to finance their mission. A look into how “crowdfunding” can sometimes provide the necessary support is also made.

Hour 2+: 4x20min segments

Segment 16: Project management – business side via marketing/funding (JC) (20)

The process of developing a CubeSat mission from beginning to end involves managing and coordinating multiple tasks, team members and stakeholders. This segment introduces the management of two of the most essential elements of astropreneurship: fund-raising and marketing in a CubeSat context.

Segment 17: Project technical requirements – what are the tools? (RP) (20)

After evaluating all the policy, size, and weight limits for our CubeSat, we will look at the software available across relevant areas (not just engineering) to support a CubeSat project, starting from technical drawing design. Here it is possible to work collaboratively and remotely between team members and tutor with continuous interaction and modification of the project. Drawing, orbit calculations, thermal analysis, attitude control and all the aspects of CubeSat operation need to be considered and each may have a different tool. We will explore a few of them.

Segment 18: Design thinking for projects – the how and the why (JC) (20)

Design thinking is about creative problem solving and enhancing the business environment. It is complementary to STEM education and closely related to innovation management. It can identify stress-points to address on Earth, including use of CubeSats for problem solving and in a comprehensive design process. This segment aims at students' design thinking mentality and skillsets - under the VUCA (Volatility, Uncertainty, Complexity and Ambiguity) environment. Students will take a cross-disciplinary project approach to creatively achieve technological, business, social and communal goals.

Segment 19: Insights for commercial exploitation of payloads (GL) (20)

In the two decades since they were developed, CubeSats have moved beyond purely educational purposes to scientific and commercial uses. This segment introduces some of the best current commercial use cases for CubeSats that may be of value for any teams focusing on a potential commercial payload application.

Tuesday November 30th – DEADLINE to submit team Video Pitch Presentation
Teams are now recommended to study the on-line resource materials provided on the BEST website for tips and advice on constructing a compelling video pitch over the next 5 weeks.

SEMESTER BREAK
PART 2 will involve the real work by schools on CubeSats

At the end of the semester everything should be in place for teams to concentrate on mission concepts, design and build plans formulated during Semester 1. During the first two weeks of the 2-month break teams will need to submit a 5-minute "pitch-type" video of their ideas (deadline for submission is Tuesday November 30th).

The HKU-LSR-OASA team will review all video pitches and present Segment 20-21 as feedback during the Semester Break. These segments, outlined below, will be put up as video materials on the programme website well before the start of the next semester.

Segment 20: General feedback on CubeSat Payload ideas (QAP) (20)

A key element of learning and improvement involves listening to constructive criticism from experienced leaders and experts in the relevant areas. In this segment some general observations, comments and feedback on behalf of the program teachers on the progress of teams across the BEST program will be provided. The intention is to help teams further refine, improve and develop their ideas and concepts.

Segment 21: General feedback on design and planning (RP) (20)

Design and planning are crucial to the successful progress of any CubeSat mission. In this segment we present some important elements of what typically constitutes a well-designed and well-planned mission. We then provide important, generic feedback on preliminary team-work and make suggestions for moving forward.

Segment 22: General feedback on the "astropreneurship" concepts (GL) (20)

The commercial and entrepreneurship potential of some CubeSat mission concepts are examined and feedback on the approaches adopted by participating teams are explored before providing further advice and insights into what is needed for success.

SEMESTER 2

JANUARY 14th, 2022 4:30-6:30pm EPISODE 4: PROJECT MANAGEMENT & FUND-RAISING FOR CUBESAT PROTOTYPE TESTING, DATA, SUBSYSTEMS, BUILD & DEPLOYMENT

Hour 1: 3x20min segments

Segment 23: Prototype project management – problems/solutions (QAP) (20)

Developing a "prototype" is an important project management goal. Prototypes are used as a mechanism to provide early feedback and garner insights into what might eventually be developed as a final product or mission. They are designed to incorporate key project requirements. A prototype may be a built working model of a product before mass production or an earlier test version of a unique item such as a bespoke satellite. Prototypes can be an effective way to sufficiently complete and test the design, build phases and operation of an item before final choices are made.

Segment 24: Deeper Dives into Marketing, Communications, Fund-raising (GL) (20)

Building upon the Fundraising and Marketing concepts and strategies introduced in Episode 3, segments 16 and 18, this segment introduces more detailed concepts and strategies for ensuring effective communication across and between stakeholders that is needed to support the fundraising and marketing campaigns for a viable CubeSat mission.

Segment 25: Management for Build and Deploy (RP) (20)

This is the final crucial stage of any CubeSat mission. Here we explore the steps necessary to ensure a smooth project build according to the agreed design, payload specifications, communications parameters etc and then the choice of rocket for launch and how this is agreed and managed and finally the orbital deployment configuration.

Hour 2: 3x20min segments

Segment 26: Testing – the why, the how and the when (CTK) (20)

Testing is a crucial component of any technical endeavor and CubeSat missions are no exception. Here we will look at what we mean by testing, why we need to test, how the testing itself can be carried out and at what different stages of the mission does testing need to be implemented. The implications for the results from all these tests also need to be taken into account, including potential "show stoppers" as the mission progresses.

Segment 27: Data applications for CubeSat problem solving (PSP) (20)

With their small size, low cost, and rapid development cycles CubeSats have a broad range of uses, including educational and commercial, attracted by possibilities in remote sensing and satellite communications. CubeSats may carry multiple sensor, potentially generating vast amounts of data. Data constraints for larger space missions are exacerbated in CubeSats, where computing power and bandwidth are limited. Ensuring high data rates at reasonable costs is a key factor to enable CubeSat missions to grow and expand into more diverse applications.

Segment 28: Key CubeSat subsystems (CTK) (20)

In this segment we look at the fundamental, typically commercial "off the shelf" components (COTS) that make up the majority of hardware in CubeSats that get launched into space. We examine their functionality and interdependence and why some are critical while others are optional, depending on the nature of the mission. All key subsystems will be described.

JANUARY 28th 4:30-6:30pm EPISODE 5:
PROJECT PAYLOAD CONSIDERATIONS & A SCIENCE OR COMMERCIAL FOCUS?

Hour 1: 3x20min segments

Segment 29: The harsh space environment – protection and mitigation (PSP) (20)

First, any spacecraft has to survive the rocket launch into space. Once there the environment is incredibly harsh. First there is the vacuum of space, which would kill organic organisms very quickly, but then there are the extremes of temperature, both hot and cold, though cold is the dominant extreme – typically just a few degrees (~2.7Kelvin) above absolute zero. Then there is extreme radiation, mainly from the Sun, with no atmosphere to protect spacecraft. Here we look at these environmental factors and what can be done to protect spacecraft.

Segment 30: 3-D printing - relevance to CubeSats and Space Exploration (DS) (20)

In the space economy of the future it is likely that most components and hardware will need to be manufactured locally in situ or in manufacturing plants on the Moon, Mars and beyond. One emerging technology that suits this need is 3-D printing. In this segment we will look at the current capabilities and future potential of 3-D printing for providing an on-demand service for "bespoke" space flight components when ordering a broken component up from earth is both impractical and prohibitely expensive. The relevance to CubeSats will also be explored.

Segment 31: What next? Startups, investors and commercial climate (JC) (20)

Starting a space business takes place within a scientific, technological, economic and social environment of research institutions, investors, entrepreneurs, customers and government bodies. This segment introduces space technology startup ecosystems and how CubeSat developers can benefit from them to achieve their mission objectives.

Hour 2: 3x20min segments

Segment 32: Pitching your CubeSat mission for a Science payload (QAP) (20)

How you need to "sell" a concept for a science payload on a satellite is very different to that needed to pitch one that is commercially oriented. Science missions generally emerge from institutes and universities that may have many international collaborators. Funding emerges from Government grant schemes and even direct government/inter-governmental investment depending on the scale and importance of the mission. Here we examine the process typically undertaken getting a space science mission funded.

Segment 33: Pitching your CubeSat mission for a commercial payload (GL) (20)

Building upon Segment 30, this segment looks further into the commercial sale of a CubeSat mission payload. It also introduces examples of current commercially operating CubeSat businesses and discusses some of the successes and failures in this rapidly emerging market.

Segment 34: The practical stuff: Launching and mission Longevity (RP) (20)

Obviously a critical component in any CubeSat mission is securing a launch vehicle and a launch window. In this segment we explore the practical limitations and considerations in achieving these key mission milestones. The mission duration in space is another critical aspect of any mission. Here we look at the constraints and requirements for securing mission security and longevity for typical CubeSat missions.

FEBRUARY 18th 4:30-6:30pm EPISODE 6:
SAFETY, LEGAL ISSUES, HAZARDS & REVIEW

Hour 1: 3x20min segments

Segment 35: Safety, cleanliness and good practice in a CubeSat build (CTK) (20)

The Satellite build component of any mission is where things can go wrong and where great care and oversight are needed. Usually clean room conditions are adopted at various stages and the safety of the satellite itself and the scientists working on it are essential aspects of the process. Here we will look at the standard health and safety and other protocols and those typically adopted in a less restricted CubeSat program.

Segment 36: Legal stuff: Licensing, communication, frequency allocation (YZ) (20)

In the modern era all space launches and telecommunications between earth and satellites in space are subject to international and national laws and regulations concerning frequency allocation for communication, licensing and other matters. This segment introduces some of the key laws and regulations that govern space missions and how CubeSat missions typically address them.

Segment 37: Trash or Treasure? – It's getting crowded up there! (PSP) (20)

Currently there are approximately 6,000 satellites orbiting the earth but most (~60%) are now inoperative making then effectively just "Space junk" and just under half are in low earth orbit. It is getting pretty crowded and the probability of catastrophic collisions between satellites and other spacecraft including manned flight and Space Stations is increasing all the time. Here we examine the risks and serious issues surrounding space junk and what mitigation strategies are needed to lower these risks and preserve the space environment to maintain safe and effective use of space.

Hour 2: 1x20min + 1x40min segments

Segment 38: Tips, ideas & issues when compiling your presentations (QAP) (20)

You may have compelling ideas, great materials and a viable mission concept but how do you convince others in a competitive environment that your mission deserves to be selected? In this segment we explore simple ways that show that it is not just what you want to convey that is important but "how" your concept is presented. This can make a big difference to prospects for funding and mission realisation – think advertising!

Segment 39: What have we learnt through this process? (QAP) (20)

We hope you have all enjoyed the journey up to now and benefited from the generic skills we have tried to embed along the way. We also hope you have come to appreciate the strength of interdisciplinarity, the importance of teamwork, the opportunities offered by this burgeoning space ecosystem, its relevance to Hong Kong and some insights into what the future may bring in the rapidly developing, high-tech space economy. In this final, taught segment we will reflect on the progress we have all made across this initiative so far and summarize the lessons and the BEST outcomes as you move forward to the final major proto-typing phase over the next 8 weeks.

Segment 40: Interactive session – questions, queries, issues and problems (all) (20)

This final segment gives all teams the final opportunity to raise any issues, questions or concerns with the program leadership before the teams work on their final presentations. All major stakeholders and team mentors will be present to assist with this process.

This completes the formal episode based teaching segment of the BEST program.

- *For the rest of February, March and into April the school teams should be busy finalizing their ideas, design and plans and for building a possible prototype of their CubeSat concepts.*
- *Advisory meetings and discussions with the BEST program Mentors and leaders will be possible and indeed encouraged during this key period*
- *Hands-on proto-type meetings will be possible either at school or at HKU's Laboratory for Space Research*

JUDGING CRITERIA FOR ALL TEAMS

Each school based project will be monitored, mentored and advised every step of the way by teachers and relevant members of the consortium. Final projects will be judged by both members of the consortium and external independent judges when selecting the best projects for awards. The principal selection criteria are below but encapsulated within an overall holistic approach that closely follows that adopted by the Science Park and Cyberport:

- Innovation and Creativity of the Proposed Project
- The Project's Commercial and/or Scientific Potential (including a business model if relevant)
- Overall Performance of the Project Management Team
- Community Engagement including Achieving the Sustainable Development Goals of United Nations (Social Responsibility)
- Technical Feasibility

<u>Judging Sessions – Ideally to be scheduled in the same week and ideally over 3 consecutive nights in the week before the Grand Final</u>

Semi Final A April (date TBC) – Venue TBC – teams will all turn up in person at HKU
Segment 41: School presentations (A) 8x8mins

The first 8 teams will present their mission concepts to the judging panel
Two teams will be selected to go forward to the grand final with one reserve

Semi Final B April (date TBC) – Venue TBC – teams will all turn up in person at HKU
Segment 42: School presentations (B) 8x8mins

The next 8 teams will present their mission concepts to the judging panel
Two teams will be selected to go forward to the grand final with one reserve

Semi Final C April (date TBC) – Venue TBC – teams will all turn up in person at HKU
Segment 43: School presentations (C) 8-9x8mins

The next 8/9 teams will present their mission concepts to the judging panel
Two teams will be selected to go forward to the grand final with one reserve

The best runner up from groups A, B, C will also be selected to go forward to the Grand Final in April (Date TBC)

DATE & TIME TBC: GRAND FINAL
(assumes 7 School Teams)

~1 Hour: 7x8min School presentations

Short 15 min break

Segment 44: Grading of projects and announcement of winners 20mins

This is the final part of the inaugural BEST program for 2021-2022. After a short wait while the judges compile their scores and select the winners there will be a special prizes and awards ceremony followed by a short reception.

Key to Program Teachers:

JC: Joseph Chan – HKU/OASA 4 segments
CTK: Andy Kong – LSR 4 segments
PL: Perry Lam – OASA 1 segment
GL: Gregg Li OASA/HKU 6 segments
QAP: Quentin Parker – LSR/OASA 10 segments
PSP: Pablo Saz Parkinson – LSR 3 segments
RP: Rosaria Prochilo – LSR 9 segments
DS: David Seeto OASA – 1 segment
YZ: John Zhao – HKU/OASA – 1 segment