Low Cost Star Tracker for Suborbital Platforms Design and Flight

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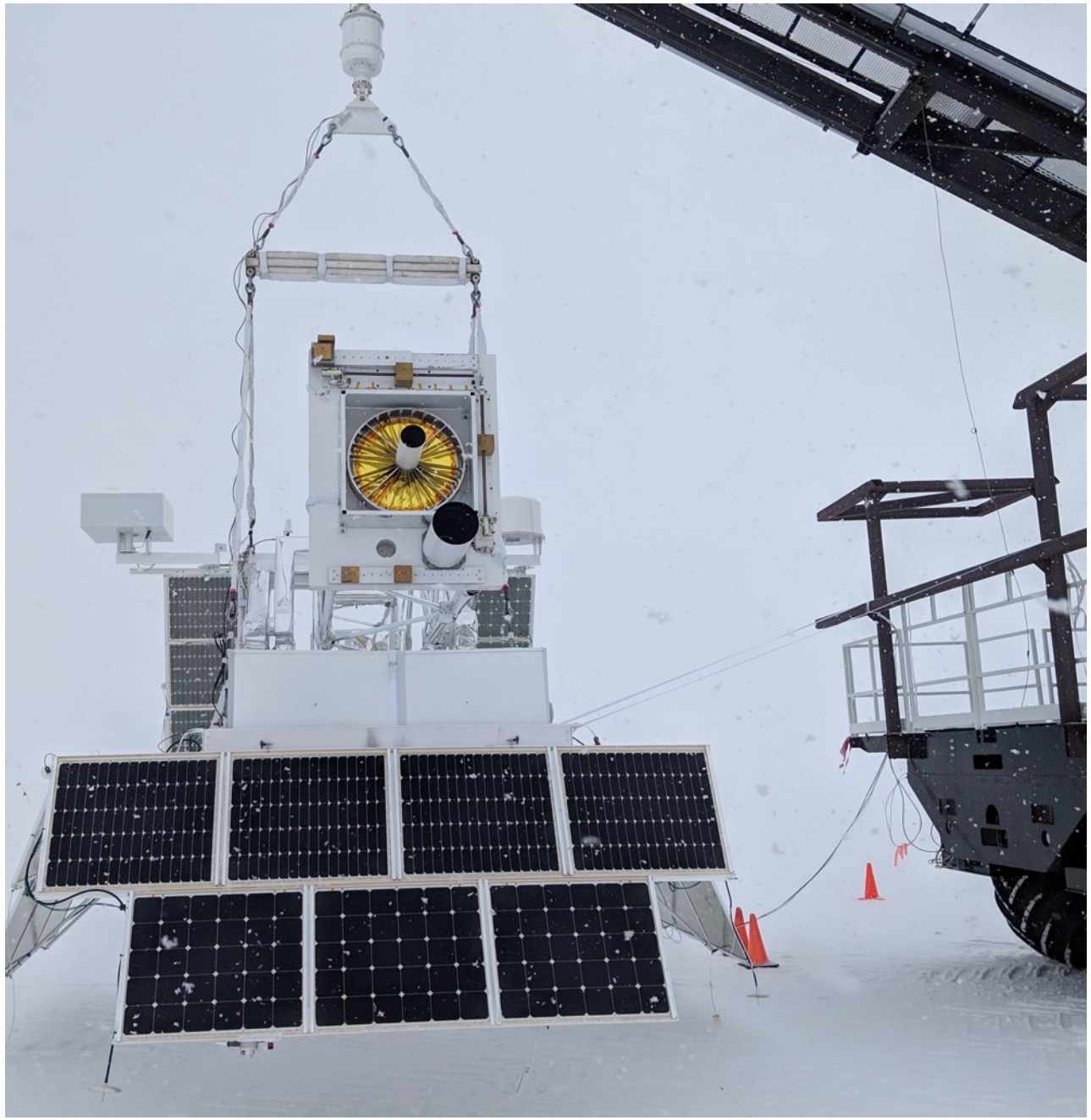
12/9/2019

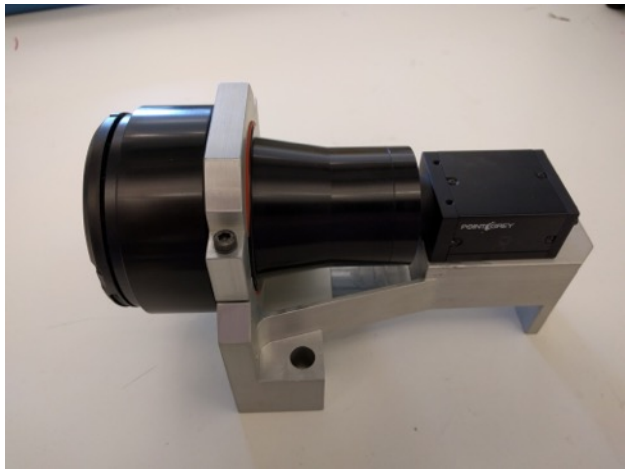
NASA Goddard Space Flight Center's

Wallops Flight Facility

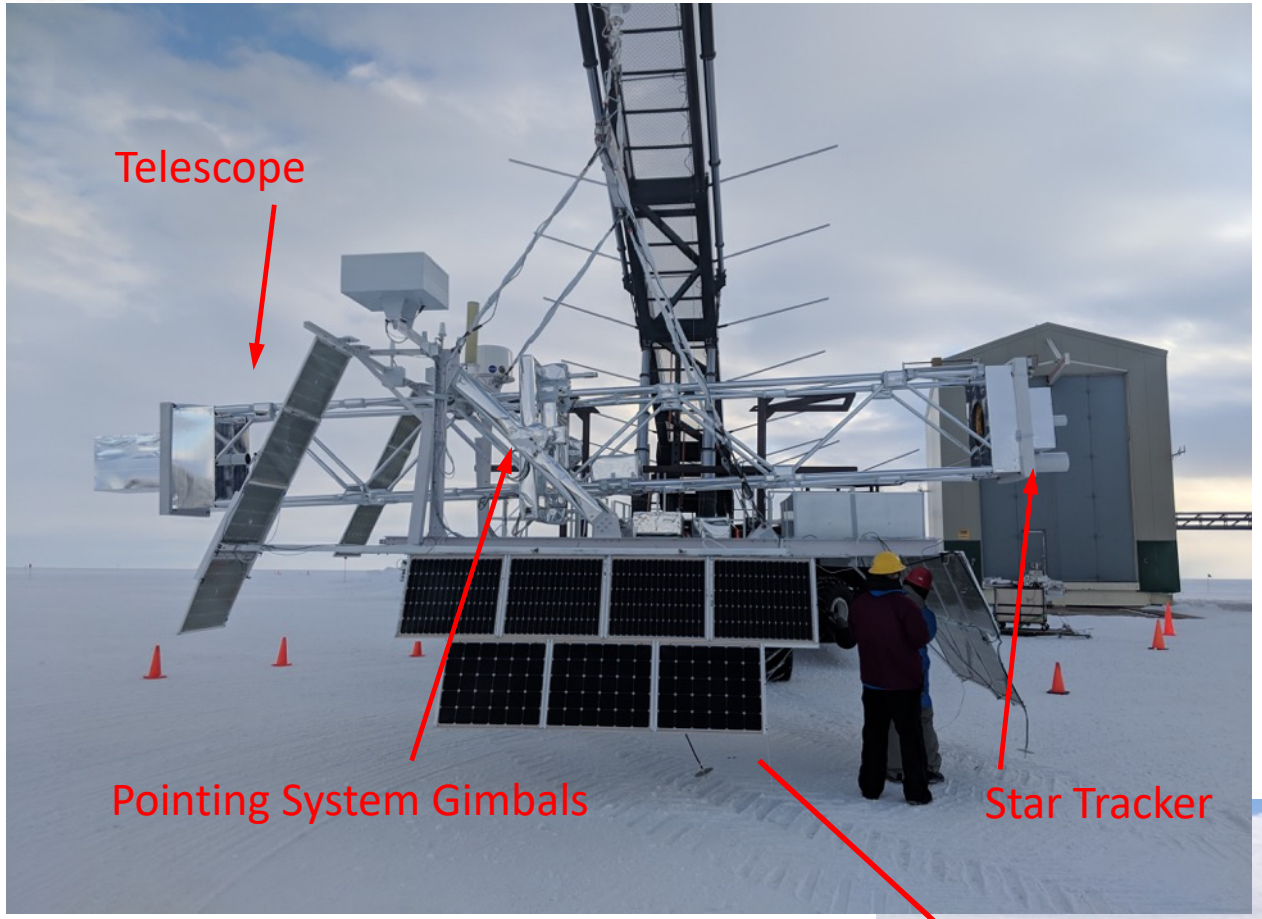


Introduction

- 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



X-Calibur, McMurdo 2018

- 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

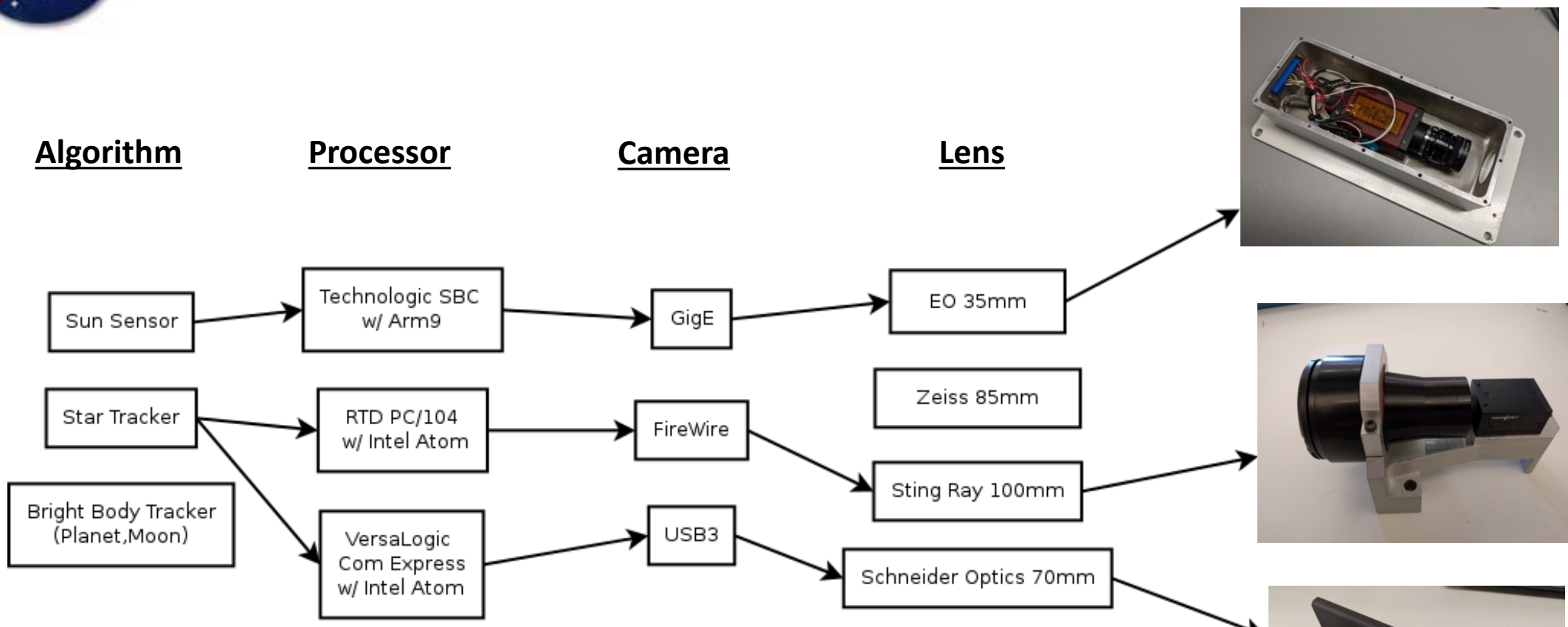
Sounding Rockets Platforms

- 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

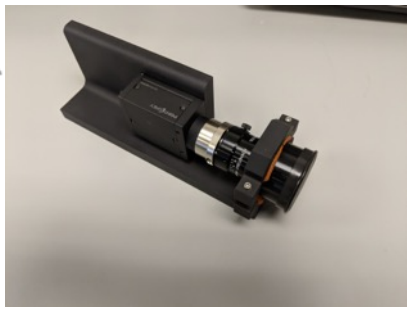
- Hardware
  - COTS COTS COTS
  - Low cost a priority and system utilizes COTS cameras, lens and processors
  - In-house software to keep system nimble to meet the changing needs of customers
- Software
  - Relying heavily on abstraction in algorithm classes in order to make system highly configurable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

CARDS Mix and Match



Sun Sensor

Daytime
Star Tracker

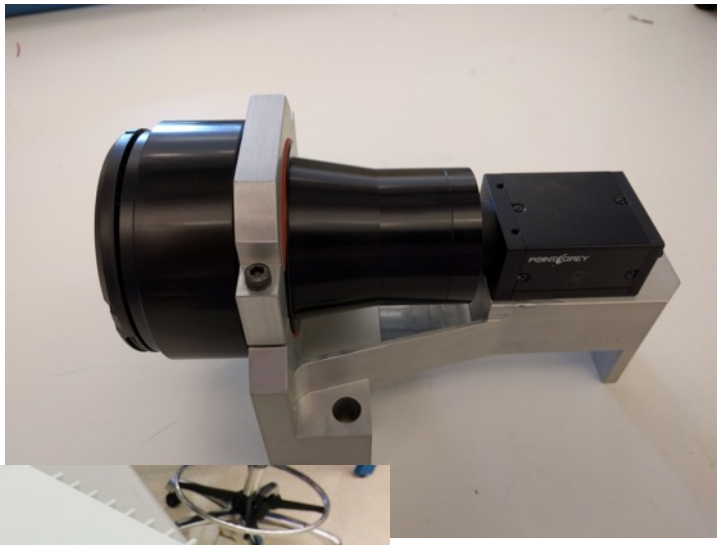


Sounding Rocket
Star Tracker

7 different configurations have been flown

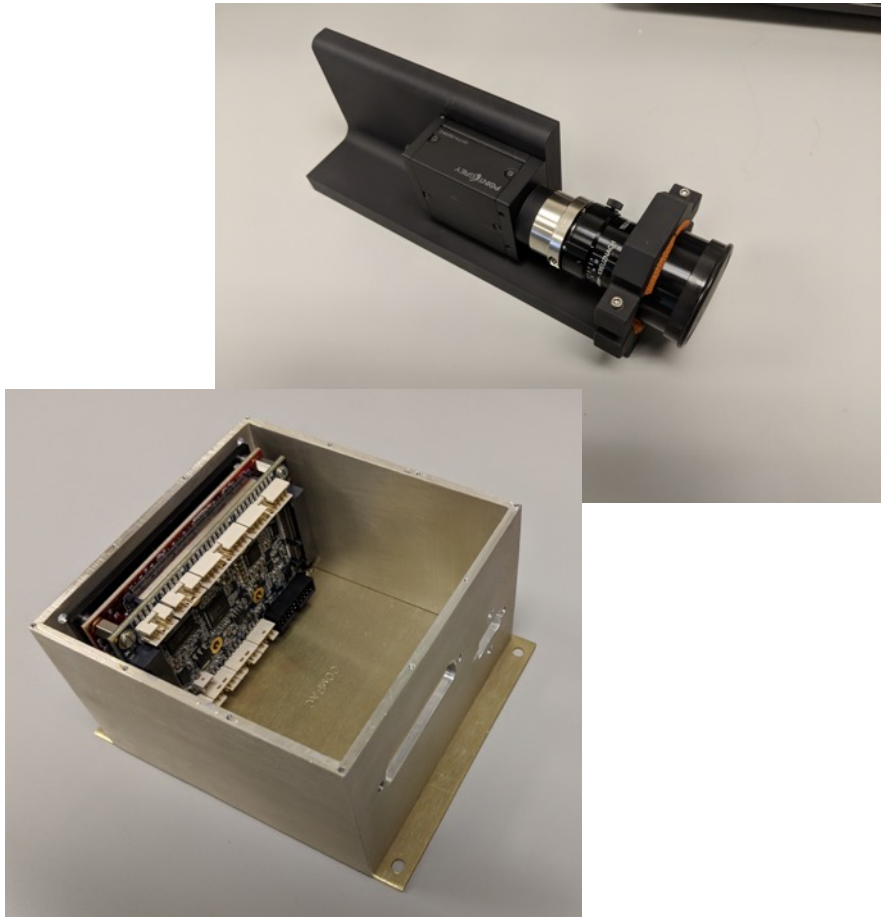
Design for WASP Daytime Star Tracker

- 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
  - Versalogic 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



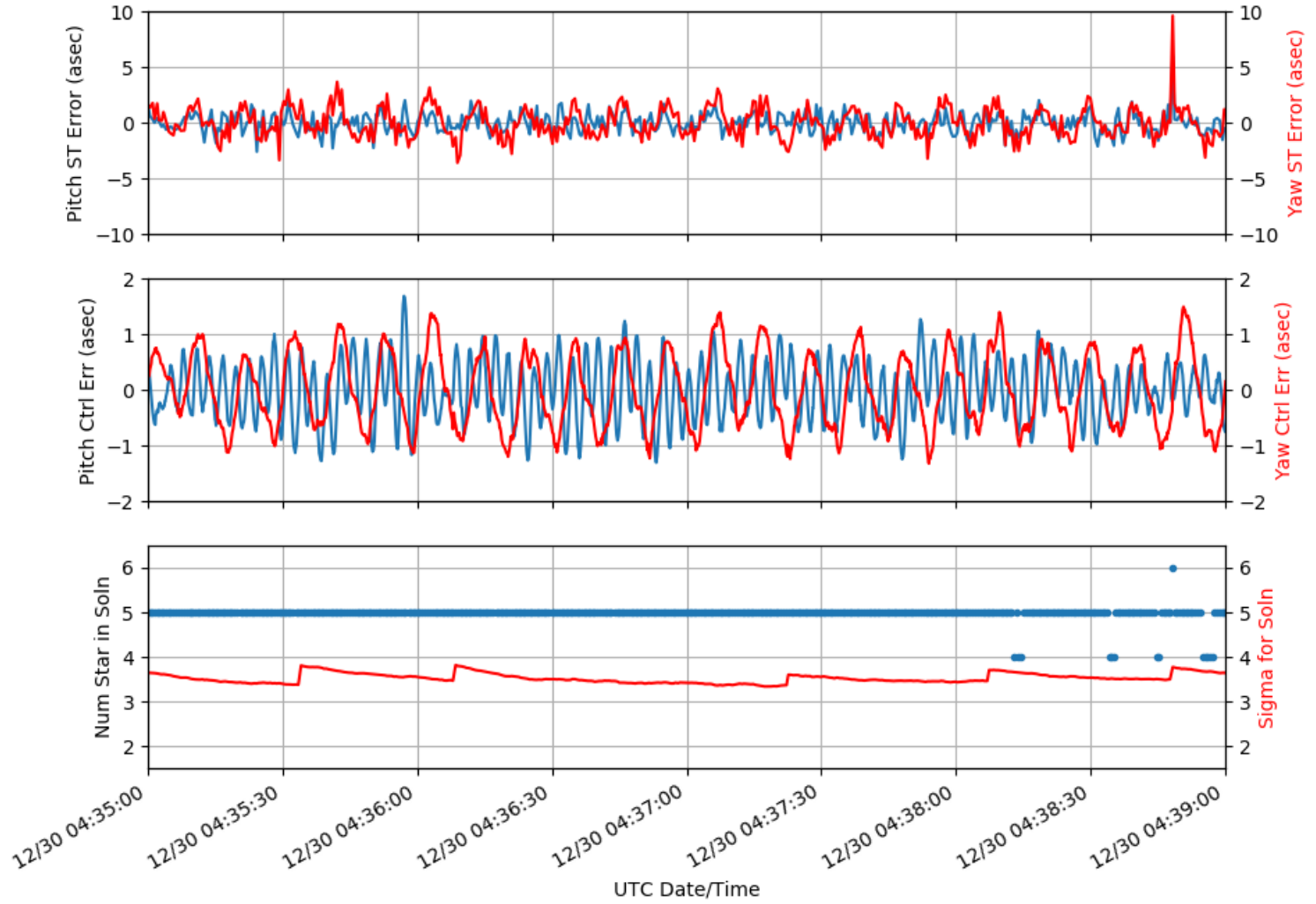
Flight History

- 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

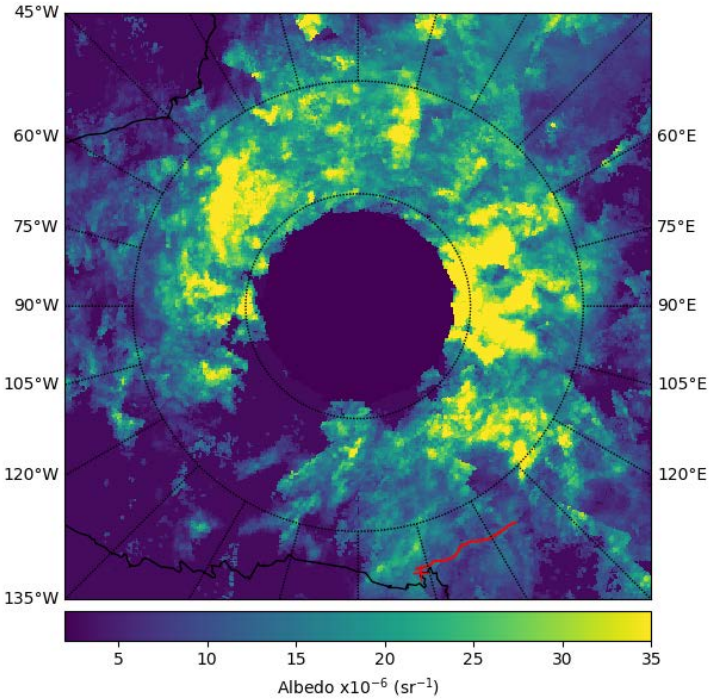
X-Calibur Daytime Star Tracker

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

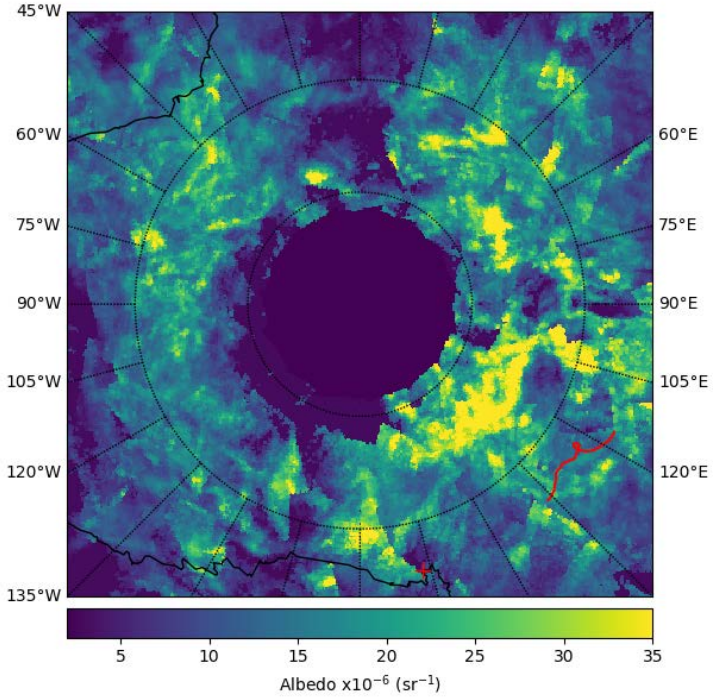


Polar Mesospheric Clouds

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



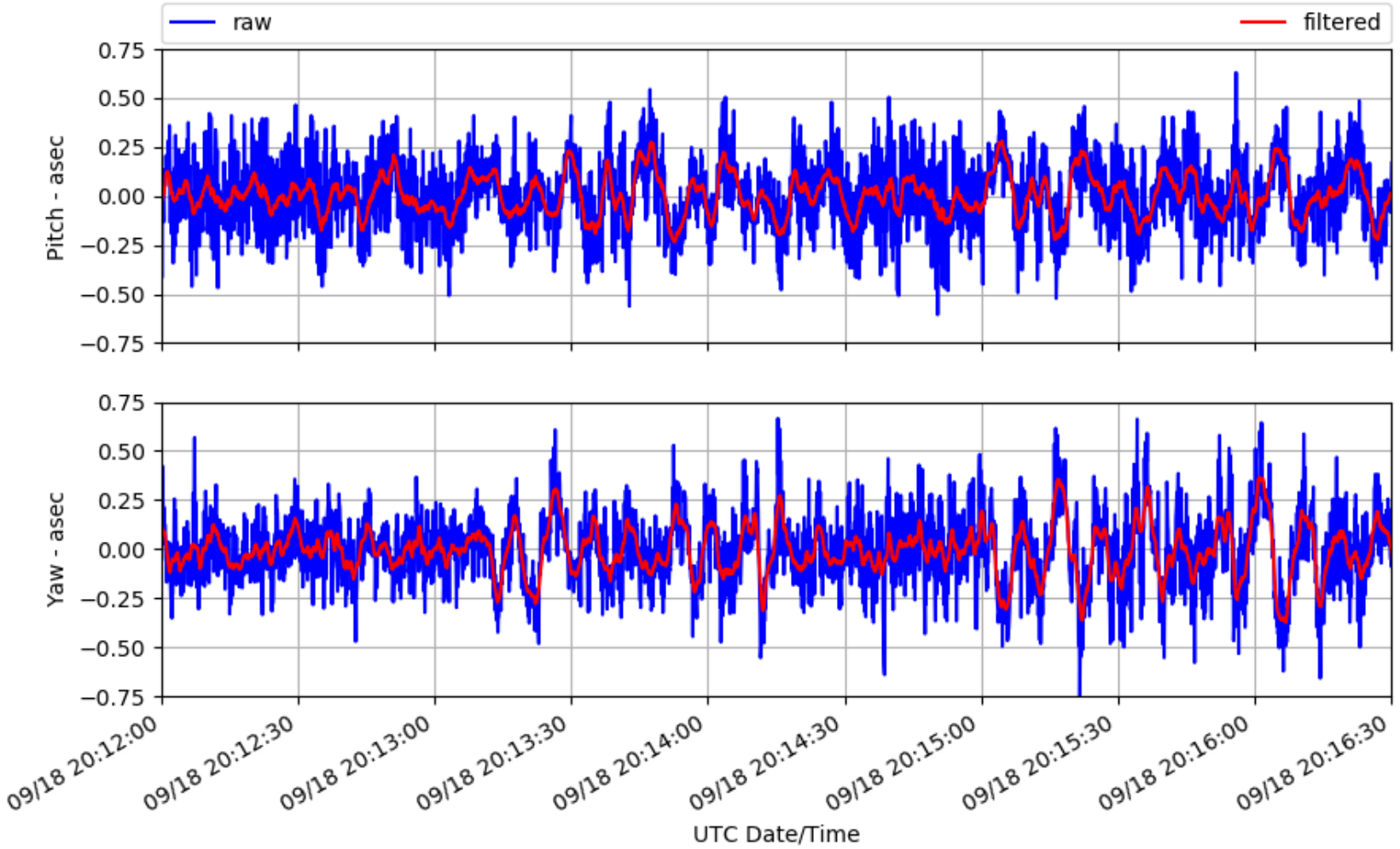
December 30, 2018



December 31, 2018

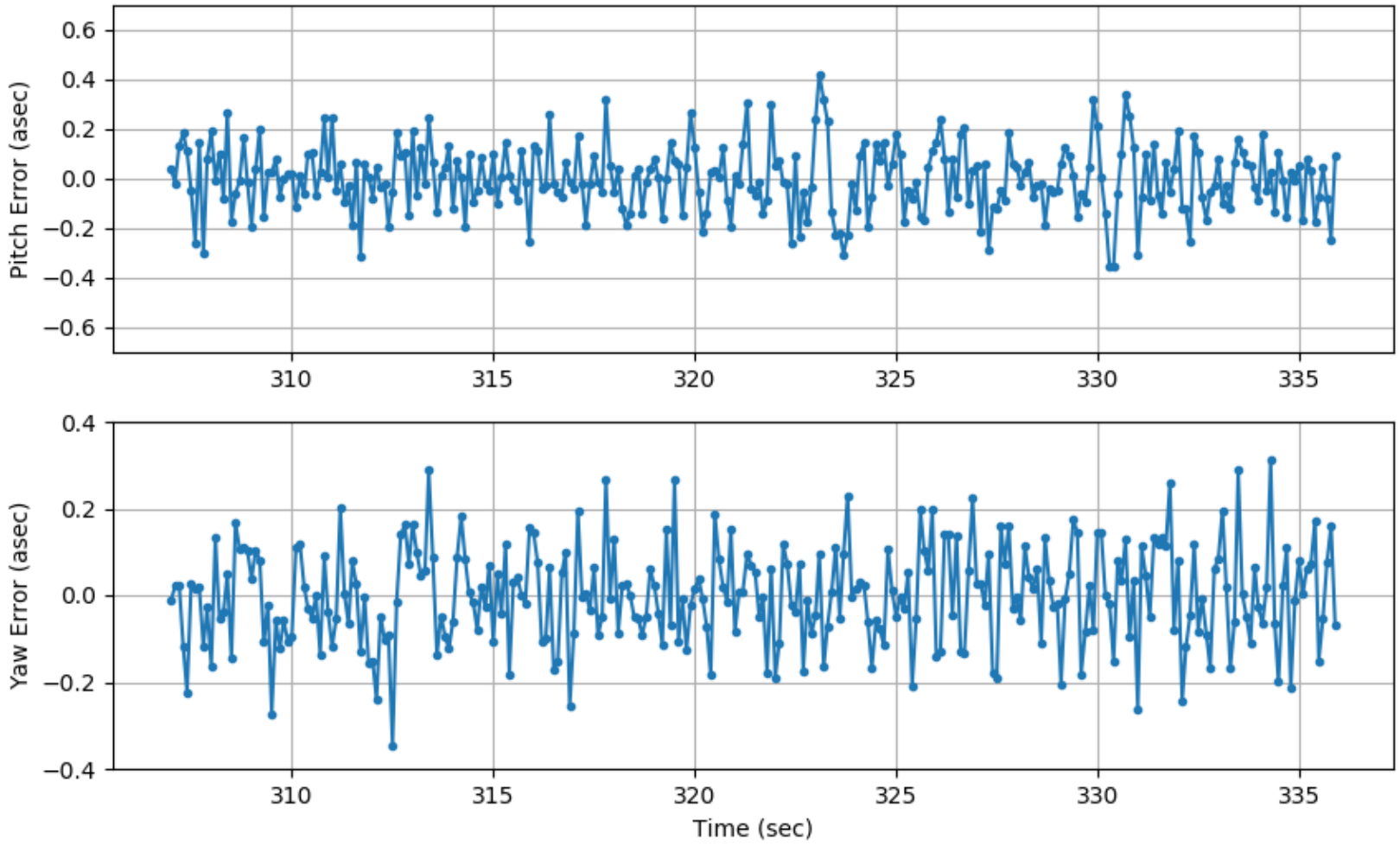
BITSE Sun Sensor

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



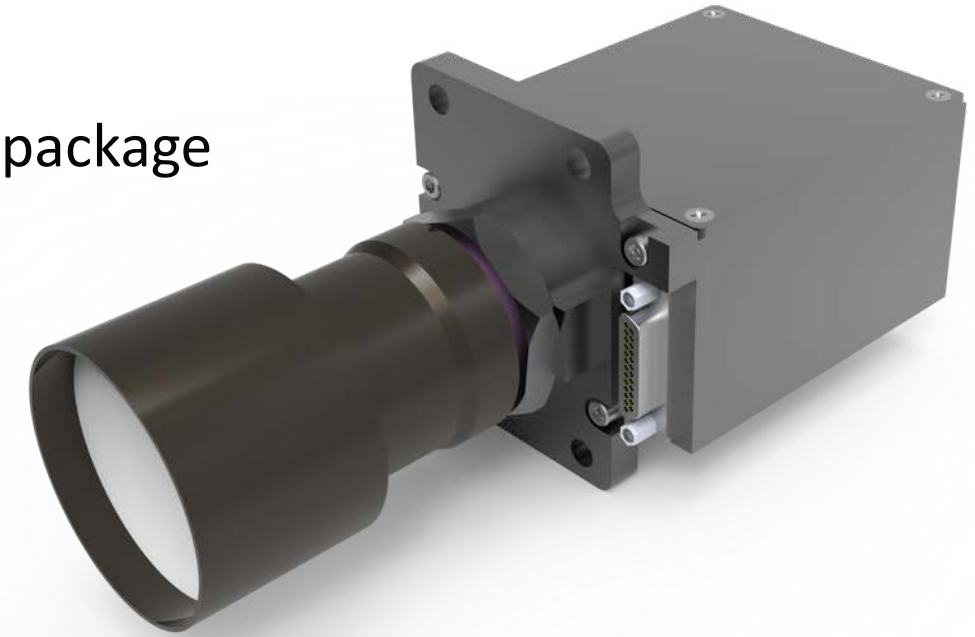
Sounding Rocket Results

- 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