

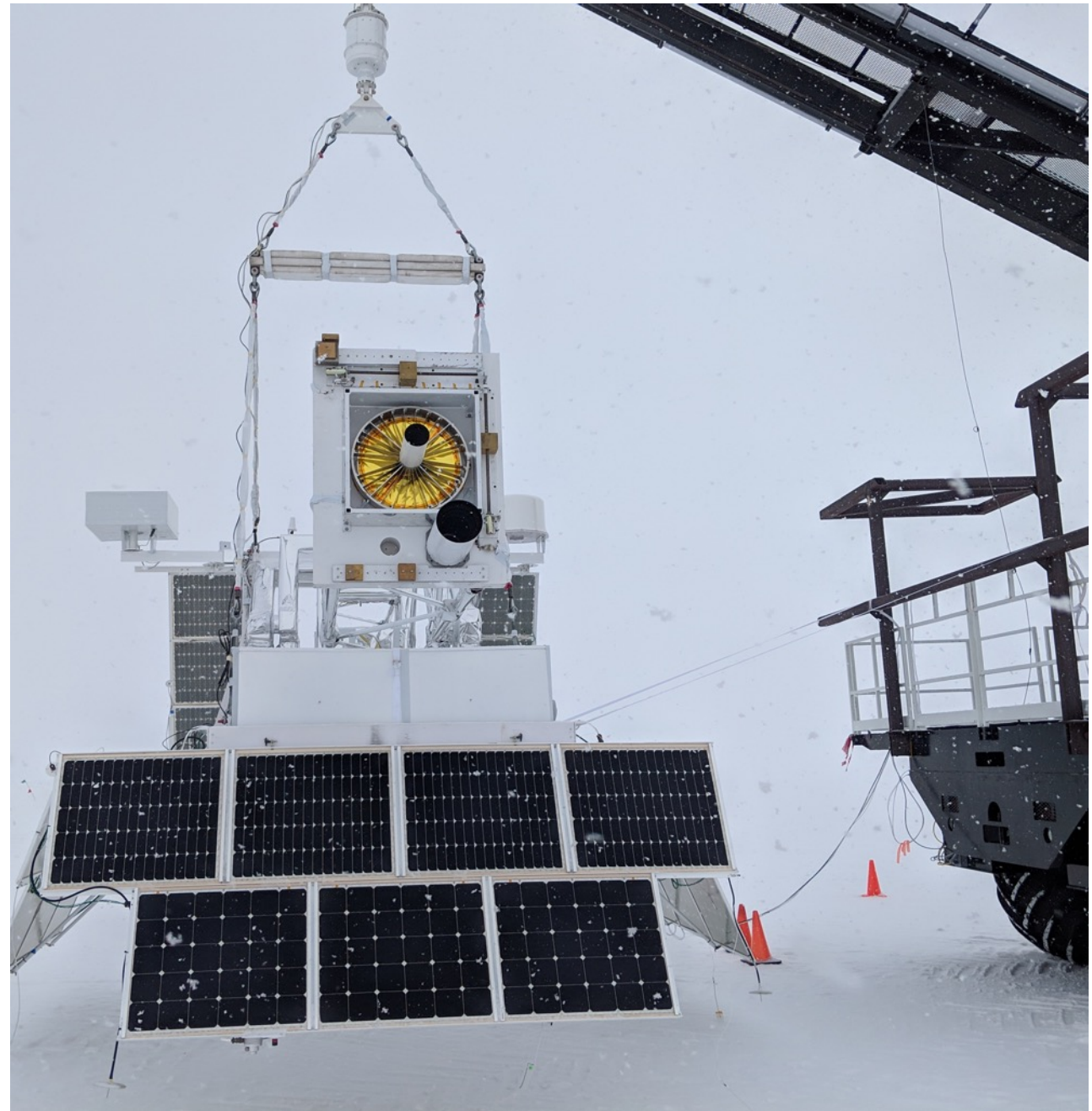
Low Cost Star Tracker for Suborbital Platforms Design and Flight

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NASA Goddard Space Flight Center's

Wallops Flight Facility





Introduction

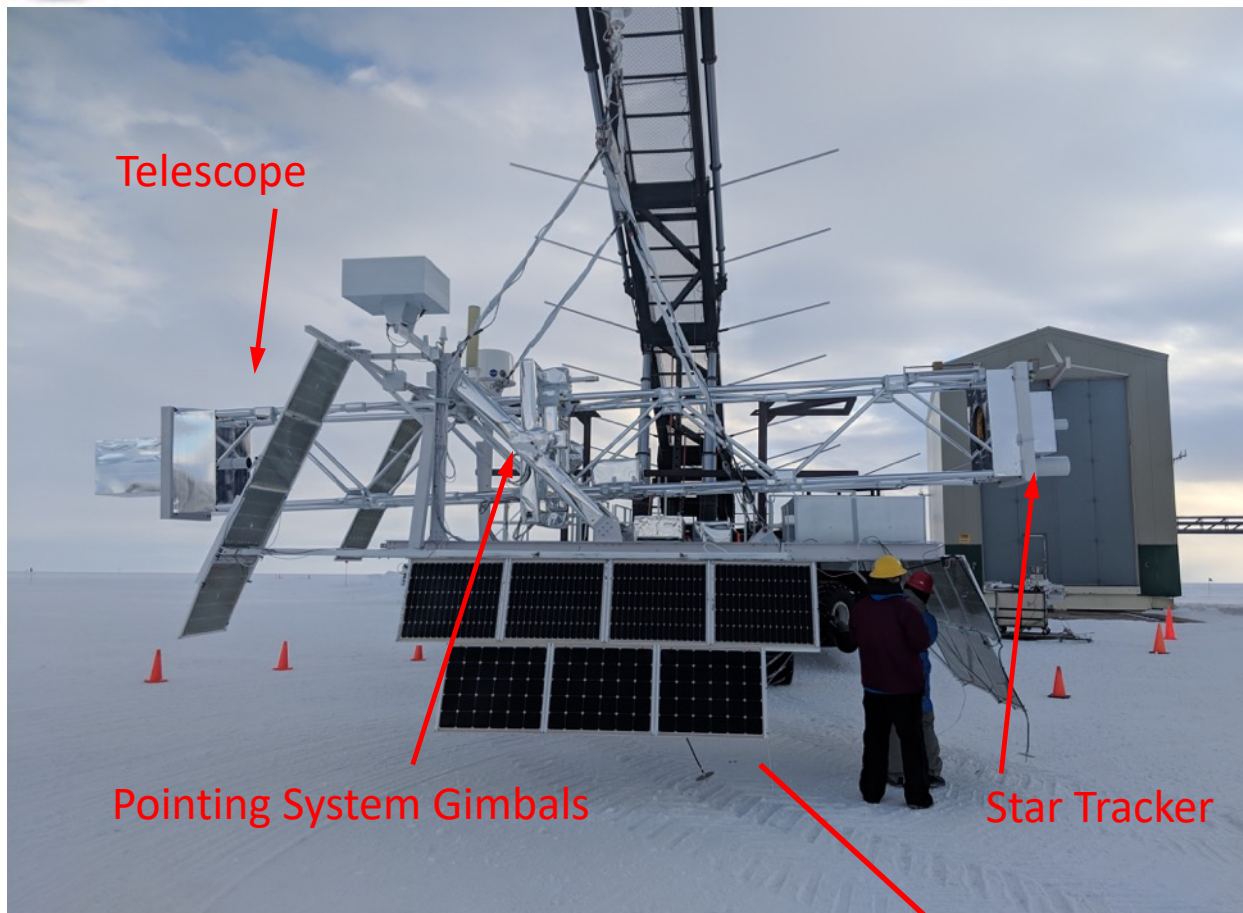


- Celestial Attitude Reference Determination System (CARDS)
 - System developed to utilize commercial off the shelf (COTS) processors, cameras and lens to quickly deploy them with a range of algorithms providing attitude knowledge to suborbital platforms
 - Developed to support sounding rocket and balloon applications
- Covered here
 - Design of the system
 - Flight Results
 - Current development



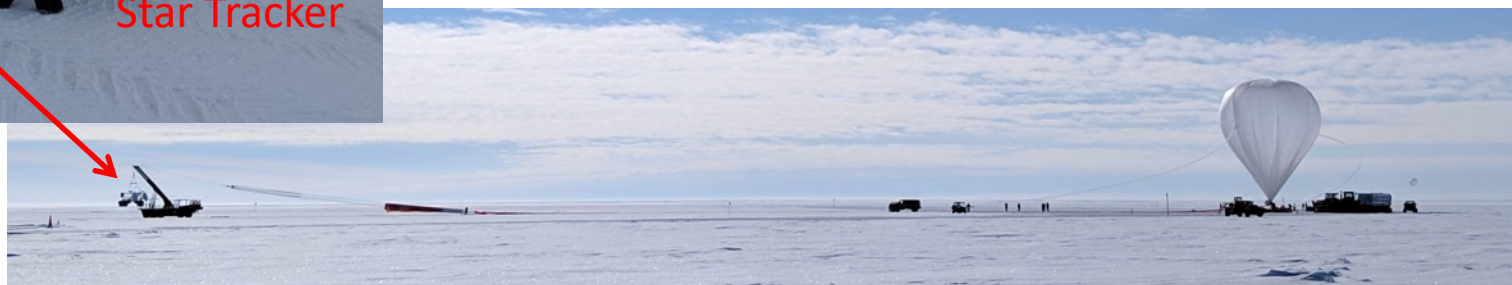


Balloon Platforms



- Balloons up to ~ 40 mcf
 - Payload up to ~ 5000 lbm
 - Altitude up to 130 kft
- Wallops Arc-Second Pointer (WASP) pointing system
 - Point instruments to arcsecond level
 - Subarcsecond jitter

X-Calibur, McMurdo 2018





Sounding Rockets Platforms



- Sounding rockets
 - Mostly DoD surplus rockets in 2-4 stages
 - Payloads up to ~1500 lbm to several hundred km
 - Hang times from 5-20 minutes
- Celestial Attitude Control System
 - Subarcsecond pointing with cold gas thrusters
 - Currently uses UWisc ST5000 star tracker with LN-251





Design Approach



- Hardware
 - COTS COTS COTS
 - Low cost a priority and system utilizes COTS cameras, lens and processors
 - In-house software to keep system nimble to meet the changing needs of customers
- Software
 - Relying heavily on abstraction in algorithm classes in order to make system highly configurable
 - XML configuration file
 - Allows for single process to be used for a wide range of applications



CARDS Mix and Match

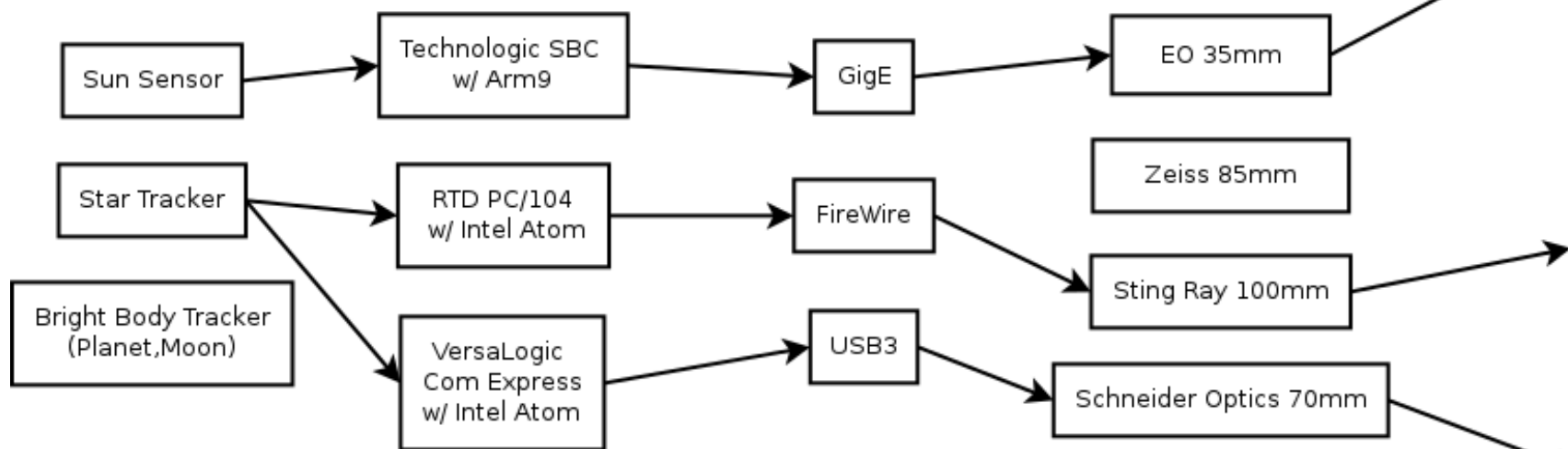


Algorithm

Processor

Camera

Lens



Sun Sensor



Daytime Star Tracker



Sounding Rocket Star Tracker

7 different configurations have been flown



Design for WASP Daytime Star Tracker



- Camera
 - FLIR (Pt Grey) Firewire Sony ICX 674 CCD
- Lens
 - Sting Ray 100mm/F1.4
- FOV = 5.0 x 3.7 deg
- Filter
 - Midopt LP645 longpass filter
- Processor
 - RTD IDAN PC/104
 - Intel Atom 1 GHz Dual Core
- Star Tracker Algorithm
 - Pyramid style Lost-In-Space
 - Nearest neighbor tracking

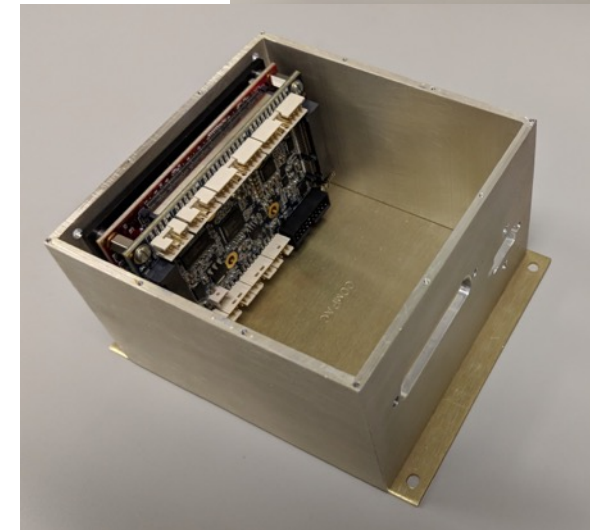




Design for Sounding Rockets



- Camera
 - FLIR (Pt Grey) Sony IMX 252 CMOS
- Lens
 - Schneider Optics Tele-Xenar 70mm/F2.2
- FOV = 5.8 x 4.3 deg
- Processor
 - Versallogic Com Express Type 10 SBC
 - Intel Atom 1 GHz Dual Core
 - Connectech Com Express Type 10 carrier card
- Star Tracker Algorithm
 - Pyramid style Lost-In-Space
 - Nearest neighbor tracking





Flight History



- **Balloons**

- Hysics2 (Aug 2014)
 - GigE Sun Sensor and GigE Bright Body Tracker
- OPIS (Oct 2014)
 - GigE Bright Body Tracker
- X-Calibur (Sept 2016)
 - FW Daytime Star Tracker
- X-Calibur2 (Dec 2018)
 - FireWire Daytime Star Tracker
- BITSE (Sept 2019)
 - FireWire Sun Sensor
- Picture-C (Sept 2019)
 - FireWire Daytime Star Tracker

- **Sounding Rockets**

- Subtec 7 (May 2017)
 - FireWire Star Tracker
- Subtec 8 (Oct 2019)
 - FireWire Star Tracker



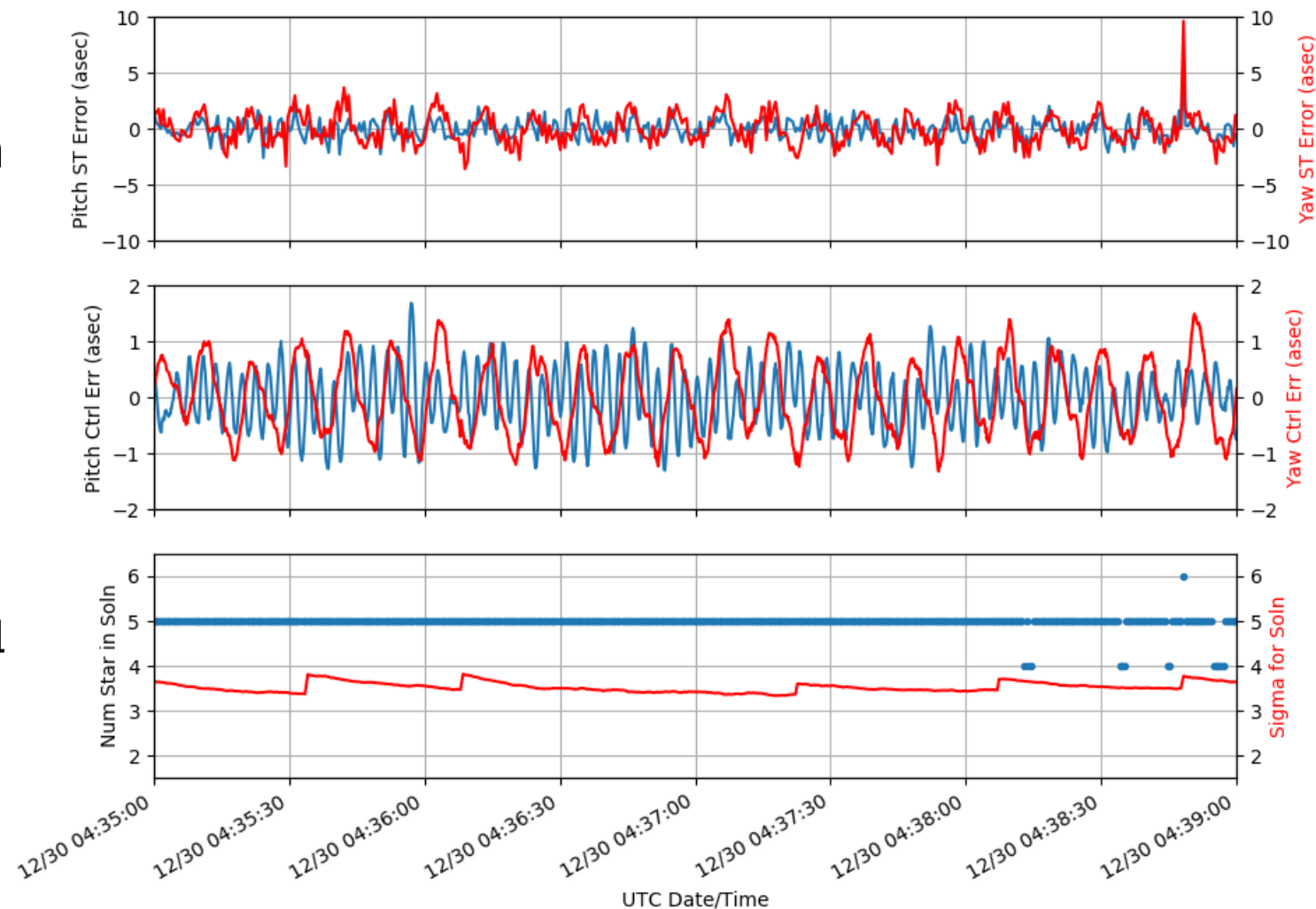
Subtec 8 launch



X-Calibur Daytime Star Tracker



- 2018 McMurdo Flight
- ST error during daytime on primary science target
 - 2.0 asec ($1-\sigma$)
- High background levels seen
 - Primary target had at least 3 bright stars always visible
 - Secondary target had only 1
 - PMCs isolated as cause

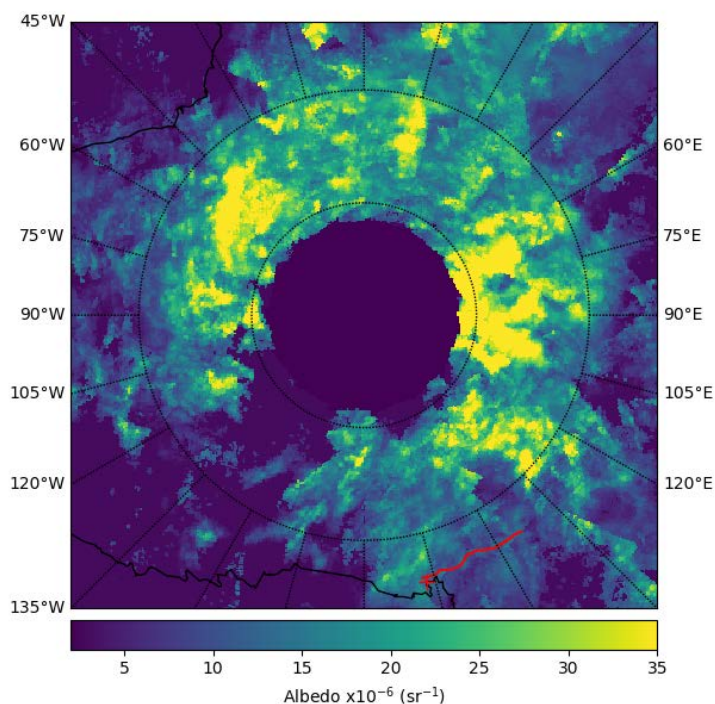




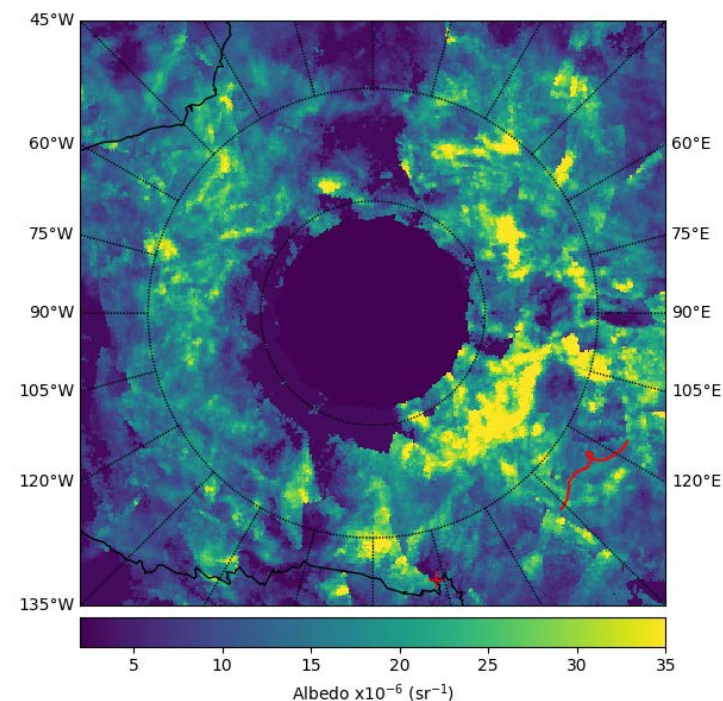
Polar Mesospheric Clouds



- High altitude clouds made of ice crystals
- Occur over polar regions during summer months



December 30, 2018



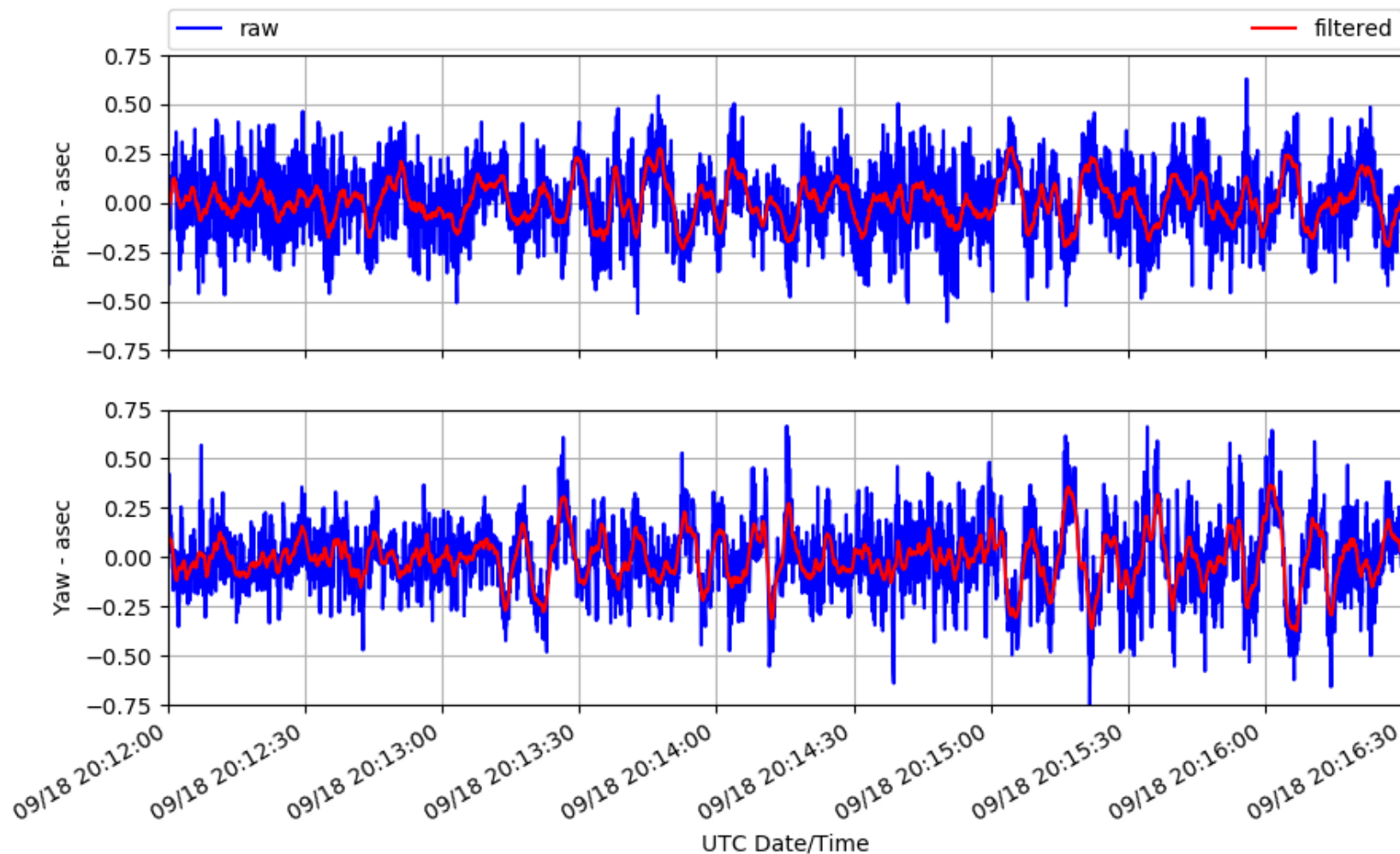
December 31, 2018



BITSE Sun Sensor



- Balloon Sun Sensor
- Blue: pointing error
- Red: window filter
 - Account for lower frequency control error
- NEA: difference
 - 0.15 asec ($1-\sigma$)

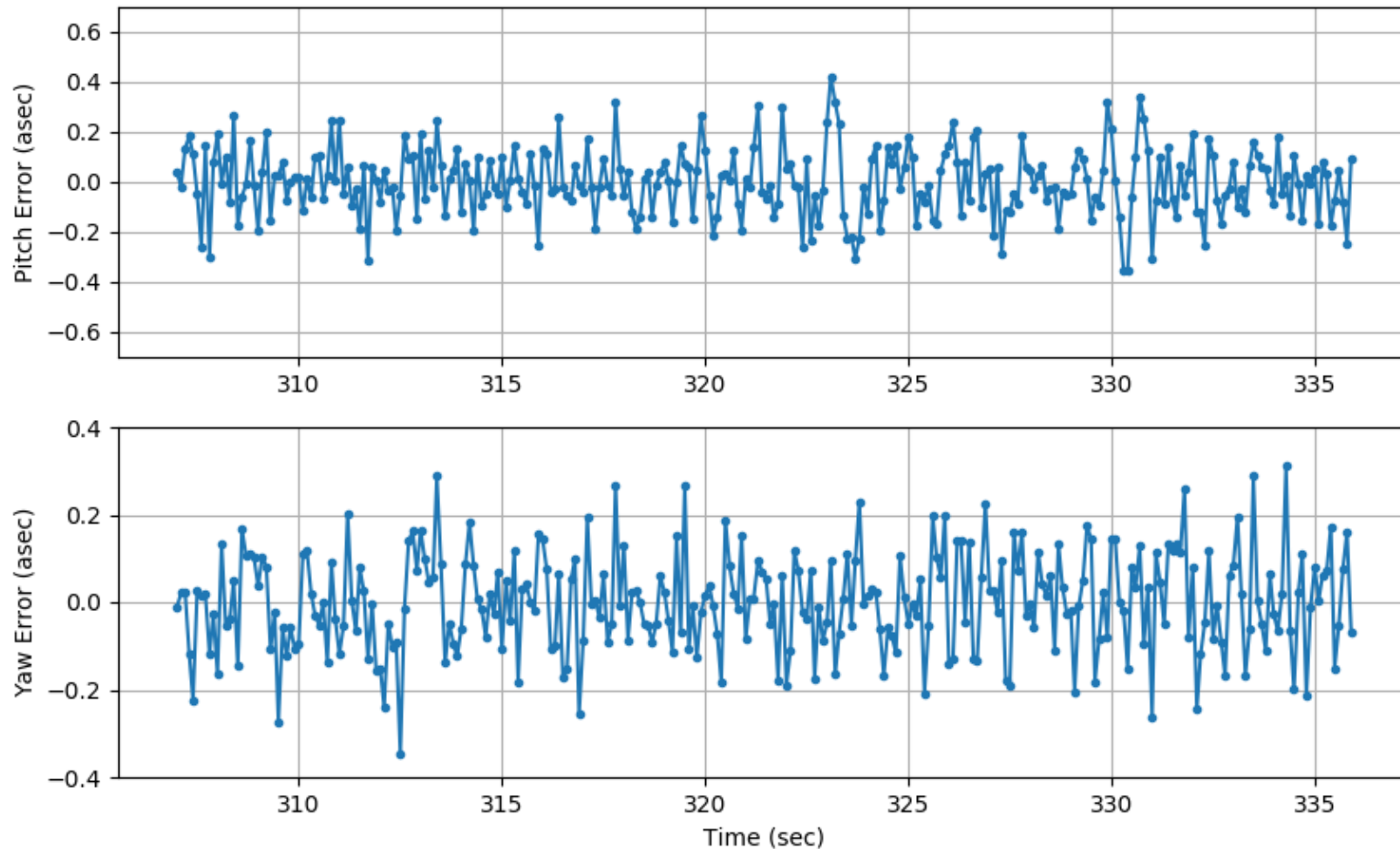




Sounding Rocket Results



- Subtec 8
- “Error” is based on difference from filtered output
 - Removes control system motion
- 0.14 asec RMS noise equivalent angle

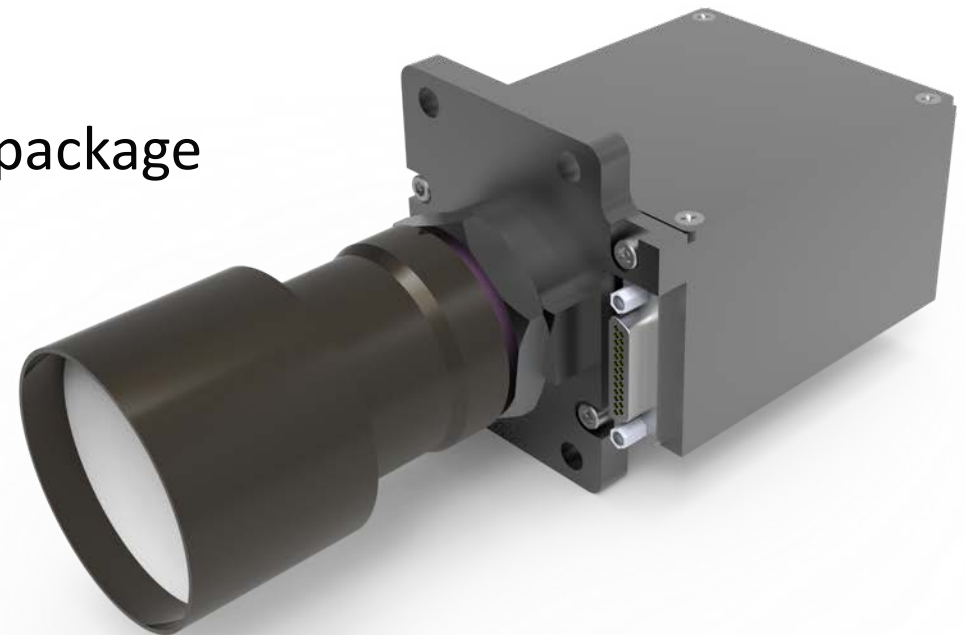




Integrated Head Development



- Moving to custom integrated design for sounding rockets
- Vision Components VCSBC nano Z
 - Smart camera based on Xilinx Zynq
 - Image processor and dual core Arm 9 in one package
 - Sony IMX 252 sensor
- Eliminates a number of things
 - No processor box
 - No high speed interfaces
 - Thus no expensive bulk head connectors
- Single small head with low power
 - 1 lbm, 3 W





Future Work



- Continued mission support for balloons
 - 3 flights already on the books for next 4 years
- Daytime star tracker sensitivity
 - Image stacking to increase star SNR
 - Increase robustness to PMCs
- Integrated head for sounding rockets
 - Build and qual test units
 - Secure a test flight

