SMALL SATELLITE STUDENT INITIATIVE

Innovation and collaboration environment

IdeaSquare is a dedicated experimental facility at CERN that hosts detector R&D projects, and facilitates cross-disciplinary student programs. Located in a technical hall next to the Globe of Science and Innovation, it offers ad-hoc meeting space and rapid prototyping facilities for innovation-related projects. It brings together CERN personnel, visiting students, and external project collaborators from domains of research, technology development and education. The purpose of IdeaSquare is to bring together people to generate new ideas and work on conceptual prototypes in an open environment with different backgrounds providing new socially and globally relevant product ideas and innovation.

IdeaSquare is an experiment itself, and it explores new ways to demonstrate the value of basic research. It aims at delivering innovation to society at marginal cost and the activities are covered outside the CERN annual budget. One of the new initiatives is to explore the use of online learning platform for distributed virtual innovation, driven by societal and technological challenges. IdeaSquare is willing to share the use of such a generic platform also with other users. (www.cern.ch/ideasquare)

Main Objective of Small Satellite Student Challenge

The objective of the student challenge is to propose a conceptual, integrated design of a next-generation small satellite combining both scientific and societal use.

Rationale of Student Challenge

The main motivations are:

- Offer to (PhD/Master) students a collaborative, multidisciplinary frontier challenge
- Establish and foster a platform in which knowledge, expertise and know-how can be openly shared

Main Guiding Principles

- Holistic, forward looking and interconnected approach which integrates all relevant aspects such as engineering design, logistics, operation, and socio-economics factors.
- Leveraging and complementing already existing resources and academic programs and activities

- Any additional resources shall be used to further strengthen the initiative and serve the communities as a whole

Success factors

- Dedication and expertise of the professors and other professionals and their support to the students
- Inspiring the students to question assumptions and generate unforeseen solutions
- A user-friendly, on-line open collaborative platform

General Objectives and Research Topics

In order to fit this initiative within the scope of IdeaSquare activities at CERN, common projects should include some physics research related aspect (e.g. study of cosmic background radiation distribution, cosmic ray coincidence measurements using multiple satellites). It should also include an end user driven need or experience which is turned into a concrete engineering challenge to fit the given boundary conditions of small satellites. For the latter, one could contemplate – but not limiting ourselves to – topics such as: based on dedicated sensors, monitoring climate change, obtaining early warning of earthquakes or volcanic eruptions; detecting suitable underground water steams to drill wells for accessing drinking water in remote areas; optimizing use of crop pesticides in remote areas, monitoring bird migration, etc. The collaborative principle relies on open science and open innovation.

Current Challenges and Limitations Associated with Small Satellites

Small satellites (cube/nano) are typically 1-10kg in weight and occupy a volume of up to a few ten cube centimeters. Due to their simple design and low cost, they are limited in terms of manoeuvrability, power consumption, and communication capabilities. These constrains impose strong design and testing challenges and require dedicated labs in the universities. Moreover, as these satellites orbit the Earth in some 90 minutes in LEO configuration, the communication coverage in a given area is just a few minutes, unless dedicated shared data receiver network is in place.

The main challenge in this initiative is to design a next-generation compact small satellite (cube/nano) which combines both scientific and societal use. This will require detailed investigations among various disciplines where both experimental and modelling aspects are welcome. Potential contributions from the attendees could align with one or more of the topics listed below, but additional ones are also welcome:

- Overall Design and Integration: conceptual design of a cube/nanosatellite with a close integration of components while optimizing the payload/orbit/launcher parameters, overall structural efficiency, multi-functional design.

- Thermal: passive thermal protection systems, heat transfer, insulation.
- Materials: light-weight materials development and characterization wrt. thermo-mechanical fatigue for designed life time characterization of mechanical frame and structures when exposed to typical thermo-mechanical loads during launch.
- Structures: static and dynamic behavior of integrated, multi-purpose structures; optimization of structural layout.
- Systems: design of on-board systems including controllers, data handling, telemetry, tracking, communications (hardware, software), multispectral camera technology, environmental conditions (e.g. radiation), on-board power generation, management and consumption, multiband antenna and RF design, communication with ground stations, mobile ground stations.
- Propulsion and Combustion: variable miniature propulsion cycles, nozzle design, combustion processes, modelling and validation of combustion processes, combustion instabilities, improvement thermal efficiencies.
- Operation, Logistics, and Business: Orbit planning permissions, launch preparations, payload preparations, satellite operation, ground system planning, market capture, cost assessment for development, manufacturing, exploitation, commercial viability.
- Environmental issues: materials selection, toxic emissions and disintegration in the upper stratosphere.

Network of Universities

Several technical universities have the capabilities to design, test and operate nanosatellites as part of their educational programs. Currently these offerings are often university specific only, and focused on developing and testing new technologies rather than integrating also society-driven educational activities. Thus, the potential offered both in terms of functionality and effective uplink time to the satellites is rather limited. Thus, there may be an interest for a geographically distributed and multidisciplinary university network.

The QB50 mission will demonstrate the possibility of launching a network of 50 CubeSats built by teams of universities all over the world as a primary payload on a low-cost launch vehicle to perform first-class science in the largely unexplored lower thermosphere.

QB50 invited universities worldwide to join the project and send a satellite to space. Numerous proposals have then been received and the CubeSats been selected. As a consequence the QB50 CubeSats will be designed and built by a great number of young engineers, supervised by experienced staff at their universities and guided by the QB50 project through review and feedback. Those engineers will not only learn about space engineering in theory but will leave their universities with hands-on experience. (www.qb50.eu)

It is clear that such a student offering must be well integrated into teaching curriculum of each participating university. This requires planning and setting up a MOOC/MOOP platform structure in a way which the universities can use to monitor and credit the contributions of their students (e.g. online courses and exams completed, material submitted and shared). This is the contribution that IdeaSquare is ready to share. Moreover, the project will require a tree-structure in which the leading universities will need to sub-coordinate at the top level: for example work groups on design, assembly, integration, launch preparation, controls, communications, and data collection. Preliminarily has been planned to use the same collaboration model with Working Groups as in High Speed Aviation Student Initiative. VKI (activity coordination), ESA (overall design and integration), and CERN (collaborative platform) would be the three members of the steering "troika".

Focusing on collaboration design and providing a MOOC/MOOP platform, the members of "troika" wish to explore the potential interest for such a common student undertaking and would be interested to understand better the necessary requirements for an online platform. The first version of the collaboration model with the technical platform for distributed collaboration has been described in appendix 1.

The drafts of the suggested work groups and of the main tasks with the high level Gantt chart are as appendices 2 and 3, respectively.