DEFIANT: A SMALL MASS-PRODUCIBLE MICROSATELLITE PLATFORM FOR DEMANDING APPLICATIONS UNDER EXTREME COST AND SIZE CONSTRAINTS

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Abstract

The DEFIANT platform is a scalable satellite bus currently slated to accommodate a wide range of demanding missions. The platform possesses a core structure and set of avionics which form the basis of all configurations for the bus and is then capable of customization based upon the specific mission requirements. The prime form factor is a 300 x 300 x 400 mm (27U) quadrangular platform massing a total of 20-30 kg including a 5-10 kg payload allocation. Contained within the core avionics are a full suite of modular power electronics, a set of cross-strapped computers for housekeeping, attitude control, and payload management, a mission adaptable set of radios (UHF, VHF, S-Band, X-Band, and more), a centrally mounted propulsion system, and a full set of attitude control sensors and actuators.

Conceptualized to serve for several new missions which require multiple satellites to be designed, constructed, and launched as a fleet, DEFIANT prioritizes modularity and accessibility. This places additional difficulties and complications to a normally very delicate task. The DEFIANT bus possesses salient features making it ideal for parallel multi-satellite assembly and management, as well as a compartmentalized approach allowing for inter-mission compatibility and late stage component replacement. In addition, the material selection is kept to mainline alloys allowing for rapid procurement and manufacturing.

Finally, the bus is designed for adaptability for the future by integrating next generation expandability into the system such as deployable solar arrays, a wide range of antenna mountings, and room to grow the power and processing capabilities. In order to accommodate the largest breadth of missions, the separation system can be mounted on different faces allowing for varied launch configurations.

This paper will examine the capabilities of DEFIANT and potential applications.

Key words: Spacecraft, Bus Design, Multi-Satellite Mission.

1. INTRODUCTION

The current trend in small satellite missions is an increase in constellations [1, 2, 3, 4, 5] which typically require concurrent spacecraft launches. They can have for goals geo-location, synthetic distributed systems, or Earth observations. Small satellites provide an attractive platform for these missions as they provide rapid, cost-effective, and reliable access to space.

The goal of this platform is to serve as a customizable spacecraft capable of meeting a wide range of mission requirements while focusing on the core benefits of concurrent, rapid development and constellation compatibility. This is achieved through having a modular core which leverages SFL's 20 years of experience and a set of peripherals which can greatly expand on the performance.

The missions combine the need for efficient production of multiple concurrent satellites as well as adaptability to different mission requirements. This led to a compartmentalized design which allows for configurable payloads and peripherals while keeping a core set of avionics intact. Furthermore, the core set of avionics is mounted onto two plates providing a simple adaptable design which can quickly accommodate incremental changes such as increased battery sizes, additional computers, or different set of radios. The plate mounting also provides an easy two-dimensional wire routing which greatly simplifies the task. Each integrated sub-module is single-point connected to allow for late stage hot-swap with minimal disassembly. The payload bay is located on an expandable side of the satellite which creates both easy access to external panels for surface mounted payloads as well as allowing for a self-contained EMI compatible compartment.

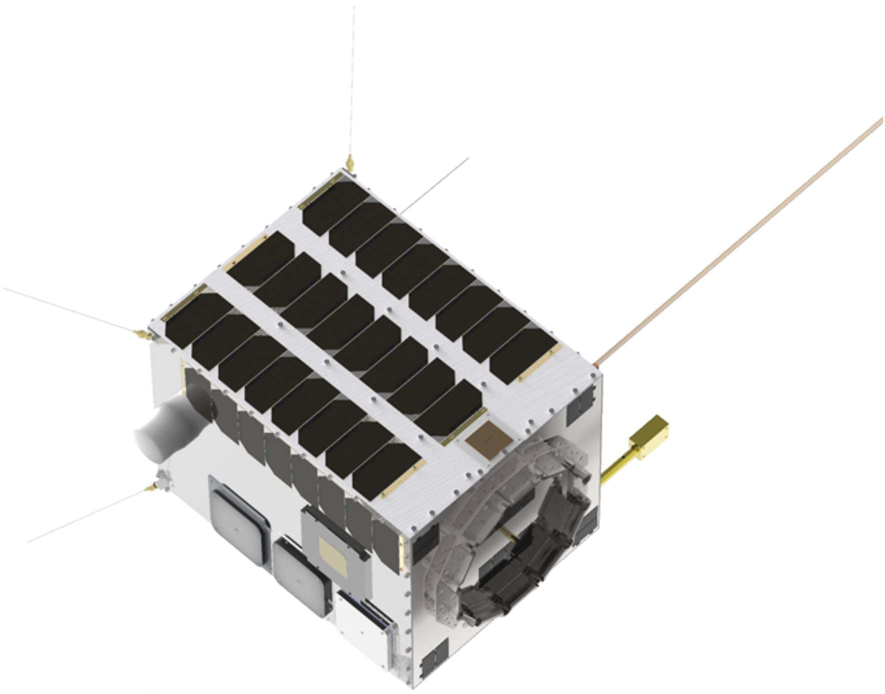


Figure 1: DEFIANT Satellite Platform

2. MOTIVATION

The Space Flight Laboratory possesses several successful multi-mission platforms which have flown previous missions [1, 6], have been adapted to different requirements, and have proven track records. These range in size of which the most popular are either the 15 kg NEMO platforms [6] providing excellent performance for the size or the larger NAUTILUS providing great scalability for payloads which can mass a total of up to 150 kg [7]. The range provided by these two is quite wide, and there is a niche to be served with an intermediary platform.

The DEFIANT bus provides the performance efficiency of a compact nanosatellite [8] with the mass efficiency of a microsatellite [7] due to not requiring a traditional small satellite deployer.

The primary driver for the DEFIANT bus design is the ability to manufacture and qualify several platforms simultaneously which can vary slightly in size, payload content, and external layout. The ability to produce, qualify, and test such platforms in parallel throughout the development of the mission allows large reductions in risks and schedules. In order to achieve this, the assembly process becomes key and the design should integrate the following features.

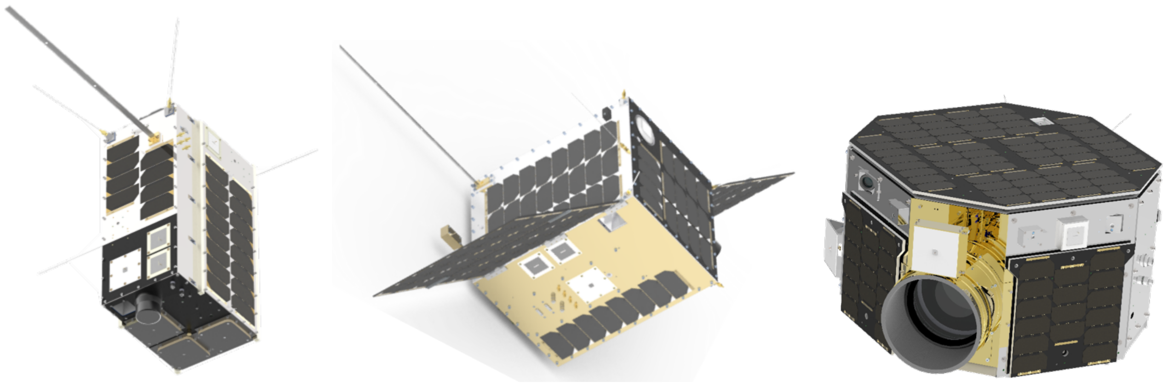
The modular subsystems should have single point connectivity in the harnessing of the spacecraft and late integration access in order to be able to remove and replace components deep into the assembly and testing phases of the spacecraft.

The harnessing for the spacecraft should be located inside the bulkhead and be limited to within this space. This can limit EMC issues which typically are only made evident late into the testing phase and keep the complexity of routing and lacing the harness to an early stage of the integration where access is at its best.

The structural components of the spacecraft should be kept relatively simple in material and manufacturing requirements. This limits long lead-time risks, manufacturing delivery times, and costs. When multiplied across several spacecraft in a multi-bus mission, the savings are compounded. Similarly, the number of parts should be reduced to limit stocking requirements and to take advantage of the time-savings during build-up.

3. DEFIANT CORE

The core of the DEFIANT bus contains the necessary set of subsystems which is part of every mission. This includes the computers, radios, ACS sensors and actuators, as well as the power distribution and management subsystems. These are



(a) NEMO (b) DEFIANT (c) NAUTILUS

Figure 2: SFL bus comparison in the mid-range sizes with (a) NEMO at 15 kg, (b) DEFIANT between 20-30 kg, and (c) the NAUTILUS at up to 150 kg

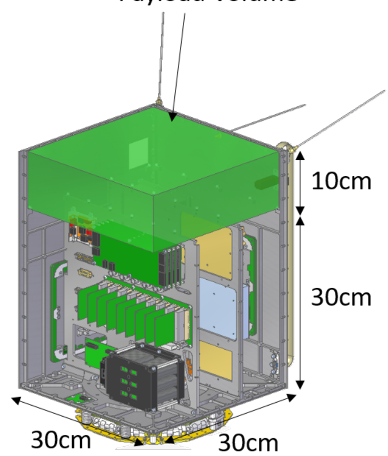


Figure 3: DEFIANT Core

mounted centrally with a focus on maintaining a balanced center of mass as well as providing expandability. The strategy also allows for flexibility on locating the separation system on any face of the spacecraft either maximizing the possible mass at launch or minimizing the footprint.

The external measurements of the platform when considering the most compact form factor is 30cm x 30cm x 40cm and has a mass of 15kg in addition to a payload mass of up to 10kg for a total of 25kg. The platform is designed to be easily expandable in the long axis while maintaining the same internal density and can be expanded in the lateral directions with minor changes.

The core is composed of two modular mounting plates which are spaced apart by 10 cm, the standard 1U dimension. This provides the internal bulkhead location for the wiring harness as well as a centrally localized space for mounting a variety of standard subsystems, the most likely of which is a propulsion system. Each of the two panels provide a 30cm x 30cm surface which can be seen in Figure 3. The components on each panel are divided based on mass balance, volume, mounting requirements, wiring requirements, and in the case of the power system, inter-connectivity. This allows us to maintain minimum wire runs and provides a good mass distribution as a general starting point.

The remainder of the bulkhead space, namely the portion nearest the payload volume, is ideally reserved for the inter-panel wiring harness as well as serving for an expandable location for the fuel tank of a propulsion system, should the mission require it. Furthermore, ACS actuators such as reaction wheels can be placed furthest away from the payload

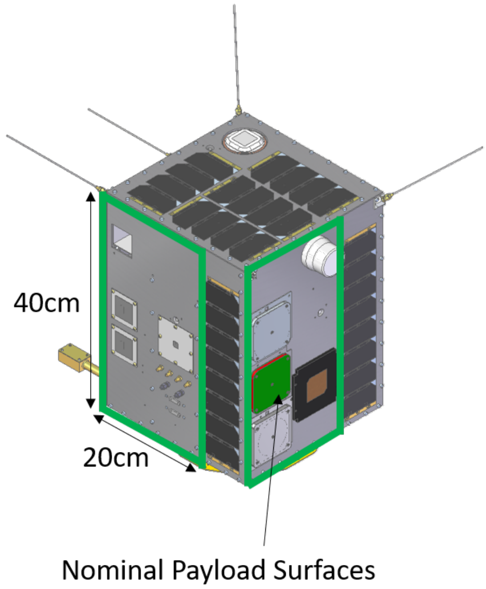


Figure 4: DEFIANT External Layout

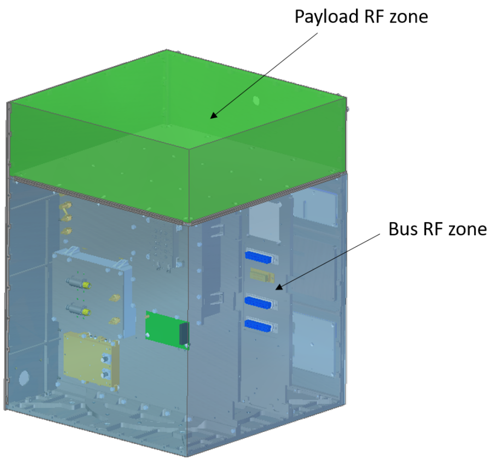


Figure 5: DEFIANT RF Zones

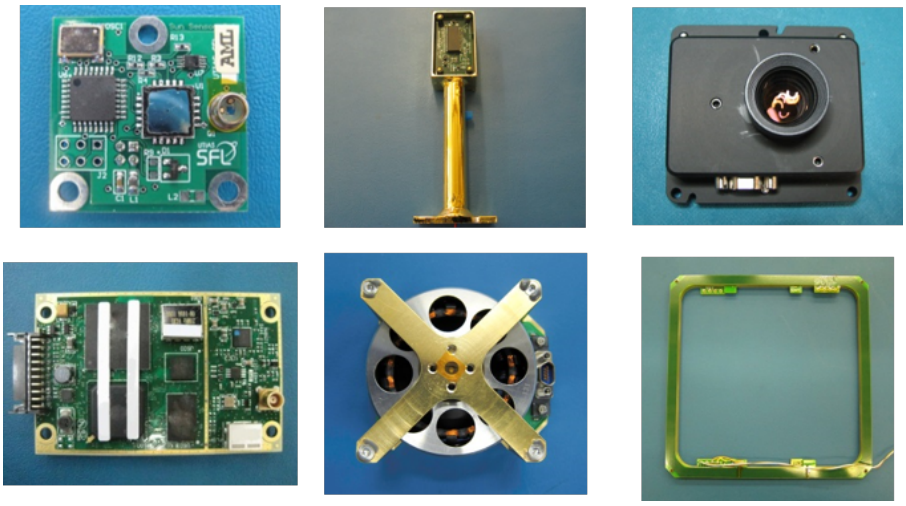


Figure 6: DEFIANT Standard ACS Components

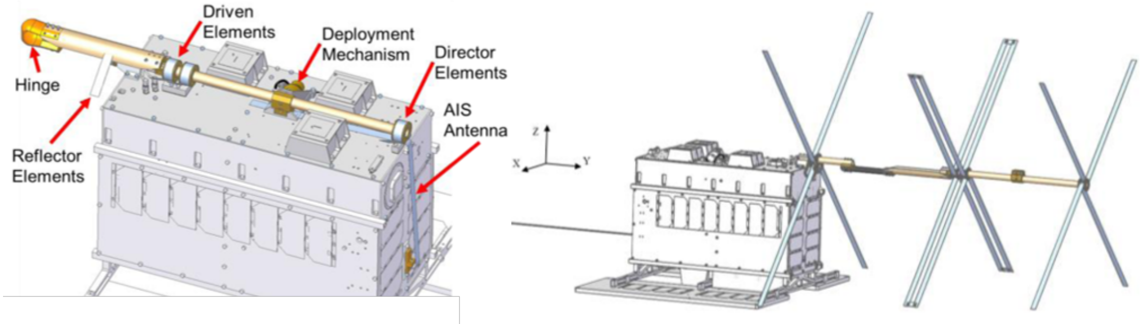


Figure 7: Deployable Yagi Antenna

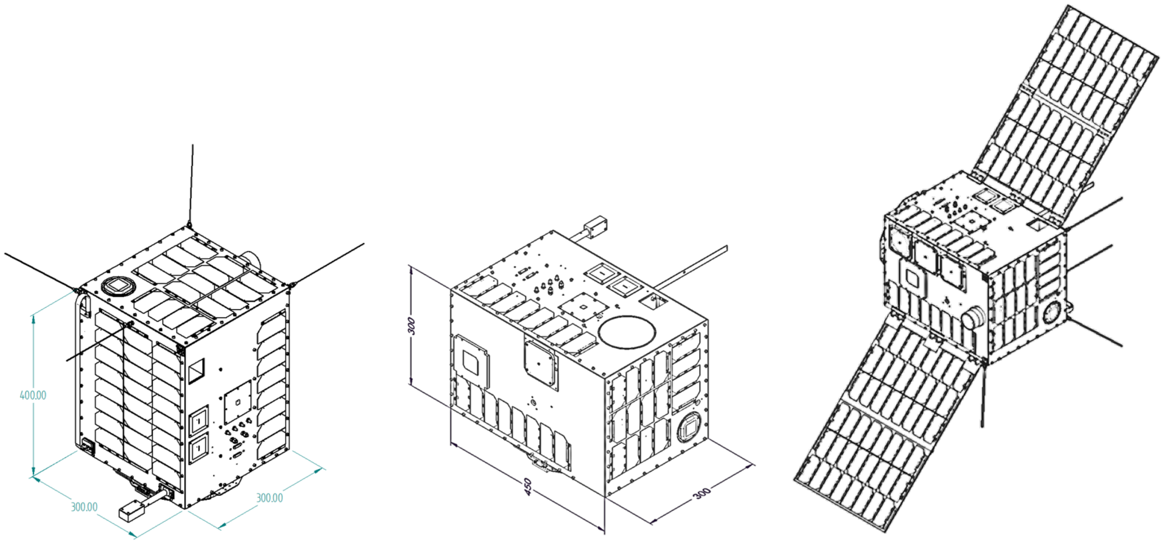
panel in this location, providing an EMI sealed enclosure for these components which can prove noisier than typically enclosed subsystems.

The external layout of the satellites can be adapted to specific missions, however the standard layout has a power favourable pointing corner, a separation system mounting face, and two areas measuring 20cm x 40cm for payload mounting. Depending on the mission concept of operation, these can be reassigned and modified without requiring any internal changes.

The basic modular power system is capable of providing 65 W of payload power, while maintaining positive power margins on the remainder of the avionics. This system is designed around SFL's modular power distribution system (MPS) which can be expanded and customized based on mission and payload requirements by increasing the number and type of power cards. This is customarily paired with a scalable battery pack designed to maximize mission lifetime.

The bus platform is broken down into several distinct RF zones (see Figure 5) by default, reducing the risk of incompatibility between subsystems and payloads. Nominally, unless changes are required by the mission, the payload bay RF zone will have 20dB attenuation at 15 GHz. These zones are self-contained environments which can be tested for self-compatibility prior to assembly in order to reduce risks early in the build stages. The zones are bridged using panel mounted connectors and can include shielded wire runs, filtered connectors, or even be further subdivided into smaller zones to additionally limit potential noise and interference issues. Finally, the entire bus can be sealed to radio frequencies in order to limit coupling and noise issues coming in from the environment.

In short, the core structure of the DEFIANT bus, while employing heritage components and systems which have flown on several missions, has been designed to be efficient, modular, and expandable, while simplifying several integration and design steps. These changes have been combined to make an ideal spacecraft structure for multi-satellite constellation missions.



(a) Compact Form (b) Optical Payload (c) High Power

Figure 8: DEFIANT peripheral options for certain mission types.

4. DEFIANT PERIPHERALS

Expanding on the core structure, the range of peripherals for the spacecraft provide less common capabilities to the bus and greatly improve the range of possible missions. The base DEFIANT platform, unless otherwise required, contains the nominal attitude control and sensor suite components (see Figure 6) such as reaction wheels, sun sensors, rate sensors, magnetometer, and magnetorquers. With this baseline complement of ACS equipment, the platform can achieve inertial stability on the order of 10 arcsecs [9]. For more demanding missions, additional configurations are available such as quad reaction wheels, star-tracker and optical communications compatible, as well as various sized SFL smart-torquers.

In order to accommodate the latest payload requirements and demanding operation schedules, DEFIANT is also capable of including deployable solar arrays to generate additional power without significantly increasing the mass and volume at launch. The backside of the panels can also provide radiating thermal surfaces or additional payload mounting area for larger antenna arrays. In combination with the expandable modular power system, the design can provide an additional 100W of power.

Moreover, the platform is compatible with the full range of SFL's next generation communication arrays [6], including standard radios from UHF to K-Band, which can be combined with custom deployable high gain arrays or future optical communications systems. In past missions these have included such systems as the deployable Yagi antenna seen on NORSAT-2 spacecraft and visible in Figure 7.

Finally, SFL possesses experience with a range of propulsion and drag sail systems [10] in order to modify, control, or reduce spacecraft orbit. The spacing between the internal panels takes advantage of the standards in the industry and provides compliance with proven systems, as well as future developments. These include deployable end-of-life deorbit drag sails such as were demonstrated on CanX-7, microsatellite propulsion systems as seen in our formation flying satellites, and even small optical payload bench such as GHGSat employed.

The breadth and range of peripherals which are compatible with the DEFIANT structure as well as the potential future systems give the platform an impressive range in performance. The bus strikes a balance between customizability and producibility while attempting to minimize risks and costs. The spacecraft also focuses on the rising trend of constellation style missions which typically require the simultaneous launch of multiple satellites concurrently.

5. CONCLUSIONS

The DEFIANT platform combines multi-satellite mission manufacturability with a modular and scalable payload capability. It takes advantage of SFL's heritage by leveraging the core electronics, power, and attitude system and providing an isolated electromagnetic payload compartment. A designed set of peripherals can be used to expand power, communications, or mission specific needs such as propulsion. The platform is compatible with all launch vehicles and can be adapted to the majority of separation systems.

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