Exploring Modular Architecture for Nano Satellite and Opportunity for Developing Countries

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Abstract. SPACE Technology has the potential to provide information, infrastructure and inspiration that meets national needs in developing countries like Bangladesh. Many countries recognize this; in response they are investing in new national satellite programs to harness satellite services. Technology related to space is one example of a tool that can contribute to development both by addressing societal challenges and by advancing a nation's technological capability. To cope up with the advanced world in space technology Bangladesh seems to be highly potential country for satellite, Robotics, embedded systems and renewable energy research. BRAC University, Bangladesh is planning to launch a nano satellite with the collaboration of KIT, Japan. The proposed nano satellite project mission is to experiment about social, commercial and agricultural survey needs in Bangladesh. Each of the proposed applications of the project will improve the lives of millions of people of Bangladesh and it will be a pathfinder mission for the people of this country. Another intention of this project is to create a cheap satellite based remote sensing for developing countries as the idea of large space systems is very costly for us therefore we have decided to make a Nano-satellite.

1. Introduction

A number of international organizations, including the United Nations, have recognized the opportunity for space technology to serve developing countries; they pursue long term programs to promote this potential. Meanwhile governments in many developing countries also view that space an important tool for their development. All nations have on-going activities to ensure that space is harnessed in their country. Bangladesh is also establishing programs to operate a nationally owned satellite which is named as BANGABONDHU Satellite. This trend is enabled by the increasing performance of smaller, less expensive satellites. The countries that are the focus of this study seek to transition from owning satellites purchased abroad to attaining national capability to design and build satellites. One approach that countries around the world are using to initiate satellite development capability is to execute a Collaborative Satellite Development Project (CSDP) in partnership with an experienced foreign agency [1]. BRAC University would like to do the same by the collaboration with LaSEINE lab of KIT Japan, JAXA, NASA, ISRO, SPARRSO etc. Collaboration with KIT and SPARRSO is under process. BRAC University has a warm relation with NASA. So, it is very possible to continue this kind of research which will open a new dimension of research in Bangladesh.

The satellite applications are mainly considered for remote sensing, to provide imagery and environmental data; communication and navigation. The primary mission objective is to monitor formation and depression of Bay of Bengal leading to major hurricane, typhoon and other storm. The reason for monitoring monsoon wind & rainfall characteristics is to because excessive rainfall causes flood which is one of the major natural disaster of our country. Meteorologists are reporting that rainfall in Bangladesh in changing drastically (early on set and late on withdrawal in monsoon rain). Moreover, weather forecast use various observations from which to analyses the current state of the atmosphere. As Bangladesh is an agricultural country and most of the people here depend on agriculture for their livelihood therefore agriculture is one of the most important application fields of satellite. By using earth observation data we can do crop inventory, yield prediction, soil/crop condition monitoring and subsidy control. Another advantageous of this nano satellite is to monitor the forestry which helps to balance the eco-system as in recent years killing animals and cutting down trees illegally increasing immensely. By analyzing earth observation data can protect natural resources and ensure the safety of the animals in forest.

2. Implementation Plan

The main target of Bangladesh is to send own satellite in space. It was figured out that the VISION of building small satellites is very possible in five years if we can give emphasis on human resource capacity building & develop an infrastructure. The very first step has been taken by The Robotics lab of BRAC University, Bangladesh to start this project by signing research collaboration with LaSEINE laboratory of Kyushu Institute of Technology, Japan who are pioneer on nano-satellite research in Japan. The project will be led by a team of faculty members from BRAC University supervising a group of undergraduate and postgraduate students.

For project management a full time research assistant will be appointed. This kind of extensive research is very expensive and need high end technology & researcher. Since it also involve the national security and interest, it is very difficult to continue without direct support of Government. So, we are expecting financial help from the government of our country. We plan to deploy our nanoSat from ISS through nanoSat launching Robotic arm. With the collaboration of KIT and JAXA, our plan is to send our nanoSat in a cargo ship such as HTV-IV.

3. Proposed Model

The proposed structure is composed of six individual pyramid shapes whose vertex has been clipped. Each Pyramid is 10 cm x 10 cm at the base with the height of 5 cm. Each pyramid structure has been clipped at 2.5 cm height (Figure 1).

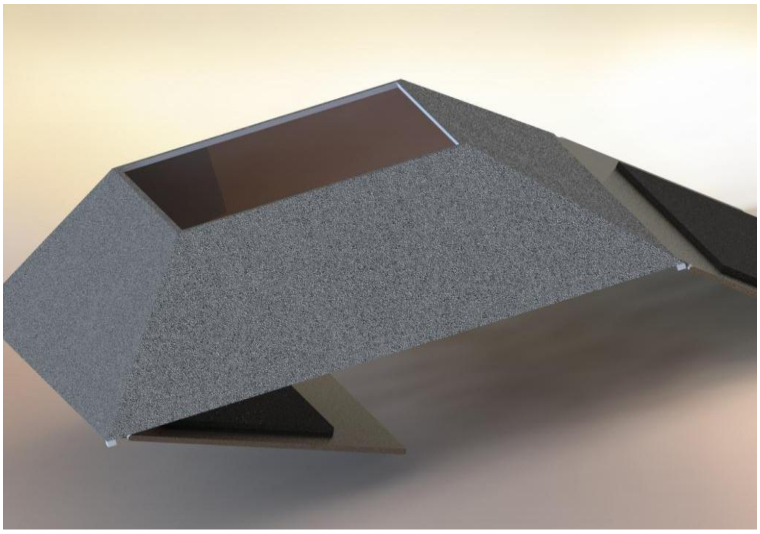

Figure 1. A single pyramid Unit

Assembling six pyramids therefore leave a cavity of 5 cm x 5 cm x 5 cm in the center. This space is mainly intended for battery (Figure 2).

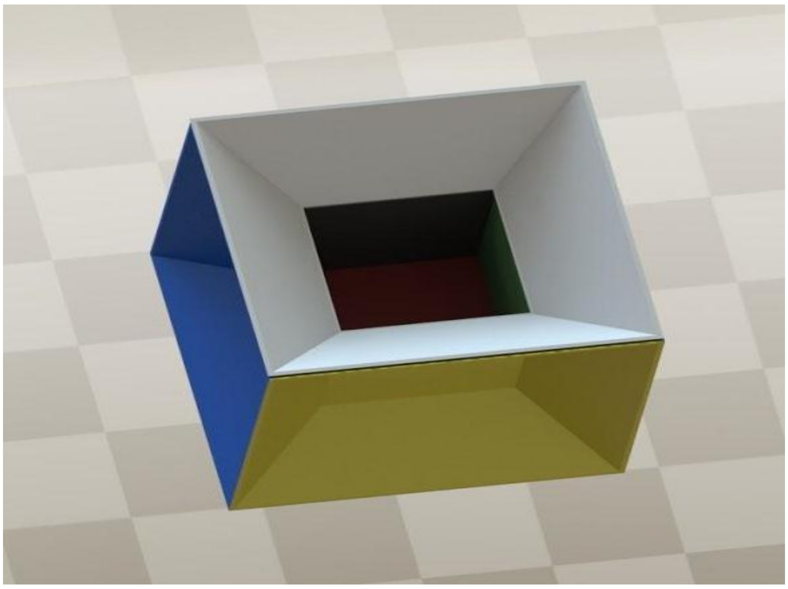

Figure 2. Six pyramids assembled to form a cube.

In contrast to usual cube sat structure, this structure allows us to setup observatory equipments to all six sides. Additionally, as the structure is made of six individual units, we can design and test each mission as a unit. This will further shorten the length of cubesat development period. Our aim is to adopt lego style architecture for cubesat. Of course, this will not allow us to build structure like 2u (10 cm x 10 cm x 20 cm), 3u (10 cm x 10 cm x 30 cm) cubesat format. By increasing the base size of the individual pyramids, the size of the cubesat can be increased.

Each unit has 2 solar panels. The solar panels match the size of the base of the pyramid structure. Two solar panels are deployable and they fold on top of the other as seen in the Figure 3. The units are assembled alternatively, so when the solar panels are deployed they take the form as indicated in this Figure 4.

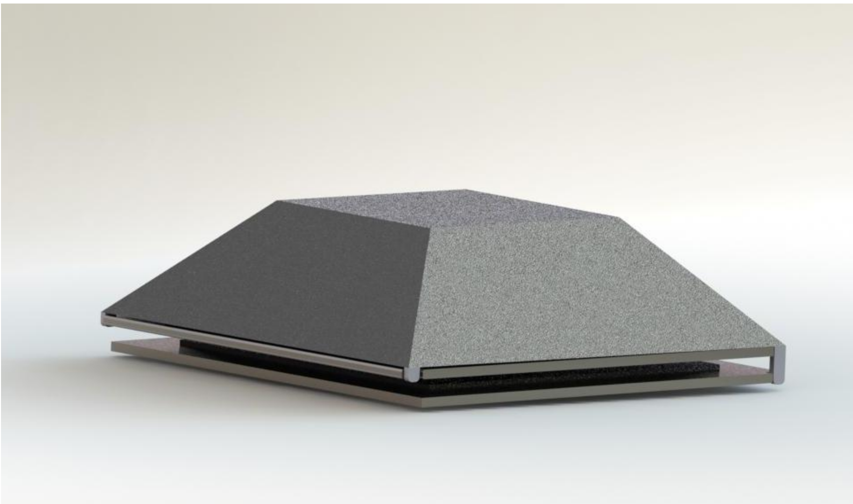

Figure 3. A single unit with its solar panels folded.

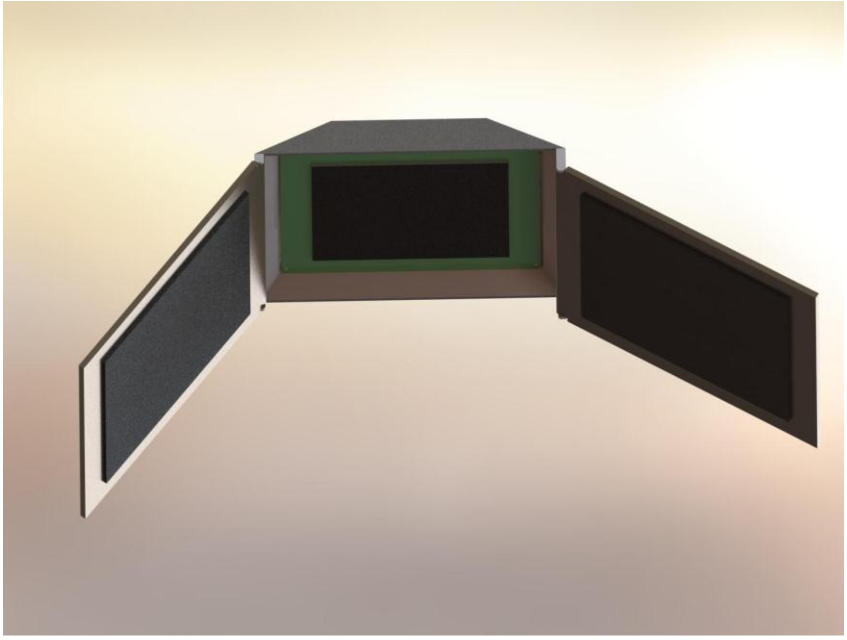

Figure 4. A single unit with its solar panels deployed.

In our design we could stack three circuit boards on top of another (Figure 5). The board sizes are 6.66 cm x 6.66 cm, 8.33 cm x 8.33 cm. Gap between top board and the middle board is 0.835 cm. The gap between lower board and the middle board is 0.88 cm. These boards can either house sensors or control circuits. Top circuit board can be a solar panel, sensor or a camera as per mission needs.

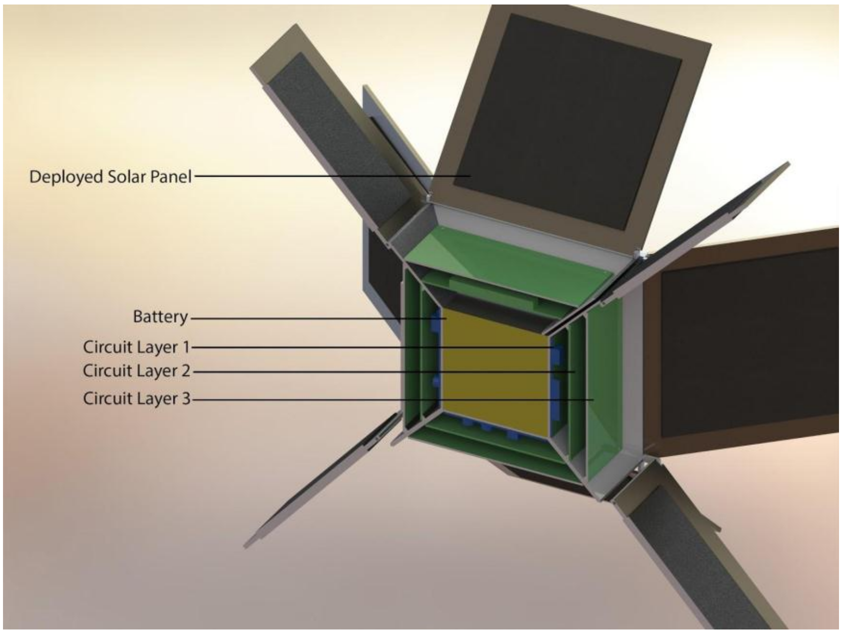

Figure 5. Cross sectional view of assembled nanoSat with solar panels deployed.

Overall, the structure is entirely modular like lego piece (Figure 6). Cubesat can be assembled and later modified as per mission requirement. Trimetric view of proposed model (solar panels undeployed) and trimetric view of proposed model (solar panels deployed) are shown in Figure 7 and 8 respectively.

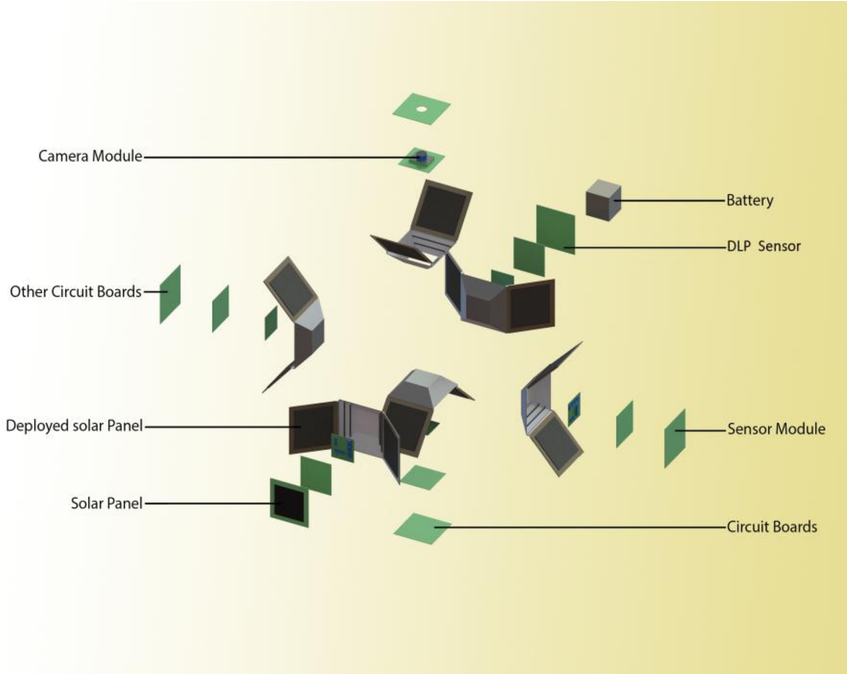

Figure 6. Exploded view of nanoSat.

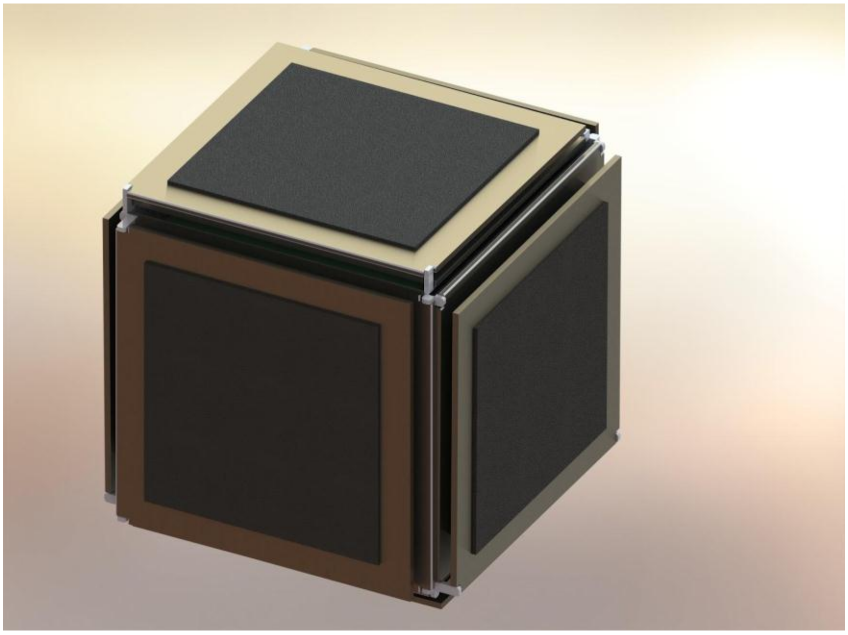

Figure 7. Trimetric view of proposed model (solar panels undeployed).

Three axis Reaction wheels are very essential for our design as there is a requirement for constant repositioning of nano satellite in order to get the maximum benefit from six open faces. Operating a single axis reaction wheel can take upto 28 watts of power, whereas a typical 1u solar panel can provide two watts of power. Continuous operation of reaction wheel will drain the battery quickly. In addition, it will put increased load on battery, decreasing its longevity. Hence we need to increase the number of solar panels so that it could harness enough power for the equipments to operate properly.

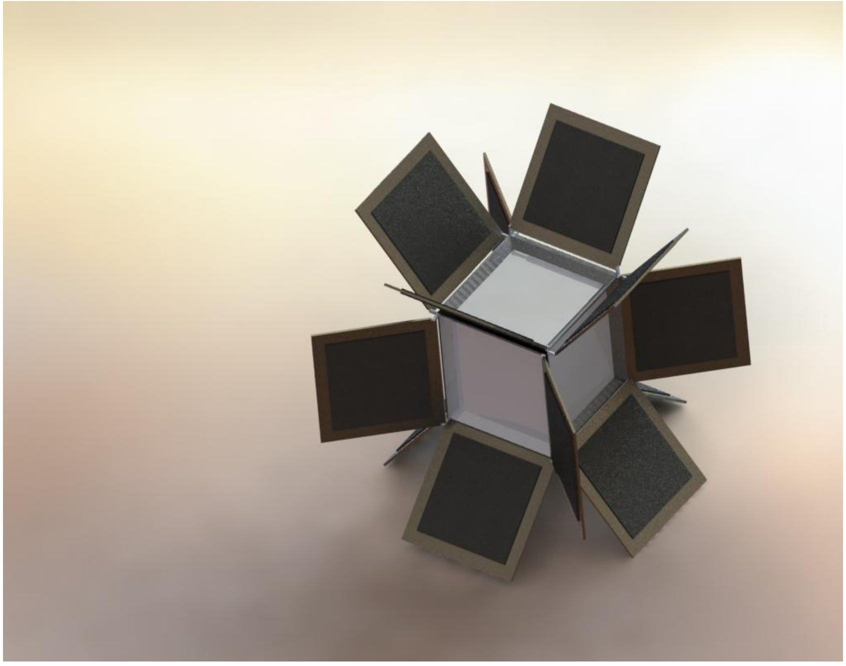

Figure 8. Trimetric view of proposed model (solar panels deployed).

4. Control Mechanism

In low-pressure plasma discharges (<1 Torr), Langmuir probes are commonly used for diagnostics purposes. Under the assumption of local thermodynamic equilibrium and known temperature, Langmuir probes may be used to measure the ion density of an ionized gas, such as a flame at high pressure (>100 Torr) [2]. It is not possible to determine plasma parameters using the Langmuir probe but the plasma current may be determined using a double Langmuir probe along with linear library least squares fitting. The current collected by the probe obviously depends on the three factors: density of the charge carriers in gas, the distribution of their velocity, its shape size [3-5]. In our proposed system we will use this type of Double Langmuir Probe (DLP) sensor to determine the electron density and to diagnosis of plasma. Although the measurements will not be precise, it should provide us with enough information to get students acquainted with space physics.

The main benefits of a GPS subsystem for a small satellite are global cover age and high accuracy at a low cost along with the real-time on board availability of navigation data [6]. The power consumption of GPS receivers vary depending on their type but are usually in the range from 100mW to a few watts [7]. Usually single-frequency receivers are chosen for general navigation applications while dual-frequency receivers are chosen for GPS- related scientific purposes. GPS can also be used for coarse attitude determination [8]. If the direction of the GPS satellite signals can be found, the orientation of the antennas can be found by comparing with the known GPS satellite positions.

Sun sensor is a kind of optical attitude sensor, which is used to get the orientation information of a spacecraft relative to the sun by determining the position of sun vector in the satellite coordinate system through sensing the position of sun vector [9]. When the satellite is in a certain position, the vector of the sun in the satellite orbit coordinate system is S_o, and the output vector of the sun by the sun sensor is S_b, therefore

$$S_b = T_o^b S_o + v$$

Where, v is the Measurement error of a sun sensor and T_o^b

As all of the six faces can have sensors, alignment of the sensors in free space is vital. Thruster will not be able to provide to enough thrust for elongated period of time. Therefore we have to rely on reaction wheel [10]. Reaction wheel allows us to align our cubesat according to our requirement and sensor data through angular momentum. Due to constant requirement for alignment, reaction wheels will consume more power. This difficulty is overcome by the deployable satellites in our model, which should generate enough electricity without needing MPPT. Three reaction wheels should be mounted without distorting load balance of the entire cubesat [11].

5. Communication & Ground System

Due to the unique structure of our nano satellite, it is required to redesign communication module that will send data back to our ground station. The main objective of the satellite is to get the scientific data and to transmit that data back to Earth, so the main challenge is the transmission the data to and from the satellite. For small size satellite it is better to use an array of frequency bands to communicate. Our purpose is to maximize the data transfer rate and minimize the hardware complication. That's why we have to increase carrier signal frequency and increase the data transfer speed. VHF/UHF transmitters are a consistent, low cost solution for data transfer. These systems are naturally used in LEO with Omni-directional antennas, and therefore do not need a high level of pointing accuracy. Transceivers/transmitters in this category can cost from hundreds to a few thousand dollars.

Antenna of onboard transmitter will be directly embedded into the deployable solar panel since solar panels will deploy in all direction. We have the freedom to place antenna on any plane best suited for the given circumstances.

For our ground station, COTS cubeSat products can be readily used. The design of the antenna is being directly related to the transceiver on the nano satellite.

6. Scope of This Research

This type of research work needs a lot of money due to the high material cost and extreme complexity. Moreover, the security of the country is involving with this issue therefore the approval and funding of government is indispensable for this project. The first target group for the proposed research will be the international organizations, in particular United Nations Specialized Agencies based in Geneva (HCR, ILO, ITU, UNOG, WHO, WMO, WTO, etc.)These organizations offer a truly international and multicultural environment.

The second circle of organizations would be the ITU Sector Members, e.g. the private sector company's members of the International Telecommunication Union, and which represent the broader ICT industry. Most of these companies are multinational entities and make a wide usage of ICTs for their own business. Both circles therefore offer a proper environment, corresponding to the framework of the proposed research.

7. Discussion

A project examined trends in the use of satellite-based technologies for needs in developing countries [12]. Their results enable the better understanding of the technology and management options that are being pursued in satellite projects. The content of that outcomes are provided for both developing country policy makers and potential development partners. The satellite applications considered in that research are as remote sensing, to provide imagery and environmental data, communications (including phone, radio, television, and internet) and navigation, which facilitates services such as air traffic management and surveying. Each of these applications can improve the lives of millions of people.

Nano satellite, which is small in volume and weight less than a kilogram is a complex system. The equipment needed for this satellite is not available in Bangladesh and we have to design this satellite by purchasing equipment's from abroad or we have to design satellite compatible sensors, solar panel, power cells, control systems and mechanical structure and make it from expert countries. We have no highly equipped lab for testing all the equipment's of satellite. We have to test all the equipment, sensors, mechanical structure, solar, panel and lastly the whole satellite. As this is the first time we are starting our research to build our own satellite, so obviously we need a lot of help. LaSEINE lab of KIT, Japan is highly equipped with entire testing facilities for the satellite related equipment's including the whole small size nano-satellite. Hopefully with the help of KIT, testing problem will be solved. As nano-satellite is very small in size and in volume so it is really tough to assemble lots of equipment in so tiny place. To find a way of this problem we need also Robotics Experts.

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