80NSSC22K0394, High Altitude Thermal IR Cloud Polarimetry

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1 Introduction

The Infrared Channeled Spectro-Polarimeter (IRCSP) measures the spectrally resolved angle and degree of linear polarization with no moving components. The IRCSP utilizes a birefringent crystal and diffraction gratings to encode the wavelength dependent polarization information in two optical paths. This channeled polarimetry concept is the same as the SPEX airborne spectropolarimeter, which has sensitivity at visible wavelengths [8]. The IRCSP was designed for sensitivity in the 7-13μm waveband with 1μm spectral resolution [2] [4] [5] [1]. The scientific motivation for the project was to measure the polarimetric signature from cloud tops because this information may help reduce error in retrievals of ice particle aspect ratio and diameter [7] [6]. The IRCSP was deployed for the first time on a high altitude balloon in 2021 [3]. The IRCSP reported brightness temperatures ranging from 250K to 285K with an uncertainty of < 1.5K. The IRCSP measured multiple intervals of statistically significant polarization with DoLPs of up to 20%. To avoid internal condensation, the instrument was heated to 30°C. In 2022, IRCSP was deployed again on a high altitude balloon, as well as a P3 Orion aircraft. The instrument is now sealed and nitrogen purged to allow cooling to -20°C without condensation. Future deployments seek to replicate high-altitude observations with the improved instrument performance given by a colder and stabilized focal plane temperature. Investigating the thermal polarization of ocean and land surfaces is also of interest for model validation and development.

This document explains the specifications for two versions of the IRCSP instrument. The first is an autonomous instrument. This version is designed with a single board computer that uses a cron task to run a main executable function as soon as its powered on. This script operates all thermal control and data acqusition without user engagement. Section 2 details this version. The second version of IRCSP is passenger controlled. This version was designed to be installed in the bombay of a P3 Orion aircraft with cables that interfaced with the aircraft cabin. The cables connected to a laptop that is operated by a passenger, who executes and monitors data acquisition. Section 2 detailes this version.

2 Autonomous Instrument

- SWAP
  - 14 lbs, 30W
  - Electronics enclosure: 7.130"W X 10.260"L X 3.25" H
  - Instrument alone: 7"W X 7.5"L X 4"H. See Figure 2
  - Mount (53.5° from nadir): 6"W X 5.5"L 6.75"H. See Figure 3
  - Height of instrument on mount: 10"
- Instrument Design
  - Spatial FOV: 20°
  - Context Camera: Teledyne FLIR Boson 640 X 512 55MM 8° HFOV - LWIR thermal camera core
  - IRCSP first surface lens: 25mm Dia x 20mm FL 8-12 μm Coated, Ge Aspheric Lens from Edmund Optic s

- All hardware made by Optical Engineering and Fabrication Facility (OEFF) [9]
- Main electrical components: Single board computer, Arduino, PID controller, lens heater relays, and USB hub. See Figure 4 for Arduino and sensor circuit diagram.
- Instrument and mount made from 6061-T6 Aluminum
- Nitrogen purged and sealed to minimize humidity
- New PID controller: TEC-1091 from Meerstetter Engineering
- Heat sink attached with fasteners
- Instrument coated with Chemfilm Alodine to prevent corrosion
- Pinhole replaced with 25μm x 3mm, Unmounted, Acktar Blackened Air Slit from Edmund Optics
- Thermal conduction of cameras improved with wire EDM (Electrical Discharge Machining) copper mounts
- Thermal pads at all critical thermal interface areas

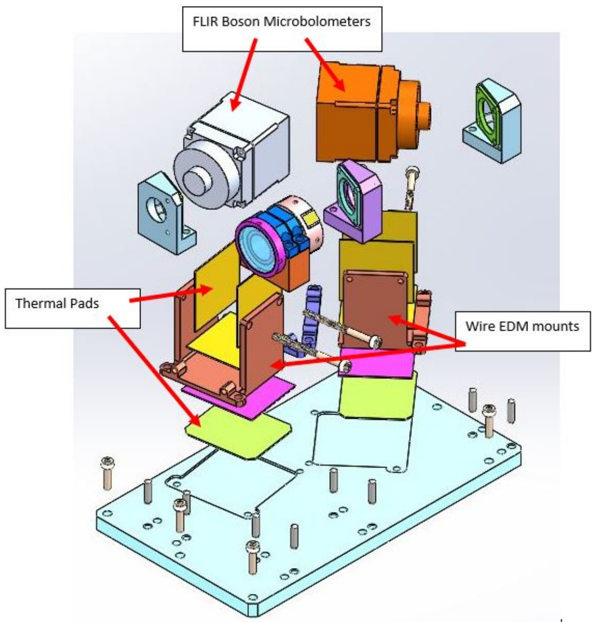

Figure 1: Exploded view of 3D model of IRCSP internal optics. Wire EDM copper mounts interface with the cameras on three surfaces with thermal pads to improve thermal contact.

- Software Design
  - Arduino script that reads 3 thermistors and 3 BMEs connnected to Arduino through a multiplexer.
  - Python script to change temperature of PID controller in flight
  - State switches on Linux single board computer: preflight, takeoff, and flight states
  - Main executable function runs on reboot as a cron task
- Telemetry
  - BME sensor internal to nitrogen purged instrument enclosure. Reads pressure (kPa), temperature (°C), and humidity (%).
  - BME sensor inside electronics enclosure
  - BME sensor exposed to ambient on side of instrument housing
  - Thermistor on first surface lens heater

Figure 2: Instrument and Electronics Enclosure

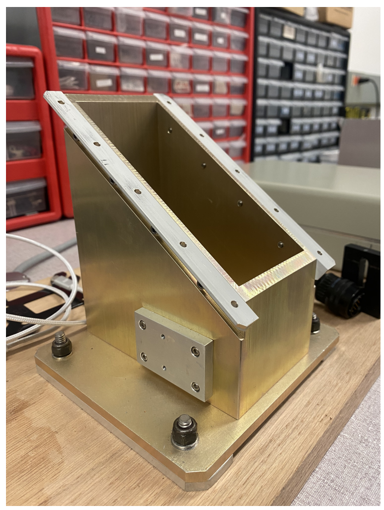

Figure 3: Static mount 53.5° from nadir

  - Thermistor on kapton heater that is wrapped around context camera
  - Two thermistors on top of instrument housing. One controlling TEC. One read by Arduino and stored to file.

- Balloon integration and deployment
  - Integration August 10th - 12th. See Figure 5
  - Salter Test Flight 721NT, launched August 23rd, 2022 at 7:35am

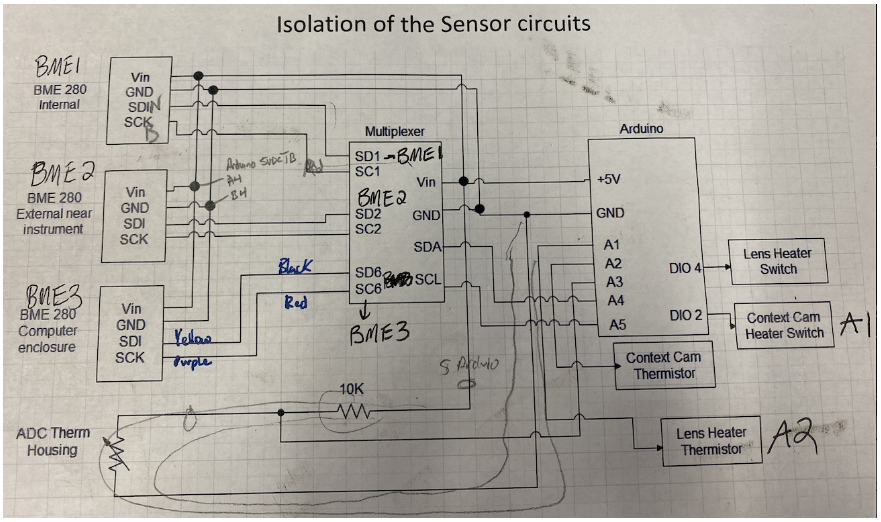

Figure 4: Arduino Circuit Design

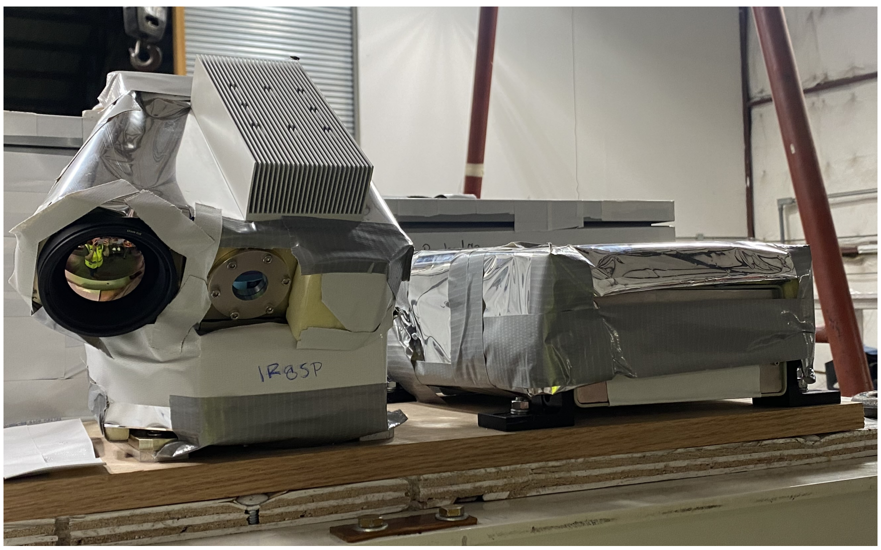

Figure 5: Integration on Balloon Payload

3 Passenger Controlled Instrument

- Instrument Design
  - Same optical design as autonomous instrument. Only difference is the lack of external camera.
  - Electronics enclosure contains only Arduino and PID controller. See Figure 6
  - Cables made in lab

- Software Design
  - Arduino python script for reading two BMEs and housing thermistor
  - Image capture python script
  - Main executable function to run during flight
  - "Set and Forget" PID parameters of 20°C target enclosure temperature

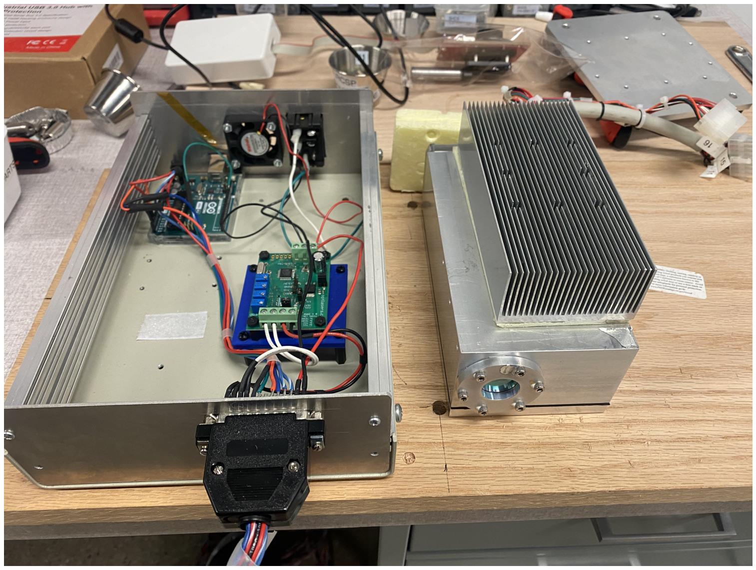

Figure 6: Instrument as deployed on P3 Flights

- Telemetry
  - BME sensor internal to nitrogen purged instrument enclosure. Reads pressure (kPa), temperature (°C), and humidity (%).
  - BME sensor on side of instrument, for measuring temperature of housing
  - Thermistor on top of instrument housing, controlling TEC, saving temperature to file.
- Integration on P3 Orion
  - Wallops Flight Facility (WFF), VA
  - June 6th-10th 2022
  - Instrument installed on mount in the bombay of aircraft. See Figure 7.
  - Electronics enclosure installed on shared rack. Rack installed on aircraft
  - Adjustments made to cable length on site
  - Connection tests revealed grounding issue. To solve this, software was adjusted to run telemetry and image capture system separately
  - Camera and Arduino powered by laptops in the cabin.
  - PID controller was given a 20W power drop from aircraft
- P3 Deployments
  - At WFF Jun 30th - July 16th.
  - Instrument Check Flight: June 30th
  - Flight attempt on July 6th. Unsuccessful data acquisition due to cabling issues.
  - Flights listed below had successful data acquisition
  - July 11th, 2022
    * Takeoff: 10:30am EDT
    * Landing: 1:55pm EDT
    * Maximum Altitude: 10,450 ft

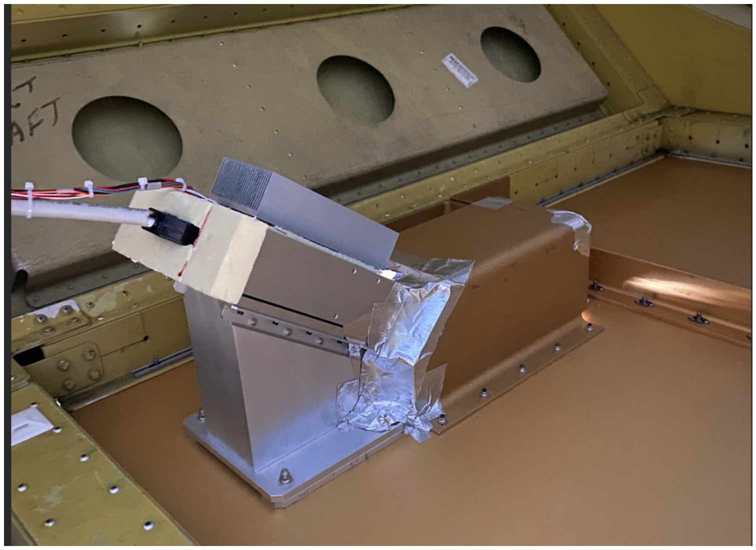

Figure 7: Integration with P3 Aircraft

- July 12th, 2022
  * Takeoff: 9:42am EDT
  * Landing: 1:12pm EDT
  * Maximum Altitude: 10,575 ft
- July 12th, 2022
  * Takeoff: 2:33pm EDT
  * Landing: 5:05 EDT
  * Maximum Altitude: 10,125 ft

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