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# PHILIPPINE EARTH OBSERVATION SATELLITE MISSIONS AND APPLICATIONS: A DECADAL SURVEY

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**ABSTRACT:**

The Decadal Survey was conducted to generate recommendations for integrated and sustainable conduct of space-based environmental monitoring and Earth observation (EO) science programs. Inputs from members of the scientific community and various stakeholders were synthesized to gain an in-depth understanding of the current status and gaps in our space- and non-space-based observation systems in addressing challenges that may persist or arise in this decade. The Decadal Survey is conducted in two phases. The first phase is the Request for Information 1 (RFI-1), where 29 experts from the scientific community were asked to describe the most pressing challenges in their field and the corresponding objectives to address these challenges. A total of 54 challenges and 94 objectives were identified across six focus areas. The second phase consisted of the Delphi Survey where stakeholders from the government, academe, private sector, and non-government organization were asked to rank the challenges and objectives identified from Phase 1. A Request for Information 2 (RFI-2) is conducted to gather information on current programs and projects and institutional capabilities in relation to space science & technology applications (SSTA). Six focus areas (FAs) were identified to adequately cover the components of Earth observation. The assessment and validation of the prioritization of the challenges and objectives resulted in the identification of the top challenges per focus area. These priority challenges and objectives were then compared with the current SSTA technology capabilities of the agencies and institutions to identify common initiatives and gaps or areas for improvement. The results provided a glimpse of how the country's current SSTA capabilities and initiatives are implemented to solve different scientific challenges and objectives. Looking at the list of previous and ongoing projects, much focus has been made on addressing challenges in resource management and disaster risk reduction and management. Fewer programs and projects center on climate and Earth processes studies. Although most of the identified challenges were matched with at least one ongoing project, there is also concern about the continuity and sustainability of these projects. The Decadal Survey provided information regarding the priority objectives, the target observables, and the mission specifications and timelines from the program of record. The collated information was used to conduct a mission gap analysis that eventually determined the satellite payloads needed to address most of the priority challenges and objectives. The performed gap analysis led to the identification of three instrument gaps that will serve as the basis of future EO satellite missions.

## 1. INTRODUCTION

### 1.1 The Philippine Space Agency and The Philippine Space Policy

In 2019, the Act establishing the Philippine Space Development and Utilization Policy and creating the Philippine Space Agency (PhilSA) also known as the "Philippine Space Act" (RA 11363) was signed into law. As mandated by this Act, PhilSA shall be the primary policy, planning, coordinating, implementing, and administrative entity of the Executive Branch of the government that will plan, develop, and promote the national space program in line with the Philippine Space Policy.

The Philippine Space Development and Utilization Policy or the Philippine Space Policy serves as the country's primary strategic roadmap for space development and embodies the country's central goal of becoming a space-capable and space-faring nation within the next decade. It focuses on six Key Development Areas (KDAs) for Space Science and Technology Applications (SSTA) development, namely, national security and development, hazard management and climate studies, space research and development, space industry and capacity building, space education and awareness, and international cooperation.

Guided by the Philippine Space Policy, PhilSA is currently implementing programs and projects across all components of the space data value chain, from upstream to downstream, bridging space technologies and its applications to the end- users. In the upstream, PhilSA is developing and building satellites, and capacitating local space industry. In the downstream, satellite data is processed, analyzed, and distributed to various users who can act on this information, thus fully realizing its socio-economic benefits.

### 1.2 2021-2030 Decadal Survey

Since the launch of the first Philippine Earth Observation (EO) microsatellite Diwata-1 in 2016, the country has maintained having sovereign satellites in orbit for the purpose of monitoring the nation's land and water resources, built environment, and impacts of both natural hazards and man-made activities, and upscaling our satellite development know-how and capabilities. The 2021-2030 Decadal Survey project was conducted to determine future EO missions addressing the country's priority challenges for this decade. Specifically, it aims to achieve the following:

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1. Assess the status of Earth observation needs and utilization in the country;
2. Define and prioritize the key challenges that could be addressed by space-based technology;
3. Serve as a basis for determining the priority missions that will address the most important challenges; and
4. Generate recommendations for an integrated and sustainable conduct of space-based Earth observation, and data utilization and mobilization.

The Decadal Survey is undertaken by engaging the scientific community and stakeholders from the government and private sector in various information-gathering activities.

## 2. METHODOLOGY

The 2021-2030 Philippine Decadal Survey was initiated by the Advanced Satellite Development and Know-How Transfer for the Philippines Project (ASP) under the Space Technology and Application Mastery, Innovation and Advancement (STAMINA4Space) Program funded by the Department of Science and Technology (DOST), and was continued by the Philippine Space Agency (PhilSA).

The Decadal Survey follows the framework adapted from the Earth Science and Applications from Space survey conducted by the National Academies of Sciences, Engineering, and Medicine (NASEM) in the United States (NASEM, 2019).

### 2.1 Phase 1

The first phase of the decadal survey was conducted from October 2020 to March 2021. The process started with the determination of six focus areas relevant to the study of the Philippine environment. With reference to the publication by NASEM, the following focus areas were selected:

1. Hydrologic Cycles and Climate Studies
2. Weather, Air Quality and Atmospheric processes
3. Earth Surface and Interior: Dynamics and processes
4. Hazards and Disaster Risk, Reduction and Management
5. Aquatic Ecosystems and Water Resources Management
6. Terrestrial Ecosystems and Land Resources Management

There are several participants to the decadal survey, grouped into *steering committee*, *experts*, and *thematic panel*. The *steering committee* (SC), consisted of the project members, was responsible for directing and implementing survey activities. Focus areas were assigned to individual members of the committee for the processing, analysis, and documentation of findings. The *experts* are members of the scientific community who had significant experience and contributions to their fields. They were assigned to particular focus areas under which they determine key challenges and objectives for the decade. When possible, they also assisted the SC in identifying data products and requirements as solutions to the given challenges. The *thematic panel* consisted of select experts who utilize remote sensing, in particular, Earth observation data. They guided the steering committee in the analysis of the expert inputs and matching of suitable solutions.

Through the first request for information (RFI-1), the experts provided their responses to key and technical questions through online form, white paper, or consultation meetings. Online follow-up meetings were held for clarification or further discussion, as needed. A thematic panel identified the science and applications objectives that represent the challenges provided through the survey. In a Science and Applications Traceability Matrix (SATM), science or societal questions supporting the identified objectives were tabulated along with the geophysical parameters needed to answer the questions and the measurement methods proposed. Measurement methods were matched with a Program of Record (POR) containing available space-based solutions and upcoming instruments. Following the RFI-1, the accomplishment of the SATM was an iterative process involving the steering committee and panel members. The implementation of the Decadal Survey Phase 1 is illustrated in a workflow shown in Figure 1.

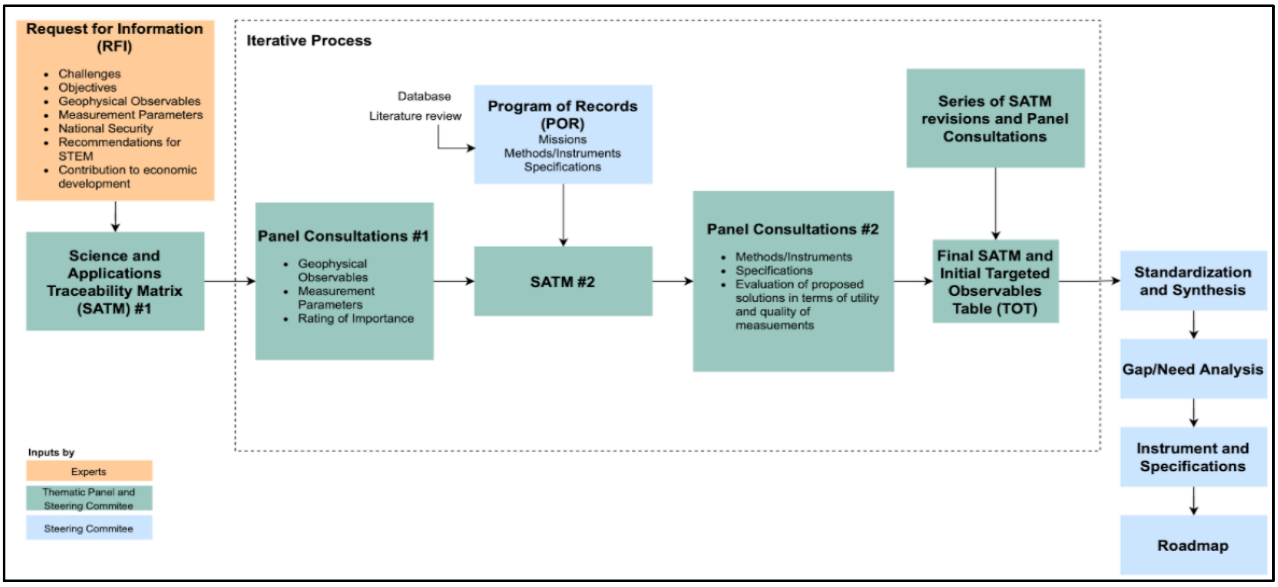


**Figure 1.** The Decadal Survey Phase 1 process.

## 2.2 Phase 2

The second phase of the Decadal Survey (Figure 2) involved three major activities that aim to gather more information to build up on the results of the first phase: the *expansion*, the *Delphi Survey,* and *Request for Information-2 (RFI-2)*.

In the *expansion***,** additional ratings of instruments were gathered to provide more information about the utility and quality of the instruments. This was conducted by having the experts give a Rating of Utility (RU), i.e. the level of objective achieved. The other one was Rating of Quality (RQ), which determines how well the required geophysical observable is obtained by the proposed measurement. The metric for both ratings are: 1- Low, 2-Moderate, 3-High, 4-Very High and 5-Highest. These ratings were used to determine the suitability of instruments in providing solutions to challenges and objectives given the identified requirements. In the later part of this study, those instruments which have at least an average rating of 3.0 for both utility and quality is considered as a suitable solution.

Consensus on the prioritization of objectives was reached using a *Delphi Survey*. Stakeholders from the government, academe, private sector and non-government organization were asked to rank the challenges and objectives identified from Phase 1. This survey was conducted in two rounds, R1 and R2, which had 122 and 75 responses, respectively. Using the POR from Phase 1, the priority objectives were matched with instruments that can provide related measurements. The objectives and corresponding geophysical observables that are associated with a common space-based observable were grouped together under a targeted observable. These targeted observables are presented in a Targeted Observable Table (TOT) with which we will propose an initial Mission Shortlist describing measurement approaches and specifications that are needed to address entries to the TOT.

A *Request for Information 2 (RFI-2)* is conducted to gather information on current programs and/or projects and institutional capabilities in relation to SSTA. These include information on remote sensing and GIS data products, ICT capabilities, agency manpower, and budget.

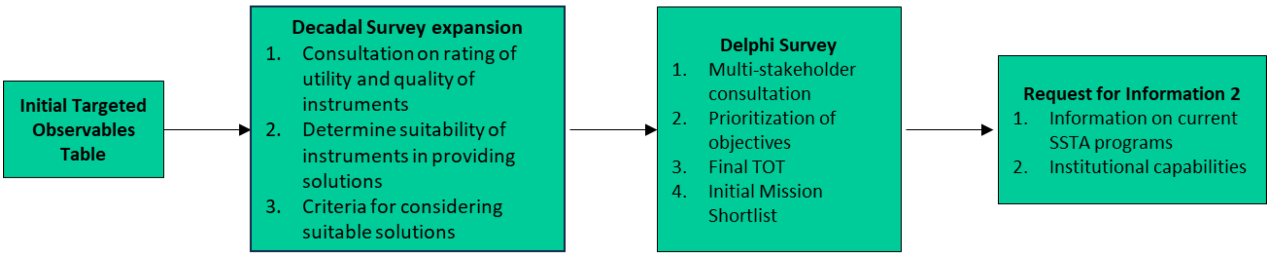


**Figure 2.** The Decadal Survey Phase 2 process.

## 3. RESULTS

In the first phase of the Decadal Survey, 29 experts from the scientific community were asked to describe the most pressing challenges in their field and the corresponding objectives to address these challenges. A total of 54 challenges and 94 objectives were identified across six focus areas. Through the Delphi Survey, the initial list of challenges and objectives were narrowed down to three to four per focus area, as listed in the Tables below:

| Priority Challenges | Priority Objectives |
|---|---|
| 1. Management of water resources and watersheds | To assess surface water runoff, groundwater recharge and other soil-water interactions |
| | To calculate water balance and surface water runoff |
| | To calculate water balance and energy budget |
| | To determine the previous and impervious features of watersheds and river basins |
| | To monitor the transport of pollutants and bacteria on watersheds and river basins |
| 2. Effects of climate change on meteorological hazards | To determine the amount of moisture in the air for the assessment of atmospheric preconditions leading to weather phenomena |
| | To derive different types of precipitation (stratiform, convective) and hydrometeor (hail, rain) from polarimetric variables |
| 3. Flooding due to river shallowing, mismanaged watershed, soil erosion and river encroachment | To provide additional and alternative methods in complementing atmospheric, hydrologic and water resources models for the assessment of flooding due to river shallowing, mismanaged watershed, soil erosion and river encroachment |

**Table 1.** FA1 - Hydrologic Cycles and Climate Studies


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| Priority Challenges | Priority Objectives |
|---|---|
| 1. Short-term weather forecasting | To continually improve data being assimilated in models (i.e., input of newer/more recent data) |
| | To improve Numerical Weather Prediction (NWP) model configurations used for operations |
| | To include additional parameter/s (to existing datasets) from polar orbiting satellites |
| 2. Understanding land-sea-air-human spheres dynamics | To provide temporally resolved measurements that will quantify changes in air quality due to weather systems and/or atmospheric processes (sea-land breeze, typhoons, human-land-sea-air interaction, UHI effect) at different scales |
| | To quantify any influence of man-made atmospheric pollutants in the development of rain clouds at diurnal and meso-scale resolutions |
| | To understand the interaction between the aerosols and meteorology |
| | To determine the effects of the planetary boundary layer on atmospheric processes |
| 3. Understanding impacts of human activities on air quality | To quantify the impacts of human activities and segregate from natural pollutants (volcanic, marine emissions) on air quality through spatially and temporally resolved measurements from satellites |
| | To determine the impacts of human activities on air quality through spatially and temporally resolved measurements from satellites |
| 4. High-resolution climate change projection | To generate impact-based climate change projection taking into account the maritime continent/ridge-to-reef environment/physical and biological attributes of the Philippines |
| | To generate impact-based climate change projection taking into account socioeconomic and cultural factors |

**Table 2.** FA2 - Weather, Air Quality and Atmospheric processes

| Priority Challenges | Priority Objectives |
|---|---|
| 1. Coastal Flooding and Sea Level Rise | Taking soil moisture into account, to forecast floods by modelling with infiltration data, initial water level and rainfall data |
| | To image vertical motion of land or motion of faults |
| 2. Lessening the vulnerability of populations to natural hazards | To have viable access to up-to-date spatial and temporal geographic information with sufficient and verifiable resolution and coverage |
| 3. Mitigation of disasters associated with natural hazards | |

**Table 3.** FA3 - Earth Surface and Interior: Dynamics and Processes

| Priority Challenges | Priority Objectives |
|---|---|
| 1. Natural hazards | To analyze hydro-meteorological hazards |
| | To analyze fault processes, earthquake hazards, and landslides |
| | To analyze volcanic processes and volcanic hazards |
| 2. Timeliness and accuracy of information in determining areas exposed to various hazards | To generate hazard information such as hazard maps and site-specific hazard assessment reports in a regular manner |
| | To develop flood models to simulate flooding |
| | To obtain topographic (elevation), land cover, and exposure datasets for hazard assessment purposes in a regular manner |

**Table 4.** FA4 - Hazards and Disaster Risk, Reduction and Management

| Priority Challenges | Priority Objectives |
|---|---|
| 1.Investigation of changes in seascapes affecting human and ecological security, and hence sustainability | To monitor location and abundance of marine resources |
| 2. Spatio-temporal detection of vegetation change in intact, restored and disturbed mangroves | To classify vegetation into maintained, improved or degraded |
| | To document instantaneous or regularly occurring disturbances (e.g. sudden increase of temperature, flooding) |
| 3. Climate change impact on sustainability and stability of fish food supply | To develop models such as projecting fish distribution and forecasting fisheries supply using vessel tracking and fish catch data |
| | To monitor primary production in nearshore and within municipal waters |

**Table 5.** FA5 - Aquatic Ecosystems and Water Resources Management

These priority challenges and objectives were then compared with the current SSTA technology capabilities of the agencies and institutions to identify common initiatives and gaps or areas for improvement.

Sixty-six (66) projects were identified from RFI-2. As can be seen in Figure 3, most of the identified projects can be classified under the three focus areas: FA 4 - Hazards and Disaster Risk, Reduction and Management, FA 5 - Aquatic Ecosystems and Water Resources Management, and FA 6 - Terrestrial Ecosystems and Land Resources Management. Majority of the identified projects match the priority challenges in all six focus areas, with most initiatives under Terrestrial Ecosystems and Land Resources Management (FA 6). All the other pressing challenges in FA 4, FA 5, and FA 6 are matched with at least one ongoing project, while the least addressed focus areas are FA 1, FA 2, and FA 3

Another result of the RFI-2 is the baseline information on the SSTA capability of research and relevant institutions in terms of human resources, specifically on technical personnel capable of processing satellite data. Figure 4 shows that most of the technical personnel work on a full-time contractual basis (e.g., project-based work). A good number of these technical personnel hold regular positions in their respective agencies. A small percentage of these personnel work part-time contractual, and around the same number as consultants. It should be noted, however, that a big number of academic researchers constitute the technical workforce.

| Priority Challenges | Priority Objectives |
|---|---|
| 1. Resiliency of the agricultural sector against high agricultural losses due to increased frequency and intensity of weather disturbances, strong winds, drought and floods, insect and pest infestation | To understand the spatial distribution of extreme weather events (e.g. rainfall, typhoon, La Nina, EL Nino) |
| | To Infer soil water content, soil texture, and soil bulk density |
| 2. Increasing intensity and frequency of droughts and flooding | To assess and determine the level/extent of flooding |
| | To assess and determine the level/extent of drought and the need for irrigation |
| 3. Locating, understanding, and quantifying the attributes (e.g., species composition and structure, biomass, vegetation traits, carbon stock and uptake, etc.), components, structure, distribution, and condition of terrestrial ecosystems (e.g. forest, grassland, and urban) and associated land resources | To locate, understand, and quantify the attributes, components, structure, distribution, and condition of terrestrial ecosystems and associated land resources |

**Table 6.** FA6 - Terrestrial Ecosystems and Land Resources Management

## 4. DISCUSSIONS AND RECOMMENDATIONS

The Decadal Survey sheds light on current SSTA capabilities across relevant stakeholders, providing insights on efficient ways in which space data can be used in addressing the pressing challenges in the country for this decade. Information from the Decadal Survey will serve as input to the creation of the PhilSA's space data utilization and mobilization plan and satellite mission development roadmap.

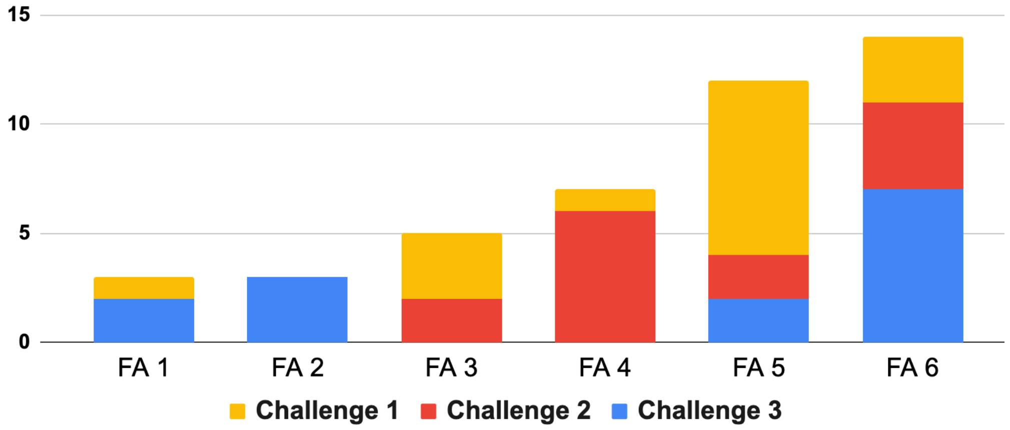


**Figure 3.** Programs and projects addressing the priority challenges per focus area

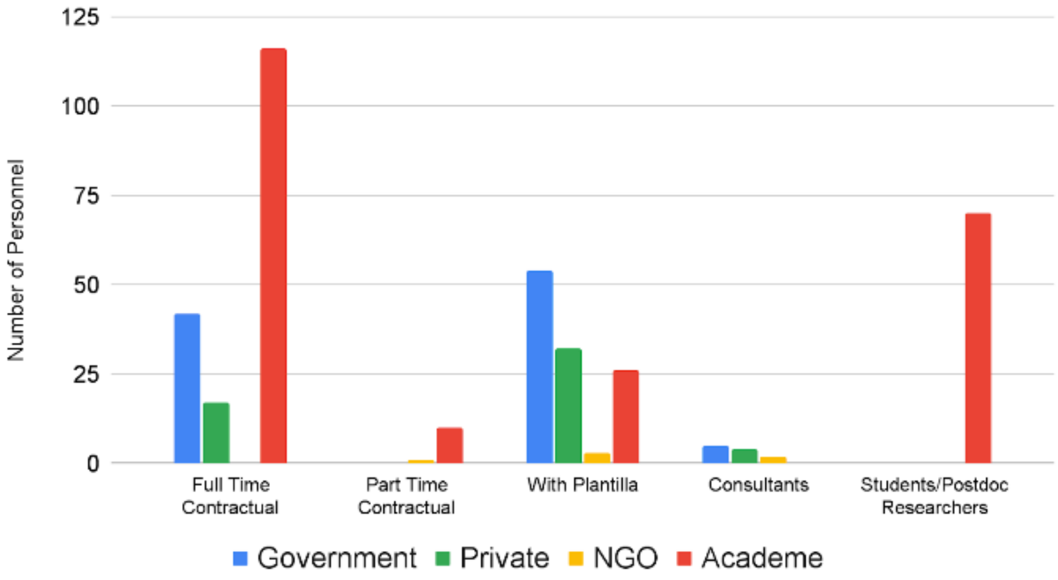


**Figure 4**. Distribution of human resource capabilities for satellite data processing

The gap analysis, which utilizes the TOT and the POR, was conducted to determine the proposed missions to be included in the 10-year space mission and technology roadmap. The analysis supports the development of Multispectral Unit for Land Assessment (MULA) and/or a constellation thereof. In addition, three other missions are proposed to be included in the roadmap: - a Very High Resolution (VHR) optical imager, an X-band Synthetic Aperture Radar (SAR), and a hyperspectral (HYP) imaging spectrometer as shown in Figure 5. The next steps in the mission assessment would include the analysis of goals, generation of design and the proof of concept, formulation of the baseline technical solutions, and feasibility studies.

In addition to identifying challenges and objectives, the Decadal Survey also provided an opportunity for the experts and stakeholders to recommend policies that govern the flow of data and the progression of satellite and data product development in the country.

Overall, sustaining the space-related programs and activities would demand efficient strategies to institutionalize initiatives and support more technical personnel with relevant expertise. It also underscores the importance of promoting the use of open-access data and open-source data processing software which can provide easier access and lower maintenance costs, as well as encourage the use of locally developed software from each agency and the possibility of sharing with other agencies. In addition, open-source data complements the use of commercial or proprietary software and subscription-based data. Furthermore, it is important to identify the needs of end users, with thorough assessment on institutional structures that can help harmonize existing initiatives across agencies. With more specific information, appropriate capacity-building activities and training programs on satellite data processing and product development can be designed that would be relevant to the needs of the stakeholders. Finally, apart from engagements with national actors and stakeholders, it is also important to benchmark and consider the best practices and lessons learned from international space actors.

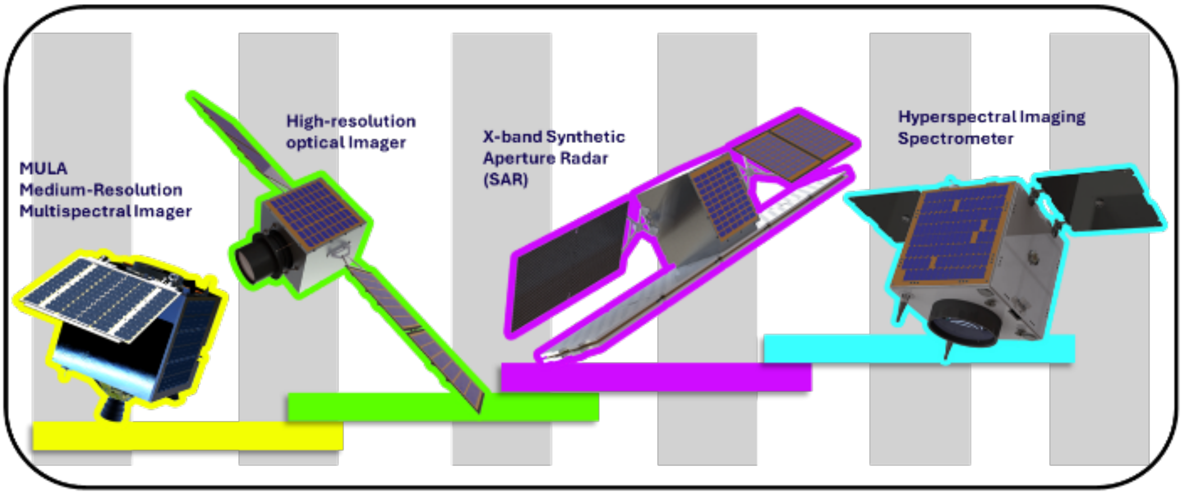


**Figure 5**. Proposed missions in the 10-year space mission and technology roadmap

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