National Aeronautics and Space Administration

Maturing HiMAP (High-resolution Imaging Multiple-species Atmospheric Profiler) System to TRL 6

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Program: FY21 R&TD Strategic Initiative **Strategic Focus Area: Decadal Survey Instruments** **PI Contact Email: Dejian.Fu@jpl.nasa.gov**

Objectives

- Develop a wide-swath, high resolution, compact remote sensing instrument concept, namely HiMAP, to fill the capability gaps of the vertical/horizontal resolution and the spatial coverage for the measurements of gaseous pollutants (O_3, NO_2) and aerosols, three Explorer-class observables identified by 2017-2027 Earth Science Decadal Survey (ESDS, see ref. 1).
- Craft operation concepts targeting at the Earth Venture and the Explore Class missions, in which HiMAP serves as a core payload in the new generation of NASA Earth System Observatory, to address three air quality-related objectives ranked "MOST IMPORTANT" in the ESDS.
- Identify and advance the TRL of HiMAP's key technologies

Background

- 2017-2027 ESDS[1] ranked three air quality-related objectives be "MOST IMPORTANT" and identified global, high-resolution, vertical profile measurements of gaseous pollutants (O_3, NO_2) and aerosols as high priorities to be targeted in the Earth Venture and Ozone and Trace Gas Earth Explorer missions
- Quantification of the societal impacts of pollutants requires a major advance in the state-of-the-art for measuring pollutants' concentrations in the near-surface layer (NSL, 0–2 km), because variations in the atmospheric column do not always well represent the changes in surface concentrations, and high spatial resolution is needed to map spatial variability at the neighborhood (intra-urban) scale and better quantify the health impacts of air pollution. To address these science needs, the HiMAP instrument concept is being developed (see Figure 1).

Approach and Results

- Conducted observation system simulation experiments (OSSE, see Figure 2) to establish HiMAP's instrument design requirements for (1) the near-surface sensitivity to capture the variability of NSL pollutants, (2) 2 x 2 km^2 spatial resolution to distinguish polluted vs. clean city regions, and (3) global coverage to fill the spatial gaps of the three GEO instruments TEMPO, Sentinel 4, and GEMS.
- Developed operation concepts (see Figure 3) which will address the high priority science objectives illustrated in the ESDS, through (1) HiMAP's unique capability to enable 3-D mapping of pollutants in NSL; (2) Synergistic measurements of HiMAP, Continuity Microwave Limb Sounder (CMLS; PI: Nathaniel Livesey) and CubeSat Infrared Atmospheric Sounder (CIRAS; PI: Thomas Pagano) to augment science return.
- Identified broadband high-efficiency metagratings as HiMAP's key technologies, and developed the optical system design (see Figure 4).
- Established the capability of design, fabrication, and characterization of the near infrared (NIR) and ultraviolet (UV) metagratings (see Figure 4).
- Placed orders to the vendors for the fabrication of HiMAP-NIR's optics system (delivery date: Spring 2022)

Figure 2. OSSE defined the design goals of HiMAP system.

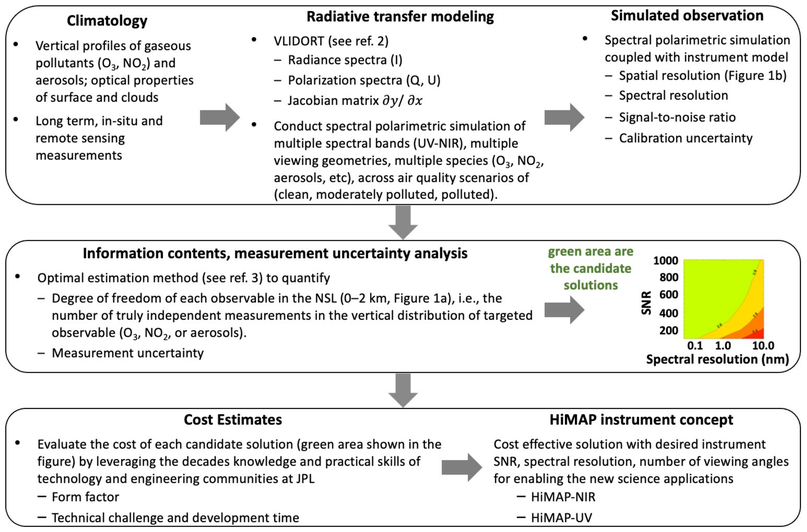
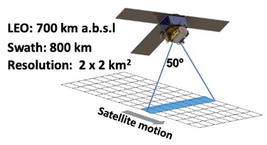
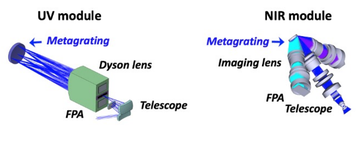


Figure 3. OSSE defined the design goals of HiMAP system.

HiMAP fly on a ESPA-class small satellite



Two independent modules provide flexibility on the constellation strategy



Module	Observables	Approach
HiMAP-UV (295 – 405 nm)	O_3, NO_2	Wide swath, multiple- angle, high spectral resolution polarimetry
HiMAP-NIR (680 – 780 nm)	aerosols, SIF, H_2O	
Joint HiMAP-UV and -NIR	all the above	

Publications

[A] Choi M., *et al.*, Aerosol profiling using radiometric and polarimetric spectral measurements in the O2 absorption bands: information content and measurement uncertainties estimation, Remote Sens. Envir., 253, 112179, (2021).

[B] Hsio H.H., *et al.*, a broadband metagrating for high spectral resolution polarimetric imaging in the near infrared, in preparation, (2021).

[C] Richter J., *et al.*, Specifying Polarimetric Tolerances of a High-resolution Imaging Multiple-species Atmospheric Profiler (HiMAP), Proc. SPIE. 10925, Photonic Instrumentation Engineering VI, (2019).

Significance/Benefits to JPL and NASA

- HiMAP is a compact, cost-effective solution that will enable the 3-D mapping of pollutants in the NSL to fill the capability gaps needed for addressing the air quality-related science objectives which were ranked "MOST IMPORTANT" in the 2017-2027 Earth Sciences Decadal Survey.
- Advancing the TRL of HiMAP will give JPL a competitive advantage for winning Earth Venture and Ozone and Trace Gas Earth Explorer mission proposals.

Figure 1. The capability gaps of space missions for air quality.

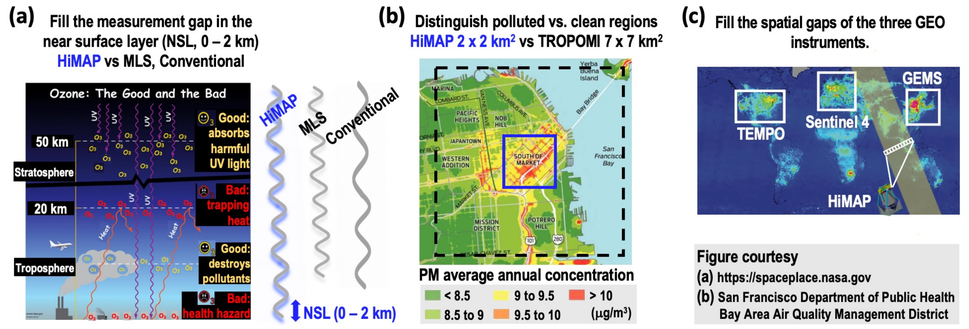
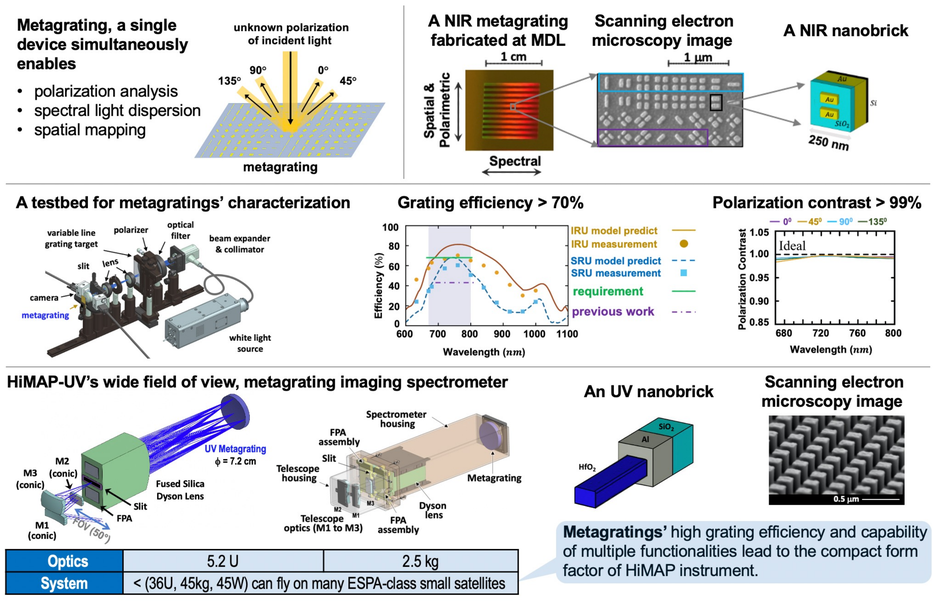


Figure courtesy
(a) https://spaceplace.nasa.gov
(b) San Francisco Department of Public Health Bay Area Air Quality Management District

Figure 4. Broadband metagratings for high spectral resolution polarimetric imaging in the NIR and UV.



Optics	5.2 U	2.5 kg
System	< (36U, 45kg, 45W) can fly on many ESPA-class small satellites	

Metagratings' high grating efficiency and capability of multiple functionalities lead to the compact form factor of HiMAP instrument.

References

[1] Available at: http://sites.nationalacademies.org/DEPS/ESAS2017/index.htm

[2] Spurr R. and Christi M., "The LIDORT and VLIDORT linearized scalar and vector discrete ordinate radiative transfer models: Updates in the last 10 years," A. Kokhanovsky (Ed.), Springer Series in Light Scattering: Volume 3: Radiative Transfer and Light Scattering, Springer International Publishing, Cham, pp. 1–62, 2019.

[3] Rodgers C.D., "Inverse methods for atmospheric sounding: Theory and practice," Word Scientific Publishing, Singapore, 2000.

Clearance Number: CL#21-4752
RPC/JPL Task Number: R19021