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Design Proposal Open Access

Proposal for a standardized backplane interface board to support the development of future Algerian CubeSats

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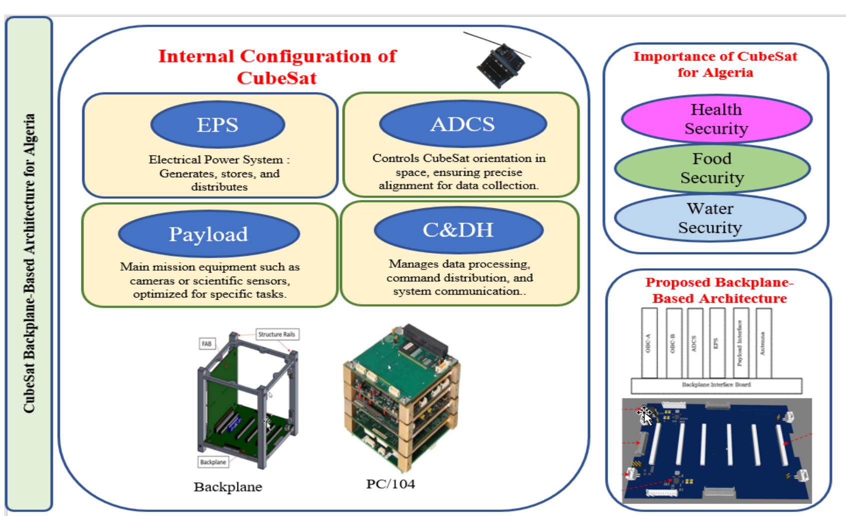
ABSTRACT

The CubeSat standard provides access to space industries without the need to manufacture complex satellites requiring specific and costly resources. This type of satellite has proven its ability to accomplish several missions, namely, the demonstration of technology, scientific research, and even commercial missions. While various internal architectures exist for CubeSats, including PC104 and backplane configurations, the backplane approach offers superior modularity and simplicity. This makes it particularly suitable for collaborative development between organizations, especially universities. This paper proposes a standardized backplane architecture for future Algerian CubeSats, presenting both an internal configuration and a preliminary design for a backplane interface board. The proposed design enhances modularity, streamlines integration procedures, and provides a scalable foundation for Algeria's emerging CubeSat program. By establishing this standard, we aim to facilitate knowledge sharing and collaborative development within Algeria's space technology sector.

Keywords: CubeSat; PC104; Backplane; COTS components.

Graphical abstract



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1. Introduction

The space industry worldwide pursues the goal of reducing resources in terms of power, size, and cost without compromising the objectives of space missions. CubeSat aims to provide a standard for designing small satellites to reduce development costs and time [1, 2]. Figure 1 represents the different sizes of CubeSats as published in the specification document [3]. A CubeSat 1U is a 10 cm cube with a mass of up to 2 kg [3].

Unlike other types of satellites, which mainly rely on specific components (space-grade) designed specifically for the space environment, CubeSats are primarily designed to use COTS (Commercial Off-The-Shelf) components [4].

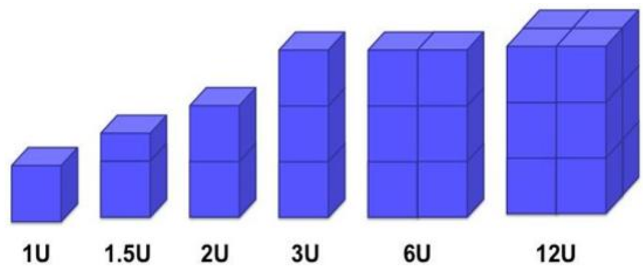

Fig 1. Different sizes of CubeSats.

The integration of COTS components in satellite systems presents both benefits and drawbacks. The major advantage of COTS is the availability of components; space-grade components are, in most cases, protected by laws, such as ITAR (International Traffic in Arms Regulations) and EAR (Export Administration Regulations) [5]. For this reason, the acquisition of these components could be impossible or difficult. Another advantage of COTS over space-grade is the cost. Unfortunately, COTS components are very vulnerable to radiation effects that are very aggressive in the space environment. This vulnerability affects the lifetime of the CubeSat, which is strongly linked to the TID (Total Ionizing Dose). Also, it affects the reliability of the different systems, which is linked to the SEU (Single Event Upset) [6].

This standard has been adopted by several space agencies (ESA, NASA, and others) to complete several projects. The CubeSat is used in several missions, which can be classified into three categories:

1. Scientific Research: CubeSats can carry small scientific instruments to conduct experiments or take measurements from space [7].
2. Technology Demonstration: CubeSats are used for the Technology Demonstration of miniaturized technologies and small payload-driven missions [8, 9].
3. Commercial Missions: The CubeSat standard is used in several commercial missions for earth observation or telecommunications [7].

The first Algerian 3U CubeSat is ALSAT-1N, which integrates three scientific and technological payloads: four thin-film solar cells, a compact optical payload, and a retractable telescopic mast equipped with a magnetometer and an ionizing radiation sensor [10]. For future applications, CubeSats can offer an attractive solution that should be considered for many Algerian needs. For example, they can strengthen information systems in different sectors such as forestry, agriculture, and urban areas.

The CubeSat comprises several electronic systems that must be interconnected to ensure proper operation. Various architectures are used to implement the different equipment within CubeSats [11]. The evolution of these architectures has been marked by continuous innovation in internal bus configurations. The traditional PC104 architecture, first introduced with the CubeSat standard in 1999, has been widely adopted by the major manufacturers of CubeSat equipment, such as Pumpkin and ISIS [12].

However, several studies have highlighted the limitations of the PC104 architecture. These limitations have led to the exploration of alternative approaches, primarily the backplane architecture [11, 13, 14]. As shown in Table 1, the backplane architecture offers several advantages that make it particularly well-suited for establishing a collaborative CubeSat development ecosystem in Algeria, facilitating collaboration among various academic and research institutions.

Table 1. Comparison of PC104 and Backplane Architectures.

Feature	PC104 Architecture	Backplane Architecture
Configuration	Vertically stacked modules connected through pass-through connectors	Centralized motherboard with perpendicular plug-in modules
Modularity	adding/removing modules requires disassembly.	modules can be added or removed easily.
Standardization	Widely adopted and standardized since 1999.	Growing adoption in academic and research institutions.
Team Collaboration	Limited collaborative development.	Facilitates collaborative development.
Space Efficiency	Optimized vertical space utilization	Requires additional space for backplane board

The backplane architecture has seen significant advancements in recent years, driven by the need for more modular, scalable, and standardized CubeSat designs. Key developments in this space include:

1. The standardized electrical interface for generic picosatellites, implemented in the UWE-3 mission [15].
2. The BIRDS project, a collaborative initiative among universities in Japan, which uses a modular backplane design to facilitate the joint development of CubeSat subsystems [11]. Several versions of backplane boards have been used in this project [16].
3. The backplane approach from the Norwegian University of Science and Technology (NTNU), proposed to facilitate collaboration between different teams [17].

Based on developments in backplane architecture, this work proposes an initial internal configuration using the backplane approach. The goal is to standardize the development and integration of CubeSat subsystems in Algeria. This approach will enable collaboration and foster a unified CubeSat ecosystem among Algeria's academic and research institutions. The proposed board design can be further modified and improved as the CubeSat system evolves and new requirements emerge during development.

This work is organized as follows: Section 2 presents the Strategic Importance of CubeSat for Algeria, highlighting how CubeSat technology can effectively address key challenges in the country, such as water security, health security, and food security, by complementing existing terrestrial systems and enhancing resource management. Section 3 presents internal configurations of CubeSats. Section 4 outlines the proposed architecture, focusing on the backplane-based design approach and methods for subsystem integration. Finally, Section 4 summarizes the key findings and contributions of the work and discusses potential future directions for research and development.

2. Strategic Importance of CubeSat for Algeria

Depending on the specific payload, CubeSats can serve a variety of purposes. They can be used for remote sensing to monitor the environment or act as communication relays to enhance connectivity. For this, CubeSats can offer versatile solutions for a range of applications, either individually or in constellations, providing cost-effective access to space while enhancing capabilities across key sectors.

This technology provides Algeria with a powerful tool to address three vital needs—water security, health security, and food security—referred to as the 'three S's,' as shown in Figure 2. CubeSats complement terrestrial infrastructures such as wireless sensor networks, drones, and other technologies. By integrating CubeSat data with these terrestrial systems, Algeria can gain comprehensive, real-time insights that optimize resource management, environmental monitoring, and agricultural oversight. Along the same lines, several CubeSat projects in the literature focus on similar missions [18-20].

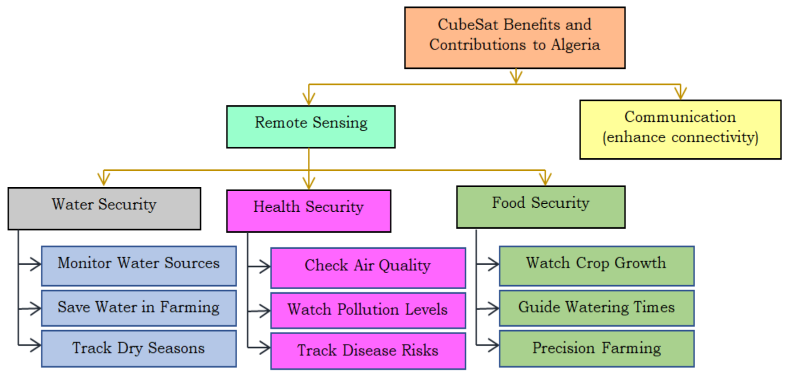

Fig 2. CubeSat Benefits and contributions for Algeria

3. Internal configuration of CubeSats

Figure 3 shows the typical block diagram of CubeSat subsystems, which includes the Power Supply Subsystem (EPS), the Control and Data Handling Subsystem (CDHS), the Attitude Determination and Control Subsystem (ADCS), and the payload [1].

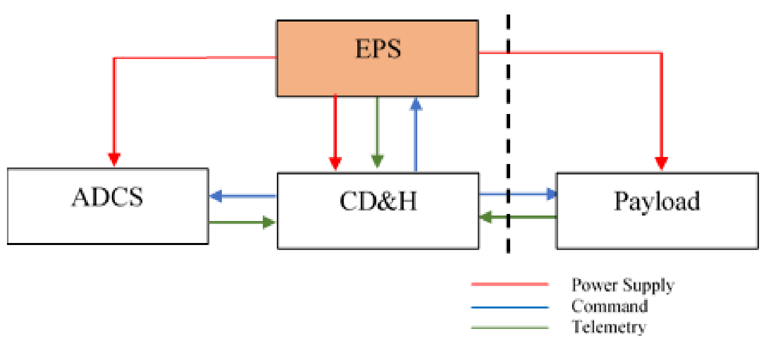

Fig 3. Typical block diagram of CubeSat subsystems [1].

EPS is responsible for generating, storing, and distributing electrical energy. ADCS provides satellite attitude control. The C&DH is considered as the satellite core. It performs several functions, including:

1. It receives, validates, decodes, and distributes commands to the various spacecraft subsystems.
2. Collect, process, and format data from the platform and Payload to transmit them to the ground station or use them by an onboard computer.

The payload refers to the party responsible for performing the mission for which the satellite has been designed. Making reliable CubeSat payloads is a key hurdle for Algeria's growing space program. These essential components - whether cameras, scientific instruments, or communication devices - must perform in the harsh conditions of space while fitting within strict size, power, and weight limits. By mastering this technology at home, Algeria can build its space expertise, reduce dependence on foreign technology, and create opportunities for its scientists and engineers.

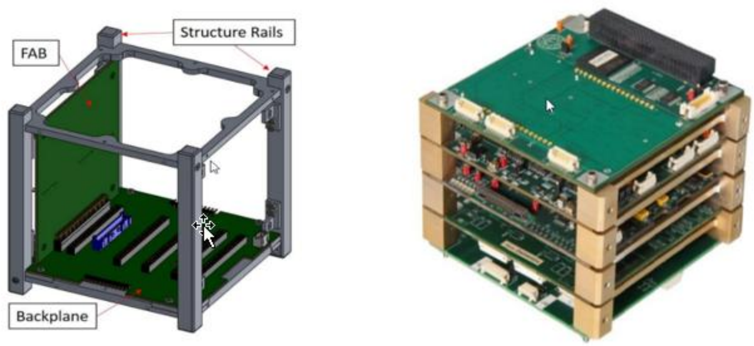

Fig 4. Backplane Approach [21] and PC104 Approach [22].

Each approach has advantages and disadvantages. The PC104 is widely used. Due to its great flexibility, major manufacturers of CubeSat equipment use it. For example, Figure 5 shows an OBC from the ISIS company based on the PC104 [12]. The disadvantage of the PC104 approach is the difficulty of disassembly.

A backplane approach has been proposed by the University of Würzburg in Germany [23]. The backplane is an electronic board that plays the interface role between the different modules using small connectors compared to the PC104 connectors (see Figure 6) [13, 24]. The backplane approach allows full harnesses to be placed on a PCB, which helps reduce the risk of harness-related manufacturing errors [11]. Moreover, the assembly and disassembly are easy in the backplane approach.

Fig 5. ISIS On Board Computer [12].

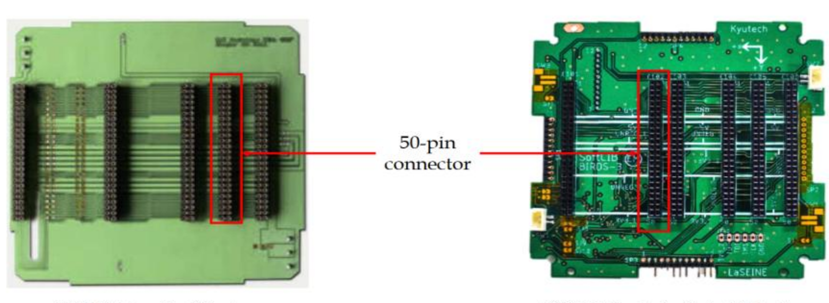

Fig 6. Examples of Backplane Interface Board [13].

The backplane-based approach can facilitate cooperation between different entities to develop CubeSat modules compared to the PC/104 approach [23]. Therefore, the Backplane approach is the most appropriate approach to developing a CubeSat ecosystem in Algeria.

The tasks that the Backplane board must perform are summarized as follows [13, 21, 24]:

1- Interface with the solar panels.
2- Distribute the power supply: The electrical energy generated by the EPS is distributed to the other modules via the Backplane.
3- Isolation in case of fault: Faulty modules must not propagate their fault to the rest of the system. The backplane should ensure the isolation of this module.
4- ensure communication between the different modules via several standard protocols, for example, I2C and UART.
5- Ensure the test during the assembly phase.

One of the characteristics of CubeSats is the preference for the use of COTS components whenever possible. This characteristic has both advantages and disadvantages. The use of these components reduces development costs and speeds up the manufacturing process, making CubeSats more accessible and rapidly deployable. On the other hand, these components, which are not always designed to withstand the extreme conditions of space, can increase the risk of failure in orbit, potentially limiting the lifetime and reliability of CubeSat missions.

4. Proposed Architecture

It is clear that standardization is vital to fostering collaboration and creating a strong ecosystem for all developments. Building on this understanding, and recognizing that every project begins with the first step, we propose the architecture of a 1U CubeSat in this section, which will serve as the foundation for future missions. The specific objectives of this standardized architecture include:

- Developing a flexible and scalable architecture.
- Ensuring modularity for easy subsystem integration.
- Maintaining cost-effectiveness and reliable performance.
- Standardizing electrical connections and communication protocols.

The modularity and use of a unified electrical interface for the different CubeSat missions are key factors in reducing costs and manufacturing times [11]. Our objective is to propose a common platform to create a collaborative framework between universities and research centers to develop CubeSats in Algeria. It is mainly based on the strategy adopted by the Norwegian University of Science and Technology (NTNU), which is used to develop the NUTS satellite [11].

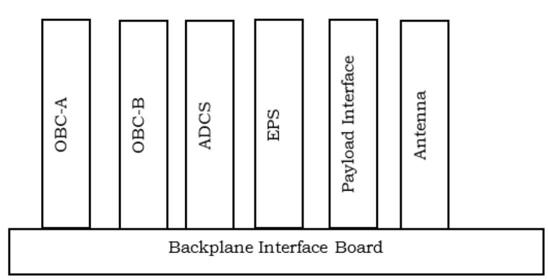

Fig 7. Proposed configuration

As depicted in Figure 7, the proposed CubeSat configuration comprises the following key components:

- OBC-A and OBC-B: These are cold redundant onboard computers that manage CubeSat's operations. The redundancy ensures that if one computer fails, the other can take over, enhancing the system's reliability.
- ADCS: This module is responsible for determining and controlling the satellite's orientation in space. It uses sensors and actuators to maintain the desired attitude for the CubeSat.

- EPS: This module manages the generation, storage, and distribution of electrical power throughout the CubeSat. It typically includes solar panels, batteries, and power management circuitry.
- Payload Interface: This module interfaces with the primary payload of the CubeSat, which could be scientific instruments, cameras, or other mission-specific equipment. It ensures the payload receives the necessary power and data connectivity.
- Antenna: This module is responsible for communication with ground stations. It transmits and receives data, commands, and telemetry.
- Backplane Interface Board: This is the central board that connects all the modules. The backplane approach allows for modular and standardized connections between the various subsystems of the CubeSat. Each module plugs into the backplane, facilitating easier assembly, integration, and maintenance.

This paper cannot include the detailed schematic due to its extensive length and multiple pages. However, Figure 8 presents a 3D visualization (version 0) of the proposed backplane design. This version can be modified and improved as needed.

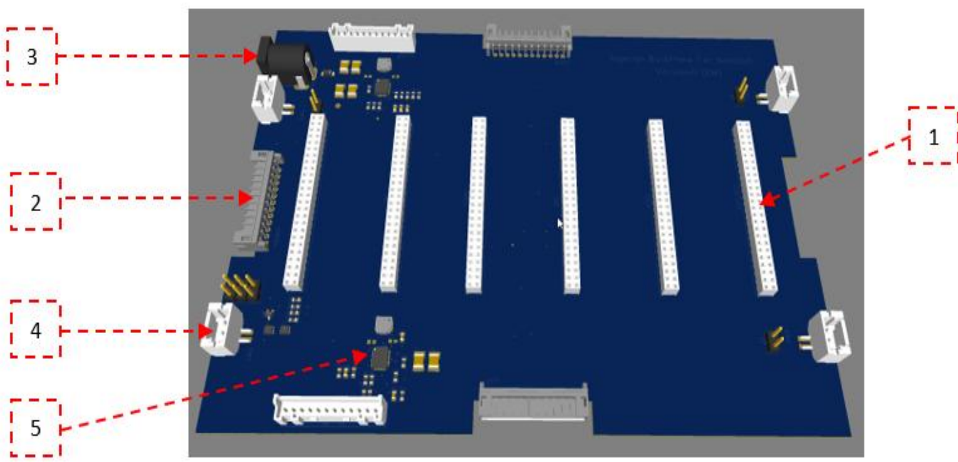

Fig 8. 3D visualization of the proposed backplane design.

Table 1. Main Components of Backplane Board.

Idx	Name	Qte	Description
1	A3C-50DA-DSA (71)	06	It is a 50-pin connector with a 2.54 mm pitch, 1A current rating, and high durability. It is used to interface with the different modules.
2	440055-12 connector	03	It is a 12-pin connector. They are used as interfaces with Solar panels.
3	External power connector	01	A Jack connector is used to power supply from an external source to test it.
4	Switch 55460-0272	04	It is a toggle switch used to control GND separation and deployment detection.
5	Power Module	02	It is based on LTC3119 circuit. This integrated circuit is a high-efficiency, step-up/step-down DC-DC converter with a wide input voltage range, suitable for applications requiring efficient power conversion and regulation.

Table 2 lists the primary components of this board. It also includes other integrated components, such as a current sensor and a temperature sensor, to monitor and manage system performance.

5. Conclusion

This paper presents a backplane-based design approach for building CubeSats and stresses the importance of creating a network between Algeria's research centers and universities. Our proposed design—version 0—is just a starting point and can be improved or adapted for different space missions. The goal is to make CubeSat development simpler and more affordable by using standard parts that fit well together.

Equally important to the design is encouraging collaboration among Algerian universities and research centers. By working together and sharing knowledge, these institutions can achieve more than they could individually, helping to strengthen Algeria's expertise in Aerospace technology.

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