


MAIA

Associating particulate air pollution with human health



Multi-Angle Imager for Aerosols (MAIA)

Satellite and Health Assessments Town Hall

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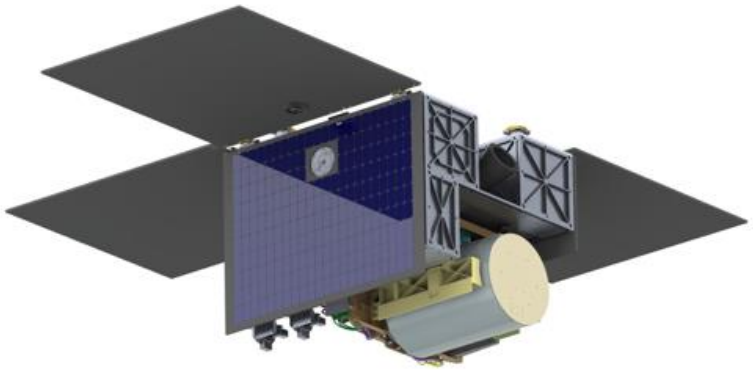
Introduction

- MAIA was competitively selected under the Earth Venture Instrument-3 solicitation in March 2016.
  - First competitively selected NASA investigation specifically aimed at societal benefit



The MAIA instrument will fly aboard the General Atomics Orbital Test Bed (OTB)-2 spacecraft

Baseline mission duration = 3 years

Baseline orbit

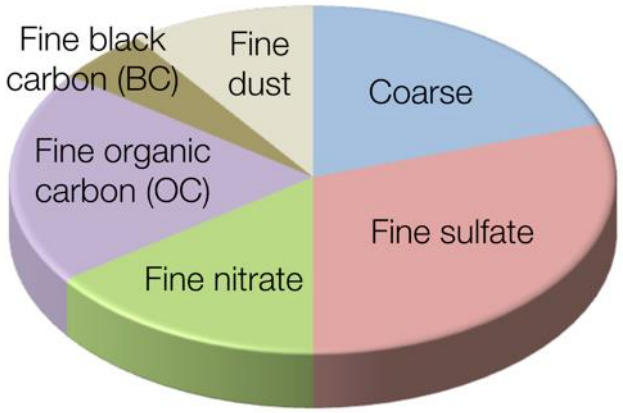
- Sun-synchronous, 740-km altitude
- 10:30 am equator-crossing time, ascending node

Launch: 2022 (to be confirmed)

MAIA's primary objective is to link exposure to different types of PM—mixtures of particles of various sizes, shapes, and compositions—with human health.

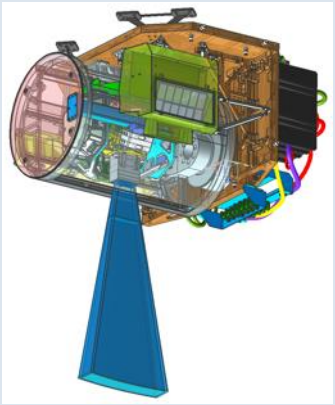
Motivation for MAIA

- Although PM is known to cause many health problems, the relative toxicity of specific PM types (fractional proportion of coarse particles, fine particles, and physical and chemical components) is not well understood.

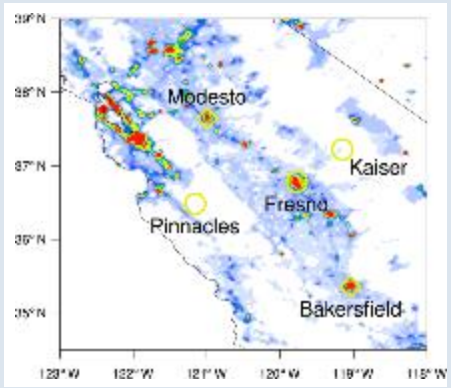


- Surface monitors alone are too sparsely distributed to solve this problem.
- Many low- and middle income countries do not have resources or expertise to monitor air pollution.
- From space, we can map PM where people live and work and observe many different regions of the globe.

Elements of the MAIA investigation



L. Tsutsui, KVPR



MAIA instrument

- Provides calibrated, georectified image data for retrieval of aerosol properties.

Surface PM monitors

- Used to calibrate the column aerosol-to-near surface PM relationships.

Chemical transport model (CTM)

- Assists spatial/temporal gap-filling.

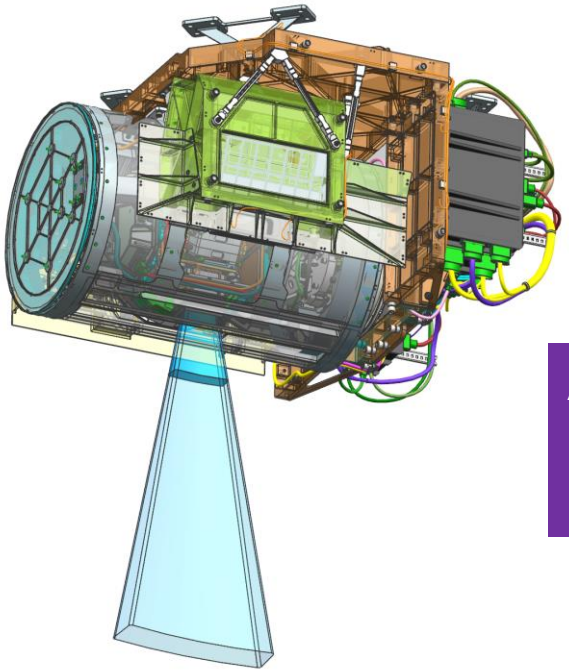
Health records

- Used to associate PM exposure with health effects.

Used to generate the archived and publicly distributed data products (free of charge) at the NASA Langley Atmospheric Science Data Center

Privacy protected, not handled by NASA

MAIA instrument provides multiangular, multispectral, polarimetric imagery



The instrument contains a pushbroom multispectral/ polarimetric camera on a 2-axis gimbal

Along-track (scan) axis provides multiangle imagery (±70º at Earth)

Cross-track (pan) axis enables ≥3 revisits/week per target (on average)

Band (nm)	365	387	415	442	550	645	749	762.5	866	945	1040	1610	1885	2125
Polarimetric				✔		✔					✔			

Aerosol absorption

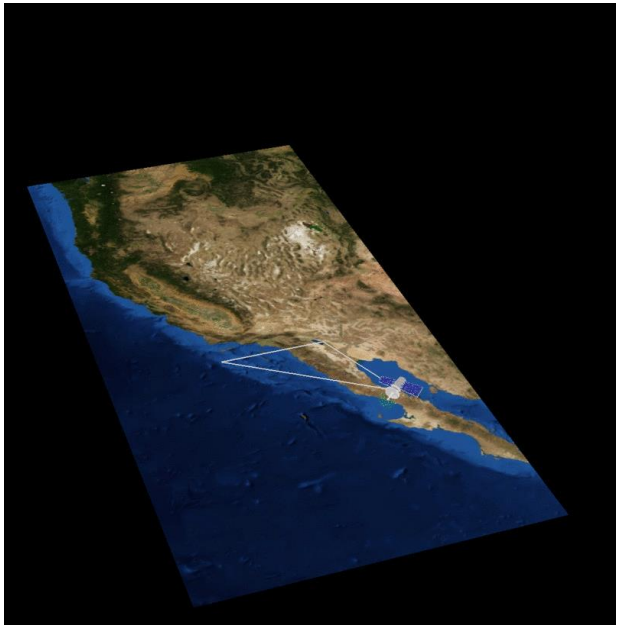
Fine particles cloud screening

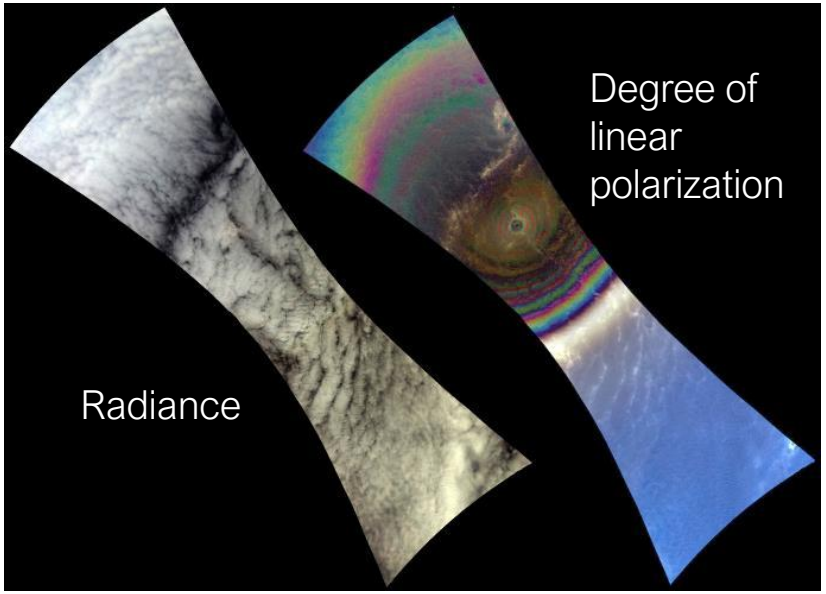
Water vapor

Coarse particles, cirrus

MAIA Earth observation modes

- Most Earth targets will be observed in “step and stare” mode
  - The scan axis allows observing at 5 – 9 view angles in sequence
  - The pan axis allows observations of targets off the sub-satellite track





Sweep mode is used for study of cloud micro-physics to support MAIA secondary investigation objectives

Geostatistical Regression Model (GRM)

$PM_{2.5}$, PM_{10} monitor data = α x Spatiotemporal terms + β x Aerosol optical depths (L2) or CTM PM (L4) + γ x Geospatial predictors (elevation, roads, vegetation) + δ x Spatiotemporal predictors (RH, PBLH, temperature, winds, additional aerosol parameters) + Errors

Collocated PM and predictor data are used to derive coefficients of Geostatistical Regression Models (GRMs).

Predictor weights are derived independently for each PTA.

A Bayesian multivariate framework is used.

The coefficients are updated as the mission progresses.

The calibrated GRMs are used to map PM at locations between monitors.

MAIA investigation is target-based

Primary Target Areas
- USA_LosAngeles
- USA_Atlanta
- USA_Boston
- ESP_Barcelona
- ITA_Rome
- ZAF_Johannesburg
- ISR_TelAviv
- ETH_AddisAbaba
- IND_Delhi
- CHN_Beijing
- TWN_Taipei

Secondary Target Areas
- PAC_OceanStCu
- USA_SanFrancisco
- USA_Phoenix
- USA_Denver
- MEX_MexicoCity
- CAN_Toronto
- CHL_Temuco
- CHL_Santiago
- BRA_SãoPaulo
- ATL_OceanStCu
- NGA_Lagos
- ZAF_CapeTown
- SRB_Belgrade
- KWT_KuwaitCity
- BGD_Dhaka
- VNM_Hanoi
- MNG_Ulaanbaatar
- KOR_Seoul
- AUS_Sydney

Calibration/Validation Target Areas
- USA_RailroadValley
- LBY_Libya4
- NAM_Gobabeb

- Primary Target Areas (PTAs):
- Secondary Target Areas (STAs):
- Calibration/Validation Target Areas (CVTAs)

MAIA Secondary Target Areas

Secondary Target Areas (STAs) are designated for addressing MAIA's secondary science objectives (e.g., cities with major pollution, aerosol source regions, climatically important cloud regimes)

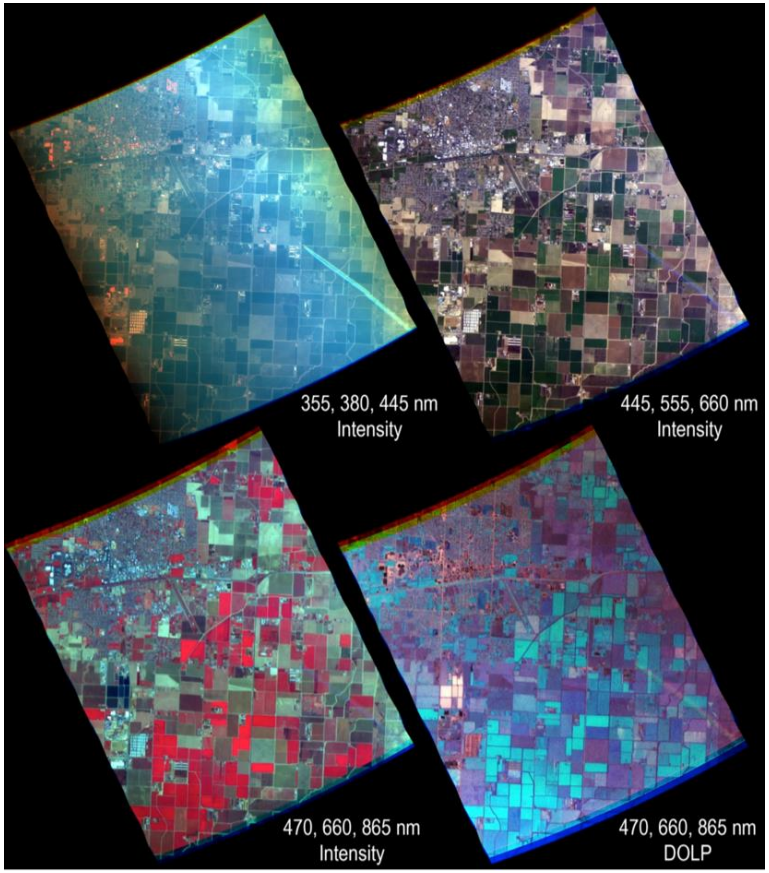
- Candidate set currently includes **19 sites**
- Selection criteria
  - Science value to the MAIA investigation
  - Inputs obtained from community engagement (e.g., universities, governmental agencies)
  - Availability of surface monitor data and potential for air quality and/or health studies if aerosol or PM processing is relevant
  - Frequency of observation from orbit and manageability of conflicts with PTAs

Reminder: There are no program-level requirements to have STAs – PTA requirements must be fulfilled first to meet our commitment to NASA. STAs are used to satisfy project goals for enhanced science.

MAIA data product summary

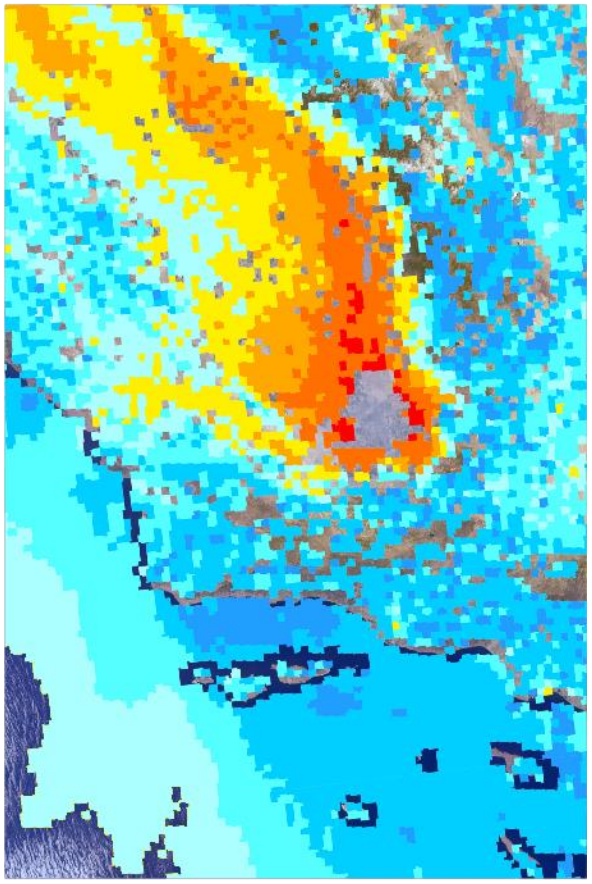
01010100 01101000
01101001 01110011
00100000 01101001
01110011 00100000
01110100 01101000
01100101 00100000
01110010 01100001
01110111 00100000
01100100 01100001
01110100 01100001
00100000 01100110
01110010 01101111
01101101 00100000
01001101 01000001
01001001 01000001

Level 0 data: raw bits from the instrument

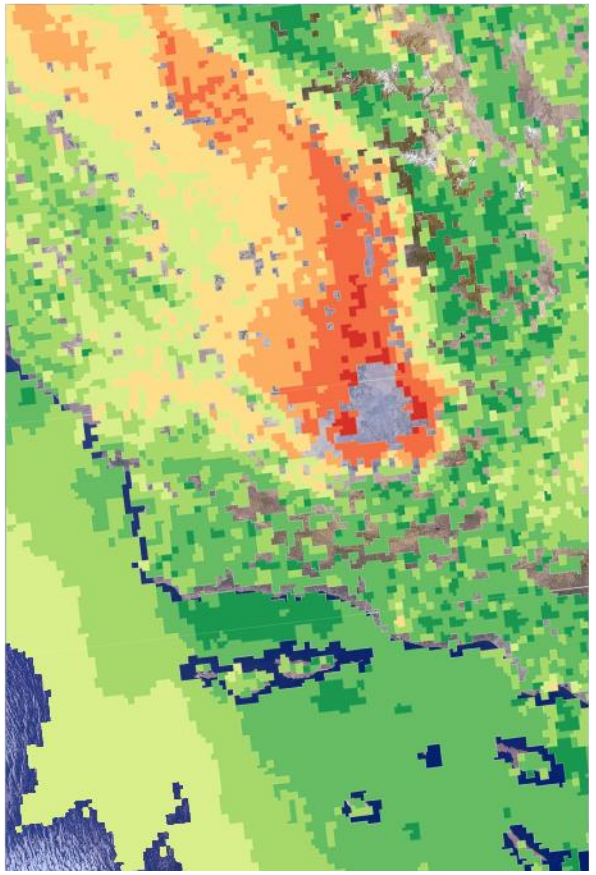


Level 1 data: what the instrument is actually “seeing”, mapped, ~250 m

MAIA data product summary

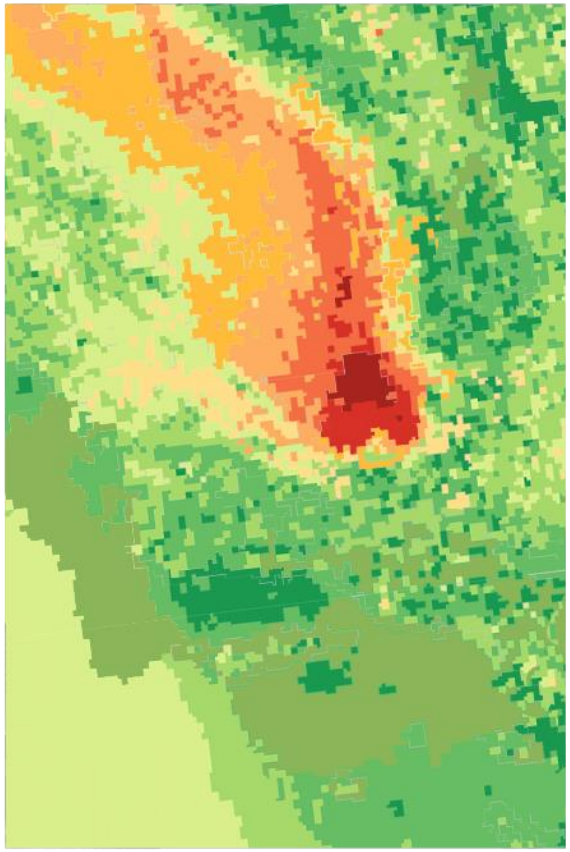


Level 2 aerosol data: AOD, other aerosol properties, mapped, ~1 km



Level 2 PM data: PM concentrations at time of overpass, mapped, ~1 km

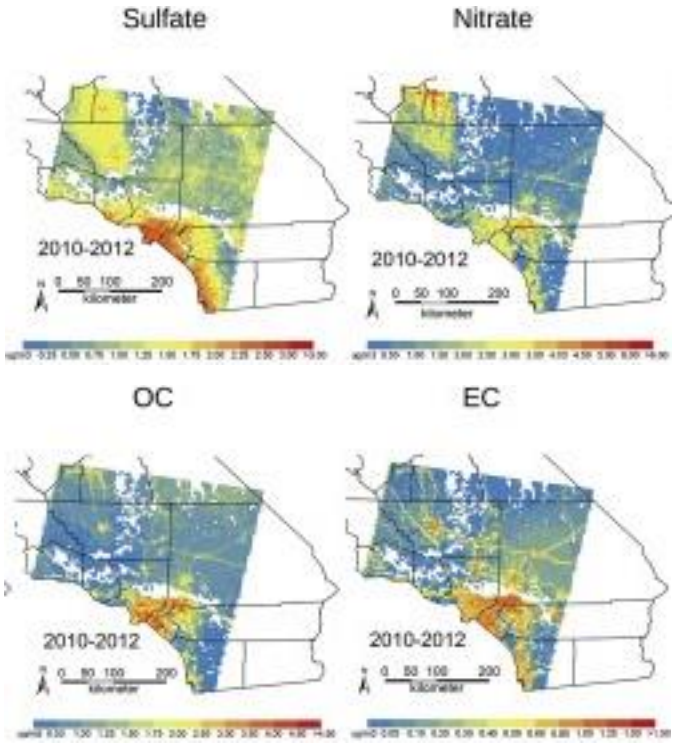
MAIA data product summary



Level 4 PM data: PM concentrations, daily averaged, mapped, gap-filled, ~1 km

Concentrations of:

- Total PM_{10}
- Total $PM_{2.5}$
- Sulfate $PM_{2.5}$
- Nitrate $PM_{2.5}$
- OC/EC $PM_{2.5}$
- BC $PM_{2.5}$
- Dust $PM_{2.5}$



MAIA data product summary

Level	Description	First production; Latency	Anticipated Users
0	Downlinked instrument telemetry	6 months; <24 hours	MAIA team
1	Calibrated and georectified Stokes parameters describing radiance and linear polarization; view and solar geometry; latitude and longitude	6 months; <36 hours	MAIA team, non-aerosol users (e.g. cloud or land surface researchers)
2a	Cloud mask and cloud-screened total and fractional aerosol particle properties at time of satellite overpass	12 months; <48 hours	Aerosol researchers, exposure researchers, MAIA epidemiologists
2b	24-hr averaged concentrations of coarse PM, fine PM, and fine PM components on days and locations coincident with cloud-free and quality-controlled instrument observations of the MAIA PTAs	12 months; <72 hours	Exposure researchers, MAIA epidemiologists
4	Spatially and temporally gap-filled 24-hour averaged concentrations of daily coarse PM, fine PM, and fine PM components over the MAIA PTAs	18 months; <72 hours	Epidemiologists, air quality modelers, air quality managers

These are the currently projected performances; subject to change

Timescales for associating PM exposure and health in the PTAs

Exposure timescale Health outcomes
Acute (days to weeks) Emergency room visits, premature deaths
Subchronic (months) Adverse birth outcomes, pregnancy complications
Chronic (years) Cardiovascular and respiratory diseases

Current health study plans in the PTAs (subject to update)

USA-LosAngeles	Cause-specific mortality
	Low birth weights, preterm deliveries
USA-Atlanta	Respiratory morbidity
USA-Boston	Mortality, heart attack, stroke, pneumonia
	Birth weight, gestational age
	Mortality, heart attack, stroke, pneumonia
ESP-Barcelona	Multiple outcomes from primary care ctrs.
ITA-Rome	Cause-specific mortality, disease-specific hospitalizations (cardiovascular/respiratory disease, diabetes, neurological disorders)
	Same as above
ZAF-Johannesburg	Cause-specific mortality due to ischemic heart disease, stroke, pneumonia, COPD, diabetes
ISR-TelAviv	Mortality, heart attack, stroke, pneumonia
	Birth weight, gestational age, congenital anomalies
	Mortality, heart attack, stroke, pneumonia
ETH-AddisAbaba	Preeclampsia, low birth weight and tuberculosis, child mortality/growth/lung function/cognition
Northern China	Atherosclerotic cardiovascular disease (ASCVD) including nonfatal myocardial infarction, coronary heart disease death, fatal/nonfatal stroke
Northern India	Cardiovascular mortality, cardiovascular and respiratory morbidity and hospitalization, possibly lung function in children and adults
Taiwan	Preterm birth, low birth weight, small for gestational weeks, and maternal pregnancy complications (preeclampsia, hypertension)

Acute | Subchronic | Chronic

MAIA data product summary

Spatial resolution: ~250 m for Level 1; ~1 km for Level 2 and 4

Temporal resolution:

- Overpass time: Late morning for most targets
- Overpass frequency: ~3.5 times per week for PTAs, and less than this for STAs.
- MAIA L0, L1, and L2 data will be produced for the time of overpass
- MAIA L4 data (daily averaged) will be produced for each day, **but will have better quality on days with an overpass**

Data product format: NetCDF

Preliminary/final products: The GRM producing the L2 and L4 PM products will be regenerated periodically to improve performance with more MAIA and surface monitor data. Therefore, preliminary data made with the current GRM will be available within a few days of overpass, but the final and best quality products will not be produced until end of prime mission.

AOD accuracy requirement: "The MAIA Project's mid-visible column AOD shall be retrieved with 1-sigma uncertainty given by ±max(0.05, 20%*AOD)."

PM accuracy requirement: "The MAIA Project derived PM concentrations shall have regression slopes compared to collocated surface monitor data between 0.5 and 1.5 after 2 years of data collection, when the matchups are statistically aggregated over all PTAs."

Early Adopter program

- Design and Fabrication (now – June 2020)
  - Publish MAIA Applications Plan
  - Gather potential Early Adopters
  - Hold initial workshops
- Assembly, Test, and Launch (June 2020 ~ 2022)
  - Continue to develop Early Adopter relationships and hold workshops
  - Develop test data products and share with Early Adopters
  - Begin developing user guides, tutorials, and short courses
  - Add applications info to the MAIA website
- Operations (~2022 ~ 2025)
  - Hold workshops, short courses, and tutorials
  - Add and maintain user resources