Subsystem Design Specification

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Payload Electrical

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Contents

1 Subteam Overview

1.1 System Introduction

The Payload Electrical team (PAY) is responsible for the electronics necessary to control the payload. The payload for the FINCH mission is a pushbroom hyperspectral imager that uses the Teledyne FLIR Tau camera. The fact that the payload is such already implies a couple of constraints: first, one spatial axis can be limited by the frame rate of the system. Second, the system must be able to deal with a lot (a lot relative to the memory of the flash of the MCU used) in a short amount of time which necessitates methods for rapid data transfer.

In order to fulfill the mission requirements, not only do the electrical interfaces need to be fast enough for data acquisition, the operations within the MCU must also be fast enough so as to not bottle neck the transfer of images to storage. The subsystem design specification exists to give an overview of the system: the electrical design, as well as methods to store the datacube.

1.2 The Hardware We're Working With

1.2.1 STM32H743IIT6

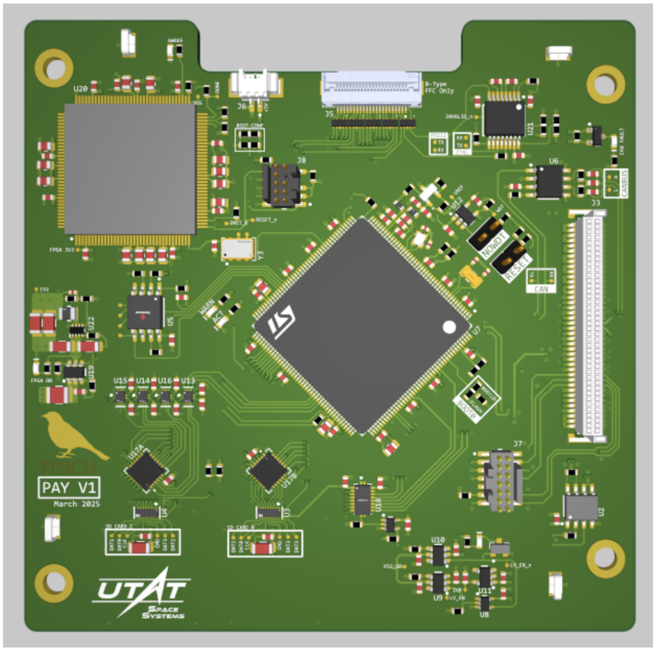

Figure 1: PAY v1.0

The Payload Electrical System utilizes an STM32H743IIT6 as the main controller. The H7 has the following specs:

Core	Single Core 32-bit ARM Cortex M7
Clocking	480MHz Max
On-chip Memory	2 MBytes Flash 1 MByte RAM 512kB Largest DMA Chunk
Peripherals	CAN I2C SPI SDMMC HDMI
Package	LQFP-176

Table 1: STM32H743IIT6 Relevant Electrical Specifications

1.2.2 FLIR TAU SWIR

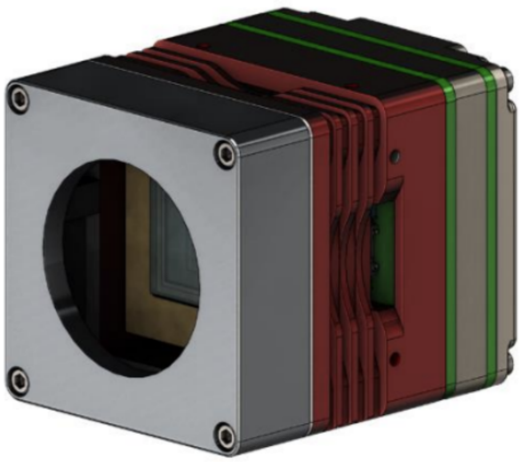

Figure 2: FLIR Tau SWIR

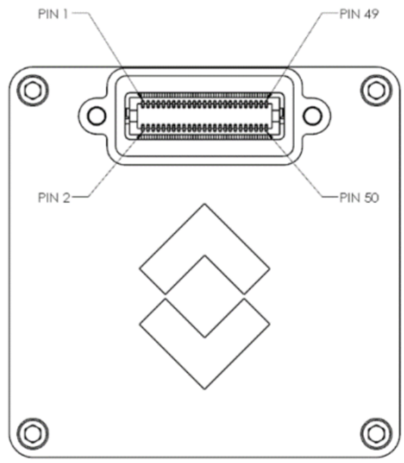

Figure 3: FLIR Tau Connector

The camera used is the FLIR Tau SWIR. A few important notes about the use of this camera: (1) A 256x320 subset of the detector is used rather than the 512x640 full frame. (2) image readout can be done while the camera is exposing[1]. (3) Commands are sent to the camera via RS232. (4) DCMI is used to readout the image with a pixel clock of 5.7048MHz. (5) The 14-bit pixels are stored in 2 bytes. (6) The team still needs to measure the QE of this camera.

For the 256x320 subset, the readout time is then given by

$$\frac{256 \times 320}{f_{CLKPIX}} \approx 14.36\text{ms} \tag{1}$$

[1] *Tau SWIR Product Specification.* Oct. 2018. URL: `https://drive.google.com/file/d/1hDU8Dk9fygd2EyuG_VCbWGHtwMtvR_7e/view`.

Given this readout time, the max frame rate is then

$$1 \text{ frame}/14.36\text{ms} \approx 69.63\text{fps} \tag{2}$$

Of course, the actual frame rate will be less considering also the time for commanding. 60fps should be a safe baseline for now. The docs claim a much faster frame rate of 120fps but we are assuming that a buffer within a camera is what makes that possible. Assuming the buffer, there must be a max number of frames that can be taken at 120fps and so this will not be suitable for the FINCH mission since imaging would last to the order of 30s.

Resolution	512x640 pixels 14-bit analog resolution
Commanding Interface	RS232
Data Interface	14-bit DCMI 5.7048MHz Pixel Clock

Table 2: FLIR Tau SWIR Electrical Summary

1.2.3 SD Cards

The data is to be stored on SD cards onboard PAY. PAY has two SD cards that it can access using a MUX. Hardware is implemented so that the logic level can go down to 1.8V to enable greater than 25 MBytes/s transfer speed to the SD card (UHS mode). More details on the SD cards are provided in Section 6.

1.2.4 Spartan 6 FPGA

Yes, there is an FPGA onboard. Initially, the FPGA was on the board for compression which recently became a "Should" requirement.

2 Applicable Documents and Standards

2.1 General Documents

- PAY Datasheet
- Master Connection Sheet
- *Tau SWIR Product Specification.* Oct. 2018. URL: `https://drive.google.com/file/d/1hDU8Dk9fygd2EyuG_VCbWGHtwMtvR_7e/view`

2.2 Specifications, Standards, and Handbooks

- Spacecraft Grounding: NASA-HDBK-4001

3 Subsystem Requirements

3.1 Electrical System Requirements

From the FINCH-Spacecraft-ElectricalSystem, requirements for the existence of OBC and PAY are derived. Seen in Table 3 are also other higher-lever requirements of the system including the common bus to connect OBC, PAY, and the board for the Electrical Power System (EPS).

Req. ID	Description	Parent Req.	Verification Method
FINCH-Spacecraft-ElectricalSystem	The electrical system shall provide the necessary electrical functionality for the mission to function.	FINCH-Mission-Objective	Demonstration
FINCH-OBC-ControlAndOps	The OBC shall control the modes of operation of the satellite.	FINCH-Spacecraft-ElectricalSystem	Demonstration
FINCH-Payload Controller-PayloadOps	The Payload Controller shall support necessary operations for executing the mission of the payload	FINCH-Spacecraft-ElectricalSystem	Demonstration
FINCH-Spacecraft-CommonBus	The spacecraft shall utilize a common bus which includes the lines for power and communication between OBC, EPS, and PAY.	FINCH-Spacecraft-ElectricalSystem	Test
FINCH-Spacecraft-CANBus	The spacecraft shall use CAN Bus for communication between nodes on the electrical system.	FINCH-Spacecraft-CommonBus	Test
FINCH-Spacecraft-Electrical Grounding	The grounding system for the spacecraft shall include a separate chassis and signal ground.	FINCH-Spacecraft-ElectricalSystem	Analysis
FINCH-Spacecraft-Electrical Soldering Standard	Electrical components shall be soldered in accordance to IPC Type 3 or equivalent	FINCH-Spacecraft-ElectricalSystem	Inspection

Table 3: Electrical System Requirements

3.2 PAY Requirements

Figure 4 and Table 4 summarize the requirements for the Payload Controller system.

Notable is the compression requirement which has only become a "should" recently after PAY was designed. The reason why the requirement suddenly became a "should" comes from a spec from optics saying that the whole sensor will not be used. Initial requirement for compression assumed the whole sensor would be used.

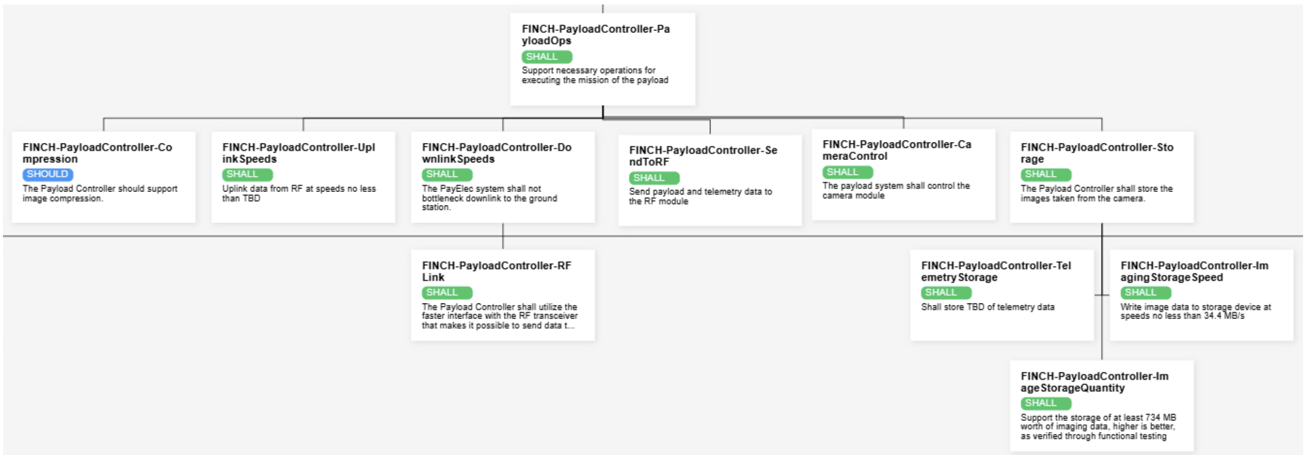

Figure 4: PAY Requirement Tree

Req. ID	Description	Parent Req.	Verification Method
FINCH-PayloadController-CameraControl	The Payload Controller shall control the camera module	FINCH-PayloadController-PayloadOps	Test, Analysis
FINCH-PayloadController-Storage	The Payload Controller shall store the images taken from the camera.	FINCH-PayloadController-Storage	Test
FINCH-PayloadController-ImagingStorageSpeed	The Payload Controller shall write image data to storage device at speeds no less than 34.4 MB/s	FINCH-PayloadController-Storage	Test
FINCH-PayloadController-ImageStorageQuantity	The Payload Controller shall support the storage of at least 734 MB worth of imaging data, higher is better, as verified through functional testing	FINCH-PayloadController-Storage	Test
FINCH-PayloadController-TelemetryStorage	The Payload Controller shall be capable of storing telemetry data.	FINCH-PayloadController-Storage	Test
FINCH-PayloadController-DownlinkSpeeds	The Payload Controller system shall not bottleneck downlink to the ground station.	FINCH-PayloadController-PayloadOps	Test
FINCH-PayloadController-RFLink	The Payload Controller shall utilize the faster interface with the RF transceiver that makes it possible to send data to the transceiver such that it does not bottleneck communication.	FINCH-PayloadController-DownlinkSpeeds	Test
FINCH-PayloadController-UplinkSpeeds	The Payload Controller system shall be capable of receiving data from the RF module directly.	FINCH-PayloadController-PayloadOps	Test
FINCH-PayloadController-SendToRF	The Payload Controller shall be capable of directly sending payload and telemetry data to the RF module.	FINCH-PayloadController-PayloadOps	Test
FINCH-PayloadController-Compression	The Payload Controller should support image compression.	FINCH-PayloadController-PayloadOps	Test

Table 4: Electrical System Requirements

4 Verification and Validation Plan

Electrical requirements will be verified via tests and demonstrations. The verification and validation plan will follow the following timeline:

5 High Level System Architecture

5.1 Grounding Scheme

The initial grounding scheme before the payload redesign was a Star grounding scheme. This was easy since the boards were just stacked together and then cables simply emanated from that stack. For the new mechanical layout, though, the EPS board will be separate from the rest of the boards.

6 Detailed System Architecture

7 Possible Risks

8 Development Schedule and Status

9 Open Issues and Future Work

References

ELECTRICAL GROUNDING ARCHITECTURE FOR UNMANNED SPACECRAFT. Feb. 1998. URL: `https://s3vi.ndc.nasa.gov/ssri-kb/static/resources/NASA-HDBK-4001.pdf`.

Tau SWIR Product Specification. Oct. 2018. URL: `https://drive.google.com/file/d/1hDU8Dk9fygd2EyuG_VCbWGHtwMtvR_7e/view`.