CHALLENGES ON THE RSI PAYLOAD DEVELOPMENT & VERIFICATION

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ABSTRACT: Unlike the very first three satellite programs outsourced to the foreign prime contractors, the National Space Organization in Taiwan is stepping ahead to take the full responsibility of consolidating self-reliant space technology capabilities. A newly initiated program FORMOSAT-5 satellite, not only to build a heritage design of a spacecraft bus but also to leap a big step toward Remote Sensing Instrument payload development, is sailing on its voyage. Regardless of challenges we may confront with, a carefully planned strategy especially emphasizing on the product realization processes is considered, discussed, and implemented. Gaining proof of the product compliant with design solution specifications and descriptive documents along with minimizing the program risk and spotting the problem in advance is the ultimate goal.

1. INTRODUCTION

FORMOSAT-5 satellite [1,2] is the fifth spacecraft development program initiated by the National Space Organization (NSPO) of National Applied Research Laboratories (NARL) in Taiwan. The primary mission goals of the FORMOSAT-5 development have two folds, first to serve as a follow-on mission of FORMOSAT-2, which is commissioned in May 2004 and still orbiting, to continuously provide images for domestic and global users and secondly to demonstrate the self-reliant space technology capability on the spacecraft bus and Remote Sensing Instrument (RSI) payload development.

The three-axis stabilized FORMOSAT-5 satellite will be deployed by the Falcon launch vehicle from SpaceX into a sun-synchronous orbit with altitude of 720 Km and inclination of 98.28 degree. It will have global coverage with revisit cycle over Taiwan and Taiwan Strait every other day to conduct the planned remote sensing mission. The RSI payload on board of the FORMOSAT-5 satellite provides 2 meters Ground Sample Distance (GSD) in panchromatic (PAN) and 4 meters in multi-spectral (MS) bands over 24 Km swath width in the nadir direction featuring five spectral bands from 450 nm to 900 nm. The assumed mission life is intended for 5 years.

Among the RSI payload development effort, an integrated circuit of the kind Complementary Metal Oxide Semiconductor (CMOS) instead of Charge-coupled Device (CCD) is chosen as the image sensor playing the leading role for the instrument. With the advanced CMOS Image Sensor (CIS), FORMOSAT-5 is anticipated potentially to be one of the first satellites flown in the space world. In addition, how a supporting structure bearing the optical lens also has to be implemented cautiously to eliminate the microscopic displacement ought not to be overwhelmed by its seemingly simple appearance. Despite the foreseen technical concerns, management issues over scheduling and documentation are also emerging owing to the payload development underwent is collaborated by the domestic industries and research centers.

2. REMOTE SENSING INSTRUMENT PAYLOAD

The RSI payload on board of FORMOSAT-5 satellite is composed of two main parts, the Telescope, which will image a portion of the earth on the image plane of the Focal Plane Assembly (FPA), and the Electronic Unit (EU), including Solid State Recorder (SSR). The RSI Payload system block diagram and interfaces of the instrument is depicted in Figure 1.

The Cassegrain-type Telescope contains two major elements: the Optic Structure Assembly (OSA) and the FPA. As shown in Figure 2, there are 1 primary mirror (M1) and 1 secondary mirror (M2), 1 corrector lens assembly (CLA), and 2 baffles constituting the OSA optics. The structure of OSA is built on the main plate made of Carbon Fiber Reinforced Plastic (CFRP) face sheet and aluminum core honeycomb panel. The main plate and support ring are installed on the spacecraft bus top panel using struts as support frame.

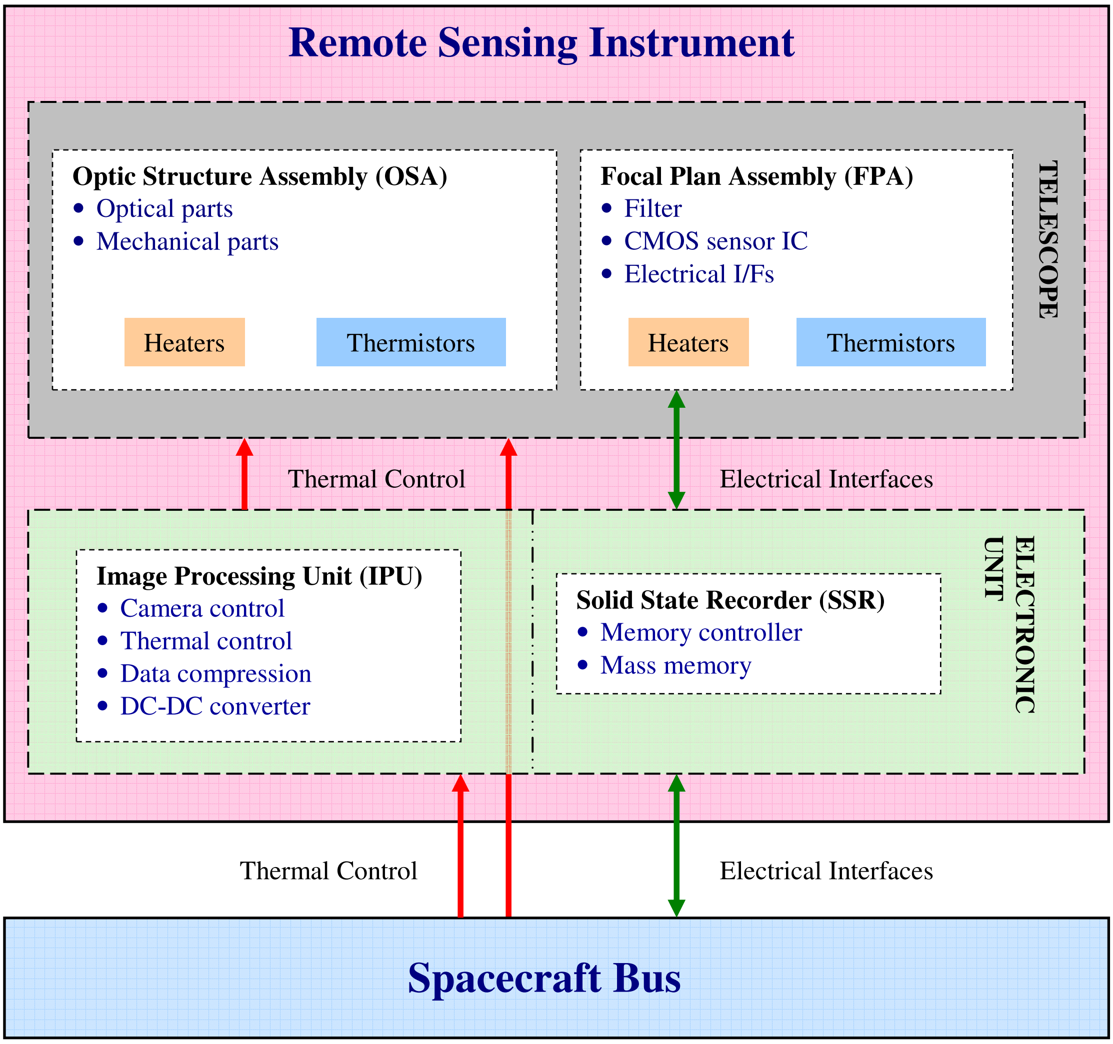

Figure 1: RSI Payload System Block Diagram and Interfaces.

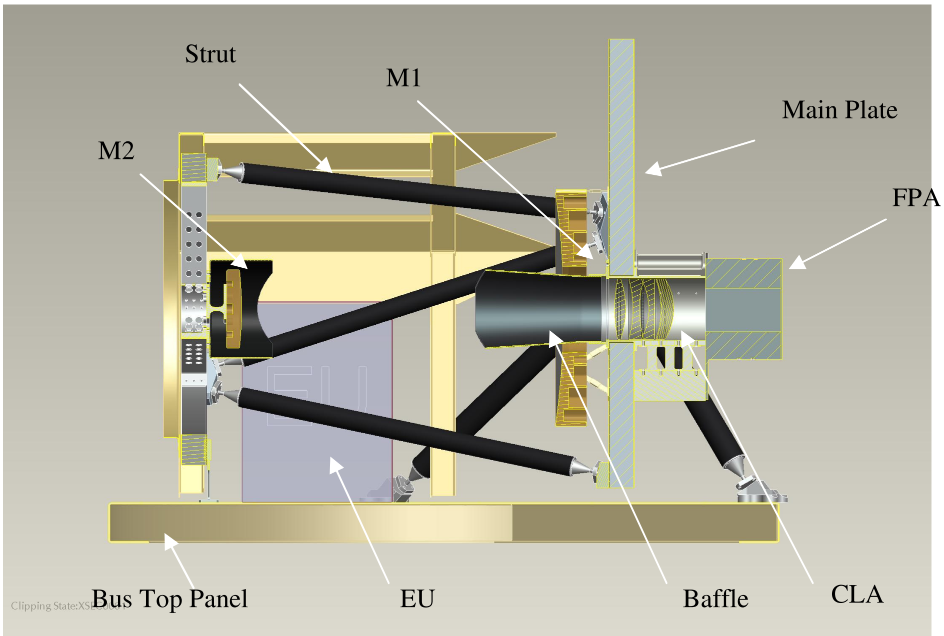

Figure 2: RSI Payload Profiles.

Adhered on the other side of the main plate, the FPA consists of CMOS sensing detector, filters, electronics, thermal control hardware, and structure to provide functions of photon sensing, detector driving, gain control, integration time adjustment, analog-to-digital converting, and output formatting. Its fixture shall be able to attach FPA to the main plate and place image sensor right on the target of telescope focal plane. A thermal control system is used to ensure that the FPA can be maintained within its thermal environment allowance to keep its normal performance.

The primary function of the Electronic Unit includes camera operation control, housekeeping data acquisition and image processing, storage, and downloading. In addition, the unit also interfaces with the Telescope to provide power, precise time, and positioning data and keep the instrument within thermal limits.

3. VERIFICATION AND VALIDATION

3.1 Verification Process

A general RSI verification and validation (V&V) process [3] with four distinct V&V methods is shown in Figure 3. These four methods are used to satisfy verification requirements: analysis, inspection, demonstration, and test.

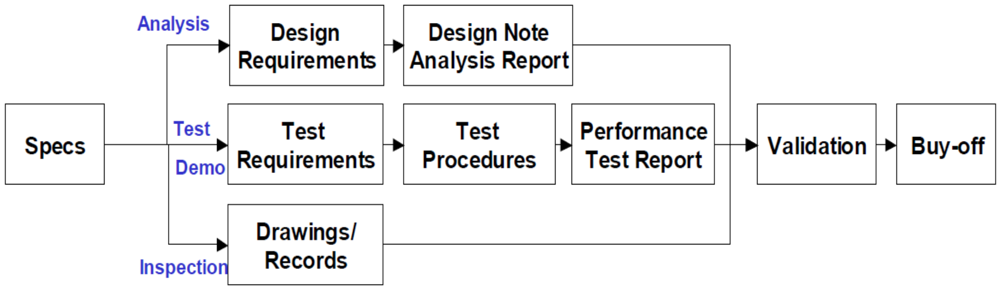

Figure 3: General RSI V&V Process

Verification Methods:

Each performance and design requirement of the RSI payload specifications is assigned a method for verification in the requirement verification matrix. Four distinct methods are used to satisfy verification requirements: analysis, inspection, demonstration, and test, or a combination of these. As the specification is developed, each requirement is analyzed and assigned a method that is documented in the verification matrix. This matrix thus provides the foundation for all further verification planning for that item. The assigned method may prove invalid as the design matures. In this case, the verification method will be updated in the verification matrix through normal document control channels, with the appropriate approvals.

Validation Methods:

Validation confirms that realized end products at any position within the system structure conform to their set of stakeholder expectations captured in the ConOps regardless of any specific set requirements, and ensures that any anomalies discovered during validation are appropriately resolved prior to product delivery. When performed early in the project, validation prevents wasted time and effort resulting from misunderstandings and wrong assumptions.

Certification Process:

The project manager provides evidence to stakeholder that the RSI payload satisfies all performance and design requirements. The verification products provide the basis for this certification and may be supplemented with any validation products. Based on this evidence, the stakeholder approves the request for certification. This process is an audit of how the project has verified each requirement

3.2 Payload Verification

The RSI payload verification process is broken down into two distinct categories, Telescope and Electronic Unit, in accordance with FORMOSAT-5 RSI Specification Document and FORMOSAT-5 BUS to RSI ICD.

Developmental/Engineering Unit Evaluation:

Telescope Structure

The supporting structure of the telescope is to be designed and manufactured and assembled with the optical parts and electronic boxes to meet the critical requirements of the following folds:

- Design and Construction: providing easy access of mounting/dismounting and adjustment, minimizing stability variation of optical tolerance
- Envelope: Accommodating optical design configuration
- Strength: Positive margin of safety for design loads and vibration stiffness
- Interfaces: Accommodating spacecraft bus components and mounting on the top of the spacecraft bus

Besides, moisture escaping from the CFRP composite material in the outer space environment may cause structural deformation and subsequently result in camera out of focus. The main plate acts as a supporting bed to the M1 mirror using three Iso-static Mount (ISM) suspension joints made of invar.

There will be different models of the telescope structure in the development process, one Structure Model (SM) and one Proto-flight Model (PFM).

Three models are also planned in the telescope development process, Engineering Model (EM), Demo Model (DM), and Flight Model (FM). After structure strength of the SM successfully verified, it is planned to be assembled with M1 and M2 mirrors and corrector lens assembly to become telescope EM. The value of the EM is to practice assembling, study moisture-deformation connection, and try to understand micro-setting. In turn, the DM is to demonstrate telescope function by integrating FPA EQM into EM. The FM is from structure PFM and space qualified optical parts and intended sitting on the satellite.

Electronic Unit (EU)

There will be different models of the EU in the development process, one Elegant Breadboard (EBB) model, one Engineering Qualification Model (EQM), and two units of Flight Model (FM).

The EBB is built using commercial grade parts and a configuration close to that of the FM to meet the functional baseline design. There are no specific requirements for EBB configuration and interface control. The EQM shall be fully representative of FM except that a lower standard of electrical parts may be used. The standard of these parts shall be the highest achievable within the schedule constraints but using the same manufacturer, the same type, and the same package as for the FM. The EQM shall be subjected to the full component level qualification test sequence, underwent more stringent environment conditions compared with FM to prove its design and workmanship. The FM shall be built to fully flight standard in accordance with Product Assurance (PA) and Configuration and Document Management (CADM) requirements. Flight standard parts shall be used and it will be on board of FORMOSAT-5 satellite subject to passing flight acceptance testing.

Focal Plane Assembly (FPA)

One check point, Critical Technology Review (CTR) of the CMOS sensor core of FPA, and two FPA models, one Engineering Qualification Model (EQM) and one Flight Model (FM), are planned in order to ensure the final flight unit being able to meet the specification and schedule requirements

The purpose of CTR validation is to prove that the applied CMOS Integrated Circuit (IC) fabrication technology for the FM can be duplicated in advance through the means of design analysis data, IC sensor hardware, and its associated test results. The EQM shall be fully representative of FM except that a lower standard of electrical parts may be used. The standard of these parts shall be the highest achievable within the schedule constraints but using the same manufacturer, the same type, and the same package as for the FM. The EQM shall be subjected to the full component level qualification test sequence, underwent more stringent environment conditions compared with FM to prove its design and workmanship. The FM shall be built to fully flight standard in accordance with Product Assurance (PA) and Configuration and Document Management (CADM) requirements. Flight standard parts shall be used and it will be on board of FORMOSAT-5 satellite subject to passing flight acceptance testing.

Verification Activities:

							RSI DM
					Telescope	EU	
			OSA	FPA			
	Structure	Optics					
Alignment			X		X		X
Quasi Static Load	X		X				
Sine Vibration			X	X		X	X
Acoustic Test							
Random Vibration			X	X		X	X
Shock				X		X	
EMC (Conducted)				X		X	
TV				X		X	X

Table 1: Verification Testing Items

All tests, inspections, and demonstrations performed on the integration hardware will be performed using a task performance sheet. All analyses will be documented on a formal memo or analysis report. The "Results" column in the verification matrix will contain the necessary information (task performance sheet number, memo number, report number, etc.) to identify where the requirement has been verified. When the verification is performed at vendor facilities, Certificates of Compliance and/or Test Reports of tests performed by the vendor will be used as proof of compliance of the requirements. The testing items are indicated in Table 1.

4. Discussion

Before the Critical Design Review, scheduled on December of 2011, of FORMOSAT-5 RSI payload, most analyses of the RSI design and performance compliance will be checked and ensured to its corresponding system requirement. In the design of RSI payload, the main plate acts as a supporting bed to the M1 mirror using three Iso-static Mount (ISM) suspension joints made of invar whose related ISM modal analyses had been conducted. Furthermore, the method of bonding between the M1 mirror and ISM is being under testing. Radiation life test of the corrector lens is planned to be carried out with 30 krad for 2,000 hours. Further verification work will be reported successively.

5. REFERENCES

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