

RELEASING THE CLOUD: A DEPLOYMENT SYSTEM DESIGN FOR THE QB50 CUBESAT MISSION

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ABSTRACT

For the QB50 project a constellation of tens of CubeSats will be launched and injected in 2014 into a 320 km orbit to perform in situ observations of the thermosphere as well as science and technology in-orbit-demonstration. Developing, deploying and operating such a system presents a whole range of challenges. One of the biggest challenges to be solved is how to safely launch and properly deploy the QB50 constellation of satellites. This paper will present the StackPack or ISIS' concept design of the deployment system designed for deploying the QB50 satellites.

Conceptually, the StackPack is a custom, reliable, non hazardous, low shock, ITAR-free, low-cost device capable of provide suitable accommodation for the various QB50 CubeSats (2 units and 3 units). It will be the first system of its kind and is specifically focused on accommodating clusters of nanosatellite systems.

This deployment system is envisioned to perform various main functionalities such as to provide optimal accommodation of the QB50 cluster of satellites on the Shtil launcher family, to provide adequate interface with the launch vehicle and to accomplish the appropriate deployment of the QB50 satellites in their correct orbit. In order to properly achieve these functionalities, the full range of requirements and constraints enforced by the mission, flight configuration, deployment sequence, launch vehicle and CubeSats are being taken into account. This system is intended to be optimized for various parameters including cumulative mass and volume as well as connectivity.

INTRODUCTION

A CubeSat or Cubesatellite is a pico-Satellite (mass between 0.1 and 1.0 [kg]) or nano-satellite (mass between 1 and 10 [kg]) that adheres to the QB50 CubeSat interface standard [1].

QB50 is the international network of 50 CubeSats for multi-point and in-situ measurements in the lower thermosphere and re-entry research.

The StackPack is the ISIS' Multi-Picosatellite Orbital Deployer and Launch Adapter concept developed within the scope of ISIS as to answer the specific QB50 project launch demand.

The StackPack is a custom integrated platform able to accommodate both, the QB50-atmospheric-research 2U CubeSats and the QB50-technology-demonstration 3U CubeSats.

MECHANICAL DESIGN PROCESS

The state of the art in terms of current deployer systems has been carefully studied to identify the needs and improvements to be introduced in the StackPack.

Since one of the main constrains and requirements of the QB50 project are related to available mass and volume within the launcher, these have been driven parameters in the design of the StackPack. One of the challenges is to reduce the ratio between structural mass of the canister and the actual mass of the CubeSat. Currently the value is the structural mass is at least 2kg. In this sense the aim is to reduce this structural mass of the StackPack until 1.25 kg, therefore this ratio will be 0,4 and 0,6 for 1U and 2U CubeSats respectively.

In order to produce an optimized system several configurations and CubeSat layouts have been studied. The selected one is the most compact and flexible one (see Figure 1).

GENERAL DESCRIPTION

The innovative concept of StackPack consists of a collection of dispenser modules that is able to accommodate and deploy the whole set of QB50 CubeSats. Figure 1 shows the StackPack concept.

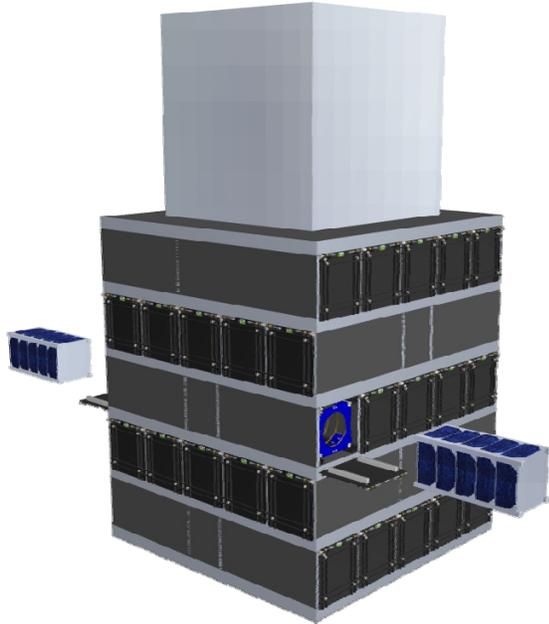


Figure 1: StackPack concept

The StackPack provides the interface between the QB50 CubeSats and the Launch Vehicle. It is a custom integrated platform that is optimized in terms of mass, volume and connectivity. Requirements and constraints related with CubeSats, Launch Vehicle, operations and environment have been taken into account in the StackPack design.

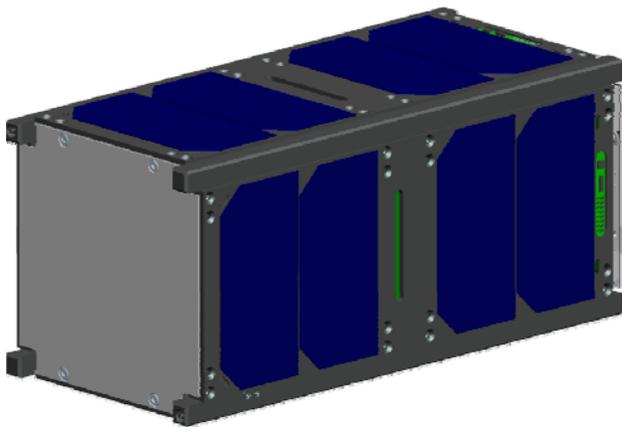


Figure 2: 2U CubeSat example

The QB50 project involves two different CubeSat types, the 3U CubeSats for technology demonstration and the 2U CubeSats for atmospheric research. Due to that, the StackPack is suitable to accommodate both 2U and 3U CubeSats. An example of a 2U CubeSat structure is shown in Figure 2.

MATERIALS

Since this is a critical element of the design, the materials selected to manufacture the different parts of the StackPack have outstanding mechanical properties but at the same time are light in order to optimize the mass of the system. The principal material of the StackPack is Al7075 aluminum alloy with a proper surface treatment (anodized and hard anodized for the sliding parts). In addition for specific loaded parts stainless steel is used. Engineering thermoplastics such as POM and PEEK have been also selected for certain parts of the StackPack.

MAIN ELEMENTS

The main elements of a single StackPack module are schematically shown in Figure 3.

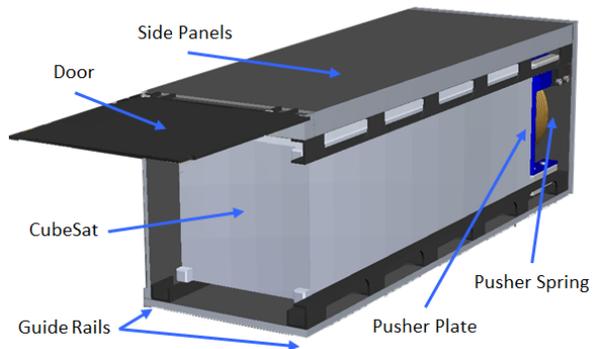


Figure 3: Overview of the major components a single StackPack module

Guide Rails

The Guide Rails transfer the launch loads from the Launch Vehicle to the CubeSats. Their final function is to guide the CubeSats during their deployment.

Side Panels

The Side Panels form an enclosure around the CubeSats to protect it from hazards coming from other CubeSats, payloads or the Launch Vehicle itself and vice versa.

Door

The Door retains the CubeSat during the launch. When the deployment signal is sent the door is opened allowing the CubeSat deployment.

Pusher Plate

The Pusher Plate is the element in charge of deploying the CubeSats out of the StackPack at the required velocity.

Pusher Spring

The Pusher Spring provides the mechanical energy required for the CubeSat deployment.

FUNCTIONALITY

The StackPack performs various functions related to the CubeSats. The StackPack protects the CubeSats from hazards coming from other CubeSats, payloads or the Launch Vehicle itself, constitutes the interface between the CubeSats and the Launch Vehicle, contains and retains the CubeSats before and during the launch, deploys the CubeSats in orbit and provides the deployment confirmation signal.

The StackPack launch adapter forms an enclosure around the CubeSat; this enclosure protects the CubeSat from other hardware present on the StackPack and vice versa. Due to this, the risk of damage in case of a malfunctioning CubeSat or the premature deployment of deployable appendices (such as antennas, solar panels, etc.) on the side of the CubeSat is minimized.

The deployment is performed by a Pusher Plate and Pusher Spring deployment system. This system has been successfully used on similar systems for the deployment of CubeSats out of their Launch Adapter. The proper confirmation signal of correct deployment of the CubeSat is provided by the StackPack.

OPERATION

Once the CubeSat has been assembly, integrated and tested, each QB50 CubeSat will be delivered to ISIS facilities. ISIS will firstly integrate all the CubeSats into the StackPack and test the integrated assembly. Finally ISIS will ship the integrated assembly to the Launch Vehicle Integrator.

The StackPack launch adapter will be mounted on the payload deck of the Launch Vehicle. Figure 4 shows schematically the deployment operation of the StackPack.

Phase 1: Initial configuration

Before launch, during launch and before deployment, the StackPack is closed and positioned on the Launch Vehicle. It retains the CubeSats until deployment.

Phase 2: Deployment configuration

Once the deployment signal is given according to the deployment sequence the StackPack door is opened, therefore the correspondent CubeSat starts being deployed by the spring loaded system.

Phase 3: Final configuration

After the deployment of the CubeSats the StackPack itself remains attached to the Launch Vehicle.

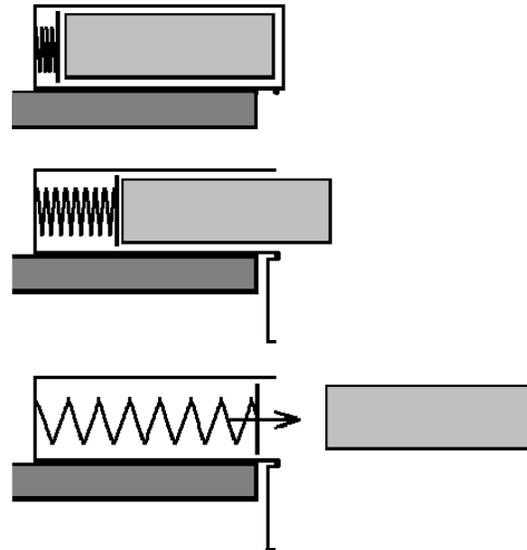


Figure 4: Schematic operation of the StackPack

Each CubeSat is inserted into the StackPack sliding downwards along the Guide Rails and resting against the spring loaded Pusher Plate. Once the door is closed the CubeSat is retained inside the StackPack.

During launch the CubeSat is enclosed by the StackPack which provides front and back support through the CubeSat feet and lateral support through the CubeSat Rails.

Once in orbit, the release mechanism is activated following the deployment sequence. As soon as the door is opened, the CubeSat is pushed outwards by the spring loaded Pusher Plate and therefore deployed.

PERFORMANCES

The StackPack has a robust, modular design in order to allow for placement of the QB50 set of CubeSats in a cluster way. The StackPack is developed with conservative safety margins against the Launch Vehicle and operational environment loads.

Deployment velocity

The deployment velocity of the CubeSats can be fine-tuned by means of the deployment spring. The nominal range of variation for this parameter is from 1 to 2 [m/s].

Tip off rate

In order to avoid as much as possible the initial uncontrolled attitude of the CubeSat after the deployment, the tip off rate of the CubeSat deployed by the StackPack based on experience is around 1.75 [rad/s].

CubeSat Mass

The StackPack is designed to accommodate both 2U and 3U CubeSat. The maximum mass allowed for the QB50 2U and 3U CubeSats is 2.0 kg and 3 kg respectively. Even though these are mission constrains, the StackPack is mechanically designed to accommodate twice the maximum of this masses, it is 4.0 kg for the 2U CubeSats and 6.0 kg for the 3U.

CubeSat Dimension

The StackPack can accommodate any CubeSat that adheres to the QB50 CubeSat interface standard [1]. One of the main advantages of the StackPack is that in addition, it provides extra volume to accommodate deployables, appendices, booms, antennas and solar panels. The StackPack offers lateral clearance between the CubeSat lateral sides and the StackPack Side Panels. Moreover the StackPack provides the capability of accommodate CubeSats with both, front and back extended volumes. In this sense the StackPack can increase the available volume of a 3U CubeSat in 1 extra unit such a way that the real volume of the CubeSat is 4 units.

Figure 5 shows the StackPack extended volumes provided for the QB50 CubeSats: lateral (-X, +X, -Y and +Y), front (+Z) and back extension (-Z).

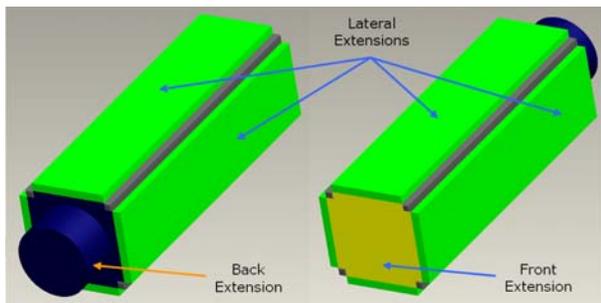


Figure 5: CubeSats lateral, front and back extended volumes.

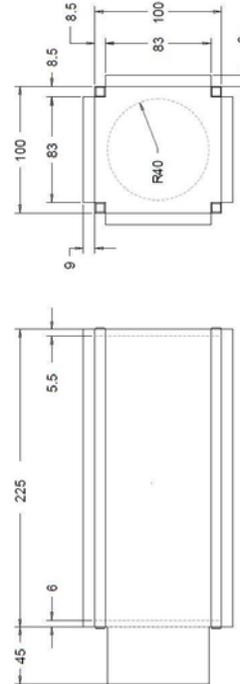


Figure 6: 2U CubeSat extended volumes dimensions.

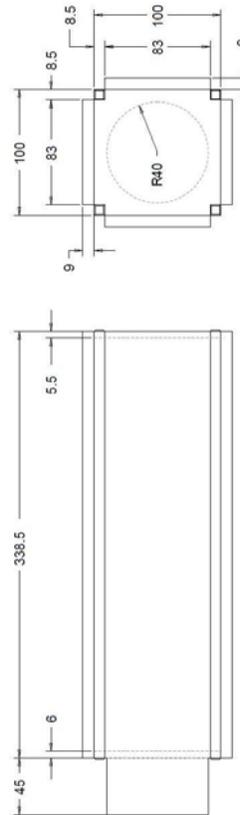


Figure 7: 3U CubeSat extended volumes dimensions.

Figure 6 and Figure 7 show the maximum dimensions in millimeters allowed by the StackPack for the QB50 2U and 3U CubeSat extended volumes respectively.

Electrical interface

The StackPack will provide electrical interface to the CubeSat before launch while it is integrated in the dispenser. The concept is to plug a connector to perform the correspondent power supply and battery charging activities of the CubeSat through a hatch allocated in the CubeSat module door.

Data interface

The StackPack will provide remote data interface to the CubeSat before launch while it is integrated in the dispenser. The concept is to plug a connector to perform remote data communication and check-out activities of the CubeSat. The data connection will be implemented through the front door hatch. By combining this capability with the remote access option, the data connection of the different teams with their correspondent CubeSat is optimized and simplified.

TESTING

Qualification test will be performed to the whole StackPack structure with dummy masses whilst acceptance test will be performed with the CubeSats integrated in the StackPack. The tests that the StackPack has to overcome are Sine Vibration, Random Vibration, Shock Test, Thermal Cycling, Thermal Vacuum, EMC and ESD as well as Bake-out.

Each of the three mutually perpendicular directions X, Y, Z of the StackPack is to be subjected to the most severe level imposed by the launch vehicle characteristics in order to make the StackPack safe and flexible in terms of launchability.

DEPLOYMENT

Deployment sequence parameters have a great influence in the dynamic and life of the QB50 CubeSats. Figure 8, 9 and 10 show respectively the variation of the eccentricity, semi-major axis and inclination of the CubeSat orbits due to the variation in the deployment direction.

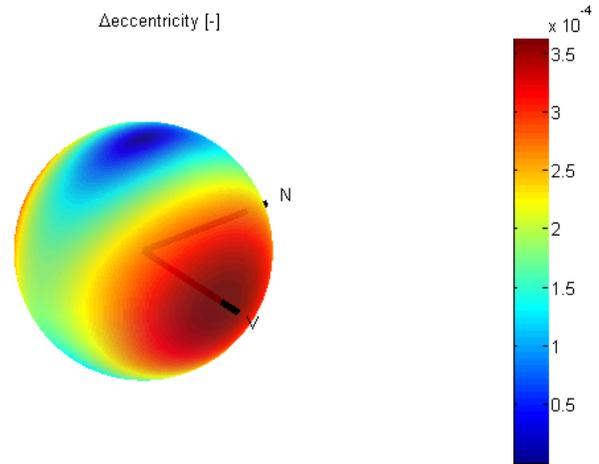


Figure 8: Influence of the deployment direction on the orbit eccentricity

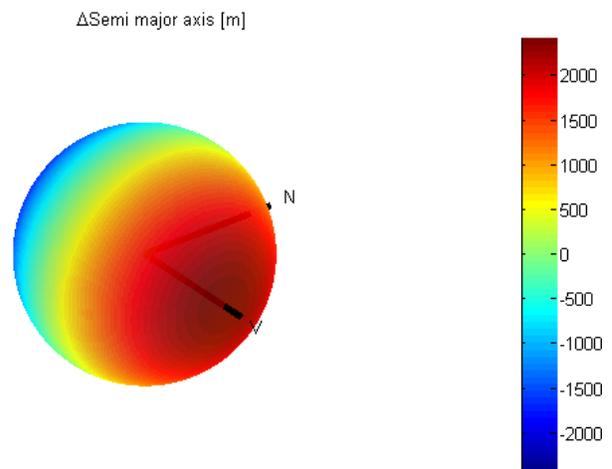


Figure 9: Influence of the deployment direction on the orbit semi-major axis

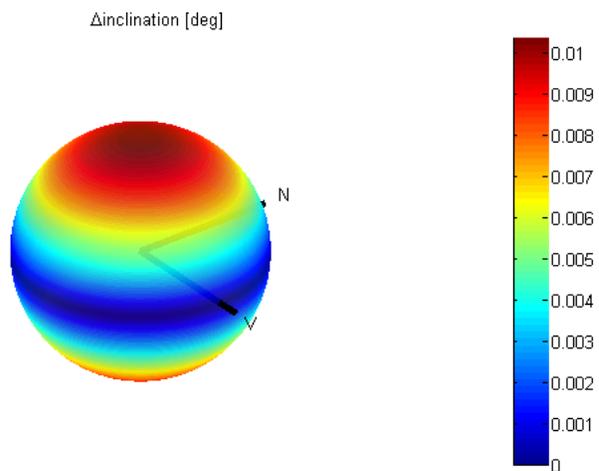


Figure 10: Influence of the deployment direction on the orbit inclination

CONCLUSIONS

The StackPack is a robust, flexible and optimized concept. In the upcoming months these will be fine-tuned and optimized since there is still time and room for improvements in terms of the structure and the sequence and parameters of deployment according with new inputs and changes in the final requirements of the mission.

REFERENCES

1. R. Munakata (2009). CubeSat Design Specification rev 12, California Polytechnic State University, USA.
2. Call for CubeSat Proposals for QB50 (February 2012). Von Karman Institute for Fluid Dynamics (VKI), Brussels, Belgium.
3. Thomas P. Sarafin (May, 1995). Spacecraft Structures and Mechanisms: from concept to Launch. SpaceTechnology Series, SpaceTechnology Library.
4. Wiley J. Larson, James R. Wertz (October 1999). Space Mission Analysis and Design. SpaceTechnology Series. SpaceTechnology Library.