IAASARS

Strategic vision for 2024-2028


IAASARS

1.0 PREFACE

In 2022, an international Evaluation Committee appointed by the Greek State provided extensive and thorough reports, covering both the Institute as an entity, as well as its three major scientific disciplines. These reports address the period from 2018 to 2021 and state that the committee was "impressed by the scientific achievements of the groups; all enjoyed international recognition and had established international relationships and collaborations". The reports also pointed out a few areas for future improvement. The five-year research plan of the Institute for Astronomy, Astrophysics, Space Applications and Remote Sensing (IAASARS) endorses all topics proposed by the Evaluation Committee. The current White Paper is mainly written by the Director in collaboration with the five-member Scientific Council of the Institute but also involves the participation of all the research personnel. The development plan of IAASARS closely revolve around all research infrastructures operated by IAASARS as well as the applied and basic research directions of the three scientific disciplines of the Institute which form the backbone of the envisaged development for the period spanning 2024 to 2028. The Evaluation Report and the procedure that we have initiated internally to draft the current White Paper in which we will lay out the strategic plan of the Institute for the next 5 years (2024-2028), would be an excellent opportunity for a close collaboration between the Institute and the Evaluation Committee aiming to further improve the performance and development of IAASARS.

Next, we provide a few highlights of our priorities.

1. IAASARS OVERVIEW

The Institute for Astronomy, Astrophysics, Space Applications and Remote Sensing (IAASARS) is the largest of the three Institutes of the National Observatory of Athens (NOA) and the largest Institute in its field in Greece. Presently, IAASARS hosts the Director, 27 permanent researchers, 1 secretary and 6 research support specialists. Moreover, 24 postdoctoral researchers, 39 PhD and MSc students, as well as 35 research associates. The three major scientific disciplines covered by the Institute are: (i) Observational Astrophysics using both space and ground-based facilities, (ii) Solar-Terrestrial Environment – Space Physics, encompassing Solar and Heliospheric Physics, as well as Ionospheric Physics, and (iii) Remote Sensing and Machine Learning for Signal/Image Processing.

1.1 ASTROPHYSICS GROUP

The Astrophysics group numbers 11 members of the research staff. It currently employs six postdoctoral research scientists and nine postgraduate students. The group is divided into three research teams, X-ray Astronomy, Optical Astronomy and Cosmology. The main research directions of the group are the evolution of supermassive black holes, the physics of galaxy evolution, the astrophysics of massive stars, symbiotic stars, planetary nebulae, supernova remnants, Cosmological and Statistical tests of General Relativity, Classical and Quantum Cosmology of scalar fields, astrophysical and cosmological implications of modified theories of gravity.
The research teams make extensive use of Space and Ground based Telescopes. The former are X-ray telescopes such as XMM-Newton, eROSITA, Chandra, NuSTAR, SWIFT, Infrared missions including WISE, Herschel and in the optical the HST, while the latter include the Gemini, VLT, Blanco, WHT, SOAR, INT, SPM and our own two telescopes.
The group supports and runs some of the largest astronomical facilities in Greece, the 2.3-m Aristarchos telescope and the 1.2-m Kryoneri telescope. Aristarchos, located at an altitude of 2340 m on mount Helmos, is a state-of-the-art 2.3-m telescope built by Carl Zeiss AG. The telescope is a member of the EU-funded Opticon RadioNet programme on Access to Large Scale Facilities. Aristarchos represents a major investment of the Greek state (over 11M€). The telescope time is devoted to both Astronomy projects as well as to optical tele-communications. The Kryoneri telescope time is devoted to Satellite Tracking and Space Security programmes.
The group has several research projects in astrophysics with a total budget of ~2.5ME. Amongst them, four large EU European grants (based on the data analysis from the above missions and optical telescopes), namely the European Research Council (ERC) project on Episodic Mass Loss in the Most Massive Stars: Key to Understanding the Explosive Early Universe, the Activities High Energy Astrophysics 2020, BiDforBest and XMM2ATHENA. Recently, the group has been awarded an ELIDEK project on Planetary Nebulae.
The group is participating in the consortium for the construction of the Widefield Imager onboard ESA's ATHENA mission. In particular, we are currently involved in the construction of

software for source detection in both spatial dimensions and time (transient sources) in collaboration with CEA Saclay. The Cosmology team is participating in the scientific planning of ESA's LISA mission. Moreover, the Astrophysics group participates in the following research consortia: the eROSITA detector all-sky survey, the XMM-Newton mission Extra-Extra Large survey, the Isaac Newton telescope Ha survey for Planetary Nebulae supernova project, and the J-PAS (Javalambre Physics of the Accelerating Universe Astrophysical Survey).
During the period 2018-2021 the group has published 221 papers in international refereed journals. The latter had a large impact in the community with 23121 citations in total.

1.2 SOLAR-TERRESTRIAL ENVIRONMENT - SPACE PHYSICS GROUP

The Solar-Terrestrial environment - Space Physics group comprises three research teams, the Solar and Heliospheric Physics team, the Space Research and Technology team, and the Ionospheric Physics team. The group focuses on basic research on Solar physics, heliophysics, geospace, magnetospheric and ionospheric physics. During the period of 2018-2021 the group consisted of 9 research staff members, 3 postdoctoral researchers, 11 research associates, two postgraduate (PhD) students, and 3 staff scientists and research technicians. It has produced 121 publications in international refereed journals with 2,854 citations and participated or managed 20 funded HORIZON, ESA projects. Furthermore, the group has coordinated 3 European Commission funded projects and has secured around ~2.15 M€ of funding from competitive grants.

The group operates important infrastructures: the ENIGMA magnetometer network, the Athens Digisonde and ionospheric computing cluster, and a small full-disk solar telescope. It has developed and provides to the scientific community, agencies and interested end-users several critical services related to Space Weather, such as the Space Weather operational unit – HESPERIA tools, SAWS-ASPECS and FORSPEF forecasting and nowcasting tools, the DIAS and ESA-SSA-SWE EIS services for ionospheric weather nowcasting and forecasting, the TechTIDE system with warning and mitigation technologies for traveling ionospheric disturbances, the PITHIA-NRF infrastructure integrating on a European scale key national and regional research infrastructures, and the Swarm Time-Frequency Analysis (TFA) tool.
Moreover, it helped in the development of the ASPIICS payload, provided information on the scientific performance of ESA's space science missions (LPUB-SAPS, TACTICIAN), and participated, under the Co-Investigator or Group Member status in several -missions (e.g., Bepi-Colombo, Solar Orbiter, Parker Solar Probe, Rosetta, Cluster, THEMIS, Van Allen Probes, Swarm etc.), and in the Swarm DISC (Data, Innovation, and Science Cluster), Validation Team and Data Quality Working Group.

1.3 REMOTE SENSING - SIGNAL PROCESSING FOR MACHINE LEARNING GROUP

The Group's mission is to conduct both basic and applied research, to generate excellence and innovation in the field of Earth Observation and Remote Sensing and to deliver sustainable environmental information services and products on an operational basis, covering the needs of the quadruple helix (research, industry, government, societal). For the reporting period the group has included nine (9) members of permanent Research Staff, six (6) Adjunct, part-time, visiting Researchers, one (1) Staff Scientist /Technician, twenty-four (24) post-docs on contract, nineteen (19) Research Associates (on contract), twenty-six (26) Ph.D. students (on contract), nine (9) Master and Undergraduate students, and ten (10) Administrative/other personnel. The group is divided into seven research teams, namely ReACT (Remote sensing of Aerosols, Clouds and Trace gases), DeformingGaia (Satellite Geodesy for Geohazards), SENSE (Satellite-derived ENvironmental Services), Signal Processing for Machine Learning, Orion Lab (Artificial Intelligence in Earth Observation and big data), ISMENE (Imaging Spectroscopy for Mineral Exploration of Natural Environments) and the Operational Unit of Earth Observation Research and Satellite Remote Sensing BEYOND. During the reporting period (2018-2021), the bibliometric output of the group includes 120 journal publications, 91 Conference Proceedings and 4268 citations. The group has received a total external funding of ~10.34 Meuros (competitive grants and service projects), including 2 ERC projects (ERC Consolidator Grant (D-TECT), ERC PoC Grant (PM-scanner)), and the EIC Horizon PRIZE for EYWA Early Warning System for Mosquito Borne Diseases.

2.0 FUTURE RESEARCH PLAN

2.1 ASTROPHYSICS GROUP

The Astrophysics group plans to continue its successful research in the areas of X-ray Astronomy (Supermassive Black Holes), Optical Astronomy (Massive Stars, Planetary Nebulae and Supernova) and Cosmology (cosmological tensions, alternative theories of gravity). Moreover, it plans to expand to the new fields of the Transient Universe and Multi-Messenger Astronomy. These new fields will be explored by means of the ARISTARCHOS telescope. The procurement of a high-throughput, low-resolution spectrograph (see section 3.1 below) is a prerequisite. In addition to the above, it is important to solidify and expand our involvement in ESA's ATHENA and LISA missions. The first one will carry the largest X-ray telescope ever constructed, while LISA will be the first gravitational wave mission in space.

2.1.1. X-ray Astronomy

The X-ray group is working on the variability of AGN and its implications on the demographics of Supermassive Black Holes (SMBH). At the same time the X-ray group has joined the consortium which analyzes the XMM serendipitous source catalog. The scientific analysis of this enormous dataset will last for many years to come. We aspire to expand the scientific analysis of the catalog in the areas of most obscured SMBH as well as on the first SMBH at high redshift. The X-ray group is a member of the consortium designing and building the Wide Field Imager (WFI) detector onboard ESA's ATHENA mission. We aspire to further expand our activities to novel source detection software preferably in partnership with Greek software companies. Moreover, the team participates in the eROSITA experiment onboard the Spectrum-RG mission, a participation that is expected to forge even stronger international collaborations.

2.1.2. Optical Astronomy

The ASSESS ERC grant has boosted the expertise and international visibility of the optical group. The group will continue investigating the last stages of massive star evolution, by combining information from massive stars both before and during their explosion. It will also take advantage of the superb resolution of JWST to probe massive stars and their circumstellar environment in nearby galaxies in the mid-infrared. The group plans to expand to observations of core-collapse supernovae using the new Aristarchos spectrograph.

Moreover, the optical group has established international research collaborations conducting studies on ionized nebulae such as H II regions, supernova remnants, planetary nebulae, and symbiotic stars. A long-term project between astronomers from Mexico-Spain-Greece on the systematic observations of newly discovered PNe and SNRs in the framework of the INT Photometric Ha Survey (IPHAS) survey is planned. Researchers of the IAASARS will continue to use the 2.3 m Aristarchos telescope to obtain deep narrow-band images of these sources for the further investigation of their morphological, excitation, ionization structure as well as of small-scale structures (knots, filaments etc.).

2.1.3 Cosmology

The Gravity and Cosmology group will focus on the construction of efficient cosmological scenarios that may solve the famous recent cosmological tensions (H0 tension, S8 tension, etc.), and their confrontation with various cosmological datasets (from SNIa, CMB, BAO, H(z) etc. observations). Additionally, it will focus on performing various tests in the theory of General Relativity and possible deviations towards modified gravity (at Solar-System, Milky Way, galaxy clusters, and cosmological scales). Additionally, the group has recently entered the LISA consortium, with the aim of examining the effect of possible gravitational modifications on the GW signals that will be observable by LISA. In particular, modified theories of gravity typically predict various effects on the gravitational wave properties (e.g. on their phase, amplitude, speed, polarization dispersion, damping, oscillations etc.). Hence, through both analytical investigations, as well as numerical simulations, the Group aims to calculate various signals on the primordial GW spectrum, and moreover propose methods to distinguish each separate signal (a procedure which typically demands for the application of machine learning).

2.2 SOLAR-TERRESTRIAL ENVIRONMENT - SPACE PHYSICS GROUP

2.2.1 Solar Physics and Heliophysics

The Solar physics and Heliophysics team targets strategic international collaborations and partnerships to guarantee both participa-

tion and immediate access to (a) state-of-the-art observations (such as the new 4-m Daniel K Inouye Solar Telescope - DKIST), and (b) relevant solar atmosphere simulations to study the small-scale dynamics of the Sun. This will maintain and further enhance the team's existing and highly-rated scientific impact and visibility. It will also actively participate in the critical plans and observing strategy of the developing 4-m class European Solar Telescope (EST) following the end of its preparatory phase at the end of 2022. Moreover, it foresees to the novel exploitation of Parker Solar Probe and Solar Orbiter data (especially from instruments suites where team members are participating as co-investigators) in combination with other near-Earth spacecraft and development of relevant tools for the study of solar dynamics and solar energetic particle events within the inner heliosphere as the current solar cycle 25 ramps up.

2.2.2. Space Research & Technology

The Space Research & Technology Team will continue the state of the art observational and modeling efforts for further integration to the European Research Area (ERA) and systematic cooperation with international networks for the development of an advanced general circulation model to assimilate data from the sun and the geospace environment. To this end, it will maintain the momentum on an international level on Solar Energetic Particle (SEP) prediction efforts through novel concepts (probabilistic, multivariate) with a focus on Machine Learning, Computer Vision and Deep Learning that will lead to increased prediction windows. The team aims to establish a leading role in the utilization and analysis of novel measurements from new solar missions as Solar Orbiter (SolO) and Parker Solar Probe (PSP) through enhanced collaborative networks. Another key target is the exploration of the Space Weather of Cool Stars and the definition of exoplanetary habitability in terms of radiation impact. Finally, the team will continue to play a key role in magnetic satellite missions like the current ESA Swarm and the upcoming NanoMagSat missions, while expanding and upgrading the current critical infrastructure of the ENIGMA magnetometer network targeting at providing regional services for the ground effects/signatures of space weather (i.e., Geomagnetically Induced Currents (GIC) risks at the Mediterranean region).

2.2.3. Ionospheric Physics

The Ionospheric Physics group for the next 5 years has as main priorities the advanced ionospheric modeling, validation, transition to operations and standardization, maintenance, and further upgrade of its infrastructures and computing facilities. Moreover, the team's main science and service drivers involve (a) the development and validation of novel experimentation techniques for the specification of ionospheric irregularities, (b) proof of concept developments for the demonstration of the efficiency of the ionospheric predictions to support the operation of critical infrastructures, and (c) the use of Artificial Intelligence tools and methods to enhance the forecasting horizon of ionospheric predictions, exploiting big data collections from space missions and global networks of ground-based instruments.

2.3. REMOTE SENSING AND MACHINE LEARNING FOR SIGNAL PROCESSING GROUP

The group plans to (a) continue to deliver excellence, research and innovative services in Remote Sensing and Earth Observation science in several areas as elaborated in the next paragraph, (b) sustain and grow in terms of human resources by enhancing efforts to add to the existing soft money staff, new research and technical staff holding permanent positions, with priority to Operational Unit BEYOND as it has been highlighted as mandatory by the Evaluation Committee, and (c) pursue new competitive contracts for research and innovation by submitting proposals for National, European (e.g. Horizon Europe, ESA), International and private funding in order to successfully sustain the research and innovation activities of its researchers and its expansion to new fields. Furthermore, it aims to (a) develop innovation in the field of new instrumentation technologies and research infrastructures (b) protect the relevant IP rights and exploit its innovative technologies via modern schemes (e.g. spin-off), and (c) continue coordination and leadership role in translational and cross-border area (North Africa, Balkans, Middle East and Black Sea countries) assigned to the Operational Unit BEYOND by EC/GEO.

The Group aims to address key research challenges that lay ahead for the next 5 years in the development of (i) novel data analysis techniques, algorithms and AI (e.g. big data, research on Machine and Deep Learning (ML

and DL) and their deployment in new rapidly growing areas and applications), (ii) data assimilation (e.g. to increase the accuracy of prediction/forecast of climate and weather models) and (iii) significant application domains (e.g., DRR, Health, Urban Environment, Agriculture, Smart Farming, Renewable Energy, Ecosystems, Climate Change, Mineral Exploration, Critical Materials, Natural Hazards, Hazard Assessments, Digital Twins, Active Tectonics and Earthquakes, Space Geodesy). Emphasis will also be given to establishing new collaborations within and outside IAASARS. Concerning the Group' s bibliometric output, as shown in the group's evaluation report, between 2018 and 2021 the group's scientific publications increased by 79%. For the next five years, the group aims to continue to increase its productivity at least at the same rate or even higher, depending on funding conditions.

Furthermore, the Group will maintain activities focused on basic and applied research (TRL 1-6). When the research output presents significant socio-economic impact and it becomes technologically mature (providing adequate funding is also available), new operational services will be developed and deployed TRL 7-9 activities.

3.0 INFRASTRUCTURES AND SERVICES: CURRENT STATE AND FUTURE PLANS

3.1 ARISTARCHOS TELESCOPE

The Evaluation Committee pointed out that the number of publications based on the use of the Aristarchos telescope is quite limited. The most important factor that led to the less than expected publication output is related to malfunctions in the telescope's electronics and in general to the lack of a steady operational budget.

In 2020, Aristarchos was selected by ESA to become the first ground station of the ScyLight programme (Secure and Laser communication technology). The ESA ScyLight project offers the necessary funding (~1.5M€) to refurbish the electronic and some mechanical parts of the Aristarchos telescope. This includes modern electronic components, a new auto-guiding system and state-of-the-art software for controlling all movable parts of the telescope. This major investment is expected to resolve long-standing reliability and efficiency problems of Aristarchos that compromised observations in the past.

The refurbishment of Aristarchos, which is expected to finish by the end of summer 2025, will open new windows in astrophysical research projects. As the current instrumentation (CCD cameras for imaging) offers limited opportunities, we plan to acquire a state-of-the-art high-throughput optical spectrograph. Our primary goal is to follow transient events including supernova and tidal disruption events.

More specifically, below we briefly present the main future plans for the Aristarchos telescope.

3.1.1 Astronomical Instrumentation

It is beyond doubt that the existing CCD cameras alone offer limited opportunities for state-of-the art research projects. A modern spectrograph must be acquired in order to fully unleash the research capabilities of a modern 2.3-m telescope. We are currently actively exploring options for a high throughput spectrograph. We are in contact with the Liverpool and Weizmann groups. Moreover, we are exploring science programmes that involve narrow band imaging.

3.1.2 Aristarchos as the Transient Universe Facility

In the last few years, studies of the transient Universe have acquired a pivotal role in astrophysical research. Alerts about transient sources come from a multitude of facilities. For example, the Zwicky Transient Facility and the Gaia mission publish a large number of daily alerts. Some of the most interesting transient events include supernovae, and tidal disruption events (TDEs). Our vision is to extend our research directions to optical follow-up observations of transient events using the Aristarchos telescope. The key instrument for these follow-up observations is a new low-resolution high-throughput spectrograph that is currently under procurement.

3.1.3 Interstellar Medium and Ionised Nebulae

The new spectrograph will broaden the research topics on ionized nebulae that can be conducted by the IAASARS personnel. In particular, spectroscopic observations will allow

researchers to study the physico-chemical properties and chemical composition of PNe and SNRs with particular interest on the newly IPHAS ones. In addition, the mechanisms behind the heating of the gas in PNe or SNRs will also be investigated through the examination of various emission lines ratios.

The rapid increase of the volume of photometric data from all-sky surveys has made the follow-up spectroscopic data of critical importance for the study of Target of Opportunity (ToO). Moreover, the use of machine learning techniques for the analysis of photometric data has led to the discovery of several candidates from different classes and follow-up spectroscopic data are essential for their classification. Researchers of the IAASARS have been conducting identification/classification projects on PNe and Symbiotic Stars for years using data from other facilities. Similar studies can also be conducted for cataclysmic variables, massive stars, white dwarfs among others obtained in photometric catalogs. Aristachos and the new spectrograph can play an important role in this new era of Big Data astronomy and follow-up surveys.

3.1.4 Optical Communications & New Technologies

The strategic partnership with ESA (MoU signed in September 2023) and thus our participation in the iconic ARTES/ScyLight project opened a new window in the use of the Aristarchos telescope. These projects brought Aristarchos to the forefront of optical communications research and equally importantly they provided the financial means to support the telescope's operations. Naturally, we plan to continue and enlarge our involvement in such projects. Current projects include the HOTSPOT (Helmos Observatory iniTiateS oPtical cOmmunicaTion), the Greek Connectivity Optical Ground Stations and the HellasQCI. The strong interest of ESA and EU to the development of optical/quantum communications guarantees the long-term funding of Aristarchos and ensures smooth operations for both applied science and basic astrophysical research.

The latter achievements have led to a new era for IAASARS, namely we are developing new synergies with Space Agencies and companies in the field of new technologies. Specifically, as part of NASA's Psyche mission, IAASARS telescopes are the only ones chosen by ESA to participate in the flagship mission aiming to create a 300-million-kilometer-long communication "bridge" in space. This novel experiment is expected to take place in January 2026. Moreover, IAASARS is participating as a key panther in the Greek-French synergy (Hellas Sat/IAASARS and CNES/Thales Allenia) on the development of an optical communication payload for the upcoming new mission to be embarked on the future Hellas Sat 5 satellite, operating in geostationary orbit at 39° East (MoU signed in January 2024). This innovative payload aims to connect with Optical Ground Station of the National Athens Observatory in Greece, Optical Ground Stations in France, Optical Ground Stations of ESA and Thales Alenia Space's LEO HydRON telecommunication satellite.

3.2 KRYONERI TELESCOPE

Our plan is to transform the Kryoneri Observatory into a major Space Hub for Space Security and Earth Observation in Southern Europe. Space Security refers to development of a European Space Situational Awareness (SSA) capability that will underpin the exploitation of European space assets, contributing to autonomous access to space for Europe. The SSA programmes will cover two major scientific segments: (a) Space Surveillance & Tracking (SST) and (b) Near Earth Objects (NEOs). Our proposal has already been funded by the European Recovery fund (~10.8ME) and by the local government of Peloponnese (~4.3ME). Recently, Greece became a full partner in the EU-SST network with NOA coordinating the activities. The 25% dedication of the 1.2m Kryoneri telescope in EU-SST activities (started in July 2023) implies that the expected funding for Kryoneri is close to 80KE/year. This is expected to sort out several issues with the infrastructure's support which were mainly related to the lack of technical personnel.

We are upgrading our capabilities by building a small 0.7-m telescope with a large field-of-view. Its fast-tracking capability (more than 10 degrees per second) will make it a unique tool for the tracking of low-Earth orbit (LEO) missions. The tracking of these missions (mainly small telecom missions) presents great commercial potential. The activities of the Kryoneri station will be supplemented with a satellite laser ranging system. This is important for the detection and localization of space debris. This will be one of the few SST facilities in Europe equipped with a LASER instrument.
The second scientific segment is currently covered by ESA's NELIOTA project. This project has transformed the Kryoneri observatory into a

unique space environment facility. During the past 6 years Kryoneri has been tracking the impact of micrometeoroids (with sizes of a few centimeters) on the lunar surface detected through optical flashes. This provides a solid record of small bodies in the Earth vicinity.

Finally, a ground laser transmitter system is expected to be placed at Kryoneri Observatory to be used in optical communication experiments with NASA's Psyche mission. ESA and NASA will carry out a joint technology demonstration of deep space optical communications with the spacecraft at distances of two Astronomical Units.

3.3 SOLAR-TERRESTRIAL ENVIRONMENT – SPACE PHYSICS

The Solar and Heliophysics Team successfully maintains and scientifically supports one of the two Operational Units of IAASARS (Space weather – HESPERIA Solar Energetic Particle forecasting tools), officially established within the governing legislation of the National Observatory of Athens (NOA). This unit provides significant space weather forecasting with unprecedented early warning also by means of precursor energetic particles. The team aims to provide and further develop/upgrade HESPERIA that is an integral part of the Space Radiation infrastructure of the ESA SSA and of NASA (CCMC and Johnson Space Center/SRAG) for usage in planned manned missions to the Moon and Mars.

The Space Research & Technology team operates the particle radiation SAWS-ASPECS tool, the FORSPEF (FORecasting Solar Particle Events and Flares) tool and the Time-Frequency Analysis (TFA) toolbox in the framework of the ESA Swarm DISC (Data, Innovation, and Science Cluster). In particular, SAWS-ASPECS and FORSPEF collate and combine outputs from different modules providing nowcasting and forecasts of solar eruptive phenomena (e.g. solar flares), solar proton event occurrence and solar proton flux and duration characteristics. Outputs of both tools have been incorporated in the NASA SEP Scoreboard. In addition, the team operates the HellENIc GeoMagnetic Array (ENIGMA), which provides measurements for the study of geospace magnetic storms and geomagnetic pulsations. The team plans to (a) maintain and further enhance the infrastructures for the development of services that meet the needs of users, following the Horizon Europe priorities, (b) establish permanent links with users, environmental management agencies and space agencies, towards future commercialization of space weather products and services, and (c) create a fully operational Regional Center for the prediction of space weather effects in the interplanetary medium, the magnetosphere and on the ground. To this end, it will further develop and update predictions on Solar Energetic Particles (SEPs) through the SAWS-ASPECS tool, being already an inbuilt part for NASA (CCMC, SRAG and M2M office) as well as the IRAP (CNRS) in the quest for human spaceflight. Moreover, it will augment ENIGMA infrastructure and services providing Geomagnetically Induced Currents (GIC) forecasts to the Hellenic Electricity Distribution Network Operator.

The Ionospheric team operates the Athens Digisonde DPS4D with the capability to perform monostatic and bistatic soundings with similar Digisonde stations operated in a range of 1500km aiming at detecting in real-time ionospheric irregularities. Furthermore the group operates the Ionospheric Computing Cluster consisting of 12 Virtual Machine with high processing and storage capability to support the production and distribution of real-time ionospheric weather services required by the ESA Space Safety Space Weather programme and for research developments implemented in the frames of Research and Developments projects coordinated by the Group and funded by the European Commission Horizon 2020, Horizon Europe and the European Defence Foundation.

The team plans to further upgrade the scientific instrumentation (Athens Digital Portable Sounder - DPS4D) and of the computing cluster operated for real-time data processing and release of products and services. It will also design and implement a unique e-infrastructure in Europe and worldwide for the monitoring, specification, forecasting and prediction of the ionosphere - plasmasphere and thermosphere environment for both scientific and operational applications. Moreover, the team aims to further pursue systematic international collaborations to enhance the monitoring, specification, and forecasting capabilities with the main target to provide space weather forecasting services to the European Space Agency.

3.4 REMOTE SENSING - SIGNAL PROCESSING

The main infrastructures and services of the

Remote Sensing - Signal Processing group that require maintenance efforts (including manpower and instrumentation) mainly concern the PANGEA climate observatory and the Operational Unit BEYOND ground segment facilities.

3.4.1 Data Processing, Storage, and Service Portals

The Group plans to sustain and enrich the content of all portals providing services and add new ones, as basic research outcomes mature. Technical as well as administrative and management support will also be needed to support all activities in providing physical, remote, and virtual access to researchers, innovators and citizens. In addition to physical servers hosted at NOA, the Group will migrate several services to outsourced cloud facilities (e.g. AWS, DIAS, DestinE, GEE platforms) and will invest resources to develop the relevant technologies. In particular, the instrumentation of the remote sensing section of the IAASARS PANGEA climate observatory is planned to significantly grow in the next 5 years (from 3 instruments currently to 36 new instruments by 2025), consequently inducing increased needs in manpower. The ReACT cluster data center will be maintained for the next 5 years, as it archives the PANGEA remote sensing datasets and the innovative space-based developed products.
The Operational Unit BEYOND will sustain and upgrade the 24/7 operation of the numerous information portals for the delivery of clusters of services, including the Attica Region Portal for informing the citizens and local authorities of 66 municipalities about the risk and preparedness for hazards. A total of 14+ service portals to support >20 clusters of services will continue to be in full operation.
The Hellenic Mirror Site with its data infrastructures, archives and repositories/DataCubes will continue being sustained and supported by the Operational Unit BEYOND together with the ground-based acquisition antennas (e.g. X-/L-band and Meteosat SG) for opening benchmark datasets and disseminating the big volumes of Copernicus and Copernicus contributing mission data in the region and worldwide.
Regarding the national GR-SST program, with the Operational Unit BEYOND being assigned the role of the National Operation Center for Greece, EU SST partnership funding for the next programmatic period (up to 2027) will be used. This has been secured in the implementation of Space Regulation and HE TOPs Actions for SST (contracts signed in 09/2023) and also through additional competitive funds from the delivery of third-party SST services (e.g. satellite operators, ESA, etc.).

3.4.2 Data Acquisition Infrastructures

PANGEA: PANGEA will target to enhance the ground-based infrastructure and services by upgrading the current infrastructure and by acquiring a new aerosol/cloud remote sensing mobile platform.
BEYOND: BEYOND will be sustaining the operation, upgrade, and maintenance of the acquisition antennas (a) X-/L-band for the reception of polar orbit satellites (EOS AQUA/TERRA, SUOMI NPP, NOAA/AVHRR, METOP), and (b) the DBV-2 METEOSAT SG antenna. The upgrade of the ground segment of IAASARS/NOA is foreseen by adding a complementary X-/L-band antenna to increase the number of acquired data/missions and the installation of a larger antenna of 5-9 meters for the direct acquisition of Sentinel missions., conditional that the needed budget from RRF and the government will be approved by mid-2023 (AEGIS project).
Deforming Gaia: The Group will install 7 additional GNSS ground stations, provided that the required budget from RRF and the government will be approved by mid-2023 (AEGIS project).

3.4.3 Sensor technologies

The Group will continue the development of new remote sensing technologies and sensors (e.g., lidar, optical fiber cutting-edge sensors) in collaboration with industry, based on existing collaborations (e.g., Raymetrics), and expand to the ecosystem of Space SMEs in Greece and abroad.

3.4.4 Spinoff

The Group intends to investigate the establishment of spinoff entity/entities as an extension of its development to exploit innovations and move towards commercialization of it. Spinoff schemes around the group will help to develop services under a separate corporate identity, focusing on a business model along with attracting new shareholders. The benefits include the reduction of complexity and administrative bureaucracy together with the improvement of focus and capital allocation. Although relevant to a few subgroups/researchers, the Operational Unit BEYOND in particular, following the recommendation by the Evaluation committee, is planning to intensify the dialogue with the management of NOA and GSRI for finding a proper solution to exploit

the delivered innovation and services via modern schemes.

4.0 PUBLIC OUTREACH & EDUCATION

IAASARS has always placed great emphasis on science dissemination and outreach. The institute's main components to this aim are the Penteli Visitor Center (since 1995) and quite recently the Thiseio Visitor Center (since 2014). Both visitor centers have joined forces and are very active, engaging in a huge variety of outreach indoors and outdoors activities covering a large age-range, which was non-existent in the previous years. The purpose is to mediate between science and the public using a diversity of activities paved by modern educational means which is always based on the interaction between the specialized staff and the audience. This has been made possible through customized schemes that serve the needs of a particular age group. The Visitor Centers have also welcomed to their educational programs unemployed people, refugees, guests of Mental Health Centers, disabled persons, and students from Special Schools. Special presentations are chosen from a plethora of topics in coordination with the main research areas of the IAASARS. Other educational activities of the Institute include the annual astrophysics summer school for high-school seniors, regular organization of international conferences and a vigorous seminar program.

Furthermore, in January 2023 the master plan which will set the baseline for IAASARS to fulfill its strategic goal for the reconstruction of the Kryoneri astronomical station aiming to transform it (a) into a Space Hub and (ii) into a public outreach center was completed. As we have already described this investment is funded directly by the Prefecture of Peloponnese, hence according to the master plan this major infrastructure is expected to be functional in 2027.

In terms of higher education, participation in MSc and PhD programs, student supervision and training schools for young researchers will be sustained. In partnership with universities, IAASARS will also develop strategic engagements with the broader community that reach diverse audiences through events and exhibits at NOA Visitor Centers. The Institute will also develop a comprehensive knowledge hub with educational material targeting knowledge-transfer activities including in-person and virtual training courses for universities and mentoring programs for businesses and educational activities for schools.

5.0 FUNDING REQUIREMENTS

5.1 FUNDING REQUIREMENTS FOR SUSTAINABLE INFRASTRUCTURE AND SERVICE OPERATIONS

In Table 1, here below, we present an overview of the estimated annual costs for maintaining

Group	Infrastructure/Service	Estimated annual cost (in Euros)
Astrophysics Group	Aristarchos	110,000
	Kryoneri	100,000
Solar-Terrestrial Environment - Space Physics Group	Space Weather Operational Unit	40,000
	SAWS-APSECS	15,000
	FORSPEF	8,000
	ENIGMA	50,000
	Athens Digisonde and the Ionospheric Computing Cluster	75,000
Remote Sensing - Signal Processing For Machine Learning Group	PANGEA-ReACT	165,000 (1)
	Operational Unit BEYOND	65,000 (2)
	Hellenic Mirror Site	35,000 (3)

and/or upgrading the IAASARS infrastructures and services.

Notes

1. *This cost includes maintenance, repair, consumable, and travel/accommodation costs for the PANGEA remote sensing station. Salaries for the personnel are not included.*

2. *50,000 for full operation of 14+ service portals that support >20 clusters of services; 15,000 for upgrades of the equipment to host the portals in terms of computer facilities and storage and UPS.*

3. *For HW/SW, cloud storage and DEvOps staff. The considerably higher costs for subsequent data analysis and service development will be supported by competitive grants.*

6.0 PERSONNEL NEEDS

Considering that the Institute will maintain the number of its current permanent research personnel posi-tions (27 positions), IAASARS foresees that its manpower additional requirements in permanent positions for the next five years include at least 3 new permanent researchers (one for each group), 1 AI specialist, 2 IT support, 3 Technical staff, 2 DevOps and 2 Administrative staff (see Table 2) that will be assigned to different groups and constituting teams according to the needs and priorities.

6.1 ASTROPHYSICS GROUP

Hiring a researcher who specializes in transient phenomena is one of the priorities of the group to advance our five-year plan science goals. At the same time, the group is heavily involved in the planning of ESA's ATHENA and LISA missions, and in particular, in the development of advanced software for the ground segment. Obviously, X-ray and gravitational wave astronomers are also among the group's top priorities. Most importantly, a software engineer or astronomer is needed to cover needs on software for the ARISTARCHOS instruments, as well as the development of software for ATHENA and LISA.

6.2 SOLAR-TERRESTRIAL ENVIRONMENT - SPACE PHYSICS GROUP

Given the highly-evaluated scientific research, crucial activities related to the operational unit that the Solar and Heliophysics team leads and coordinates for IAASARS/NOA and major space agencies, the long-term sustainability of the services that the Space Research & Technology team and the Ionospheric team implement and provide to major space agencies and the international scientific community, the large number of European Commission and European Space Agency research projects coordinated by the group, as well as its multiple other international activities, at least one new research position is required, as well as substantial technical, IT, DevOps and administrative support.

6.3 REMOTE SENSING - SIGNAL PROCESSING FOR MACHINE LEARNING GROUP

Considering that the Group has significant scientific research activities, maintains the operational unit BEYOND for IAASARS/NOA and includes the REACT team which operates the large ground-based infrastructure and services of PANGEA, it is important for group not only to maintain the number of its current permanent research personnel positions, but to acquire at least one new research position and consider-able additional technical manpower in AI, IT DevOps support as well as administrative staff.

The IAASARS needs in personnel are presented in the following Table.

Table 2. IAASARS personnel needs by group.

Positions	New	Retirement	Total
Researchers	3	3	6
Technical/Administrative	9	1	10

7.0 FUTURE LEGAL/FUNDING ENVIRONMENT: BEST-CASE AND WORST-CASE SCENARIOS

Proper continuation, enhancement and upgrading of all aforementioned research activities, services and infrastructures as well as personnel numbers are, however, pertinent to available funding from national resources and/or competitive European/international projects.

Here we list various issues the resolution of which lies within the responsibility of the Greek authorities, namely the Ministry of Civil Protection, the General Secretariat of Research and

Innovation and the National Council for Research, Technology, and Innovation hence, our five years plan are heavily depended on these factors. Specifically,

1. Bureaucracy, complex and administrative procedures. We need a stable legal framework. Every time a new legal framework for procurement, staff recruitment, and many other aspects relative to running projects, which is applied in the public sector, it is also applied in the research institutes without exceptions. The necessary exceptions for the research institutes are legislated only after some time and after causing insurmountable obstacles to the project execution. Additionally, the change of the legal framework sometimes happens in the middle of the project execution. These factors are causing a serial loss of resources, manpower and funding absorption.
2. Increasing operational costs (energy, communications etc.) not covered by the national budget.
3. Brain-drain and ability to attract specialized personnel. The low salaries of the permanent scientific personnel render the hiring of prominent scientists from abroad difficult.
4. Lack of links with the Greek Universities. The situation is getting worst in the new legislation for higher education (e.g. the researchers are not allowed to supervise PhD students, while the participation of the research centers in the postgraduate courses are not allowed as well).
5. Operation (and maintenance) of large research infrastructures requires a stable funding environment and support at the national level. Recent projects such as PANGEA, NOA/AEGIS, Scylight offer new opportunities for further expansion, hence additional income to the institute and further possibilities for collaboration.
6. There is a need for a stable funding environment. The current funding environment is distinguished in government funding and funding through research projects. The former has an impact on the number of permanent staff and working facilities. The latter, which is higher, concerns Regional, European, and National funding schemes related to each group research activity fields. The latter are generally known for the next 4-5 years (e.g., HORIZON 2020, ESA). On the other hand, although national funding agencies (cf. Hellenic Foundation for Research & Innovation -ELIDEK) contribute to scientific excellence, they have yet to adopt international practices. When a national call appears, it is very limited and extremely competitive (success rate ~7% or even lower). In the past the evaluation of the proposal in the national funding framework has lasted even three years. Moreover, in the past the budget that has been approved and in the middle of the project execution, suddenly a horizontal cutoff has been decided and applied. Obviously, unforeseen changes in funding conditions will have a direct impact on the IAASARS group activities. The impact will depend on the specific needs versus the available funding.

Below we briefly present the impact and mitigation of best-case and worst-case funding scenarios on IAASARS activities compared to the current status and needs. If funding remains at present levels, then the current status, as described above, remains unchanged.

Best-case scenario:
The best-case scenario will lead to decreased bureaucracy and a stable legal framework and funding environment. Consequently, this will result almost immediately to additional permanent and/or on-contract staff, continuous operation of service facilities, further infrastructure development, development of new technologies and applications, expansion to new research fields and higher bibliometric output productivity..

Worst-case scenario:
The worst-case scenario means reduced funding opportunities which will directly affect mainly the infrastructure and service maintenance and/or the upgrading as well as the relative technical personnel on contract to support the infrastructures/services. In particular, concerning the Astrophysics group, the involvement of IAASARS in the design and planning of ESA's flagship missions ATHENA and LISA will be compromised if there are no sufficient funds either through the ProdeX project or through new technical positions.
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8. CONCLUSION

The next five years are expected to provide novel challenges for IAASARS. We expect to continue our research work in a variety of scientific fields making full use of our experimental and observational facilities. Our ultimate goal is to address key research challenges that lie ahead for the next decade. At the same time our top priority remains offering

our services to society. In a nutshell our main goals for the next five years are to:

sustain and expand the good record in attracting external funding & prestigious grants

increase scientific excellence as reflected in the number of refereed publications and citations.

support the operation and development of the PanHellenic GEOphysical observatory - a central research infrastructure of NOA - at the island of Antikythira. This unique climate, atmospheric and geophysics observatory constitutes a new NOA research infrastructure aimed to provide crucial data for climate change, atmospheric and geophysical conditions to global and European initiatives like the World Meteorological Organization, ESA, the European Research Infrastructures ACTRIS, ICOS and EPOS, etc.

aid the BEYOND operational unit to continue to be at the forefront of environmental research activities providing at the same time a vital cluster of services to society

enhance the role of NOA/IAASARS in European Research Infrastructures, global networks and ESA Cal/Val programmes.

complete (early 2026) the refurbishment of Aristarchos telescope (funded by ESA). The strategic partnership with ESA, EU and worldwide space companies for optical/quantum communications will guarantee the long-term funding of Aristarchos and will ensure smooth operations for both applied science and basic research. The development of a new high throughput spectrograph is expected to transform Aristarchos to a world-class facility geared to observations of the transient Universe

convert Kryoneri Observatory to a major Space Hub for Space Security and Earth Observation in Southern Europe. This decision by NOA's administration was based on National priorities regarding the participation of Greece in the European Space Security network. These priorities encompass the development of a European Space Situational Awareness (SSA) capability that will underpin the exploitation of European space assets, contributing to autonomous access to space for Europe. According to the master plan this major infrastructure is expected to be functional in 2027.

Our recent investments in the Antikythira, Kryoneri and Helmos observatories are expected to boost IAASARS, NOA but also Greece to a robust player in the SST/SSA area, optical and quantum communications, climate change but also transient and multi-messenger Astronomy. They will also help us to play a crucial role as a National Hub and contact point for major space agencies (ESA, NASA) as well as other relevant organizations (e.g. EUMETSAT, WMO, GEO, EAS).

Naturally, the success of our five-year plan depends on several external parameters as described in detail in section 6. In particular, our development plans critically depend on a stable external funding environment. This relates to both competitive research projects (e.g. the generous increase of the HFRI funding), the continuation of the KRIPIS infrastructure support programs but more importantly the opening of new permanent research and technical positions. Only under these circumstances we will be able to fully exploit our new investments in state-of-the-art facilities.


IAASARS