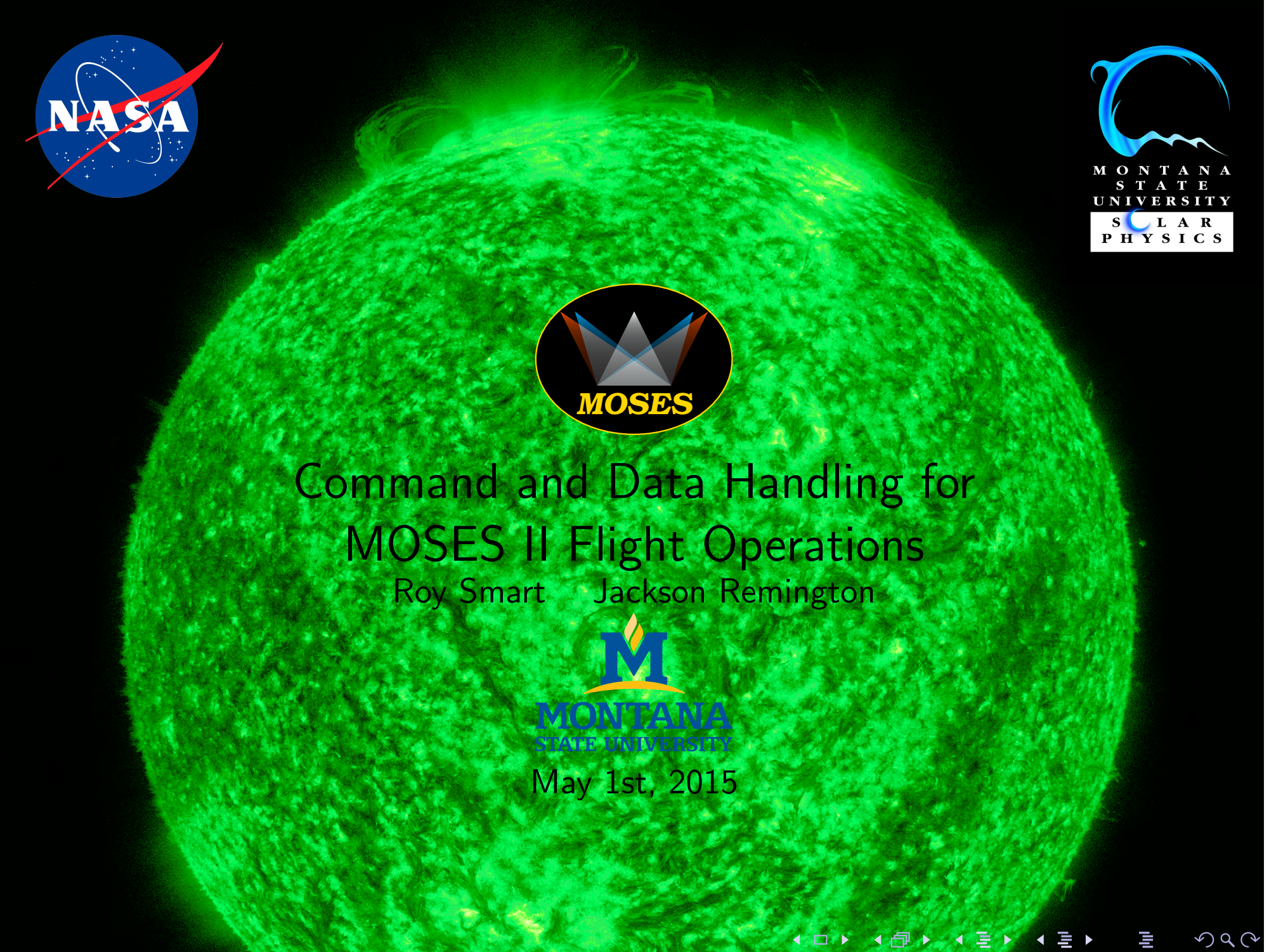

Command and Data Handling for MOSES II Flight Operations

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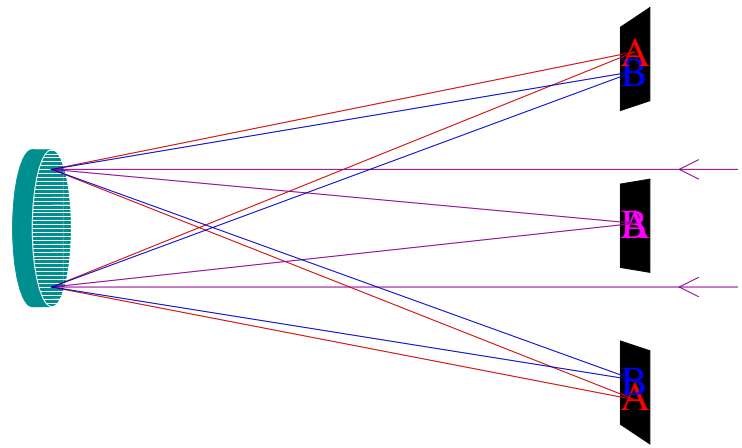
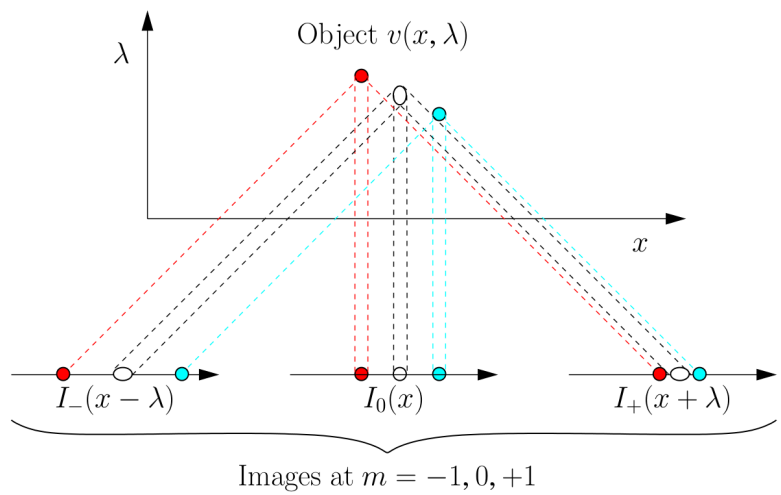
MOSES Scientific Goals

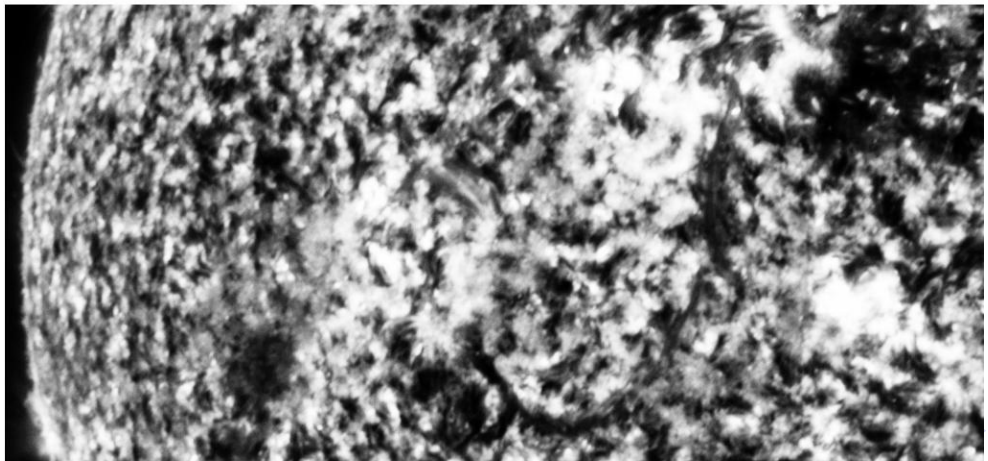
- Transition region Explosive Events (EEs)
- Extreme UltraViolet wavelengths (EUV)
  - Each of the three orders $(m = -1, 0, +1)$ are dispersed by multilayer diffraction grating
  - Observes Ne VII (465Å) and C III (459Å) spectral lines
- Atmospheric absorption of EUV requires space-based observations.
- Sounding rocket provides ~ 300-seconds above 160km.





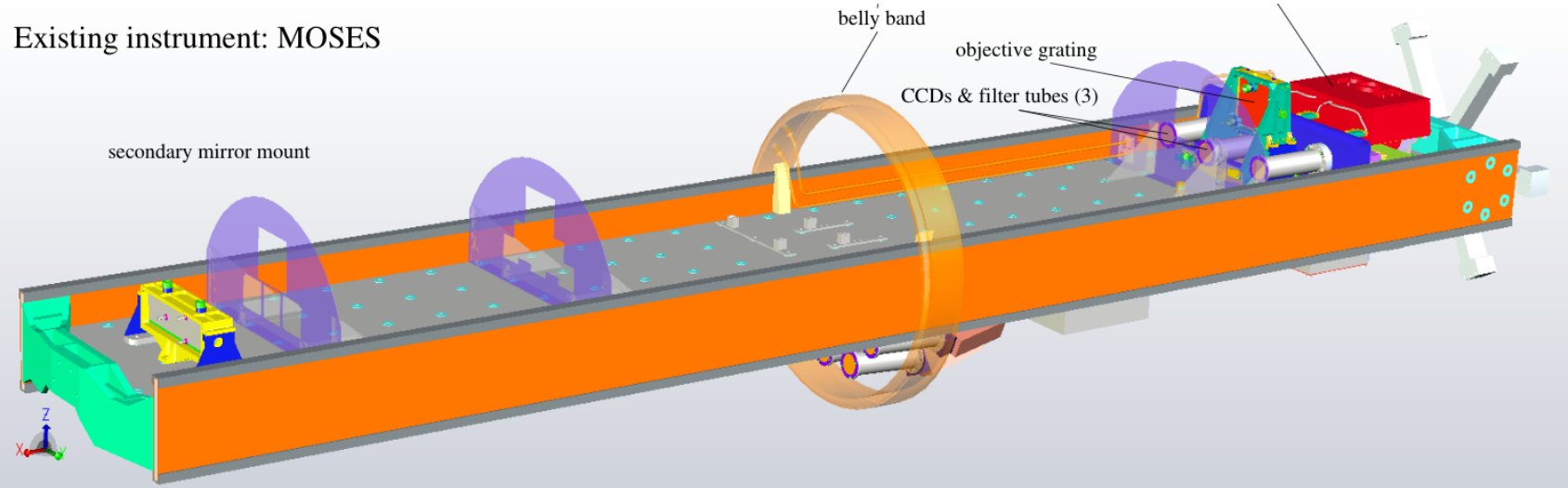
First Launch

- MOSES first launched on February 8th, 2006 [1].
  - Utilized a Black Brant IX sounding rocket
  - Observed the Sun in He II 304 Å
  - Identified a Transition Region Explosive Event.
- MOSES II
  - Since the previous launch the Hercules flight computer has failed, and a exact replacement is no longer available.
  - New flight computer was to be developed to act as a drop-in replacement for the old system.



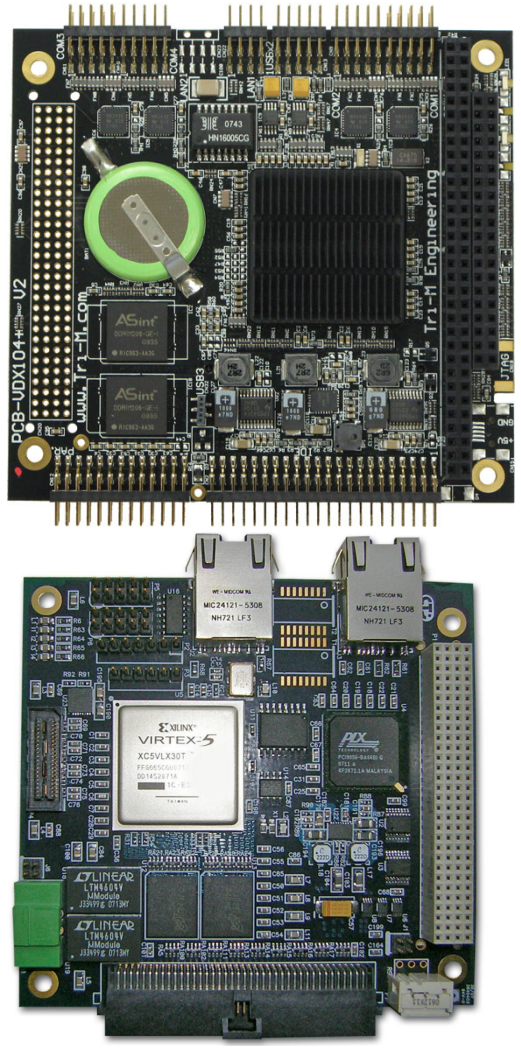
System Requirements

- Data characteristics
  - MOSES captures the sun in three spectral orders $m = -1, 0, 1$.
  - Each spectral order is captured by CCDs at 2048×1024 resolution.
- Challenges
  - Short flight time, FC must be responsive enough to capture real-time data.
  - Camera data is presented as 32 Mbit/s unbuffered 16-bit parallel data.



Hardware Overview

- Originally planned to replace the Hercules EBX with the TS-7600 embedded system.
  - Found that the FPGA implementation was too slow to keep up with the data rate.
- VDX104+ Flight Computer (Upper)
  - Moderates communications between the ground, cameras, and FPGA.
  - Executes custom flight software.
- Connecttech PCI104 FPGA (Lower)
  - Captures parallel data produced by cameras and saves it to a buffer.
  - Data buffer is copied to the VDX104+ via Direct Memory Access (DMA).

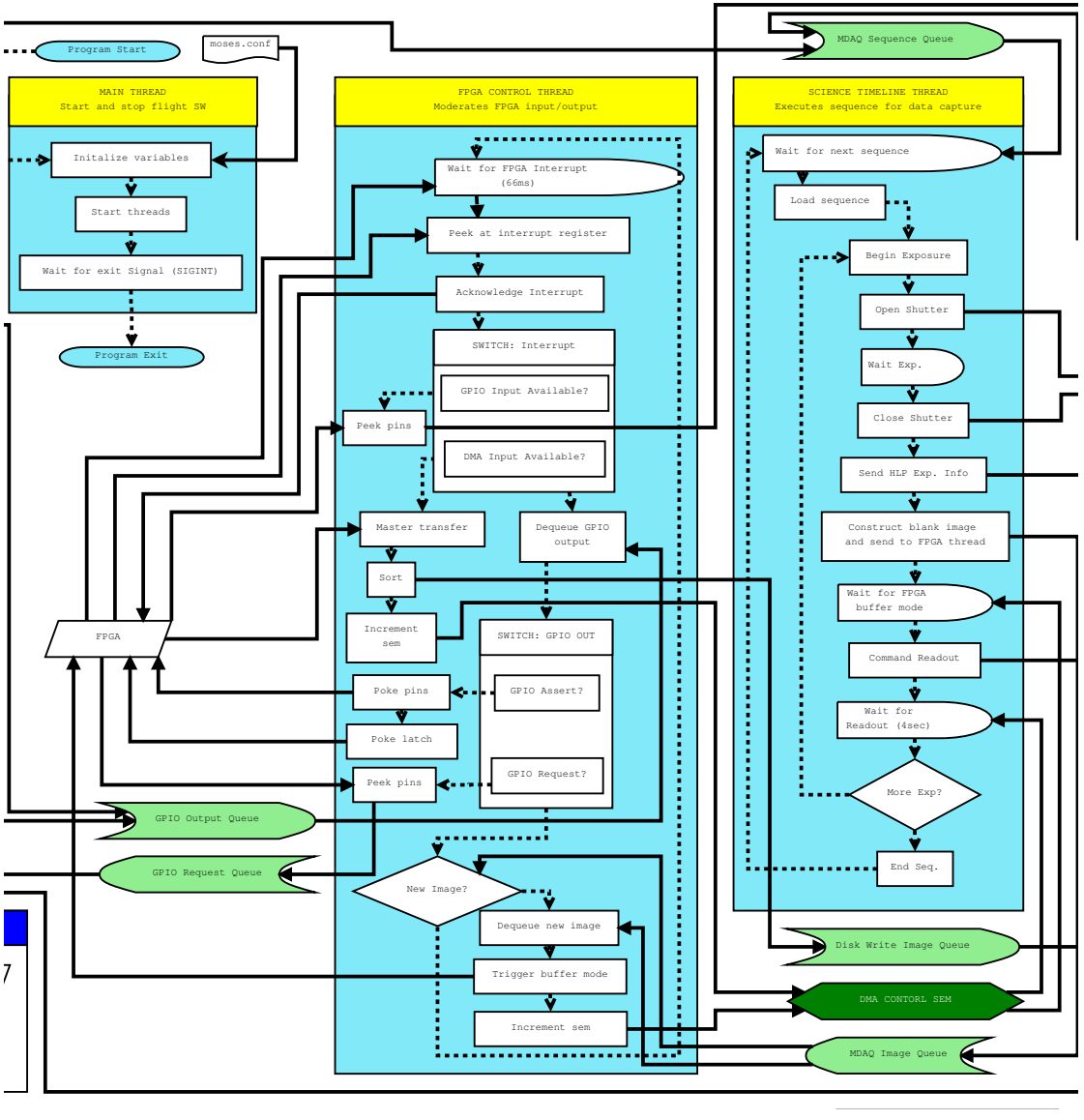


Software Enviroment

- VDX104+ Flight Computer
  - Ubuntu 10.04 GNU/Linux operating system with custom kernel.
  - Flight Software written in the C programming language.
  - Synclink and ConnectTech software drivers for interfacing with hardware.
- Ground Station Computer
  - Ubuntu 14.04 GNU/Linux OS
  - Ground station software written in Java.
  - High-Speed Telemetry software written in the C programming language.

THE C PROGRAMMING LANGUAGE

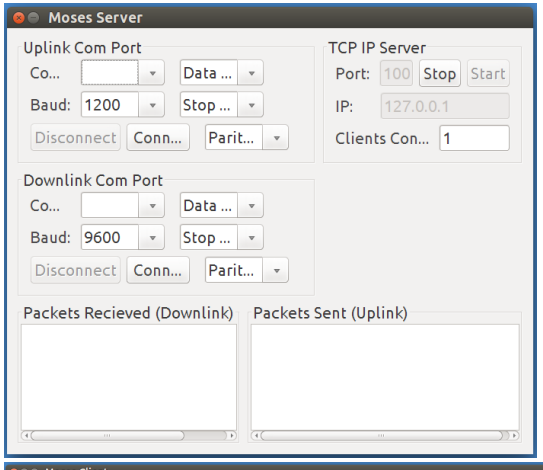
Flight Software

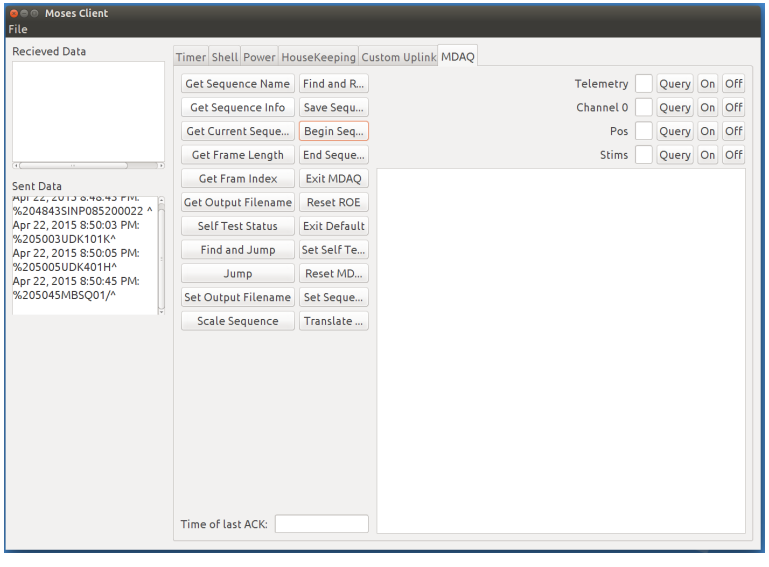


- Organized into eight concurrent threads for real-time IO.
- Main Thread
  - Initializes all child threads
- Science Timeline Thread
  - Executes exposure sequences
  - Informs FPGA Server of impending images
- FPGA Server Thread
  - Waits for HW interrupts indicating Timers
  - Initiates DMA transfer once image is ready

Ground Station

- Server module: mediates communications between client and payload.
- Client module: transmits Housekeeping Link Protocol (HLP) packets to server via ethernet.
- Debugging communication
  - Serial console
  - Ethernet
- Main in-flight communication
  - Pre-defined Timers
  - Uplink push-button switches





Capturing Data

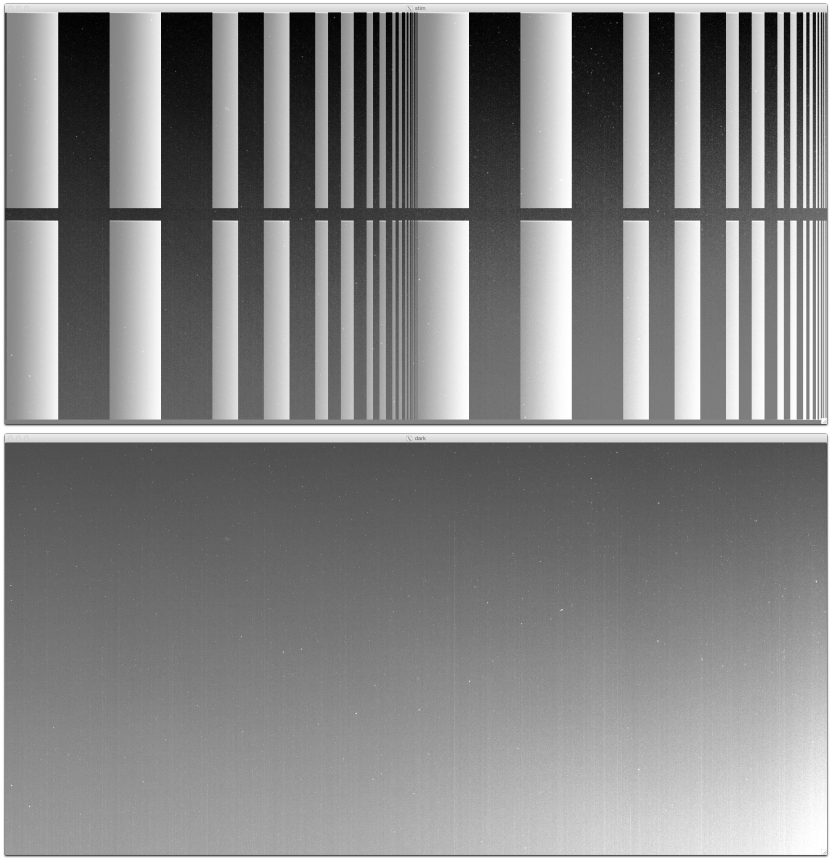


Figure 1 : STIMS test image (upper) and a dark exposure (lower).

- ReadOut Electronics (ROE)
  - Each CCD pixel reports 14-bit value proportional to total photons detected over exposure time.
  - FPGA captures these pixel-maps in three 2-megapixel images
- Flight Software
  - Opens and closes shutter.
  - Commands ROE to transmit data after exposure complete.
  - Copies data from FPGA to disk.

Data Retrieval

Figure 2 : Synclink USB Adapter (above) and MOSES I after landing at WSMR (below)

- Data is recovered off of SD card after landing.
- High-Speed Telemetry at 10 Mbit/s.
  - Provided as backup in the event the payload is not recovered.
  - 10.1 s per image.
  - Each image takes > 5 s.
- Synclink USB Adapter
  - Transmitting and receiving units.
- Groundstation Laptop
  - receiveTM program with IDL image viewer.

Next Launch

- Scheduled for launch August 20th.
- Horizontal test
  - Proving control and functionality over other payload components.
  - Successful STIMS and dark exposure test confirms ROE functionality.
  - Shutter and other subsystems have yet to be tested.
- Flight model still needs to be completed.
- System must undergo thermal and vibrational testing.

References and Acknowledgements

This work is supported by NASA grant NNX14AK71G.

Charles C. Kankelborg J. Lewis Fox and Roger J. Thomas.
A transition region explosive event observed in He II with the moses sounding rocket.
The Astrophysical Journal, 719:1132–1143, August 2010.
http://solar.physics.montana.edu/MOSES/papers/2010/FoxKankelborgThomas2010.pdf.