CHAPS-D: The Compact Hyperspectral Air Pollution Sensor–Demonstrator

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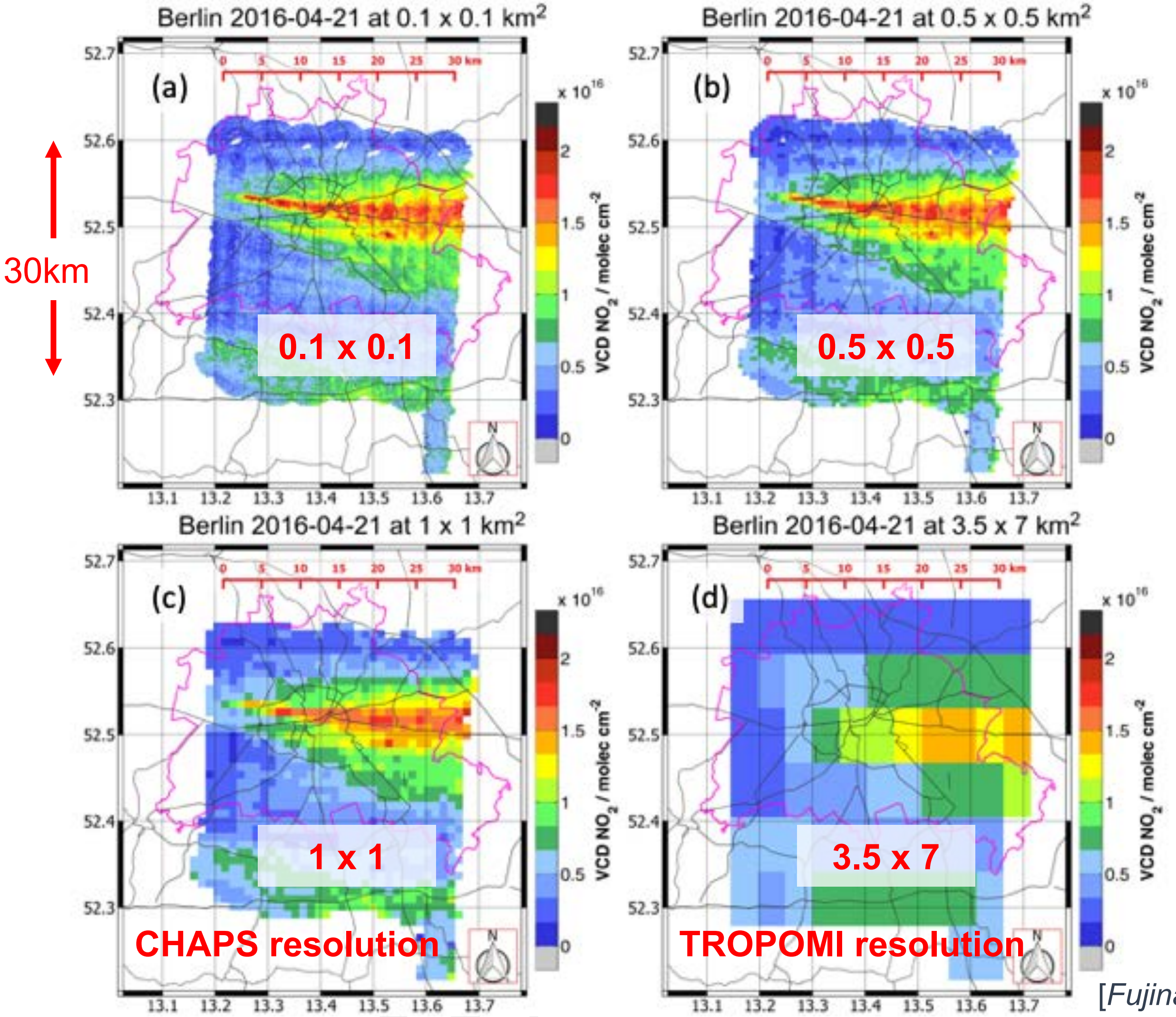
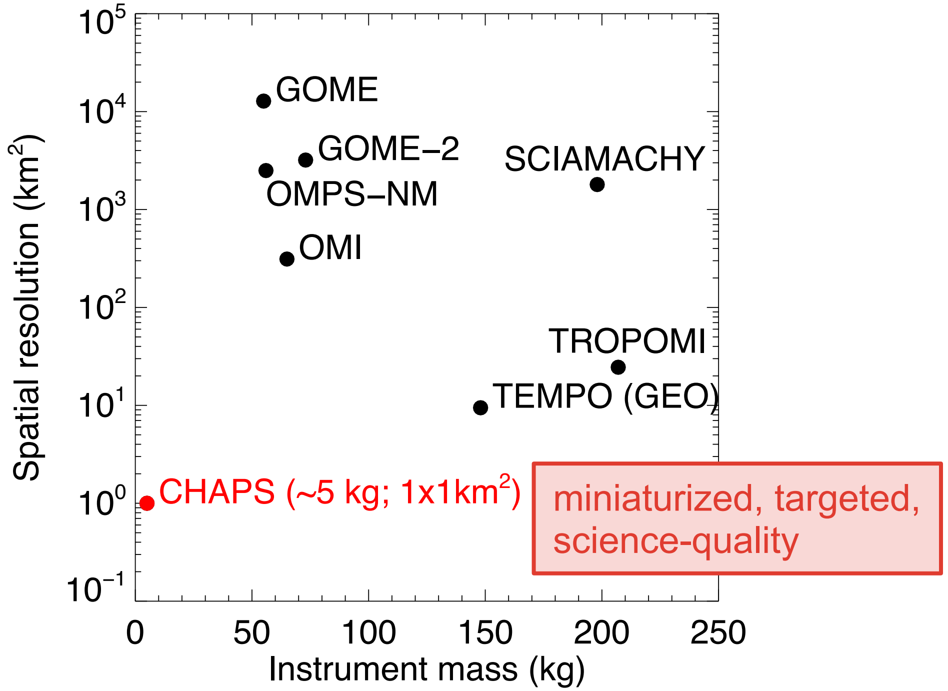
Program: IIP-2019 (80NSSC20K0323)

Spatial resolution is critical for understanding air pollution emissions and evolution, cloud avoidance



[*Fujinawa et al.*, 2019]



1 x 1 km² resolution provides:

- more cloud-free observations
- effectively separate clustered point sources in polluted regions
- understand mixing of emissions, their transport and transformation; short-term evolution of pollution plumes

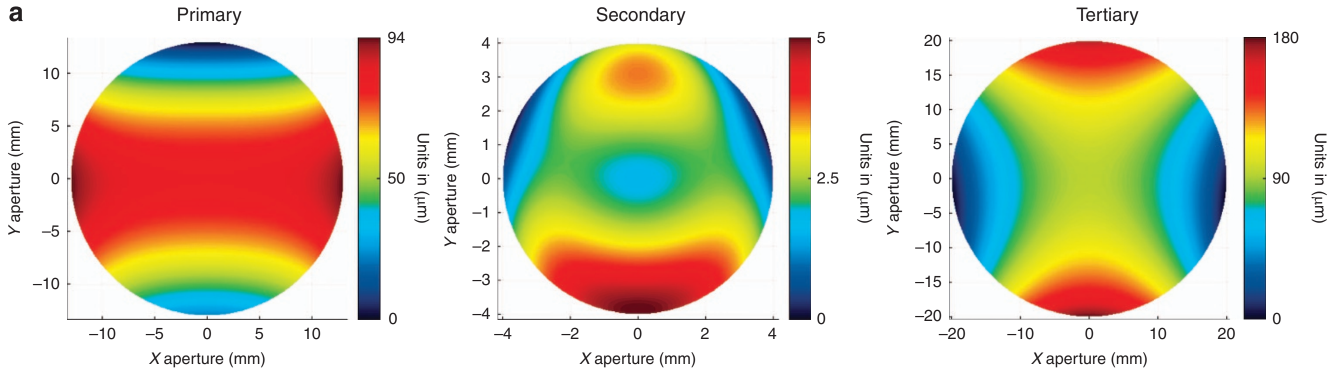
Freeform optics enables miniaturization

Polaroid SX-70 (1972–1981)

https://www.eyemartexpress.com/lenses

TROPOMI (launched 2017) with TNO optics
Awesome, yes, but big, kitchen sink, global surveys

- Freeform optics: *An optical surface that lacks translational or rotational symmetry*
- Freeform optics offers superior optical aberration correction, compared to spherical and aspherical alternatives
- In an imaging spectrometer, this has several advantages
  - spectral band broadening: increased spectral range
  - spatial broadening: increased slit length (and swath width)
  - increased compactness: unprecedented miniaturization

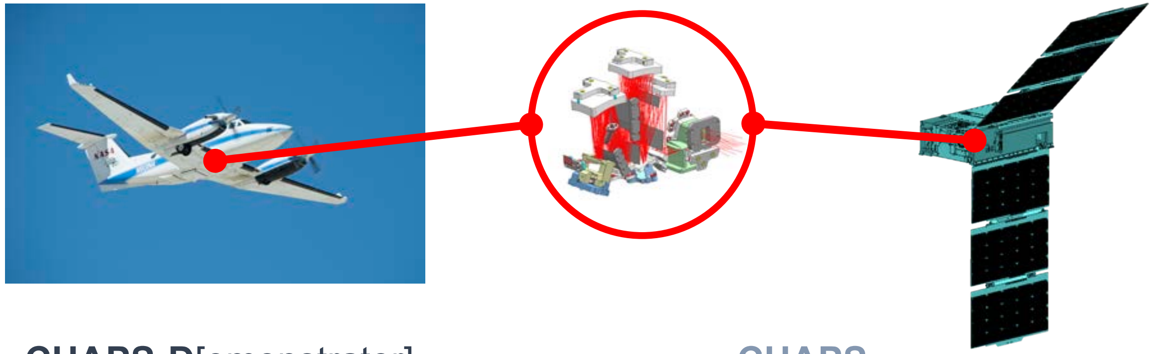


Example freeform surface shapes (departures from base spheres) [*Reimers et al.*, 2017]

Proposed investigation

- Design, fabricate, calibrate, and test prototype CHAPS-D, conforming to 6U constraints and space requirements, where reasonable
- Conduct ground-based, zenith-sky measurements as a real-world test of the instrument under controllable conditions and ambient pollution at GSFC
- Fly CHAPS-D on the NASA B200 King Air from LaRC, making nadir observations of tropospheric pollution
- Retrieve tropospheric NO_2* vertical column density using well-established techniques, demonstrating end-to-end capability
- Compare retrieved NO_2* (and others) with correlative measurements on the ground, potentially from another instrument co-manifested on the aircraft and operational space products from OMI and TROPOMI
- Use lessons learned to improve the CHAPS design and define the spacecraft interface requirements

* Also SO_2, ozone, glyoxal, clouds



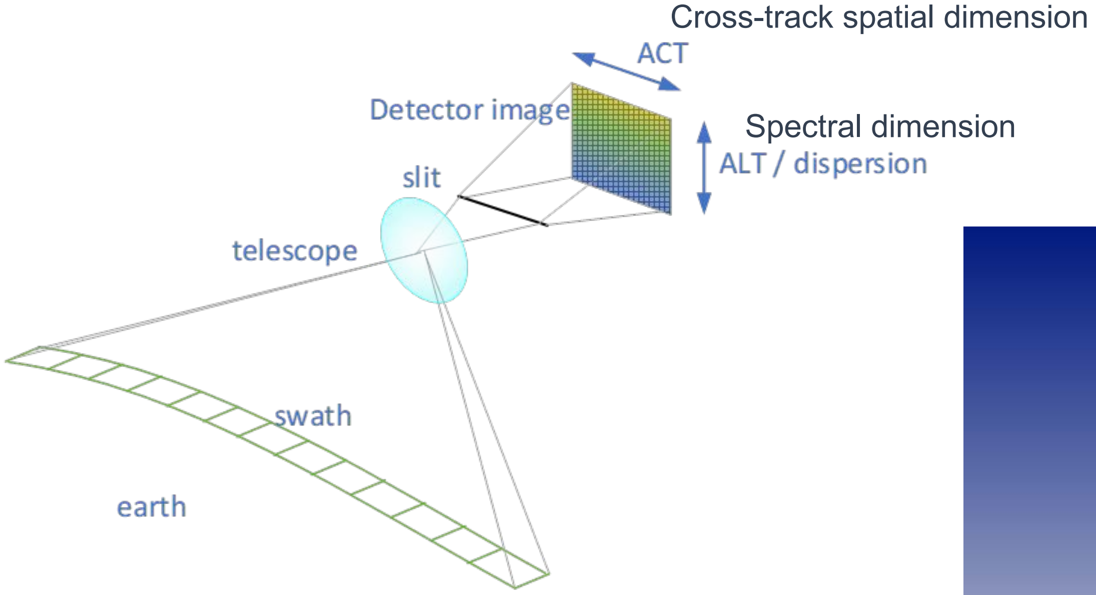
CHAPS-D[emonstrator]
(this IIP)
Altitude ~8 km
Spatial resolution ~40 m

CHAPS
(future project)
Altitude 400–600 km
Spatial resolution ~1 km

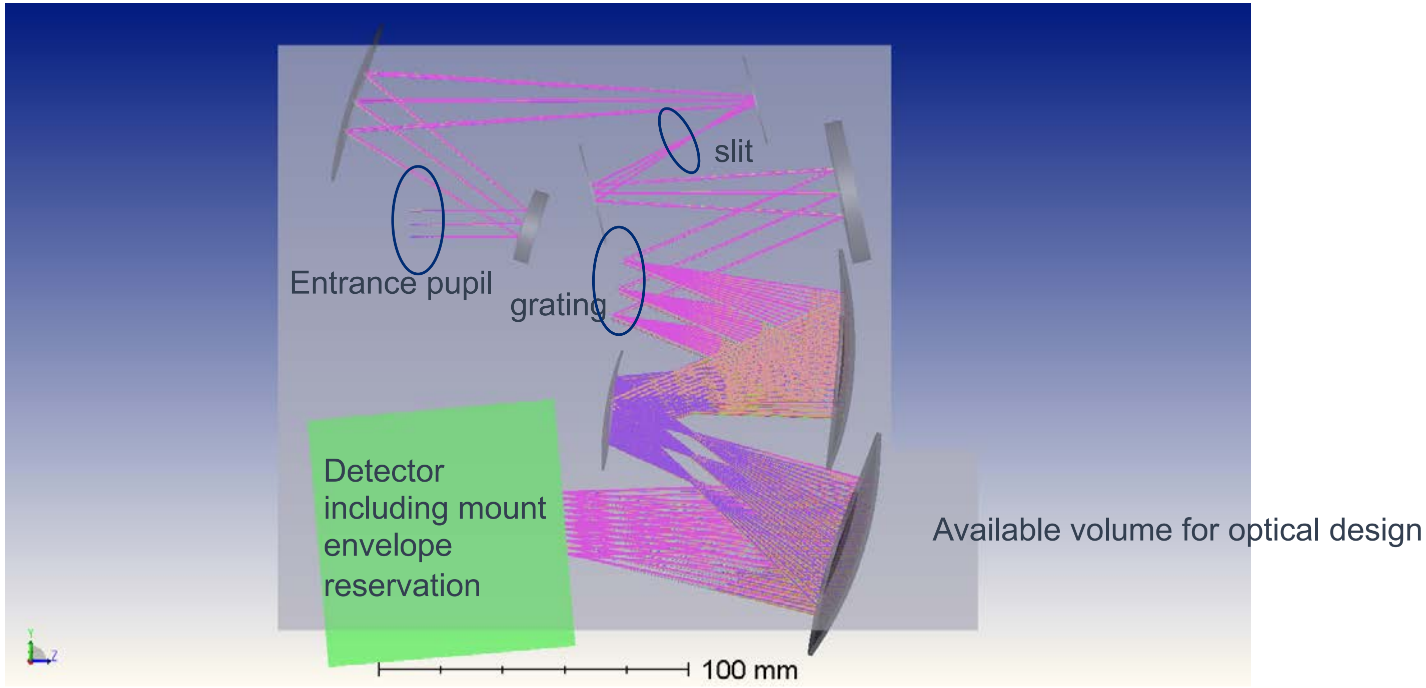
Driving requirements: Science-quality measurements

Parameter	Value	Driver
Spatial sampling	<1 km (space) <40 m (aircraft)	Adequate isolation of individual pollution sources
Swath width (across track)	100 km (space) 400 m (aircraft)	Adequate coverage of urban environments
Wavelength range	300–500 nm	Retrievals from NO_2, SO_2, ozone, glyoxal, cloud absorption features in this range
Wavelength resolution	0.5 nm	Needed to resolve trace species absorption features
Spectral oversampling	>3x	Needed to resolve trace species absorption features
Signal-to-noise ratio	500	SNR required for spectral resolution and oversampling of NO_2

Preliminary optical layout meets requirements and fits within a 4U (payload) volume



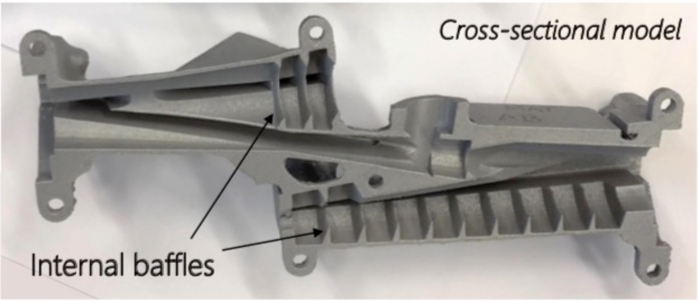
CHAPS(-D) is a push-broom sensor



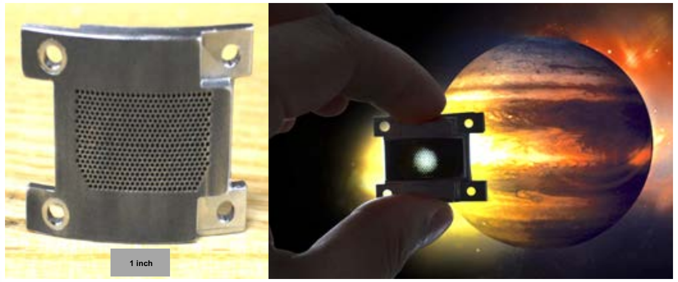
CHAPS-D preliminary optical layout

Next steps

- CHAPS-D currently in design phase
  - Working on preliminary optical design and packaging, detector selection
  - CDR Dec 2020
- Exploring the use of additive manufacturing (AM), which provides a number of potential advantages
  - Use topology optimization for mass, thermal, vibration, and (additive) manufacturability
  - Internal baffling fine structure (critical for stray light control) is very amenable to AM
  - Reduces complexity of housing (idea: AM entire housing and baffling in one go)
  - AM of the mirrors would reduce mass
  - Reduces manufacturing time and cost of future instruments



Telescope internal baffling (TNO)



JUICE JOEE Collimators (APL)