Virginia Tech Cubesat Camera for AMSAT FOX-1

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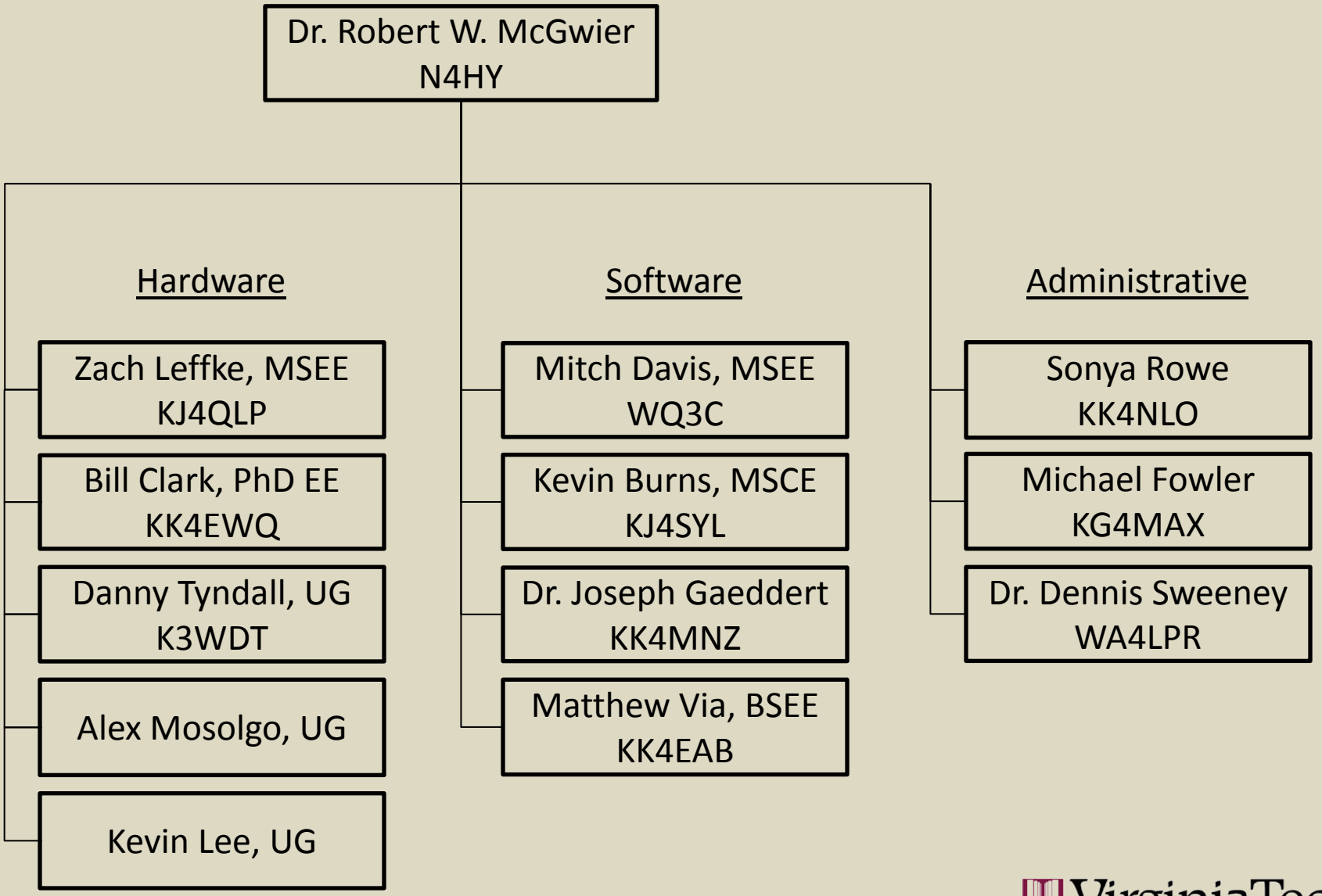
Agenda

- Personnel
- Givens & Constraints
- Camera Location / Orientation
- Camera Selection
- System Block Diagram
- Space Environment Concerns
- Power Budget
- Software Overview
- Expected Image Characteristics

Personnel



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Givens & Constraints

- 640 x 480 Pixel, JPEG Image taken from orbit.
- 250 mW Orbit Average Power Consumption.
- Top two experiment boards of the Fox-1 Spacecraft, Experiment 4 & 3 Boards.
- The camera oriented along the +Z Axis.
- Image packetized for download, before transfer to the spacecraft IHU.
- Commands and Data will be exchanged with the IHU via the spacecraft bus using the Experiment Serial TXD/RXD interface.
- The IHU will control the power of the Camera Board via the *Experiment 4 Enable* signal on the spacecraft bus.
- We must deliver TWO Final Flight Units for Launch.

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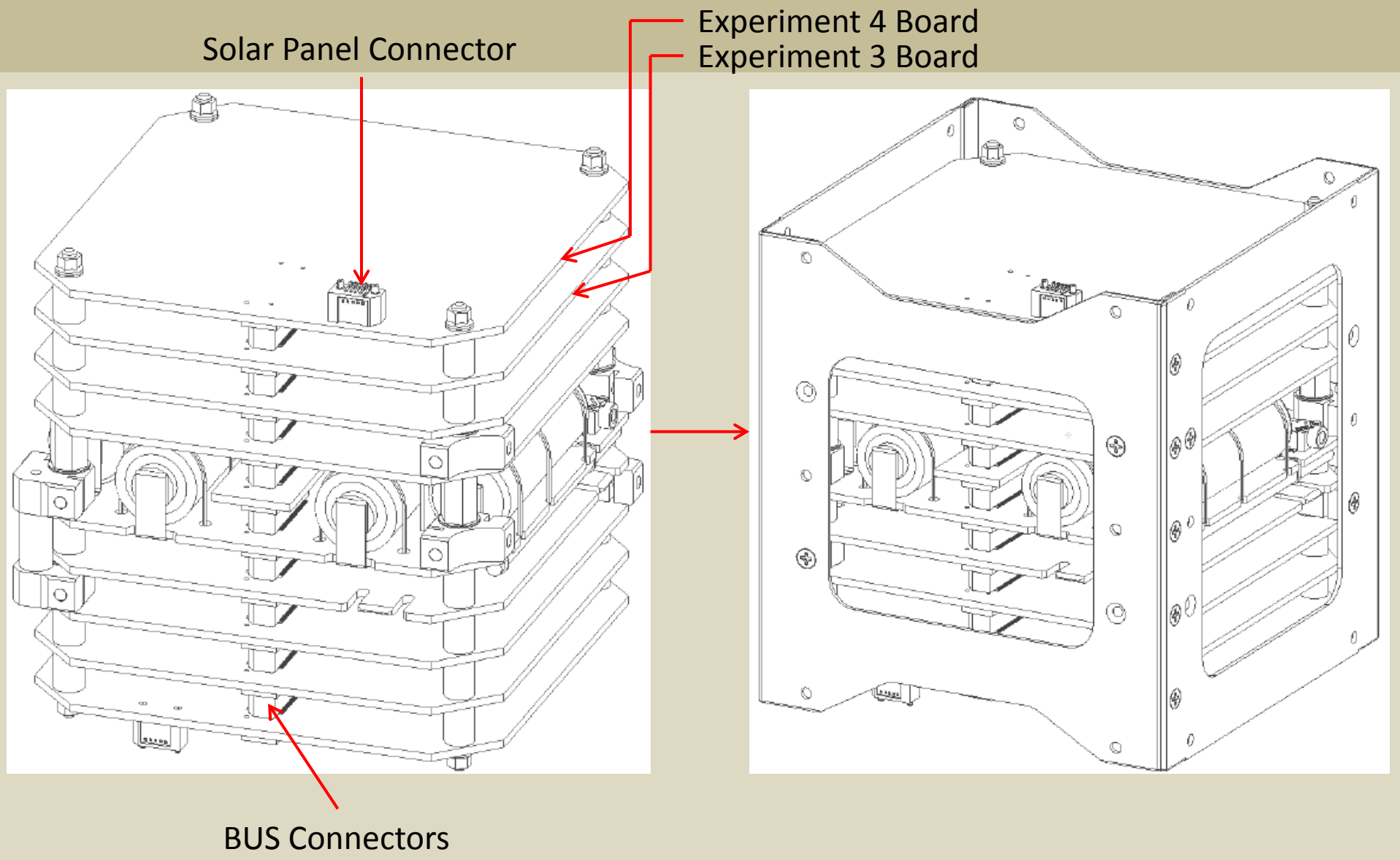
Camera Location / Orientation



Images from Fox CubeSat Mechanical Design by Robert Davis KF4KSS and Steve Christie, presented at the 2012 AMSAT Symposium.

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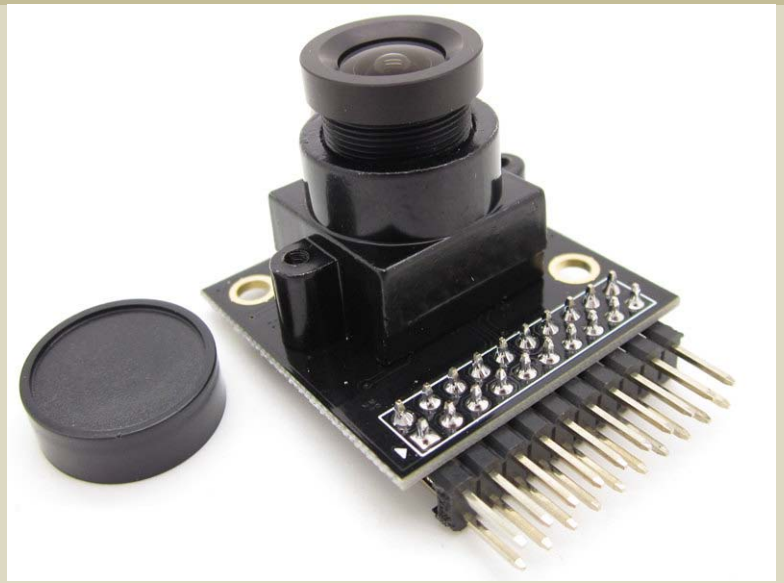
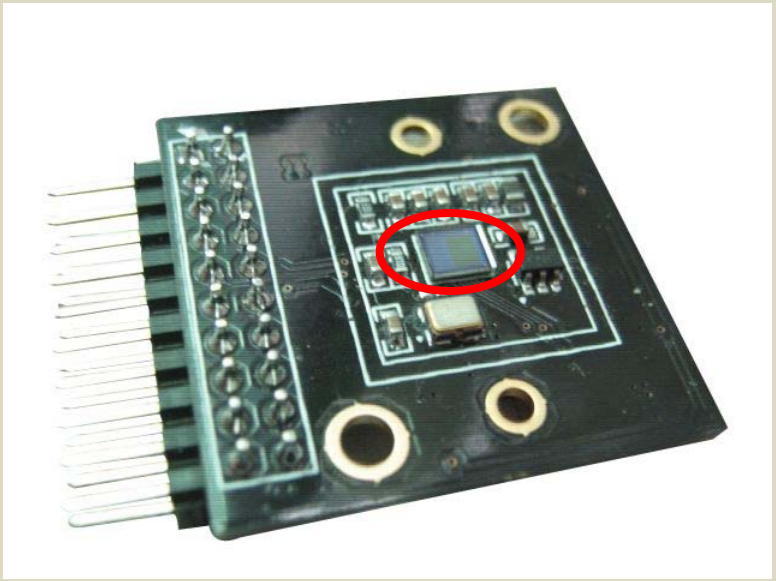
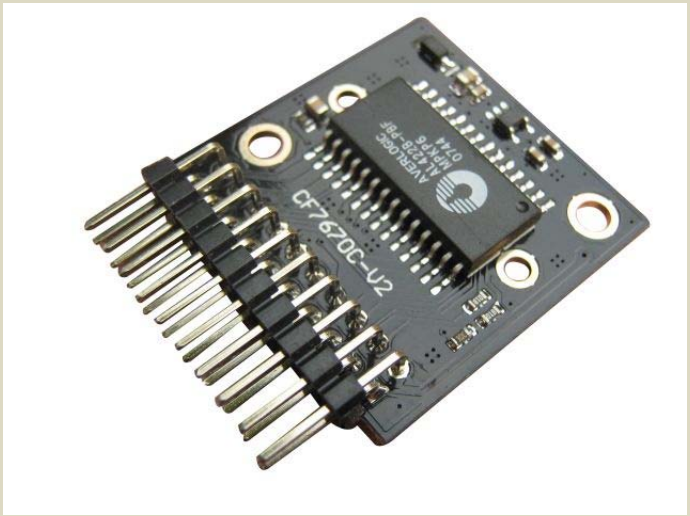
Camera Selection

OmniVision OV7670







Images from: http://www.hotmcu.com/ov7670-al422bfifo-camera-modulev20-p-19.html

Camera Selection
Specifications & Features

OmniVision OV7670

Specifications:

Active Array size:	**640 X 480 Pixels**
Power Consumption:	**60 mW**
Operating Voltage:	**Analog: 2.45 – 3.0 V**
	Digital Core: 1.8V
	I/O: 1.7 to 3.0 V
Standby Current:	<20 µA
Lens Size:	1/6”
Chief Ray Angle:	25 Degrees
S/N Ratio:	46 dB
Dynamic Range:	52 dB
Sensitivity:	1.3 V/lux-sec

Features:

- High Sensitivity for Low Light Applications
- Low operating voltage and power consumption for embedded applications
- Automatic Image Control Functions: AEC, **AWB**, **AGC**, ABF, ABLC
- Image Quality Control including: color saturation, hue, gamma, sharpness, anti-blooming
- Noise reduction, defect correction
- Lens shading correction
- Edge enhancement level auto adjust
- De-noise level auto adjust

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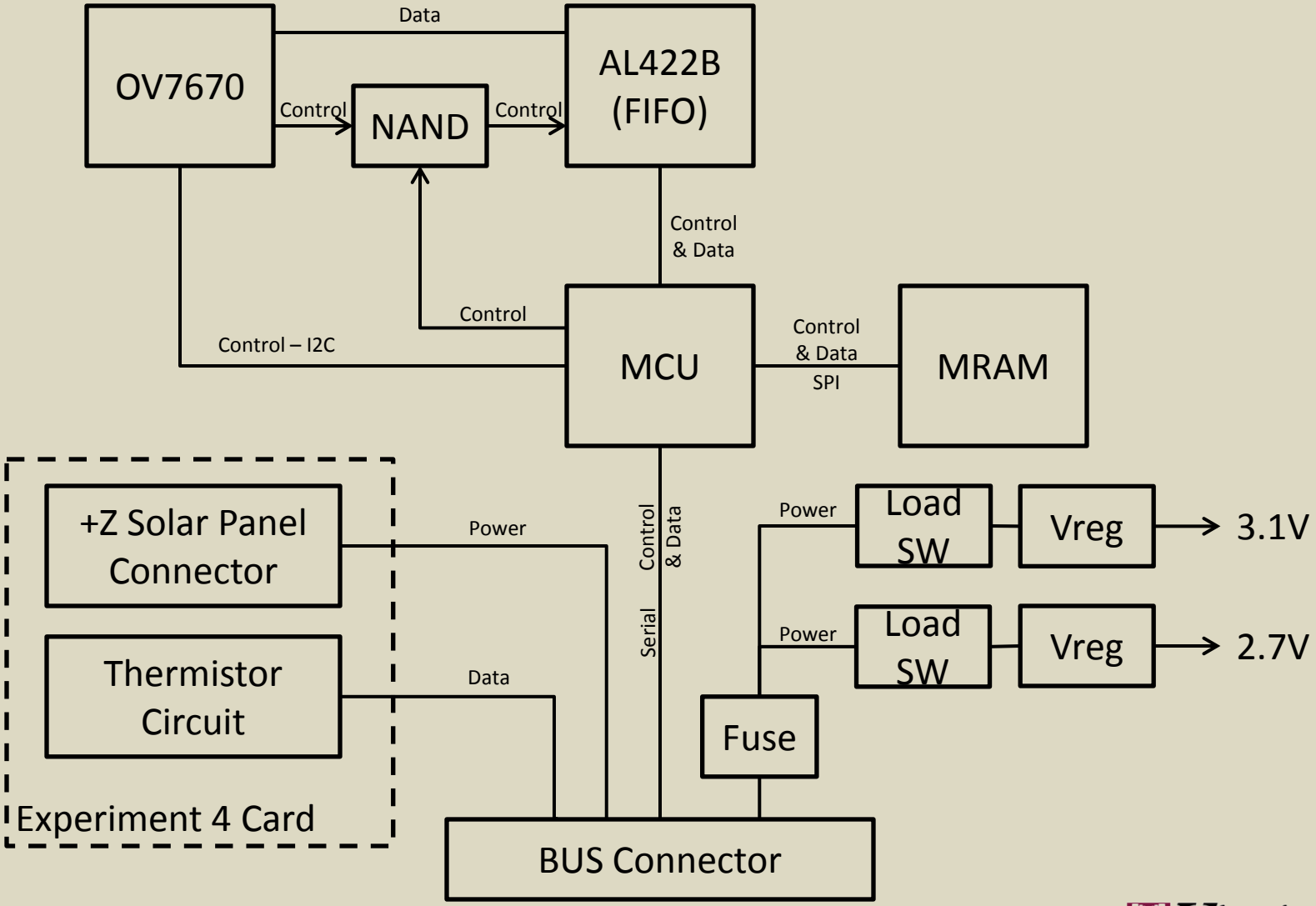
System Block Diagram



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Space Environment Concerns

All values from component Data Sheets

Component	Storage Temperature	Operating Temperature	Note
OV7670	-40°C to +95°C	-30°C to +70°C	Operating
OV7670		0°C to +50°C	Stable Image
NAND	-65°C to 150°C	-40°C to +85°C	"Operating free-air"
AL422B FIFO	-55°C to +125°C	0°C to +70°C	
MCU	-65°C to 150°C	-40°C to +85°C	
MRAM	-55°C to 150°C	-45°C to 95°C	Industrial Grade
Voltage Regulators	-65°C to 150°C	-40°C to 150°C	

- Thermal
- Vacuum
- Radiation

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Power Budget

All values from component Data Sheets

Component	Operating Voltage	Operating Current	Power consumption	NOTE
OV7670	2.7V	22 mA	60 mW	
NAND	3.1V	10 uA	0.031 mW	
AL422B FIFO	3.1V	33 mA	102.3 mW	
MCU	3.1V	6.72mA	20.832 mW	@ 32 MHz
MRAM	3.1V	27 mA	83.7 mW	@ 40 MHz (operating @ 16MHz)
TOTAL PEAK POWER CONSUMPTION:			**266.863 mW**	

Power Limit Constraint: **250mW** Orbit AVERAGE Power Consumption

Power Budget – States

Operating State	OV7670	FIFO	MRAM	MCU	Peak Power
Image Acquisition	ACTIVE	ACTIVE	STANDBY	ACTIVE	**183.132 mW**
JPEG Compression	STANDBY	STANDBY	ACTIVE	ACTIVE	**104.532 mW**
IHU Standby	STANDBY	STANDBY	STANDBY	ACTIVE	**20.832 mW**
IHU Download	STANDBY	STANDBY	ACTIVE	ACTIVE	**104.532 mW**

Power Limit Constraint: **250mW** Orbit AVERAGE Power Consumption

NOTE: When the Camera Board is *Disabled* by the IHU, the Experiment 4 Enable Pin will be LOW. The two voltage regulators, 3.1V and 2.7V, will still be connected to the Bus Battery Pins. These regulators will draw <2 µA each when in shutdown mode.

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Software Overview

System Architecture

- Processor: STM32L151ZDT6
- Operating System: ChibiOS/RT

Hardware Capabilities

- 32MHz Processor @ 238 uA/MHz
- 382 KB ECC Flash, 48 KB SRAM, 12 KB ECC EEPROM
- 382 KB Dual-Port DRAM FIFO
- 1Mb 40MHz SPI MRAM
- 400 kHz SCCB (I2C compatible) Camera Control
- Two 19.2 kbaud UART

Key Features

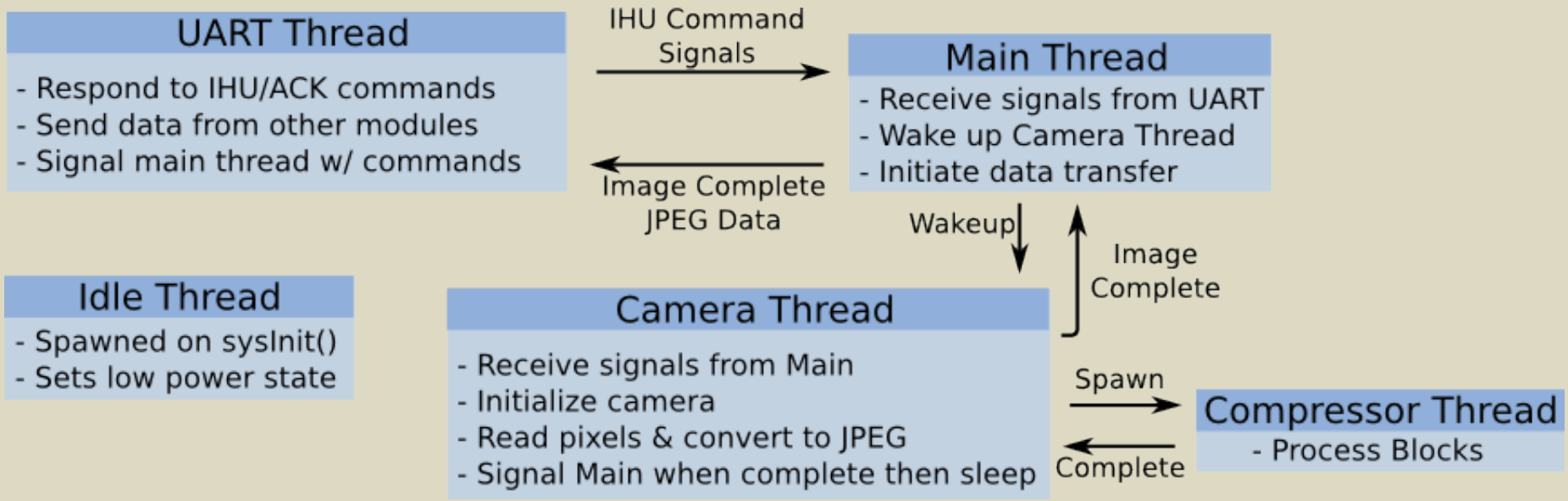
- 1.2-5.5 KiB Kernel Size
- 128 thread priority levels
- Preemptive scheduling, Round-Robin schedular for like priorities
- Mutexes, Semaphores, Events, Message Queues
- Thread-safe Heap
- Hardware Abstraction Layer with DMA support for STM32L1
- GPLv3

JPEG Compression

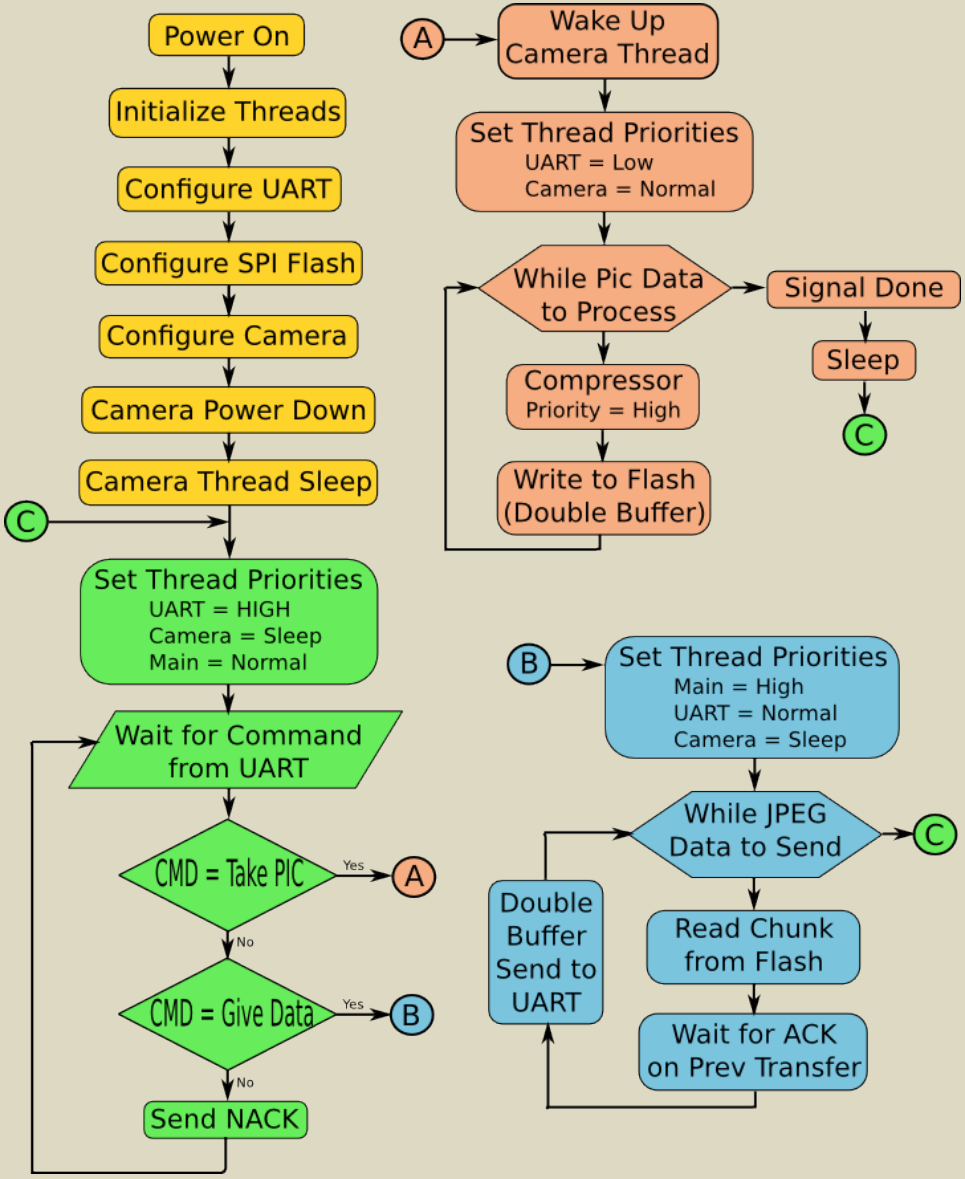
jpegant

- JPEG Compressor code is based off the jpegant lightweight JPEG library
- Integer DCT
- Low memory footprint
- GPLv2 (Author will re-release under GPLv3 per our request)

Software Threads



Operations Flowchart



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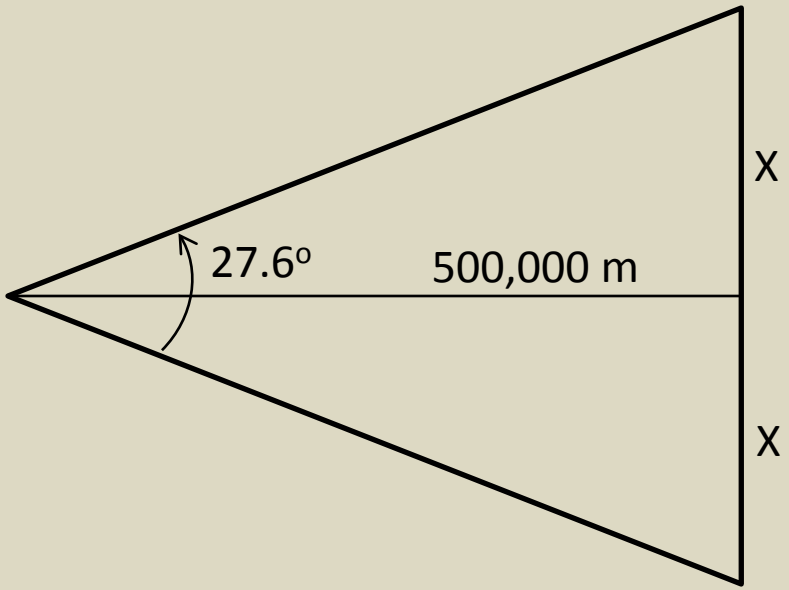
Expected Image Characteristics

500 km, Nadir pointing

$$X = 500{,}000\ [m] * \sin\left({}^{27.6}/_{2}\right)$$
$$= 119{,}267\ [m]$$
$$2X = 238{,}533\ [m]$$



CAM pixel resolution: 640 x 480 pixels

Diagonal: $\sqrt{(640)^2 + (480)^2} = 800\ [pixels]$

Diagonal FOV: 27.6 degrees

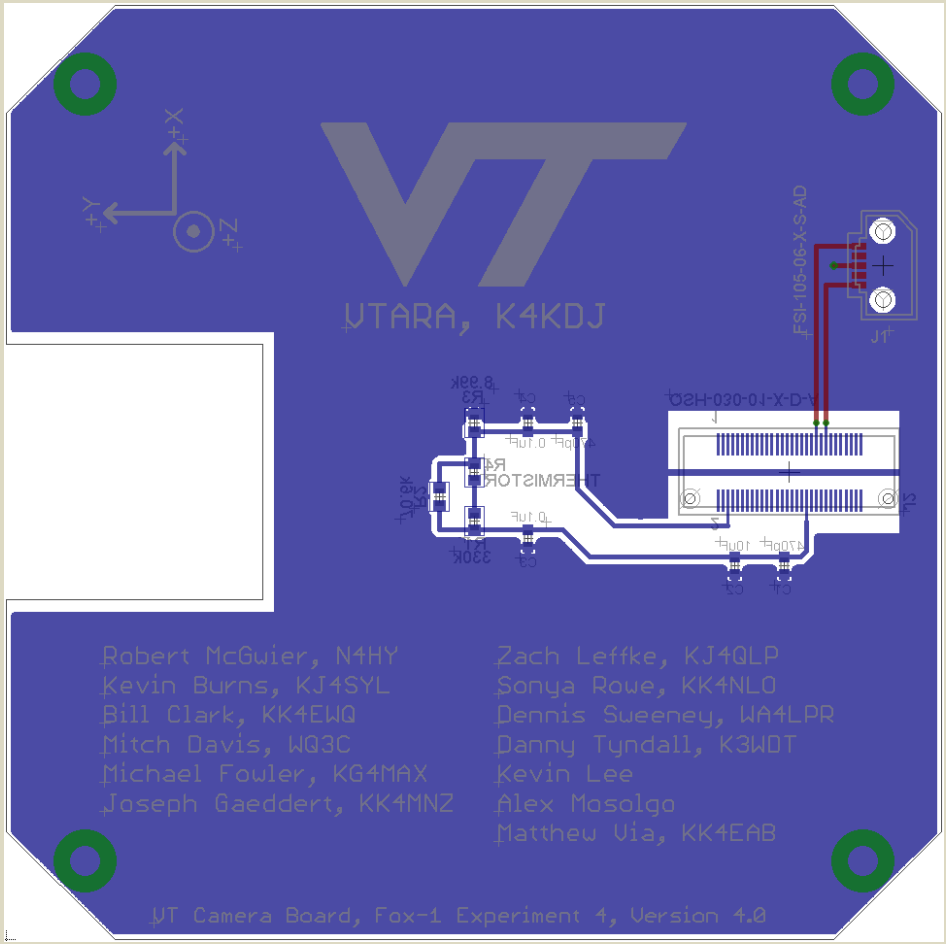
THUS:

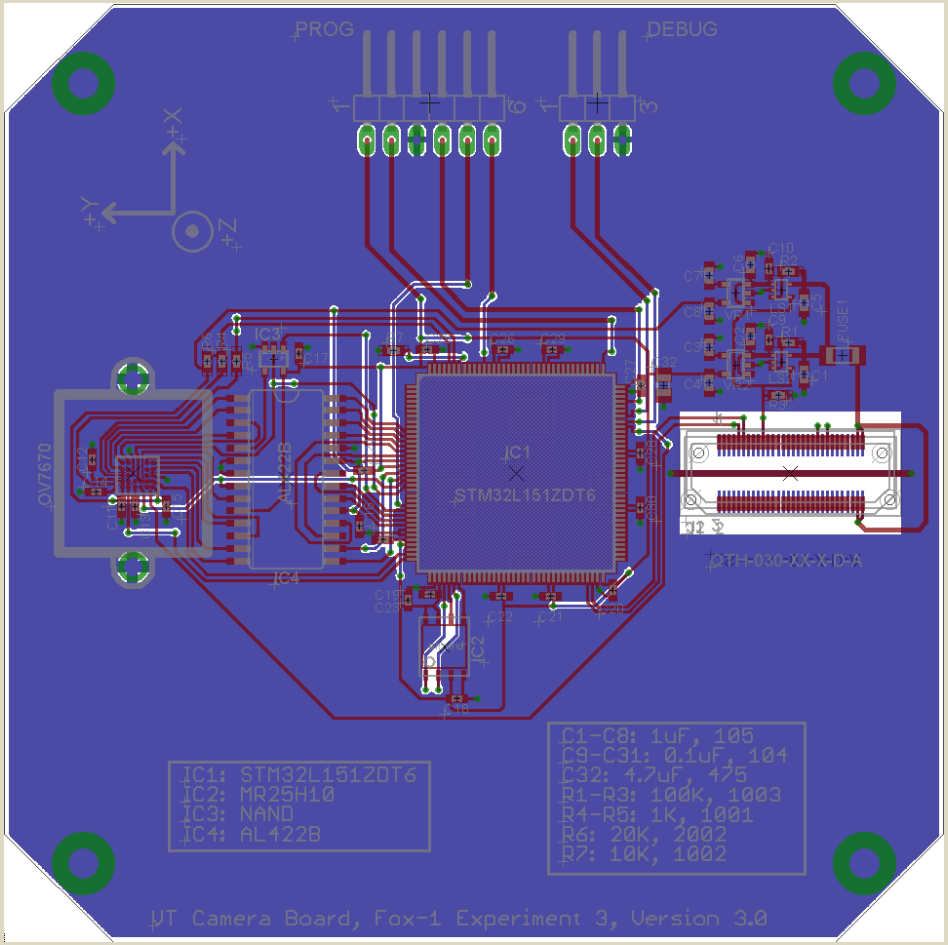
$$RES = \frac{238{,}533\ [m]}{800\ [pixels]} \cong 300\ {}^{m}/_{pixel}$$

$$300\ {}^{m}/_{pixel}$$

- before jpeg compression
- 2m antenna expected to be in field of view

Questions…???





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