# Educative Platform based on the PocketQube60 Specification

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**ABSTRACT**

We present the results of workshops aimed to high school students in the State of Zacatecas, Mexico using an educative platform based on the PocketQube60 (PQ60) electrical specification. The purpose of the workshops was to motivate new generations of students to enroll in STEM related careers. In order to achieve the traced goal, a set of five PQ60 platforms and a receiving node were designed and assembled at the Autonomous University of Zacatecas by undergraduate students. The design activities included schematic draws for each of the subsystems encompassed in the platform (EPS, OBC, COMMS and the payload), PCB layout, selection of electrical components, soldering, testing and programming. The workshops were offered to public and private institutions, instructing a total of 185 attendees on the use of the PQ60 platform.

## INTRODUCTION

Nowadays, within the worldwide integrated economy, it is recognized the value that science-based innovation plays in modern societies as a source of prosperity and economic growth. The skills and knowledge of trained specialists in science, technology, engineering and mathematics (STEM) are highly valued in developed countries since they are the principal actors in the knowledge economy. Governments have adopted different actions in order to promote participation in STEM related disciplines and ensure a highly skilled labor workforce that will allow them to maintain their competitiveness in technology and innovation [1][2]. In developing countries, STEM education has also been a concern for policy makers, since it is recognized that possessing human resources trained in science and technology is a factor of economic growth.

In Mexico, different programs have been implemented to promote STEM education, some of them supported with federal and regional funds. The state of Zacatecas, which is located in the center north part of Mexico, has launched ambitious endeavors to encourage students from low-income families to pursue science and technology disciplines. The state and federal councils for science and technology support these social programs and their main objective is to promote science and technology among the population located in rural areas.

In this paper, we present the design and development of an educative platform based on the PocketQube 60 (PQ60) electrical specification [3]. The assembled platform was used to provide a series of workshops in the metropolitan area of Zacatecas, to promote the benefits of space technology as well as encourage the study of STEM related careers among the population. The workshops were intended primarily to high school students in public institutions.

The project comprised two main objectives. The first one was leading a group of undergraduate students in designing a system containing the modules that constitute a small satellite. The restrictions imposed were that the modules should adhere to the PQ60 electrical specification and be elaborated with open-source tools. Furthermore, all the subsystems should be developed at home, avoiding the acquisition of "shields" from third-party vendors. The reason for this was to motivate the members of the team to augment their skills in the design of electrical circuits of moderate complexity. All the participants were required to take part in all the activities involved within the project. Additionally, equality of gender was also promoted among the team members.

The second objective of the project was to provide a series of workshops, with no cost, to high school students in the state of Zacatecas. Their purpose was to motivate STEM education in the next generations of students that will enroll in high-level institutions. A total of 8 workshops were given in the metropolitan area of Zacatecas, instructing a total of 185 attendees in the usage of the platform. The project received considerable attention from the society due to the achievements obtained. The results were publicly shared through social networks, radio, local television and international conferences.

The paper is organized as follows. The motivation of the project is presented in the Introduction. The subsystems that constitute the platform developed are presented in the Educative Platform section. In the Workshops section, we report some statistics related with the training sessions given in the visited institutions. Finally, the article finalizes with the conclusions were the goals achieved are summarized and future work is identified.

## EDUCATIVE PLATFORM

In this section, the educative platform used in the workshops is detailed. The system adheres to the PQ60 [3] electrical specification and comprises most of the modules that are typically included in a small satellite.

### *PocketQube*

A PQ is a satellite of reduced dimensions and mass. It has a cubic geometry of 5cm per side and a mass less than 250g. Prof. R. J. Twiggs, from Morehead University, introduced PQs with the purpose of reducing their design time and launch costs [4]. Due to their dimensions, 1/8th of the volume of a CubeSat, the PQ architecture simplifies the design in terms of time and complexity

### *Project Goals*

For the PQ60 educative platform designed at the University of Zacatecas, the following objectives were stated at the commencement of the project:

1. The system should integrate most of the modules that constitute a small satellite. This is, an Electric Power Subsystem (EPS), an On-board Computer (OBC), Telemetry and Data Handling (COMMS) and a Payload.

2. The subsystems constituting the educative platform should adhere to the PQ60 electrical specification [3].

3. None of the subsystems integrating the platform should be acquired from a third party vendor. Hands on activities should be considered in order to acquire the know-how at the University of Zacatecas.

4. The electrical circuits (schematics and PCB layouts) and mechanical designs should be done using open-source software.

5. The development and assembly of the platform and a receiving terminal should be done in a time lapse of 5 months with a budget constraint of 5000USD.

6. The electronic circuits used in the PQ60 platform, should operate friendly with its electromagnetic environment. This is, the educative platform should not be a source of electromagnetic noise for other devices operating in the same frequency bands.

7. Equality of gender should be promoted. All of the undergraduate students involved in the project should participate equally in all the related activities.

8. The results of the project should be documented and communicated to the society of Zacatecas (since it is supported through public funds).

### *PQ60 Subsystems*

The subsystems that constitute the educative platform are addressed in this section. They include an On-board computer (OBC), an Electric Power Subsystem (EPS), a communications module (COMMS), payload (sensors), board to hold the battery used to energize the system and a mechanical structure.

The activities encompassed in the development of the aforementioned subsystems included literature research, definition of a set of requirements for the operation of each module, draw of schematics, PCB layout, selection of components, soldering, testing and programming.

### *Battery Holder*

The board termed as battery holder provides support to a 3.3V Lithium battery used to energize the complete system. It contains a 60-pin connector to interface with the EPS board, which is stacked to the battery holder board through a set of four brass spacers. In Figure 1, it is depicted a computer generated model of the battery holder board. The schematics and PCB layout was done using KiCAD [5].

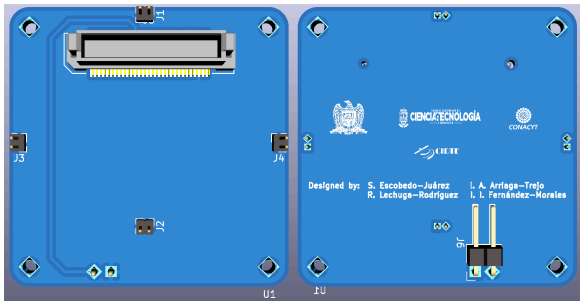

**Figure 1: Battery holder board**

### *Electric Power Subsystem (EPS)*

The EPS module is responsible for regulating the voltage provided by the Lithium battery, distributing it in two voltage lines. The first line maintains the 3.3V delivered by the battery and the second one goes up to a reference of 5.7V though a boost circuit. In Figure 2, a computer model of the EPS subsystem is shown.

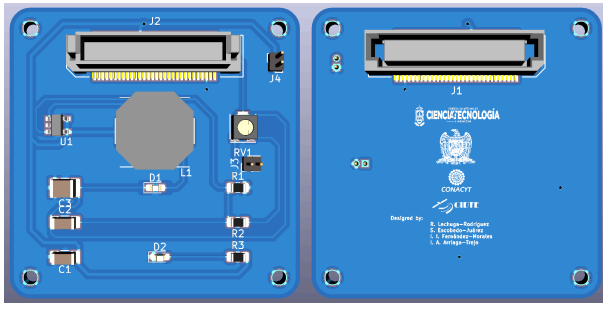

**Figure 2: EPS subsystem**

### *On-board computer (OBC)*

The On-Board computer (OBC) contains the discrete components used to handle all the functionalities of the PQ60 platform. An ATmega328P [6] microcontroller is employed as a main processing unit, which can be programed via in-circuit serial programming (ICSP) or through a USB port of a personal computer. The OBC board also integrates protection against short-circuit and over-voltage through an auto-reset circuit breaker (LTC1153) [7]. Regarding the supply lines, the OBC provides a 3.3V (LP2985-3.3) and a 5V (LP2985-3.5) [8] regulated source lines to energize the discrete components in it. Additionally, a micro SD slot for storage purposes is also incorporated in the OBC. The electrical interface of the OBC board with the EPS subsystem and the sensors board is done through the 60 pin connectors FX8C-60P-SV1(91) and FX8-60S-SV(21), respectively.

In order to facilitate the identification of short-circuits or possible flaws in the design, a series of test points and ports were included in the OBC board. This encompassed terminals to monitor voltage sources as well as lines for serial communication with the main microcontroller. In Figure 3, it is shown a digital model of the developed board.

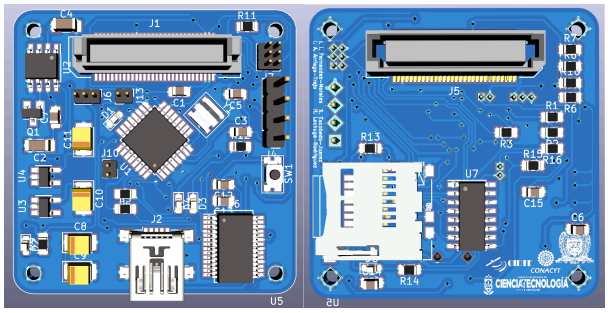

**Figure 3: On-Board Compute**

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### *Payload (sensors)*

The payload contains a set of sensors that enables the measurements of physical variables of interest such as temperature, atmospheric pressure, and magnetic field intensity among others. Like the OBC, the payload board contains two regulated lines of 3.3V and 5V. The sensors that are integrated in the board are listed below,

1. Altimeter, thermometer (BMP280) [9].

2. Three axis digital output gyroscope (STM - L3GD20H) [10].

3. Three axis digital output accelerometer (STM – LSM303C) [11].

4. Three axis digital output magnetometer (STM – LSM303C) [11].

The transfer of data between the sensors and the microcontroller in the OBC is via the I2C serial transfer protocol. It is worth to comment, that a bidirectional level shifter is also included in the board to convert 3.3V signals used by the sensors to 5V signals managed by the microcontroller. In Figure 4, it is depicted a digital model of the sensors board.

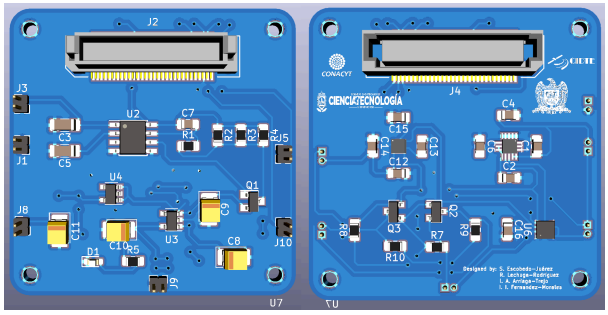

**Figure 4: Sensors board**

### *Communications (COMMS)*

The communications (COMMS) board is in charge of transmitting all the information collected by the OBC to a receiving terminal. The transceiver included in the COMMS board is the NRF24L01 [12], which operates in the 2.4GHz. The reason for having selected this radio, instead of one operating in a UHF/VHF band, is to avoid being a source of interference to other users. Furthermore, with the NRF24L01, a limited transmission range of 50m is achieved, which can be considered to be acceptable for the goals aimed with the project. The registers of the NRF24L01 transceiver are configured by the microcontroller in the OBC, through SPI protocol. The board includes a regulated source line of 3.3V to energize all the components included in it. A computer model of the COMMS subsystem is depicted in Figure 5.

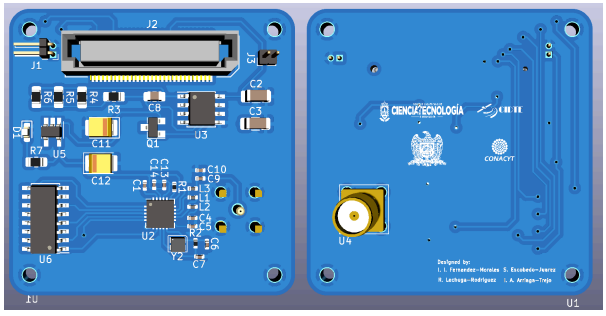

**Figure 5: Communications (COMMS) subsystem**

### *Receiving terminal*

A receiving terminal (portable ground station) was also designed to collect the data transmitted by the educative platform. It contains an NRF24L01 radio to demodulate the information sensed through the antenna, which is then processed by microcontroller and transmitted serially to a personal computer via a USB port. The receiving terminal incorporates most of the electronic design of the OBC board and the COMMS board. For the visualization of the collected data, any available tool for monitoring the serial port can be employed. Additionally, it is not required to perform additional procedures in the personal computer to recognize the connected device, since it is recognized automatically by most of the common operative systems in use. The arrangement of the components in the receiving node is shown in Figure 6.

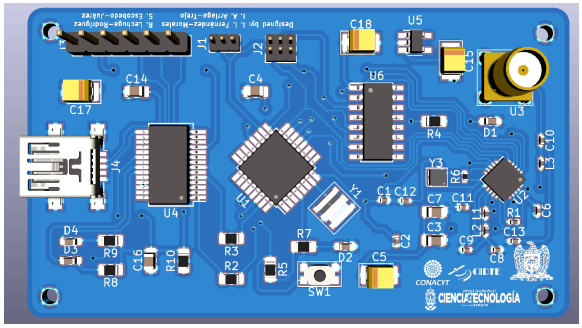

**Figure 6: Receiving node**

### *Educative Platform*

The platform employed in the workshops is depicted in the Figure 7, where all the developed subsystems are stacked using brass spacers.

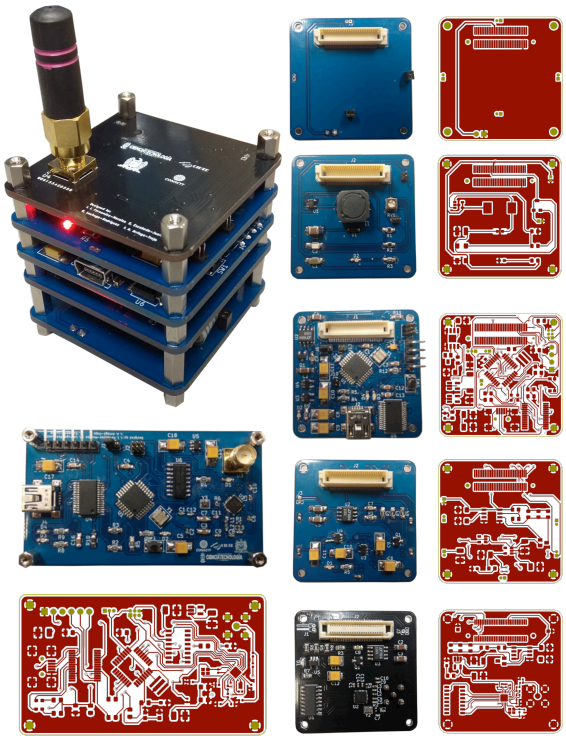

**Figure 7: PQ60 educative platform**

The modules of the PQ 60 platform are arranged in the following order (bottom to top): battery holder, EPS, OBC, Payload and COMMS.

***Structure***

The mechanical structure used to enclose all the subsystems was not yet designed at the time the workshops were provided. As the project continued new undergraduate students joined the team and proposed a design that will be constructed with a 3D printer. A computer model of the proposed mechanical structure that will be fabricated is depicted in Figure 8.

**Figure 8: Prototype of the mechanical structure**

## WORKSHOPS

The system described in the previous section was employed to provide a series of workshops in the metropolitan area of the city of Zacatecas. The workshops were advertised on social networks, emphasizing that they were oriented primarily to high school institutions. The course had no cost at all, and the only requirement imposed to the interested schools was to provide a place were the attendees could receive an introductory course on small satellite technology and assemble the system by their own hands.

The workshops were given in five different institutions,

- *Unidad Académica Preparatoria Programa II* located in Av. Preparatoria s/n, Hidráuilica C. P. 98068, Zacatecas, Zacatecas, Mexico.
- *Colegio de Bachilleres* located in Av. Pedro Coronel 5, Los Genarios, C. P. 98619, Guadalupe, Zacatecas, Mexico.
- *Preparatoria Francisco García Salinas*, located in Mariano Jiménez 7, Alamos, C. P. 99390, Jerez de García Salinas, Zacatecas, Mexico.
- *Centro de Estudios Tecnológicos industrial y de servicios 114* (*CETis 114*) located in Paseo Alameda, Jardines de Ramón López Velarde, C. P. 99390, Jerez de García Salinas, Zacatecas, Mexico.
- *Unidad Académica Preparatoria Programa IV* located in Carlos Lazo, Javier Barros Sierra, C. P. 98090 Zacatecas, Zacatecas, Mexico.

The pedagogical activity was divided in two sessions. During the first part, an introductory course to small satellite technology was provided. In here, the topics covered are the main characteristics of the subsystems that typically constitute a small satellite. Additionally, the platform that is going to be assembled by the attendees is also presented. The second part is a practical session, were the students assemble the PQ60 educative platform, following the indications provided by the instructors. For this purpose, the attendees were organized in groups of 4 to 5 members in order to motivate team collaboration.

***Workshops results***

The main results obtained from the workshops are listed below,

1. Eight workshops were given, with no cost, in the referred institutions.

2. A total of 185 students participated in activities encompassing the workshops.

3. From the 185 attendees, 134 were boys and 51 girls.

4. The workshops were advertised on local TV network and the local University TV network.

In Figure 9 it is shown some of the activities carried out during the workshops.

**Figure 9: Workshops using the PQ60 educative platform**

## CONCLUSIONS

We have presented a platform based on the PQ 60 electrical specification, which was used to motivate the study of STEM related disciplines in the state of Zacatecas. The project involved the direction of undergraduate students (which designed, developed, programmed and assembled the system) as well as high school students (attendees to the workshops) in the metropolitan area of the city of Zacatecas. The project as a whole, had a good opinion from the society of the state of Zacatecas, due to the results obtained, being also well received in high school institutions. Further work remains to be done, as to incorporate a mechanical structure and solar panels. Additionally, some of the modules require modifications, such as the COMMS subsystem. In particular, considering use an amplifier stage to increase the transmission range.

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