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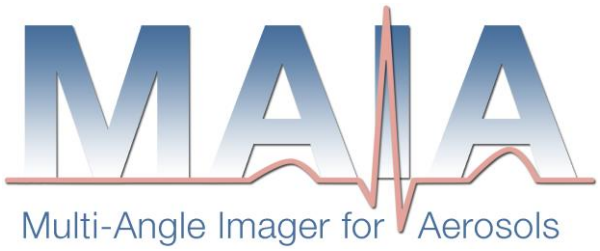

MAIA Applications Plan

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1. PURPOSE

The purpose of this document is to establish the guidelines for the implementation of an Applications program for the National Aeronautics and Space Administration (NASA) Multi-Angle Imager for Aerosols (MAIA) investigation.

This document is intended to provide guidance and outline existing and potential future activities, partners, and communities. Activities will be focused on engaging, encouraging, and developing targeted user communities. These communities include users who have a clear and well-defined need or use for MAIA data products, as well as groups that may be unfamiliar with NASA data and capabilities, but can benefit from MAIA information and data products in their processes.

2. MISSION DESCRIPTION

Particulate matter (PM) air pollution is known to be a serious risk to human health. The Global Burden of Disease (GBD) Study is a ground-breaking report that examines global morbidity and mortality rates due to disease, injury, and other risk factors. In the GBD Study 2016, outdoor air pollution was reported to cause 4.1 million deaths in that year, predominantly affecting those populations living in rapidly developing countries. Exposure to PM air pollution is recognized as the largest environmental risk factor, as opposed to personal risk factors like heredity and behavior, for premature death. This means that improving global air quality has the potential to lengthen millions of lives.

In order for governments to make the most effective decisions to improve air quality, they should understand which sources of PM are most dangerous to human health. A major step to reach this objective is to characterize the impacts of different types of PM (mixtures of different size and compositional constituents) on disease and mortality, which is what MAIA is designed to investigate. MAIA will use a combination of spaceborne technologies to collect multispectral, multi-angle, and polarimetric observations, which provide information about the size, shape, and composition of the particles that comprise air pollution. The data collected from the instrument will be combined with other information, including measurements from air pollution monitors on the ground and outputs from a chemical transport model to calculate the concentrations of various PM types over a globally distributed set of Primary Target Areas worldwide. Epidemiologists on the MAIA team will conduct studies on the health impacts of these aerosol mixtures.

MAIA's science objectives are to:

- Assess the impacts of different size and compositional mixtures of airborne PM on adverse human health outcomes; and
- Collect multi-angle spectropolarimetric imagery over targets of interest to the air quality and climate science communities.

MAIA is an Earth Venture Instrument (EVI) managed by NASA's Earth Science Systems Pathfinder (ESSP) Program Office. The MAIA instrument will be hosted by a commercial

spacecraft to be built by General Atomics Electromagnetic Systems (GA-EMS), and will be launched in 2022 (to be confirmed) into a low-Earth, sun-synchronous orbit. The baseline mission length is 3 years. MAIA is NASA's first competitively selected instrument investigation with societal benefit as its primary objective. From the very beginning, MAIA has included co-investigators from the Environmental Protection Agency, National Institutes of Health, Centers for Disease Control and Prevention, and National Oceanic and Atmospheric Administration. This unique and diverse science team will help ensure that MAIA data products and science advancements are able to make a concrete impact to those managing public health air quality issues. More recently, collaborations with the US Agency for International Development (USAID) and the US Department of State have been established. This both underscores the importance of MAIA's Applications Program and presents unique challenges and opportunities in carrying out the program.

2.1 Primary Target Areas and other observation opportunities

The MAIA instrument captures multi-angle views using a "step and stare" approach to observe given target areas. With a baseline of one observation per orbit on the daylit side of the Earth, MAIA has approximately 100 orbits per week to allocate among targets. There are four major types of MAIA targets:

a. Primary Target Areas (PTAs): MAIA's Level 1 requirements state that MAIA will produce (baseline)/contribute (threshold) to health studies in ten-plus globally distributed Primary Target Areas representing a variety of PM concentrations and particle types. The PTAs must also be observed at least three times per week, averaged seasonally, and Level 0-Level 4 products (see section 2.2) must be produced in each area. The selection of the PTAs thus depends on several factors that determine whether a location is suitable for a MAIA health study, including population, cloudiness, availability of surface monitor data, a MAIA epidemiologist who will conduct or oversee the health studies in the region, and the concentration and types of PM present in the region. For more details on the selection of the PTAs, see the MAIA Target Science Implementation Plan. With the current set of 11 PTAs, approximately 40 of the 100 weekly orbits will be dedicated to PTA observations (with some margin built in).

b. Secondary Target Areas (STAs): Secondary targets are not required to meet the same observation frequency or data processing level requirements as Primary Target Areas. The current STA candidates include regions where epidemiologists (and potentially other environmental health researchers) within and outside the MAIA Science Team are interested in conducting health studies, and also include regions of persistent cloud over oceans where MAIA will provide "sweep" observations for the scientific community. Data from the STAs may be processed to a variety of product levels, depending on team resource availability, surface monitor data availability, and community desires. The STAs may also change over the course of the mission.

c. Calibration/Validation Target Areas (CVTAs): MAIA will observe a number of land and ocean targets to provide calibration and validation data to the team. Of the three

CVTAs over land, two of them are in desert regions where the surface reflectance is relatively stable for vicarious calibration.

d. Targets of Opportunity (TOOs): The MAIA team will have the ability to add targets to the weekly observation plan with one day notice to observe additional targets of interest. TOOs could include wildfires, areas experiencing unusually poor air quality, or other regions experiencing transient events of interest to the air quality and climate science communities.

The current candidates for the first three types are illustrated in Figure 1.

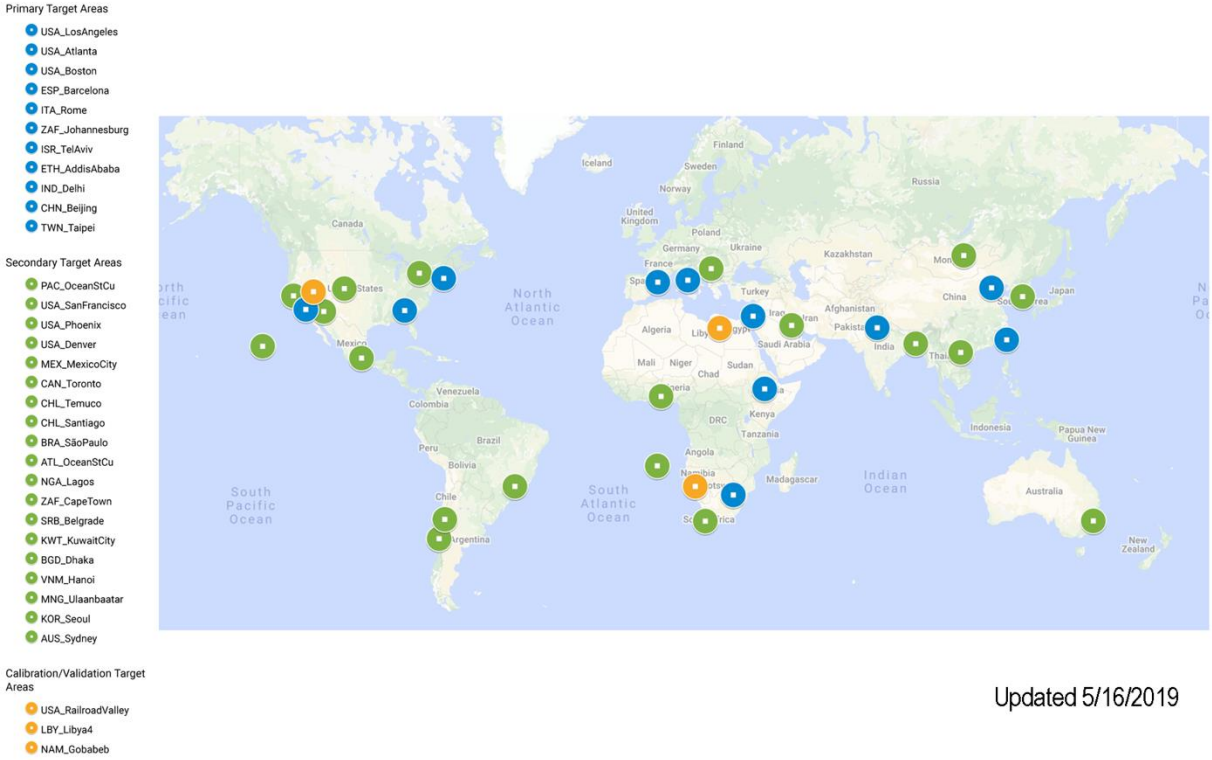

Figure 1. MAIA candidate target areas (as of 5/16/2019).

2.2 Data Products

MAIA's Level 1 requirements state that the project will produce the following data products. All products are required to be produced in the Primary Target Areas; only some products may be produced in Secondary Target Areas and Targets of Opportunity. Calibration/Validation Target Areas will be processed only through Level 1.

Level	Description	First production; Latency	Users
0	Downlinked instrument telemetry	6 months; <8 weeks	MAIA team, GA

1B2T/1B2E	Calibrated and georectified Stokes parameters describing radiance and linear polarization; view and solar geometry; latitude and longitude	6 months; <12 weeks	MAIA team, non-aerosol users (e.g. cloud or land surface researchers)
2AER	Cloud mask and cloud-screened total and fractional aerosol particle properties at time of satellite overpass	12 months; <20 weeks	Aerosol researchers, exposure researchers, MAIA epidemiologists, environmental health researchers
2PM	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; <20 weeks	Exposure researchers, MAIA epidemiologists, environmental health researchers
4PM	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; <28 weeks	Epidemiologists, environmental health researchers, air quality modelers, air quality managers

These data products will be produced, stored, and distributed at the Atmospheric Science Data Center (see section 2.3 for more details). MAIA's core data products are expected to be produced in NetCDF format, with metadata conforming to ISO 19115 and NASA Earth Observing System Data and Information System (EOSDIS) standards. Browse imagery and other ancillary products will also be produced.

The health studies conducted by the epidemiologists on the MAIA Science Team using the above data products are also considered a product of the investigation. They may be used by governments, air quality agencies, nonprofits, or commercial entities to evaluate the effectiveness of regulations and other purposes. Each epidemiologist and his or her collaborators are solely responsible for obtaining access to the health data needed for the study and maintaining the privacy of the health records. The studies will be available through publication in scholarly journals.

Challenges and opportunities for maximizing MAIA data product use

The MAIA investigation, including the instrument design and operations strategy, is extensively customized toward the primary science objective of conducting epidemiological

studies. However, this presents challenges in regards to building capacity with user communities with differing needs. These challenges include:

1. Data latency: MAIA's Level 2 and Level 4 PM products depend on surface monitor data as an input, including data from speciation monitors that collect particles on filters and must be analyzed in a lab. It may take up to 12 months for the MAIA team to receive the data from these monitors. The team plans to produce initial versions of the data products using historical data from the monitors while awaiting the final data, but these initial products will have reduced quality.

2. Data reprocessing: The Level 2 and 4 PM products are produced by a sophisticated geostatistical regression model (GRM) method, with the satellite data, surface monitor data, chemical transport modeling, and other datasets as inputs. The performance of the GRMs in the target areas will improve over time as more satellite and monitor data are available for analysis. Therefore, the data products will be periodically reprocessed with the latest GRM throughout the lifetime of the mission.

Both of these considerations are of less concern to epidemiologists, who sometimes have a long latency on health records or use publically available health records for their studies. Other communities of potential, especially other environmental health researchers and end users, air quality forecasters, and members of the public interested in day-to-day air quality, may have different requirements for latency. As MAIA data products will be open access and publicly available, the MAIA project encourages the larger community to develop their own research products using MAIA data. For example, model-based methods of partitioning $PM_{2.5}$ into constituent species would mitigate dependency on ground-based speciation monitors, but would require concurrent evaluations and improvements of model performance. It will be the responsibility of data users to remain mindful of the performance assessments and limitations associated with each operational release, which will be documented as new releases are generated.

2.3 Partnership with the Atmospheric Science Data Center

The Atmospheric Science Data Center (ASDC) is one of NASA's 12 Distributed Active Archive Centers (DAACs), which process, archive, document, and distribute data from NASA's past and current Earth-observing satellites and field measurement programs. The ASDC is responsible for the processing, archival, and distribution of NASA Earth science data in the areas of radiation budget, clouds, aerosols, and tropospheric composition, and is the DAAC partnered with the MAIA investigation.

ASDC will receive the functional product generation executables (PGEs) developed by the Jet Propulsion Laboratory (JPL). The data received from the GA-EMS ground system will be transferred to ASDC, where it will be processed through the PGEs and the standard data products generated. ASDC will then store the data products and provide public access. ASDC will also reprocess the data products (see section 2.2) when the MAIA geostatistical regression models are updated or other software changes are made.

In addition to these responsibilities, ASDC will also be MAIA's partner on capacity building. ASDC will assist JPL to prepare workshops, courses, and tutorials for MAIA Early Adopters

and other potential users (see section 4). ASDC will also consult with JPL to develop tools to effectively visualize and distribute MAIA data, and can assist in the distribution of the Simulated Data Products (see section 4).

2.4 Synergy with other projects and missions

Satellite aerosol data have been increasingly used for applications purposes in the last few decades, especially to study the connection between air pollution and human health. NASA missions in operation, especially the Moderate Resolution Imaging Spectroradiometer (MODIS) instruments on the Terra and Aqua satellites and the Multi-angle Imaging SpectroRadiometer (MISR) on Terra, are currently extensively used for these applications. Both MODIS and MISR may still be operating when MAIA is launched, which could provide opportunities for cross-platform synergies. Regardless, the MAIA Applications efforts will encourage MISR and MODIS scientific and operational users to apply MAIA data to their efforts and help recruit new applied data users, along with their associated decision makers.

There are two other NASA Earth Venture class missions concerned with aerosols and air quality currently in development. One is Earth Surface Mineral Dust Source Investigation (EMIT), which will study dust source regions on Earth via spectroscopy from the International Space Station, with launch currently scheduled for 2024. This overlaps with MAIA's planned baseline mission, and dust is one of the types of particulate air pollution MAIA plans to study. The second is Tropospheric Emissions: Monitoring of Pollution (TEMPO), a spectrometer studying gaseous air pollution including ozone and NO_2. TEMPO will be hosted on a commercial geostationary satellite observing North America, and is currently planned for launch in early 2022. TEMPO and MAIA are complementary and can provide opportunities to study both the gaseous and particulate fractions of air pollution, and as both have ASDC as their DAAC, ASDC can also facilitate synergy between the projects' data products. Furthermore, TEMPO is part of an international constellation of geostationary satellites observing gaseous air pollution, together with GEMS (Asia) and Sentinel-6 (Europe). MAIA will observe targets within each of these areas from low-Earth orbit.

The MAIA instrument is largely based on designs developed for an airborne instrument built and operated by JPL, the Airborne Multiangle SpectroPolarimetric Imager (AirMSPI). AirMSPI has been flying aboard the NASA Earth Resource-2 (ER-2) high-altitude aircraft since 2010, and has participated in numerous field campaigns. Georectified and calibrated radiance and polarimetric imagery from these campaigns are available from the ASDC. A second-generation instrument called AirMSPI-2, even more closely similar to MAIA, is undergoing engineering work to prepare it for scientific flight readiness. AirMSPI and AirMSPI-2 have the potential to provide simultaneous, higher-resolution measurements concurrent with MAIA and could provide input to simulated data products to be used by Early Adopters.

The 2017 Earth Science Decadal Survey outlined a designated mission to study aerosols, nominally composed of a backscatter lidar and multi-angle imaging polarimeter. This could potentially be flown in conjunction with another designated mission to observe cloud convective processes, nominally with a dual-band radar. MAIA will provide applications lessons learned to the Aerosols and Cloud Convective Processes (A-CCP) study team, which may be able to provide capability beyond MAIA for health and air quality applications.

3. OBJECTIVES & OPERATING PRINCIPLES

The primary objectives of NASA's Applied Sciences Program (ASP) are to promote and fund activities to discover and demonstrate the innovative uses and practical benefits of data, scientific knowledge, and technology that stem from NASA's Earth science missions.

NASA ASP is committed to developing and implementing a broad-reaching applications program that includes early-phase NASA Earth observing satellite missions. In this interest, ASP funds a MAIA Deputy Program Applications (DPA) Lead, who acts on behalf of the ASP. Lawrence Friedl, the NASA ASP Director, and John Haynes, ASP Health and Air Quality Program Manager, oversee the MAIA applications efforts.

The primary goal of the MAIA Applications program is to maximize the benefit of the NASA Earth Science Directorate (ESD) investment by enhancing the applications value and overall societal benefits of the project. The MAIA Mission Applications effort will create resources and conduct various types of events to provide inspiration, information, and capacity-building among practicing and potential users of MAIA data. Because MAIA is an applications-focused mission, the applications efforts are customized to capitalize on MAIA's applied science objectives and existing science team collaborations. See Appendix C, the MAIA Applications Traceability Matrix, for more detail on how the applications objectives trace to the MAIA data products.

3.1 Objective 1

The primary objective of the MAIA applications effort is to engage the epidemiological, environmental health and research, and air quality communities of potential to maximize the usability and utility of MAIA science data products.

Epidemiologists on the MAIA Science Team funded under the PI-managed cost cap are tasked with conducting health studies in each of MAIA's PTAs. The current candidate set of PTAs is shown in Fig. 1. Success of these efforts requires engagement of local epidemiologists outside of the Science Team who will facilitate access to the required health records and co-lead the health impact studies, particularly in the non-US PTAs. In addition, engagement of epidemiologists and environmental researchers interested in prospective STAs, but as yet unknown to the MAIA project, would expand the application of MAIA data to additional regions of the world and broaden the value of MAIA data products. An STA is a location where additional health impact or particular matter exposure studies may be conducted, or where MAIA data could be used for a different application, such as air quality forecasting, other environmental studies or climate research. In addition, the success of the MAIA project also depends on close engagement with governmental air quality agencies to facilitate access to surface monitor data; the MAIA applications effort seeks to work with these agencies to maximize the utility of MAIA's data products to them in turn, for siting monitors, evaluating regulations, and managing exceptional events.

3.2 Objective 2

To the extent possible, the MAIA applications effort will also help facilitate the use of MAIA data among governmental and non-governmental entities to support decision-making, protection of public health, and education.

Currently, government agencies are hesitant to employ satellite-based data in their regulatory processes, due to the fact that they are legally liable for the accuracy of their products. On the other hand, satellites provide greater spatial coverage compared with surface monitors, and have the potential to inform pollution control strategies, regulatory decisions, and public health assessments. To explore current perceptions and future needs, MAIA can leverage its governmental Public Health Partners. In addition to governmental agencies, several private foundations are investing in efforts to understand the relative risks of air pollution and disease on human health, and to develop strategies for mitigation of risk. Several representative and influential organizations will be identified on the MAIA Community Contacts list and potential collaborations will be explored.

3.3 Operating Principles

The operating principles for the MAIA Missions Applications program are as follows:

- Partner with proven, effective organizations, groups, and/or individuals with aligned goals and objectives (Appendix A);
- Identify and develop specific target audiences and venues; and
- Provide inspiration, information, and capacity-building opportunities (Section 4) to potential data users.

The applications effort will evolve through MAIA's mission life cycle:

Phase C (Final Design and Fabrication):

- Develop a broad community of potential MAIA applications users.
- Assess unmet applications needs.
- Devise strategies to maximize the utility of MAIA data to meet those needs, within the scope of the project.
- Communicate the MAIA applications strategy to a broad audience.

Phase D (System Assembly, Integration, Test, and Launch):

- Continue to develop the MAIA applications community.
- Engage in an iterative product review process with our Early Adopters and other identified users to ensure maximum utility of the MAIA data products.
- Begin developing capacity building resources for users.

Phase E (Operations and Sustainment):

- Promote the use of MAIA operational data products.
- Conduct applications data validation, verification, and transition with established partners.
- Build capacity of operational data users via training events and online resources.
- Continue to develop the MAIA community of practice.

- Expand the inventory of MAIA data resources and information.
- Evaluate and improve the utility of MAIA data products.
- Continue to develop new applications partnerships as opportunities arise.

The communication strategy for the MAIA Applications Program will include:

- Printed content to be distributed at in-person events
- Easily discoverable online resources shared through the DAAC and the MAIA website:
    - Data tutorials/handbooks
    - Video (Data Product Tutorials, testimonials)
- In-person and online events
    - Focus sessions at meetings and conferences
    - Workshops and Short Courses

4. ACTIVITIES

This section describes applications activities aligned with the maturity of the mission and its data products. A table of activities mapped to phase/calendar year can be found in Appendix B.

Activities associated with Objective 1 (Section 3.1) are considered to be part of MAIA's Core Applications Program.

1.1. Document the MAIA Applications Plan, describing MAIA's planned applications activities and reasoning for these choices (this document). A traceability matrix (Appendix C, this document) will be included. The Applications Plan will be revised on an annual basis if deemed necessary.

1.2 Establish and cultivate Community Contacts, consisting of interested parties in various communities relevant to MAIA including existing partners in the PTAs, new partners as plans for STAs are developed, and representatives from synergistic government and privately sponsored air quality and human health programs and initiatives, including the NASA Health and Air Quality Applied Sciences Team (HAQAST).

1.3. Establish an Early Adopters program. Early Adopters are a subset of the Community Contacts who agree to use MAIA data for an exposure assessment study, health impact study, or other purposes, in return for early access to prototype and simulated data and technical support. Specific activities include:

1.3.1. Conduct Applications Workshops/Focus Sessions to provide hands-on discussion and instruction for using MAIA data products, obtain feedback on user needs and how MAIA can best meet them, evaluate the effectiveness of the products, and update the list of STAs based on community inputs. Workshop reports will document the needs of the community and collected feedback.

1.3.2. Generate Simulated Data Products, in partnership with the MAIA Science

Data System, to facilitate usability and utilization of MAIA data products by the Early Adopters and ensure availability of data browsing and visualization tools. Feedback from the MAIA Early Adopters or Applications workshops would be solicited to inform future updates to actual MAIA product formats or content generated during the mission. At the minimum, these Simulated Data Products will allow Early Adopters to evaluate the format, metadata, and content fields and formatting. If science team resources allow, the Simulated Data Products may also contain data content derived from MISR, AirMSPI, and/or model output.

1.3.3. Conduct Short Courses/Tutorials, in partnership with ASDC and the MAIA Science Team, during the active mission phase to provide hands-on instruction to new users on where to find and how to use MAIA data products. These would be organized in conjunction with relevant scientific conferences and/or MAIA Science Team Meetings, with a focus on developing professional skills, including data discovery, access, and visualization techniques. These events will also provide opportunities to elicit feedback on DAAC user services and online tools. Online materials will be generated to aid potential users of MAIA data and will nominally be available from the MAIA and/or DAAC website and can also be used in Applied Remote Sensing Training (ARSET) workshops/webinars.

1.3.4. Increase applied science community awareness and engagement as a presenter and exhibitor at selected air quality and environmental health community events, such as the International Society for Environmental Epidemiologists annual conference, the International Society of Exposure Science Conference, the Environmental Protection Agency's National Air Quality Conference, the American Thoracic Society's annual conference, and the World Health Organization's Global Conference on Air Pollution and Health, as well as other events identified by our epidemiologist, environmental health, and other partners.

1.4 Fulfill the reporting requirements of the DPA Lead with semi-annual reports to NASA Headquarters on accomplishments, plans, budget, and schedule.

APPENDIX A: List of Partners

The following are partners which oversee MAIA or its Applications Program, work with the MAIA project to site needed surface monitors, can provide resources to assist in the implementation of the Applications Program, or with demonstrated interest in satellite air quality applications. Over time, the MAIA Missions Applications Program will continue to grow its partnerships with effective organizations, groups, and/or individuals with aligned goals and objectives.

NASA
- Earth Sciences Division (ESD)
- Earth Science Systems Pathfinder (ESSP)
- Applied Sciences Program (ASP)
- NASA SERVIR
- Atmospheric Sciences Data Center (ASDC)
- Goddard Space Flight Center (GSFC)

MAIA International Air Quality Monitor partners
- Institute of Environmental Assessment and Water Research (Spain)
- ARPA Lazio (Italy)
- University of Johannesburg (South Africa)
- Council for Scientific and Industrial Research (South Africa)
- Technion Institute of Technology (Israel)
- Lund University (Ethiopia)
- Addis Ababa University (Ethiopia)
- Indian Institute of Technology (India)
- Fuwai Hospital (China)
- National Taipei University of Nursing and Health Sciences (Taiwan)
- US Agency for International Development (USAID) (Ethiopia and South Africa)
- US Department of State (various US Embassies)

MAIA Instrument and Remote Sensing partners
- Naval Research Laboratory
- University of Arizona
- University of Illinois
- Washington University in St. Louis
- University of Iowa

MAIA Epidemiology partners
- International Society for Environmental Epidemiology (ISEE)
- University of British Columbia
- University of California – Los Angeles
- University of California – Davis
- Emory University
- Harvard University

MAIA Public Health partners
- Centers for Disease Control and Prevention (CDC)

- US Environmental Protection Agency (EPA)
- South Coast Air Quality Management District (SCAQMD)
- National Institutes of Health (NIH)
- National Oceanic and Atmospheric Administration (NOAA)
- ITT Delhi

APPENDIX B: Products by Development Phase

	Phase C	Phase D	Phase E
Project Phase	Final Design and Fabrication	Systems Assembly, Test and Launch	Operations and Sustainment
Dates	6/2018 – 6/2020	7/2020 – launch (~2022)	~2022 – 2025
Purpose of Applications Effort	Develop the MAIA Community of Potential and lay groundwork for Early Adopters.	Design the MAIA data products for maximum applications utility. Begin developing resources for users.	Promote the use of MAIA data products, conduct applications projects, and evaluate impact
Activities	Develop and maintain a Community Contact List	Maintain and add to the Community Contact List	Maintain and add to the Community Contact List
	Hold Early Adopter and Applications workshops	Continue to hold workshops/focus sessions to evaluate the planned MAIA data products	Continue to hold workshops/focus sessions to help Early Adopters and other users begin using the data products
	Offer Early Adopter partnerships	Begin developing tutorials, short courses and other resources	Create online resources and Conduct Workshops, Short Courses, Tutorials, and Focus Sessions
	Develop and maintain a Community Contact List	Share simulated data products with Early Adopters	Maintain the user information section of MAIA's website and add new resources
	Begin developing simulated data products	Add information about MAIA data products and other user resources to the MAIA website	Continue to present about MAIA applications
	Present about MAIA applications	Continue to present about MAIA applications	
Deliverables	Applications Plan (AP)	Updated AP (annual) and ATM (as needed)	Updated AP (annual) and ATM (as needed)
	Applications Traceability Matrix (ATM)	Simulated data products	Applications Workshops, Short Courses, Tutorials, and Focus Sessions
	Community Contact List	Updated Community Contact List	Updated Community Contact List
	Early Adopter Workshop(s)	Tutorials, short courses, other data resources	MAIA Applications Posters/Presentations
	MAIA Applications Posters/Presentations	MAIA Applications Posters/Presentations	Information for Senior Review submissions
Mission Events	CDR: Critical Design Review	SIR: Systems Integration Review	Commissioning
		ORR: Operations Readiness Review	Operational data availability
		MRR: Mission Readiness Review	
Gate Reviews	KDP-D	KDP-E	KDP-F

APPENDIX C: Applications Traceability Matrix

Applications Objective	Applications Questions	Applications Concept	Applied Science Category	End-users/ agencies	End-use	ARL	Applicable MAIA data product(s)	Projected MAIA Instrument Performance	Ancillary Data
O1: The primary objective of the MAIA applications effort is to engage the epidemiological, environmental health and research, and air quality communities of potential to maximize the usability and utility of MAIA science data products.	**Q1:** For which PM types is: a) short-term (daily to monthly) exposure linked to illness (e.g., asthma flare-ups) and premature death? b) maternal exposure linked to adverse birth outcomes such as restricted intrauterine growth, preterm delivery, and low birth weight? c) chronic (multi-year) exposure linked to cardiovascular and respiratory disease?	The objective of the MAIA investigation is to determine the relative toxicity of different PM types and to assess the impacts of particle size and composition on adverse birth outcomes, cardiovascular and respiratory disease, and premature deaths. This wil be accomplished via use of the MAIA data products by epidemiologists, both on the MAIA team and outside of it, to produce health studies. The MAIA applications effort also seeks to further optimize the MAIA data products to meet the needs of the air quality and environmental health and research communities.	*Public Health and Air Quality*	**Epidemiologists:** NIH, CDC, WHO, university researchers	Epidemiological studies	**3:** While the use of satellite-derived PM data in aerosol, epidemiological and environmental studies is well-established, and the air quality community has been increasingly incorporating satellite data over the past years, the MAIA method of deriving speciated PM has yet to be utilized in a study. Proof-of-concept studies of the MAIA method include Meng et al (2018), Franklin et al (2017, 2018).	**MAIA Level 2 AOD product:** Total and fractional AOD on 1-km grid •Sulfate •Nitrate •Organic carbon •Black or elemental carbon •Dust	Uncertainty: AOD ≤ ±0.05, ±15%	MAIAC surface reflection, aerosol light scattering model, transmission model, climatology, meteorology
	Q2: What associations exist between various PM types and effects on the health of humans, other living organisms, and the Earth environment as a whole?			**Environmental researchers:** NIH, WHO, university researchers	Studies concerning the impacts of PM on human, animal/plant, and environmental health		**MAIA Level 2/4 PM products:** Total PM2.5 and PM10 and partitioned PM2.5 on 1-km grid: •Sulfate •Nitrate •Organic carbon •Black or elemental carbon •Dust	Bias ≤ ±10% Error ≤ ±30%	Surface monitors; smoke emissions data (FLAMBE); quasi-static emissions inventories, GEOS-FP/MERRA-2 boundary meteorology + chemistry
	Q3: How can satellite-derived data concerning the spatial and temporal distribution of various types of PM be incorporated into the decision-making processes for regulating and monitoring PM?			**Governmental air quality managers:** EPA, state and local air quality organizations, international air quality organizations	Siting monitors, evaluating and improving regulations, managing exceptional events		PM exposure- response relationships	N/A	Health records* (vital statistics, hospital admissions, cohort studies)
	Q4: How can satellite-derived data concerning the spatial and temporal distribution of various types of PM be used to improve our current understanding of aerosol science and improve aerosol models, including air quality forecasting?			**Air quality researchers:** NASA, university, and other researchers	Air quality forecasting, aerosol climatologies, aerosol modeling				
O2: To the extent possible, the MAIA applications effort will also help facilitate the use of MAIA data among governmental and non-governmental entities to support decision-making, protection of public health, and education.	**Q1:** To what extent can the MAIA data products and body of health studies inform decisions that will positively impact individuals' lives?	The epidemiological studies that the MAIA investigation will produce can be used by governments, health professionals, commercial organizations, nonprofits, and citizens to make decisions on how to cost-effectively address the health impacts of PM and manage air quality. Some users may also be able to entrain the MAIA data products into their decision-making processes.	*Public Health and Air Quality*	**Governmental health agencies:** CDC, NIH, USAID, WHO, international health agencies	Issuing health guidance, assessing the health and economic impact of air pollution	**1:** Concepts only	**MAIA Level 2 AOD product:** Total and fractional AOD on 1-km grid •Sulfate •Nitrate •Organic carbon •Black or elemental carbon •Dust	Uncertainty: AOD ≤ ±0.05, ±15%	MAIAC surface reflection, aerosol light scattering model, transmission model, climatology, meteorology
				Health professionals: doctors, hospitals, insurance companies	Issuing health guidance to patients		**MAIA Level 2/4 PM products:** Total PM2.5 and PM10 and partitioned PM2.5 on 1-km grid: •Sulfate •Nitrate •Organic carbon •Black or elemental carbon •Dust	Bias ≤ ±10% Error ≤ ±30%	Surface monitors; smoke emissions data (FLAMBE); quasi-static emissions inventories, GEOS-FP/MERRA-2 boundary meteorology + chemistry
				Commercial organizations: Manufacturers of air quality monitors, businesses concerned with employee health	Targeting monitor technology to particular PM types, issuing health guidance to employees				
				Nonprofits: 100 Resilient Cities (Rockefeller Foundation), Global Burden of Disease (Gates Foundation), Resources for the Future, environmental justice organizations	Targeting nonprofit resources for cost-effective mitigation of health risks		**MAIA body of epidemiological studies**	N/A	N/A
				Individuals	Making decisions about where to live and work, how to mitigate personal health risk by limiting exposure based on normal seasonal or daily trends				

*Health records, unlike the other ancillary data, are not part of the publicly available MAIA data products and will be viewed and/or stored ONLY by the responsible epidemiologist conducting the health study, in accordance with privacy guidelines.