Evolution of the Multi-Angle Stratospheric Aerosol Radiometer

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Matthew DeLand[1,3], Matthew Kowalewski[2,3], Peter Colarco[3], Luis Ramos-Izquierdo[3], William Mamakos[4]

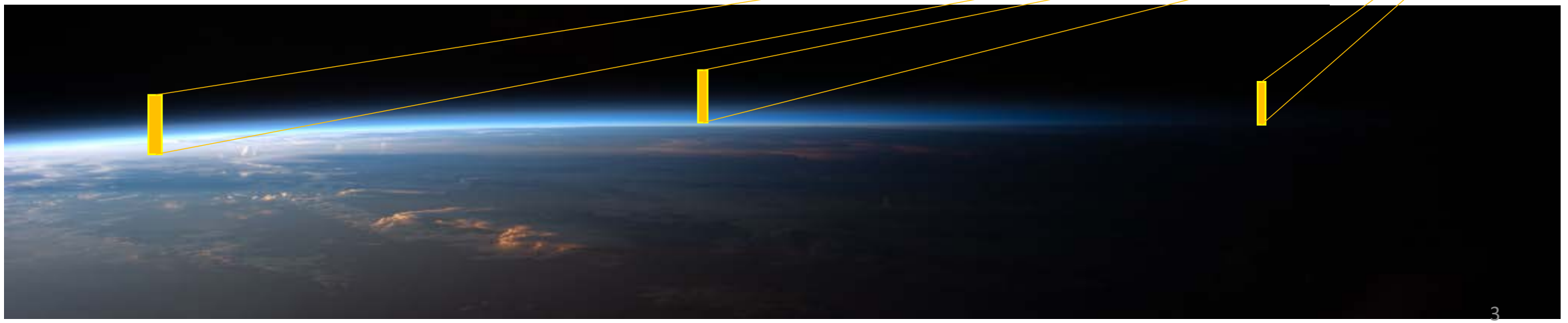
[1]Science Systems and Applications, Lanham, MD
[2]Universities Space Research Association, Columbia, MD
[3]NASA Goddard Space Flight Center, Greenbelt, MD
[4]Design Interface Inc, Finksburg, MD

Introduction

- Stratospheric aerosols (15-30 km) include a naturally occurring background component (magnitude varies with latitude and time), as well as transport of anthropogenic sources from the troposphere and impulsive injections from volcanic eruptions and pyroCumulonimbus events.
- Cooling caused by stratospheric aerosols (reflection of incident solar radiation) can offset some of the warming caused by increasing greenhouse gases.
- Monitoring stratospheric aerosols requires satellite measurements with good temporal sampling, spatial sampling, vertical resolution.
- **Limb scattering observations** (looking horizontally at the Earth's atmosphere, measuring scattered sunlight) can satisfy these requirements.

Multi-Angle Stratospheric Aerosol Radiometer (MASTAR)

- **SmallSat/Cubesat sized instrument** to force simple design, allow rapid development, enable multiple instruments for future constellation.
- Keep OMPS Limb Profiler measurement approach (**limb scattering**) for best spatial sampling along orbit.
- **Multiplicity of viewing directions** helps balance scattering angle sampling between hemispheres, increase spatial sampling between orbits, and aerosol phase function information.

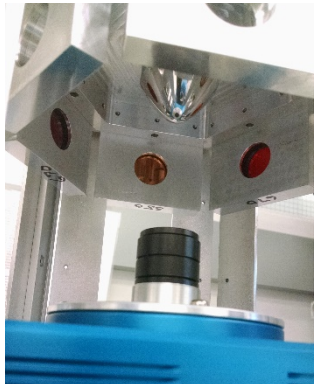


Science Parameters and Requirements

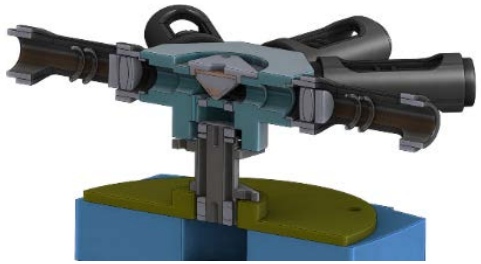
- **Goal:** Retrieve vertical distribution of stratospheric aerosols by simultaneously observing Earth's limb at multiple wavelengths and azimuth angles.
- **Instrument:** Compact, imaging radiometer consisting of individual viewing apertures with fore-optics and bandpass filters, and a central multi-faceted mirror to illuminate a 2-D CCD.

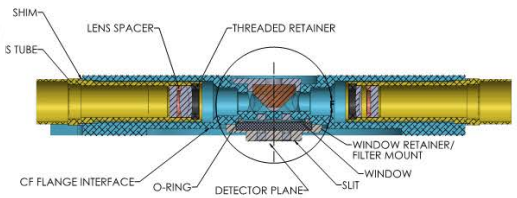
Parameter	Requirement
Elevation range (for each aperture)	< 2.5 degrees
Azimuth width (for each aperture)	0.1 degrees
View angle separation (dual apertures in six of eight directions)	1 degree
Overall azimuth range	> 60 degrees [minimum] 360 degrees [desired]
Wavelengths	350 nm, 670 nm, 850 nm
Bandpass (each filter)	10 nm
SNR	1000:1 [nominal]
Vertical spatial resolution	1.0 km
Vertical spatial sampling	0.5 km
Pointing knowledge	1 arc-minute [desired]
Altitude range to measure [nominal]	10 km – 60 km

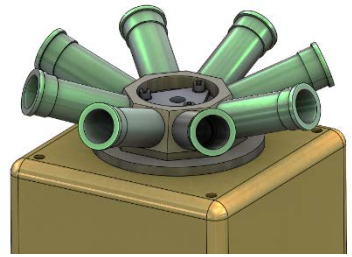
Evolution



crawl → Walk



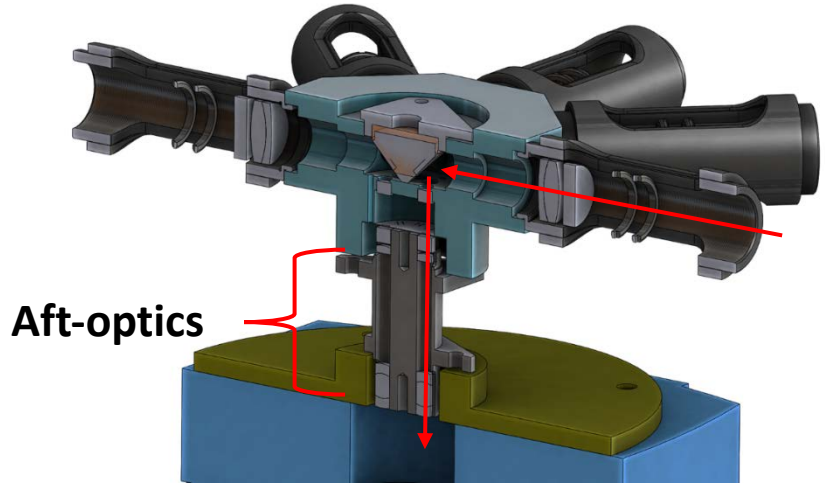


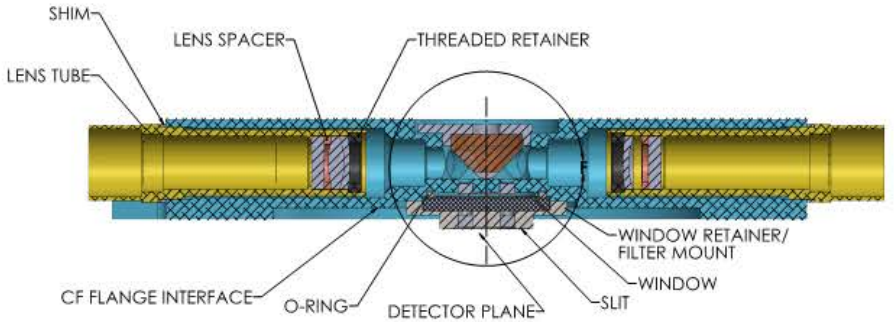


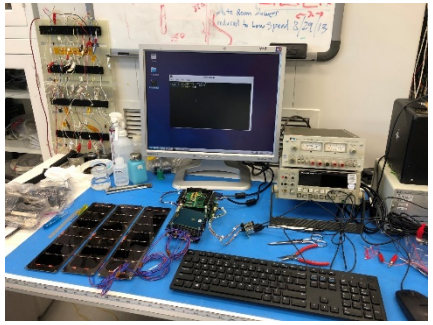
Parameter	IRAD [2016]	IIP [2017]	IIP-Extension [2019]	Future – SmallSat
Azimuth Angles	6	8	8	8
#Wavelengths	2	3	3	2
Detector	Apogee (COTS)	Andor (COTS)	Andor (COTS)	Custom package (e2V array)
Size (L x W x H)	8” x 8” x 15”	7” x 7” x 14”	6.5” x 6.5” x 8”	5” x 5” x 6.5”
Power	< 40W	30W	85W	18W (est)
TRL	3	4	6	7 – 8
Capability	• Concept demonstration. • Single wavelength per aperture angle. • Lab operations only.	• Breadboard validation in lab environment. • Two science wavelengths in 6 of 8 apertures. • Single UV channel in 2 of 8 apertures for RSAS alt reg. • Lab and roof ops only.	• System prototype demo in relevant environment. • Size reduction & improved stray light performance. • Autonomous operations. • Suborbital flight capable; high altitude balloon flight in Fall 2020.	• System (prototype) flight qualified/demo in space. • Size reduction with custom detector. • Increased TRL with flight heritage detector and control electronics. • Space flight capable.

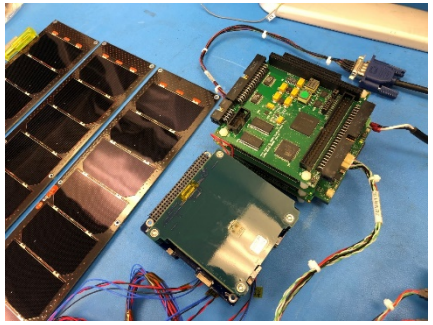
IIP “Crawl” to IIP-Extension “Walk”

- Eliminate aft-optics to reduce size & weight, simplify design, and improve optical performance.
  - Integrated slit/filter assembly with detector assembly.
  - Moving slit/filter assembly closer to FPA eliminates need for relay optics required in IIP design
- Slit aperture shape is tapered to mitigate large altitude-dependent dynamic range in limb signal.
- Stand-alone, autonomously operating system enabled through flight support electronics and software.

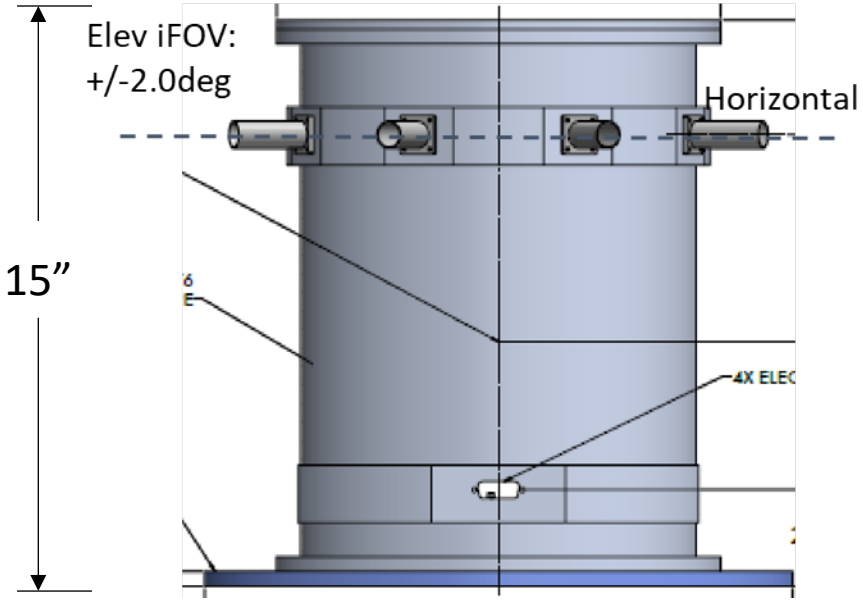








High Altitude Balloon (HAB) System



HAB Enclosure

Baffle extension

MASTAR V2 Optics

1 2 3

Vacuum Flange holder

custom slit+filter

3 2 1

Baffle extension

Purge port

Purge port

4) RH/P/T

Batteries Mounted Externally

Power Connector

Data I/F Connector

CIP RS232 Balloon Interface

Internal Support Structure

Andor CCD, electronics & Heatsink

4) RH/P/T

Fans

Solar Panel (4x)

Control Board (AD590, heaters)

Inclinometer

Housekeeping DAQ

Battery

Computer

Power distribution &

Aperture Mech Driver

Solar Power Dist. & Mon. Brd

Vibration Isolation (2x)

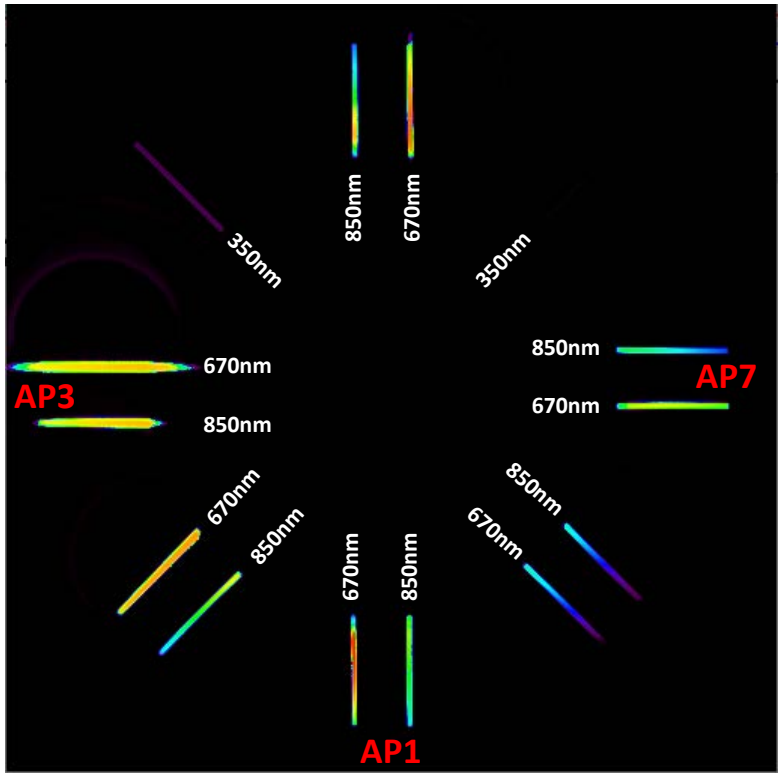
1. Hermetically Sealed Window
2. Aperture Mechanism
   a) (DIFF/OPEN/OPAQUE)
3. Long/Short pass filter
4. Rel Hum, Press, Temp brd

NOTES:
- High Altitude Balloon (HAB)
- Enclosure hermetically sealed
- Enclosure Back-filled with GN2

HAB Concept of Operations

- Flight software to mimic anticipated space flight operations as well as using evaluation modes.
  - Space flight data rates:
    - Approximately 1 Major Frame every 40 seconds.
    - Major frame consists of average of N measurements (final number TBD).
    - Sub-sample image FPA, centered around each aperture → Reduce data storage requirements.
  - Evaluation mode data rates:
    - Configurable frame rate and integration time.
    - Full frame images.
- IMU data recorded for platform attitude and pointing information.
- On-board storage eliminates need for high speed real-time down-link.

Sample clear sky data 2018 @NASA GSFC

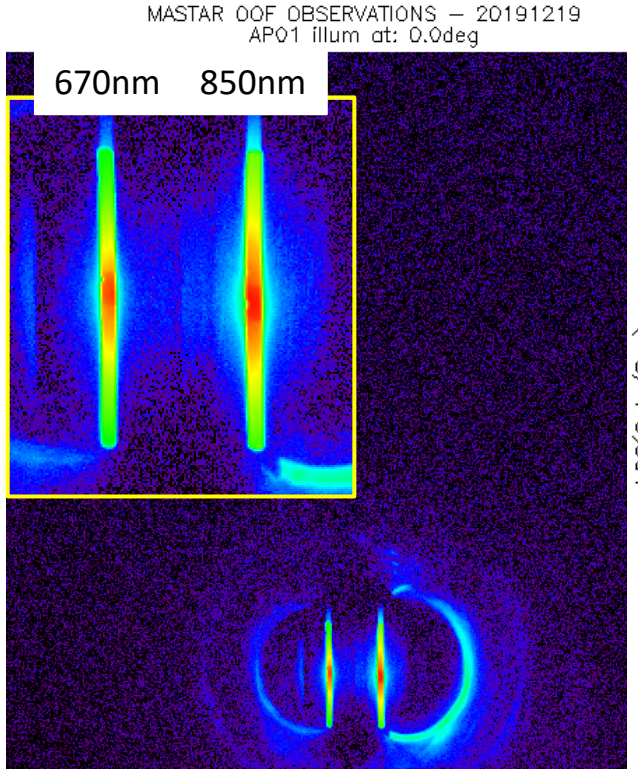


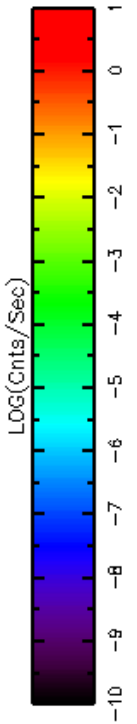
Reality Check

- Goddard Space Flight Center facilities were shut down in response to COVID-19 on March 18.
- Procurement, fabrication, assembly, software development for MASTAR have been affected.
- Highly uncertain if quality instrument could be assembled and tested to meet flight schedule [delivery expected on 8/19].
- We have withdrawn from Fall 2020 balloon flight schedule.
- We plan to complete assembly of MASTAR and conduct environmental testing later in 2020.
- *Possible flight in 2021*?

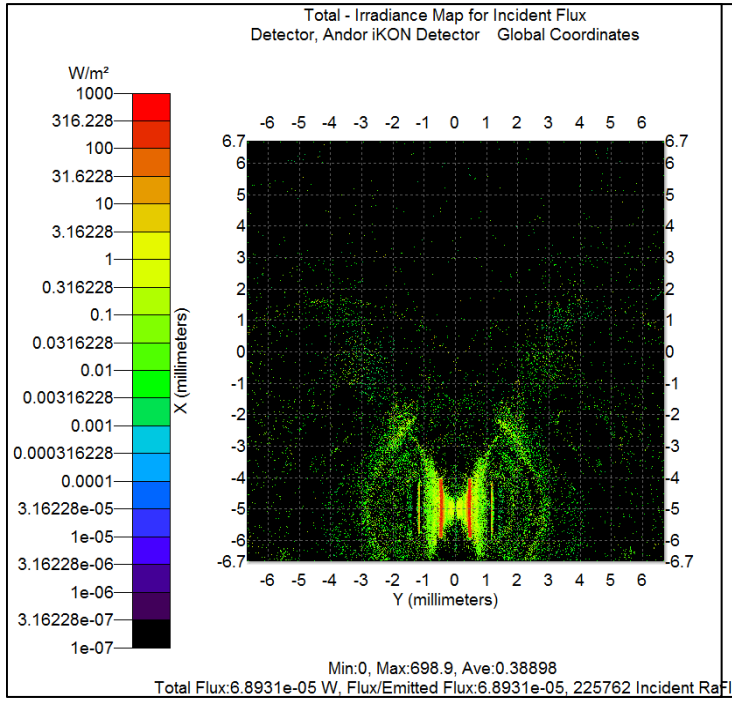
Backup Slides

Out of Field Scatter: Aperture 1 / 0° Illumination

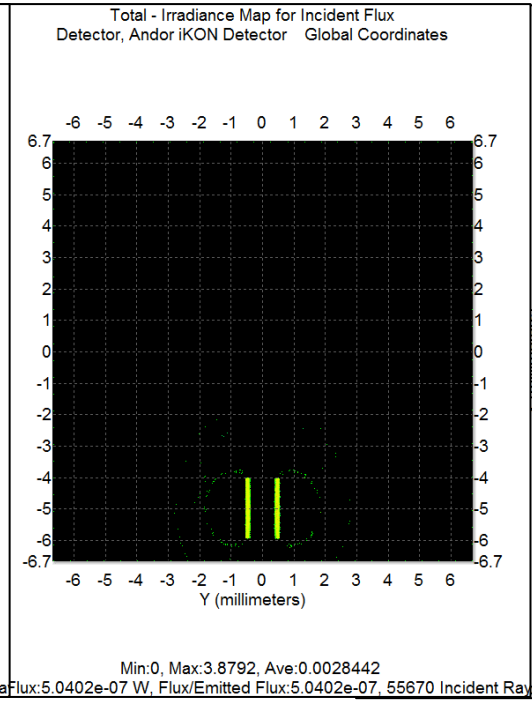




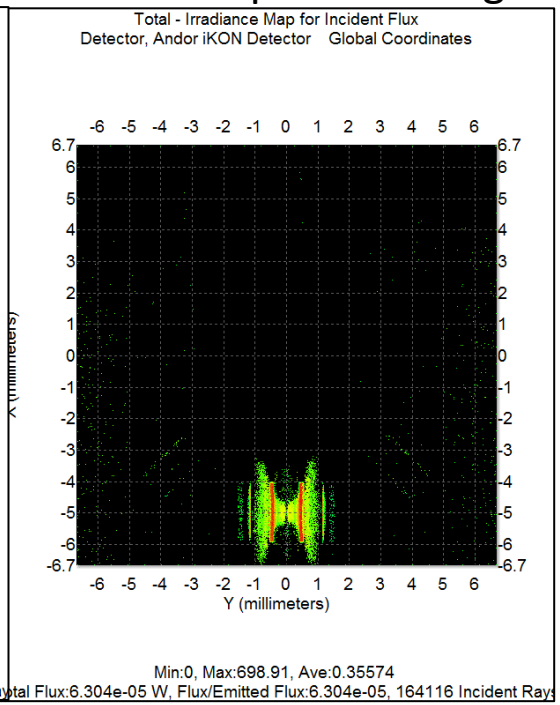
Nominal instrument



Black slit plate



Black aft-optics housing



- Nominal IIP instrument configuration with uncoated slit plate and opto-mechanical housing.
- Collimated QTH+sphere source at 0deg input incidence.

- Ring structure reduced.
- Residual lens ghosting.

- Ring structure eliminated.
- Slit plate and Lens ghosting.