Towards a Science and Technology Agenda for an integrative approach to the Atlantic:

Climate Change and Energy Systems, Space and Ocean Sciences, through North-South Cooperation

Atlantic International Research Center (AIR Center)

A draft white paper developed by an International Scientific Committee put together by the Fundação para a Ciência e a Tecnologia (FCT) with the support of an open international consultation and a series of research WS

Fundação para a Ciência e a Tecnologia (FCT), Portugal

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Preparatory events:

Workshop 1, Institute of International Education (IIE), New York City – US, June 10th 2016

Workshop 2, University of Azores (UAç), Ponta Delgada, Azores – PT, June 27th 2016

Workshop 3, "Ciência 2016", Lisbon – PT, July 4th 2016

Workshop 4, European Space Agency (ESA), Paris – FR, August 29th 2016

Workshop 5, Technological Park, São José dos Campos, BR, September 6th 2016

Workshop 6, Portuguese Permanent Representation to the EU, Brussels – BE, September 19th 2016

Workshop 7, Maloka, Bogotá, CO, October 5th 2016

Workshop 8, Brasilia – BR, October, 31st 2016

Forthcoming event:

Terceira, Azores – PT, April 20-21th

International Scientific Committee (preliminary, invitations in progress):

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Preface

A commitment to knowledge towards future transatlantic and North-South cooperation

The preparation of this white paper has been associated with an open and new debate about multilateral cooperation in complex systems engineering and science towards an integrative approach to, climate change and energy, space and ocean science in the Atlantic, together with emerging methods of data science management. The ultimate goal is to help building the future through an effective commitment to knowledge through transatlantic and north-south cooperation.

We are entering critical times that require the creation of conditions for the strengthening of knowledge-based international cooperation. Lessons learned over the last decades with international partnerships in science, technology and higher education, including those established over the last decades between Portuguese and US Universities, among many other Intergovernmental scientific ventures, have clearly shown that the future can only be built based on an exchanged of solid knowledge, skills and ideas.

A new paradigm of structured international research relationships is emerging, which is shaped by a new era of Government and Industry intervention in association with scientific knowledge. Cross-disciplinary new frontier research should be the result of ambitious initiatives yet to be stimulated and developed from the huge potential of Intergovernmental research laboratories and joint ventures. It is under this context that the debate of the potential installation of an *Atlantic International Research Center (AIR Centre)* is focused on. This debate is centered under two main priorities: i) new data collection for innovative research; and ii) Space/Air/ Sea synergies towards new knowledge production and diffusion.

Our ambition is driven by an increased perception by society of the growing evidence for the potential benefits resulting from the human, social and economic appropriation of the results and methods of science. We aim to stimulate the necessary knowledge-driven conditions to build in the Azores an Intergovernmental research center with strong international cooperation, taking advantage of the strategic Atlantic positioning of Azores to foster North-South cooperation in science and technology. By promoting new knowledge on climate change and related issues in the Atlantic, we are fostering conditions to provide the world with more science, more knowledge and more scientific culture. The exceptional position of

Azores and other atlantic islands stimulates the access to new frontiers of knowledge, together with the development of new space and marine industries. Also, by promoting new research in the deep-sea of Azores and in other Atlantic regions we facilitate the access to a better understanding of living organisms in extreme environments and also of non-living resources.

Moving towards the goal of sustainability requires fundamental changes in human behavior as well as more knowledge and more scientific culture, ensuring the access to science and education as an inalienable right of all. More science and the systematic democratization of access to knowledge mean more equal opportunities, more social mobility and a new stimulus for entrepreneurial activities and well-being.

Manuel Heitor

Minister for Science, Technology and Higher Education, Portugal

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Part I - A vision to better understand the interconnected North and South Atlantic through an Atlantic International Research Center

Science is an essential tool for rationally addressing critical societal challenges such as those concerning climate change by intertwining space, ocean and energy systems. The importance of an integrative approach drives the current efforts to establish an *Atlantic International Research Center* (AIR Center).

1. An holistic approach to the Atlantic

Bearing in mind that the ocean is an interconnected system without physical boundaries and that should be addressed as a whole, as it is stated in the United Nations Convention on the Law of the Sea, takes us to a new dimension of science and to a new technological approach.

This idea is completely in line with the 2030 Agenda For Sustainable Development and its Goals which addresses, besides others, the scientific cooperation, technology and innovation.

The transatlantic cooperation experienced several models and features though were always based in common values and economic interdependence.

In areas like space the international cooperation is an indispensable requirement to sustain an effective development and translate it in growth and innovation to well-being of future generations. The promotion of transatlantic space cooperation will enhance the international security, defense and surveillance capabilities, new geospatial data and support cooperative research programmes.

Looking to the scientific transatlantic cooperation on a water dimension is also an opportunity to boost the knowledge on the ocean as an interconnected system and develop new technologies to face new challenges. It is worth notice that was signed in 2013 the Galway Statement on Atlantic Ocean Research Cooperation between European Union, Canada and the United States of America that fosters the idea of a transatlantic cooperation.

It is now time to go further and promote North-South cooperation in the areas referred above and in other interrelated areas becoming a pivot in the international research context.

The Atlantic Ocean comprises about 20% of the Earth´s surface, and is still understudied in terms of its natural resources, ecosystems dynamics and the interdependences with human activities. A better understanding of the Atlantic and the sustainable management of this common resource requires the alignment of research strategies through international cooperation allowing a better understanding of the Atlantic dynamic and its response to the climate change. Interdisciplinary research able to face today's challenges and the economic transitions, in particular environmental changes, security conditions, natural hazards, and other human dimensions, calls for the design of an international partnership that aims for resilience and leadership for the Atlantic and related North-South mainly in five thematic areas:

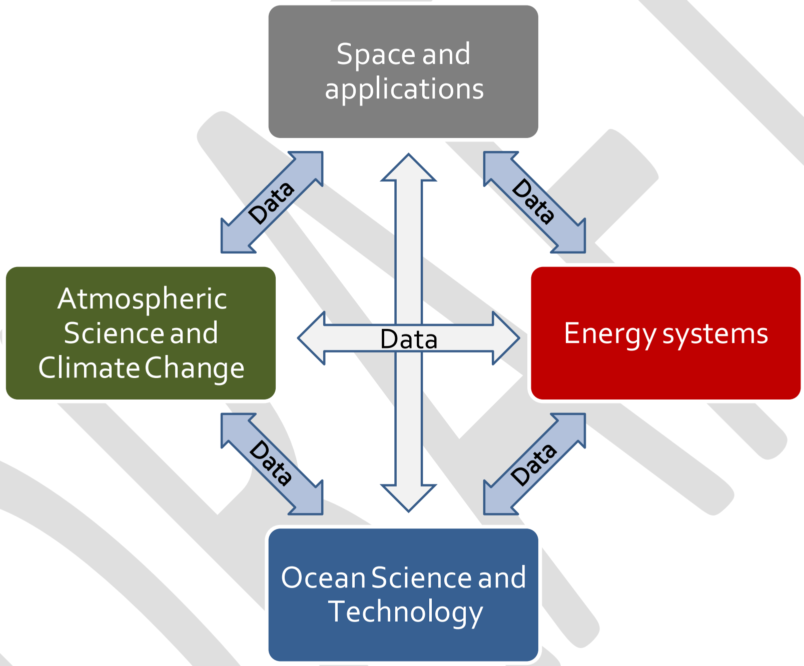

Fig. 1 – Five thematic areas for a Research Agenda towards an AIR Center

In this regard, the establishment of an Atlantic International Research Center (AIR Center enables such cooperation and provides an ideally located center of excellence in a unique venue to address issues that impact society on a global level. It will be comprised by a network of islands regions: Azores; Madeira, Canary Islands, Fernando Noronha and S. Pedro-S. Paulo, both in Brazil; Mindelo in Cape Verde and Bermuda.

The AIR center will be particularly suited to provide unique knowledge about Earth systems, focusing on space science and allowing the knowledge and technology development to understand interactions of atmosphere- ocean and climate change making use of advanced space and ocean science and technology.

Climate Change research is the area that will benefit the most from the establishment of the AIR Center as a changing climate is directly associated with a dynamic ocean and also benefits from space-driven observation and monitoring systems. In particular, it is estimated that 90% of the excess energy accumulated in the climate system since 1971 is stored in the oceans, and about 30% of human-emitted carbon dioxide has ended up in the oceans, causing ocean acidification.

Significant heat absorbed by the ocean through spatially and temporally varying atmosphere-ocean energy and momentum exchanges has been redistributed internally and sequestered at depth through complex dynamic mechanisms involving waves, ocean currents, small-scale eddies and other processes. Biogeochemical tracers transferred to the ocean through air-sea-gas exchanges and, in particular, carbon dioxide and oxygen, have been redistributed in similar ways. That absorbed energy has caused thermal expansion of the oceans, which is responsible for approximately half of the rise in sea level to date.

Accurately, projecting the future path of climate change and monitoring whether current mitigation efforts are effectively reversing unsustainable pathways requires a, globally distributed ocean-observing system, especially at depths where very few observations currently exist, as well as detailed measurements of atmospheric circulation changes, along with the determination of the Earth’s net radiative imbalance from space. Seasonal to decadal climate information is needed to improve seasonal predictions, El Niño forecasts and other climate phenomena that are crucial for agriculture, water management, and disaster risk reduction.

Operational climate information (days to months) is needed because sustained ocean observations underpin early warning systems for ocean-related coastal hazards, such as storm surges and hurricane predictions, as well as more accurate medium-range weather forecasts that can improve the safety and efficiency of the maritime economy. The Azores archipelago is particularly well placed to monitor two of the most relevant large-scale climate patterns that affect the Northern Hemisphere, namely the North Atlantic Oscillation (NAO) and the Atlantic Multi-decadal Oscillation (AMO). These patterns are crucial to understand the past, current and future climate of both Europe and North America. The AIR Center will also promote a better knowledge of these processes and a much deeper understanding of the systems governing the South Atlantic Atmosphere-Ocean Interactions.

Weather has a profound and well defined influence on business. Scientists and society are coming from a time when some weather events were highly unpredictable to an approach led by scientific organizations where anticipation, preparedness and prompt response are the ultimate goal.

A better understanding of major Earth processes such as the formation of oceanic crust and seafloor spreading at ocean ridges, lithospheric plate interaction and tectonics at triple junctions, hydrothermal processes and the formation of natural resources, deep sea extreme chemosynthetic ecosystems and the frontiers of life, is crucial. The Azores archipelago is located over the Mid Atlantic Ridge, at a triple junction of the American, European and African tectonic plates, in the vicinity of active hydrothermal systems with associated extreme chemosynthetic ecosystems, and in an area with significant seismic and volcanic activity. Therefore, the AIR Center provides unique conditions for such integrated multidisciplinary studies of high scientific and societal relevance.

Space science and technology can play a major role in the Atlantic, including the provision of access to Space through safe and reliable spaceports, as well as satellite control and data transmission and collection. Satellite data processing opens opportunities for new ventures with economic, environmental and social impact, namely in areas such as climate change and sustainable energy systems design, fisheries and aquaculture, maritime safety and security, managing marine resources. Space is thus critical to address climate change, sustainable energy systems potential and design challenges, and also sustainable ocean exploitation

In this context, satellites play an important role on Earth observations providing an unique and critical global perspective. Used to monitor a many climate variables like changes in glaciers, emissions of greenhouse gases by industry and deforestation, sea level rise, temperatures changes and many other parameters, satellites and space research are the clue-giver for climate change advanced research.

More suitable and coordinated data is needed to better understand and clarify human impact on the ocean ecosystems and the basic ecosystem services such as coastal protection, food security and other livelihoods, and tourism that foster blue economy. In this regard the knowledge stills evolving through research and will leap forward when we have sustained observations for theory validation.

Energy dependency on fossil fuels is another great challenge that cannot be dissociated from climate change. There is a growing need for more efficient, renewable, cost-effective energy systems which will allow for significant reductions in our dependency from non-renewable fuel energy sources while maintaining energy security, economic growth and the global environmental goals.

Permanent and long-term observation systems are required to observe, monitor and collect reliable data in order to improve local and global models as mentioned before. Such models will improve understanding of the complex earth systems, enable the assessment and monitoring of human activities and inform decision-making in a number of different areas of key importance, therefore leading to an improved human well-being and to sustainable growth of all nations. Integrated large-scale environmental observations are absolutely critical for producing an efficient and effective data system in any environment.

Given the expected exponential growth of data available due to new sensors (Internet of Things), we also need to develop scalable data analytics capabilities as well as leverage emerging cognitive computing as well as advanced data analytics.

These systems will rely on a solid data foundation to source and manage data, and will analyze diverse datasets to create more meaningful insights, use advanced analysis approaches pervasively and harness talent that combines business knowledge and analytics.

Addressing these challenges requires international cooperation as well as interdisciplinary collaboration with existing research infrastructures. This white paper proposes an *Atlantic International Research Center* committed to the study of space, climate change, energy and oceans sciences in the wider Atlantic Ocean – North and South, from Iceland to the Cape of Good Hope and the Strait of Magellan – as a key enabling platform to successfully tackle these pressing, global challenges.

2. A network of Island Research Stations

Island research stations are extremely well placed to enable the advances of frontier research in the 21st Century. Darwin's expedition to the Galapagos Islands is the paradigmatic example, given the paramount influence it had on the practice of modern science, and how it highlighted the importance of islands and archipelagos for scientific progress.

Islands are ecosystems perfectly suitable for holistic research studies through experiment and observation of natural processes. They represent natural laboratories enabling and facilitating the design of scientific studies of international relevance. Island research stations are ideal for designing and achieving those direct and precise observations especially required for studying biophysical phenomena, but also for validating concepts, techniques and methodologies, particularly in remote places and/or in circumstances where reliable platforms are scarce.

As an example, Figure2 illustrates the composition of a global geodetic observing system (GGOS) and all its core sites. Including the AIR Center islands research stations as reference point in this global network of geodetic science, will underpin the North-South, East-West cooperation will incorporate both infrastructure and data to support global change research in the context of Earth system sciences.

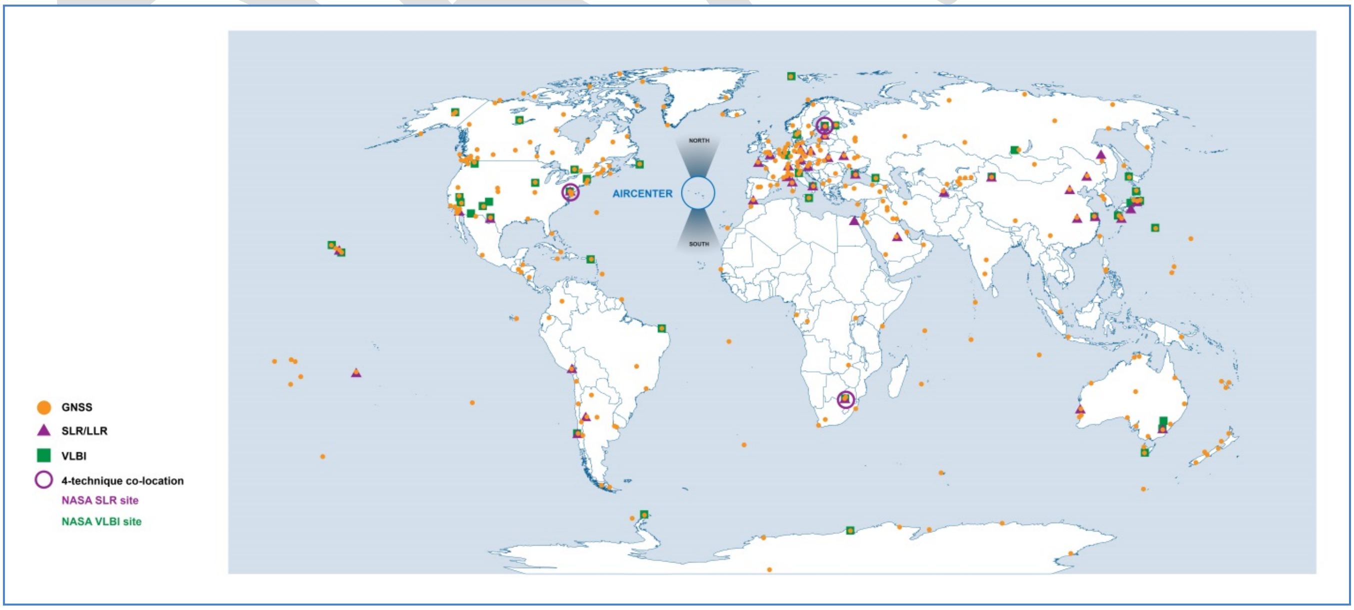

Fig.2 – Illustration of a Global Geodetic Observing System (GGOS) and all its core sites

Source: Juan Sanchez, AIR Center workshop in Azores, June 2016

When combined with space and ground segments, it will foster new research areas such as global reference frames (a basis for precision metrology – positioning, and gravimetry), regional coastal hazard assessment (measurement, vulnerability), global sea-level measurement (climate and Earth system science), global essential climate variables, and space weather and signal propagation (ionosphere, troposphere, scintillation, among others). This combination would be symbiotic with the development of new capabilities, state-of-the-art technologies, together with a space port for the launching of small satellites.

In sum:

- Island sites provide a unique capability for integrated earth and ocean observations (e.g., atmosphere, ocean, lithosphere, biosphere);
- Islands of volcanic origin usually offer a large number of lakes that are suitable to reconstruct long-term past climate conditions with high temporal resolution, allowing evaluating current and future climate change scenarios, built on instrumental data and models, in a much longer perspective;
- Islands located at active oceanic ridges provide unique insight into major Earth processes (geodynamic, tectonic, hydrothermal, volcanic, seafloor spreading, adaptation of life to extreme environments and formation of natural resources);
- Islands can be excellent space ports;
- Islands can be superb calibration/validation sites for global satellite missions;
- Islands are ideally suited as reference places to monitor changes in the ocean forced by human activities;
- Islands serve as a base for scientific studies and a center for maritime information and technology development; and
- Island research stations are an ideal place to build scientific capacity in the marine sector, and also for the development of ocean-related products to support the blue economy, due to its easy access to deep-sea and open ocean.

Fig.3 – Illustration of a Atlantic Network of Island (and mainland) research Stations

2.1. The Azores Archipelago

The Azores archipelago is located in the northeast Atlantic in the midst of complex ocean currents, which transport important water masses impacting global climate. Moreover symbiotic datasets among the Azores, Madeira and mainland Portugal, Canary Islands, Cape Verde and São Pedro e São Paulo, for example, can provide flux measurements that single point data sets cannot.

Below are highlighted some of its main unique features:

- The marine ecosystems and oceanographic conditions associated with the Mid-Atlantic-Ridge confer a unique opportunity for deep-sea research (ecosystem science, biodiversity and geodiversity, as well as economic activities). The Azores Exclusive Economic Zone (EEZ) covers about 1 million km^2, of which about 99% is deep sea (defined here as below 200 meters depth), with more than 450 seamounts, several known hydrothermal vent fields, deep fracture zones and trenches, deep and isolated holes and basins , and a considerable extension of the Mid-Atlantic Ridge (MAR) and abyssal areas.
- It sits over the Azores Triple Junction (ATJ) where the North American, Eurasian and African tectonic plates meet over a divergent tectonic system, which is of fundamental relevance in geology and geophysics, as well as providing an avenue to explore sub-

seafloor processes. The chemical and biological processes that are impacted by the geological processes at the Ridge are potentially of global significance. Establishment of a long-term, near real-time observing presence in the Azores will be of immense scientific value.

- The proximity and accessibility in the Azores region to the open ocean and the diverse ecosystems of the deep sea present unique possibilities for ocean observation systems and also research on ocean-atmosphere interactions and other climate change-related issues.
- The Azores are located in the path of intense meteorological and oceanographic activity that arises from the collision of warm air and sea water coming from the south, against colder air and colder water that comes from north, in evolution along the Gulf Stream and Polar Front.
- The richness of marine boundary layer clouds makes the location ideal for maintaining long-term observations of the responses of shallow marine cloud systems to aerosols and greenhouse gases, which are a source of uncertainty in global climate models. Situated at the southern demarcation of the North Atlantic storm track, the downwind location from the North American continent, and its impact by continental pollution aerosol, the air circulation properties of the Azores turns it into a uniquely suited place for the monitoring of the influx of pollutants into Europe.
- The orographic diversity of the nine islands makes them ideally suited for cloud studies (e.g., Graciosa) or pollution monitoring (e.g., Pico).
- The proximity of land and deep sea make for an optimal platform to study ocean-atmosphere interactions.
- Moreover, situated at the eastern margin of the Sargasso Sea, the regional oceanography of the Azores is determined by several distinct ocean circulation features, notably the subtropical gyre and the Azores Current.
- A high diversity of open and deep sea ecosystems and habitats are hosted by the ATJ, one of the most interesting and singular areas on the planet and an international reference for testing oceanic scientific instruments and platforms.
- The Azores islands with its steep topography far from anthropogenic sources of nutrients are of particular interest to carry out interdisciplinary studies involving vertical transport.
- The proximity and accessibility of the open ocean and the different ecosystems of the deep sea render the region a unique and strategic position in the middle of the Atlantic Ocean for maintaining ocean observation systems, conducting research on ocean-atmosphere interaction, and for studying other climate change-related issues.

- The most important large-scale pattern of atmospheric circulation variability over the entire Northern hemisphere (North Atlantic Oscillation, NAO) is deeply related to the Azores archipelago as its Islands are uniquely situated in the southern lobe of the usual NAO definition. This mode of variability is crucial to characterize the climate variability observed in Europe and over the North American continent.
- As part of the Meridional Overturning Circulation in the North Atlantic, which has been identified as a highly important, but poorly understood aspect of the Earth's climate system, the Azores Current is a topic of significance in physical oceanography.
- Closely related to the Meridional Overturning Circulation is the Atlantic Multi-decadal Oscillation (AMO) that, among other impacts, is highly related to the number of tropical cyclones and hurricanes that are active every year, and usually affect the southern regions of USA.
- The geostrategic position of the Azores is already serving space missions through a range of ground segment infrastructures currently operating. This infrastructure cluster contributes to a new growth paradigm for the upstream and downstream space industry in relation to the "newspace" market (e.g., implementing a European spaceport in the Azores, or promoting the development of small launchers).
- The archipelago of the Azores offers a set of unique features for studying the transition from prototype to sustainable energy systems. Firstly, it is composed of nine islands and, therefore, nine independent energy systems with different dimensions and contexts, which makes the Azores a unique multiple scale system. The systems range from Corvo, a small rural island with less than 500 inhabitants, to São Miguel, a "services" island with more than 130,000 inhabitants. Hence, it is possible to test different transition solutions with a diverse set of socio-economic characteristics, and also sizes, in the controlled environment of the archipelago.
- The Azores has a large and diverse set of renewable endogenous energy resources, which enables testing different conversion technologies, while also posing different integration challenges. Two islands have geothermal resources (São Miguel and Terceira); most islands have high wind resources – in fact, some wind parks in the islands of Terceira and Pico possess very large capacity factors for onshore wind park (above 30%); some islands, such as Santa Maria and Graciosa, possess significant solar resources; most islands present considerable biomass resources; and, finally, all islands face the challenge of managing their waste.
- For many years the island of Flores has utilized an integrated hydro-wind system with a flywheel that enables it to operate a significant number of hours in the winter relying

solely on renewable energy. The island of Graciosa hosts a recent project that makes use of large-scale battery integration to maximize the use of wind and solar energies. The islands of São Miguel and Terceira will soon have pump-hydro storage systems to transfer excess renewable electricity production from wind and geothermal from off-peak periods to peak periods; the island of Corvo has a 100% deployment of solar thermal systems for domestic hot water generation that can be used to integrate renewable energy resources like wind. All these initiatives make the Azores as the perfect ground to develop and test large scale renewable energy based energy systems of different sources and with a variety of technologies.

- The Azores archipelago is located east of the magnetic anomaly of South America, constituting therefore a privileged setting for the monitoring of magnetic variations due to solar explosions that cause magnetic storms, and which have the potential to affect satellite navigation.
- Santa Maria has a regional space capability that has excellent potential for expansion into a significant regional space research hub. The current capabilities include: European Space Agency (ESA) Tracking Station; Galileo Sensor Station (GSS); Copernicus Collaborative Station: The Sentinels; Earth Observation (EO) station; Project RAEGE (Atlantic Network

The unique "living laboratory" characteristics of the Azores, together with the already existing infrastructures in the archipelago, make the Azores a prime location for the headquarters of the proposed *Atlantic International Research Center* that will focus on space science and well as ocean-atmosphere science, climate change and energy systems, and. This unique combination of natural and anthropogenic factors allows the creation of high-level technology centers in the mentioned areas and complementary technologies (and connecting research and development) directed toward enhancing the exchange of knowledge and experiences.

2.2. Other islands (to be developed by participating countries)

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Part II - A Research and Technological Agenda for an Atlantic International Research Center

3. Space Science and Technology for the Atlantic

3.1. Opportunities for international collaboration

- ***Establishment of an Atlantic Spaceport for low cost access to Space including launchers for mega constellations and small satellites in the Azores***

“New Space” and the related democratization of the access to space has become a research and development-intensive sector open to many players, with significant opportunities for science-based innovation and “new space industries” in a wide range of applications. With the development of a number of non-governmental firms that are developing satellite launch vehicles, there is a competing need for launch sites, or space ports, to accommodate this demand. Future perspectives will experiment major expansion with the maturation of the nanosat and microsat bus and instrument capabilities.

The global demand for coverage by these satellites emphasizes the need for a polar launch infrastructure, which because of its unique geographical location would be a very appropriate role for the AIR Center. The extensive runway facility would provide conditions for both take off and return-to-earth for horizontal launch vehicles. Consequently, a future Spaceport in the Azores for mega constellations and small satellites will provide many new opportunities, as, for example:

- It will create a pull effect for new companies working on new propulsion systems, small launcher development, ground segment for space, lower cost launches, and satellite validation and calibration, among other themes;
- It can serve as a launch and landing facility for an orbital space plane (long runways). Example: Lages airfield was a backup landing site for the U.S. space shuttle;
- It will provide a comprehensive launch capability for nano/micro satellites (payload development, testing and integration services; satellite platform production, integration, testing; constellation networking and operation services; data reception, storage, analysis and dissemination;;

- Spacecraft design and testing and the development of novel technology and experiments for the International Space Station (ISS) will be possible;
- It will facilitate series production of satellites and subsystems and can serve as a data-hub for data processing for EO satellites in close interaction with on-site observation capabilities with aircraft, unmanned aerial vehicles (UAVs), ships, and remotely operated vehicles/autonomous underwater vehicles (AUV);
- It can serve as a research hub for conception and development of human spaceflight demonstration projects — development and improvement of materials and manufacturing processes for the purpose of space exploration (protection of spaceships, astronaut protection, protection against corrosion and wear, exposure to extreme conditions) and science- specific experiments that utilize the orbiting spacecraft environment.

3.1.1. Space based initiatives transversal to other Atlantic International Research themes

- ***Establishment of an Atlantic Surveillance Center to leverage the scientific leadership in the Atlantic (North and South)***

This center would cover the following activities:

- Monitoring piracy, illegal and narco activities in Gulf of Guinea & Africa west coast;
- Supporting search and rescue (SAR) Atlantic activities;
- Supporting scientific missions and new economic endeavors concerning the Portuguese extended continental shelf;
- Conducting research and testing for UAVs for maritime applications, including a staging and deployment site for regional campaigns.

- ***Implementation of an upgrade program for the existing ground segment stations and infrastructure to support Space missions***

AIR Center activities would include development and implementation of a larger antenna of 15.5 meters in the ESA tracking station infrastructure, development of a new infrastructure to accommodate activities for the Space Surveillance and Tracking (SST) program and NATO's Future Surveillance Control Project/AGS.

- ***Establishment of ESA/ Launchpad Technology Incubation facilities***

These facilities spread across the AIR Centers associated member states would be characterized as a "start-up campus" for NewSpace companies that are "high-risk, high-reward" from an investment view point.

- ***Installation of an operational network/platform for an efficient "Atmosphere - ocean monitoring and environmental management"***

Basic characteristics of the Atlantic waters, such as seasonal temperature variability, mean anomaly fields and biological activity need to be precisely measured to better understand the impact of climate change in the North Atlantic. Past, current and future satellite remote sensing data have been successfully processed to produce daily-to-monthly composites of these parameters on both regional and global scales. In addition to being decisive information for studies of regional and global climate change – weather and climate monitoring and forecasting, time-series of SST (sea surface temperature) composites, SSH (sea surface height) and most recently SSS (sea surface salinity) – this information is applicable to a number of application areas such as providing support for the analysis of mesoscale variability at the scale of ocean basins affecting fishing activities in the Atlantic ocean current and wave height as an aid in maritime ship routing. Synthesis of these diverse observational data streams into a unifying modeling, analysis, and prediction framework centered in the Azores would provide a powerful way to enhance the value of these data.

The data reception capacity allows a real time reception of the satellite data allowing the development of a more immediate answer to both anthropogenic and natural hazards. In addition, the near real time products would provide a basis for commercial exploitation of the data that can be developed and could be a basis for small business startups.

The real-time data acquisition can foster the collaboration with US, European, African and South American activities, such as a consortium that formed the European Gravity Service for Improved Emergency Management. The EGSIEM is a multi-instiutional effort to improve the response time for regional emergencies. The initiative is funded by EO-1 Space Call of the Horizon 2020 Framework Program for Research and Innovation for 2015-2017 . The AIR Center can be important an important spot for similar regional remote sense-data applications.

- ***Establishment of innovative geo-information services based on Earth Observation (EO) data for adoption and enhancement of the EU Atlantic Strategy (in particular EU Horizon 2020 project "AtlantOS") and its action plan and of National Ocean Strategies***

Promote a transversal initiative with applicability in many areas related to coastal and ocean management that will allow AIR member states to meet the challenges for the promotion, growth and competitiveness of the maritime economy, in line with the European Commission initiatives such as Blue Growth, in particular, the important changes legal and strategic framework at an worldwide level. This objective is in line with the activities discussed in the applications of the Sentinal program, the RADARSAT data acquisition, and the NewSpace,

- ***Installation of a ground facility incorporating high resolution radars***

The AIR center could manage a ground facility with high resolution radars for the monitoring of active and obsolete satellites (space junk/debris). This facility could be a "mirror site" for example of the Haystack radar of MIT Lincoln Laboratory imaging at W band for NORAD (North American Radar Air Defense). The availability of high resolution images of virtually everything in orbit could be managed as a service.

4. Atmospheric Science and Climate Change for the Atlantic

4.1. Key Research Challenges

- ***Understanding global, regional and local climatic patterns and climate change impacts***

Small Islands developing states worldwide are highly dependent on their climate and have been identified as particularly vulnerable to climate change (IPCC WGII TAR, 2001; IPCC AR4, 2007, AR5, 2014). Major risks include sea-level rise, tropical and extra-tropical cyclones activity, increasing air and sea surface temperatures and changing rainfall patterns (high confidence, robust evidence, high agreement). The future probable impacts associated with these risks include loss of adaptive capacity and damage of ecosystem services critical to lives and livelihoods in small islands developing states.

- ***Understanding the effects of aerosols in the cloud condensation nuclei (CCN) budget***

A quantitative understanding of the effects of aerosols in the cloud condensation nuclei (CCN) budget is currently missing for some of the processes underlying perturbations of CCN population by aerosols. Remote marine low cloud systems are particularly susceptible to perturbations in CCN associated with anthropogenic emissions because of their relatively low optical thickness and low background CCN concentrations. The CCN population is driven by a range of processes, including generation of sea spray aerosol through breaking waves, entrainment of free tropospheric aerosol, and removal of aerosol particles by drizzle. The indirect effects of aerosols in CCN budget is one of the main research themes at the Eastern North Atlantic (ENA) Atmospheric Radiation Measurement (ARM) site at Graciosa Island (28ºW 39ºN).

- ***Understanding cloudiness transitions through the integration of in situ ground based, airborne and satellite data***

Marine low cloud fields display coherent mesoscale organization (mesoscale cellular convection, MCC) on horizontal scales of 5 - 100 km. Key processes controlling MCC are currently not well understood. The horizontal scales of MCC present a significant modeling challenge to global change models, as the dominant scales are comparable to the horizontal resolution in the next generation of climate models. There is currently no consensus on how to characterize MCC in observations and in models.

Ground-based remote sensing techniques, including ENA-ARM's new scanning radar and lidar capabilities, offer new ways to probe mesoscale structure and dynamics. Combining newly available ground-based views with aircraft and broader-scale satellite data will provide insight into the structure and dynamics of MCC and how it impacts cloudiness transitions.

- ***Monitoring the influx of atmospheric pollutants into Europe***

The air pollution observatory station at Pico mountain in Pico Island (PICO-NARE) which is located at 2225 meters above sea level, provides a ground base for free tropospheric measurements on the central North Atlantic region and is suitable for observation of air pollution and boreal fire plumes from North America, occasional African dust and European air pollutant emissions. On the other hand, simultaneously the ENA-ARM site (Graciosa Island) is downwind of the North American continent and is periodically impacted by continental pollution aerosol.

- ***Integration of the atmospheric and ocean information in global climate models***

The responses of shallow cloud systems to changes in atmospheric greenhouse gases and aerosols are major sources of uncertainty that limits the accuracy of predictions of future climate. Low cloud systems over the remote oceans are a key research challenge because they are poorly represented in climate models. Interactions between cloud microphysical and macrophysical processes play a fundamental role in modulating cloud dynamics and entrainment and precipitation, all of which help determine cloud radiative properties that impact global climate. The ENA-ARM site at Graciosa Island provides unprecedented conditions as an International research platform dedicated to the understanding of key processes of ocean atmosphere interactions in a remote marine environment along the boundary between the subtropics and mid-latitudes, and the southern demarcation of the North Atlantic storm track, where great diversity of meteorological conditions can be observed.

- ***Towards regional earth system model for the Atlantic Ocean***

Climate variability over the Atlantic Ocean ranges from seasonal migration of storm tracks to inter annual and decadal-scale variability of the most important modes of climate variability, such as the NAO (North Atlantic Oscillation) and the AMO (Atlantic multi-decadal oscillation), and to long-term climate trends. On weather scales, hurricanes can influence the Gulf Stream and associated oceanic eddies. An increasing number of tropical cyclones have reached the Azores archipelago in recent decades and it is necessary to evaluate if this is a trend or not.
The relevance of the North Atlantic to global climate is twofold - the production of deep

waters on the subpolar gyre and the corresponding heat transport into the deep global ocean circulation (AMOC) and uptake of anthropogenic greenhouse gases especially carbon dioxide into the ocean biogeochemical cycles -both these processes are driven by surface air-sea fluxes on the North-Atlantic and depend on the upper ocean circulation, mixing and biogeochemical interactions. These involve a wide range of spatial and time scales and cannot be studied by observations alone. Understanding and predicting such wide-range variability from weather to climate scales requires Earth System Modeling (ESM). The EC-Earth consortium is developing such an ESM that integrates atmosphere, ocean and biogeochemical cycles at eddy-resolving scales (0.25 deg.), as well as other components like soil, vegetation, snow, glaciers, ice sheet, lakes and rivers. ESM is required for processes studies in the North Atlantic, to understand how heat anomalies are produced, how the carbon is subducted and how they circulate and impact the climate at global scales. These studies need to be extended to South Atlantic making use of the capacity provided by the AIR associated member states.

- ***Understanding major Earth Processes at Ocean Ridges and Ocean Crust Formation***

Oceanic ridges are the places where ocean crust is formed and particularly little is yet known about the intricate interaction between tectonics, magmatism and hydrothermalism at slow-spreading ridges such as the Atlantic, which are of global significance and of high impact to the formation of deep sea life in these systems. Oceanic crust serpentinization is another major oceanic process, still not yet fully understood, that can contribute to the global carbon cycle, namely through the liberation of potentially significant quantities of methane and hydrogen to the hydrosphere and the atmosphere. Hydrothermal processes, with impact on ocean crust rheology and mechanical behavior (which impact on earthquakes and tsunami generation), the formation of mineral resources, the supporting of chemosynthetic ecosystems and the deep biosphere, are also poorly understood. The AIR Center, providing easy access to the observation and monitoring of such systems can lead such studies through international multidisciplinary scientific cooperation.

- ***Towards a sophisticated data analysis and modeling capability for the Atlantic Ocean***

Vast data sets from various fields, different satellite platforms and *in situ* sources must be synthesized, stored, catalogued and processed. A data distribution center must be established to support model development, testing and validation. Data assimilation capabilities must be developed to integrate atmospheric, oceanic, geophysical and biogeochemical data into a

Regional Earth System Model (RESM). This effort is critical for effective monitoring and predicting phenomena in the Atlantic Ocean and surrounding continents.

- ***Using the high number of lakes available in different islands of Azores to reconstruct the climate of the Holocene, including the NAO and AMO***

Lakes are freshwater ecosystems and their physical, chemical, and biological properties respond rapidly to climate-related changes. Lakes represent ideal natural traps which continuously collect sediments and, therefore, very long climate time series extending over millennia can be reconstructed with sufficient reliability. However, factors that include geography, limnological complexity, morphology and human influence may be a key factor masking climatic signals and, then, these records would be susceptible to local environmental bias. Nevertheless, the high number of lakes available in different islands of the Azores archipelago show a straightforward response to large-scale climate variability on long timescales overlapping the local susceptibility to environmental factors.. In this context, the large set of Azorean lakes can be very useful to reconstruct the NAO and AMO evolution trough the Holocene and their impact on the natural ecosystems.

- ***Towards a cognitive process to predict future ocean conditions using a combination of physically-based models and large, heterogeneous data sets***

Physically based models as well as large and heterogeneous data sets could leverage advanced three-dimensional circulation models and utility analytics to describe and forecast marine system dynamics. Tightly coupled meta-models guide the precision of forecasts by means of adaptive mesh refinement which targets compute resources at locations where precision of solution is of most importance. The development of processes and tools to provide forecasts of events including marine spill migration, forecasting of water temperature, SSH, currents and other factors that influence production efficiency and development of coastal focused industries would be of great interest to all.

- ***Towards a cognitive models to a fast - response to severe weather events***

It is crucial rely on historical and real-time data, integrate it with weather data and apply deep analysis , data visualization and real-time collaboration to plan for and manage response efforts during natural disasters, public safety emergencies and common but unexpected incidents with the goal to deliver approximately 1.5 days additional lead time over publicly available forecast information to allow government officials around the world make far better planning, resource positioning and logistical decisions.

Also for disaster management, the possibility of establishing partnerships with national and international initiatives such as SERVIR-Global, the International Charter on Space and Major Disasters and UNOOSA’s United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER, www.un-spider.org). Collaboration with US centres for hurricane monitoring would also increase the reach of the AIR Centre.

5. Ocean Science and Technology for the Atlantic

5.1. Key Research Challenges

- ***Monitoring the large-scale Atlantic subtropical gyre circulation variability***

The Azores are situated at the eastern perimeter of the Sargasso Sea, a sea not bounded by land but by one of two large basin-scale ocean gyres in the North Atlantic, the Subtropical Gyre. It is also influenced by the Azores Current, a rather unique and energetic current that is strongly connected to Mediterranean dense water outflow into the Atlantic Ocean. Because of their critical role in regulating regional (and ultimately global) climate through heat and greenhouse gas uptake, lateral redistribution and vertical sequestration, monitoring these circulation features is an important task of the established global ocean and climate observing systems (GCOS, EOOS and GOOS). On a regional scale, the Azores can play an important role contributing to the implementation of such observing systems through deployment and maintenance of required ocean-observing platforms combined with basin-scale analysis and forecasting systems.

- ***Observation and monitoring of large-scale Atlantic variability and change***

Islands are very suitable for the installation of ocean observatories because they provide unique geographical locations that allow us to measure ocean data that can be directly linked to land stations, facilitating data analysis and equipment maintenance.

The potential to receive, process and analyze data from complementary satellite, atmosphere, surface, and sub-surface ocean observatories at a mid-Atlantic location, as the Azores, would be a unique contribution to improve knowledge and understand the Atlantic Ocean. It is also important to link up these efforts to the ones being held either by national initiatives, such as local and regional ocean observing systems, or international endeavors, such as the EU Horizon 2020 project "AtlantOS".

The circulation in the Atlantic Ocean can be understood as a component of a global-scale turbulent, yet strongly organized system of ocean currents. Local processes at small scales play an important role for horizontal and vertical redistribution of water masses and associated nutrients. As such, a multi-scale approach is considered the suitable approach to study the Atlantic Ocean circulation, with the global-scale circulation and climate influencing

– and being influenced by – regional and local processes. Local-scale manifestations of global change provide the strongest link between science and society. They also provide the most direct ways for verification and validation of scientific projections.

The Azores archipelago constitutes a strategic location for the establishment of an advanced marine monitoring post in the Atlantic, complementing other marine monitoring posts in mainland and other islands, in the scope of an Atlantic monitoring grid framework. Moreover, building a network of ocean observatories that utilize similar protocols for data collection and analysis would be a great leap in better understanding large-scale processes and ocean variability and change. In terms of extreme events, such a network would enhance our predictability and monitoring of ocean and atmosphere dynamics, feeding models on Earth and climate.

This would be particularly relevant for monitoring biological communities, as for example looking at changes in species ranges, detection of potential invasive species, links between benthic communities and associated planktonic larvae and keeping track of fisheries resources.

In this context Azores can become a pilot site for the application of state-of-the-art biological monitoring tools, such as environmental DNA (eDNA) monitoring, based on new generation DNA sequencing technology.

- ***Building knowledge on the deep ocean***

Less than 10% of the deep sea ecosystems has been fully mapped so far. There is an urgent need to invest in mapping of the seabed and its habitats and deep-sea observing systems to understand deep-sea ecosystems, their resilience and interactions. value of organisms found in extreme environments under the influence of hydrothermal vents.

Sustained observations of the deep ocean should also include an effort to attract commercial ships to collect scientific data underway, particularly helping on seabed mapping and physical variables. Also, there is an increasing interest in accessing deep ocean resources. Emerging areas of activity may include deep sea mining for rare earth elements and minerals as well as the exploration of the economic

- ***Conservation of marine biodiversity***

The Azores, the Canary islands and other atlantic islands is an ideal location to study patterns and processes of oceanic functioning and biodiversity at multiple scales, from bacteria to top predators, relevant to the Atlantic basin (amphi-Atlantic population connectivity) and large-scale migrations.

Besides the interconnectivity of the marine environment the isolation of populations and limited connectivity and gene flow with mainland and other Macaronesian archipelagos, suggests that the Azores can constitute a key location for biological conservation programs focused on local endemism, unique genetic variants and gene pools, of multiple marine species from the North Atlantic.

- ***Blue biotechnology for the sustainable exploitation of biological resources***

The genetic and functional diversity of the marine life, associated to millions of years of adaptive evolution to selective stresses (e.g. extreme pressure), constitutes an unparalleled source for bioprospecting. The biological resources gathered in the marine environment provide a library of natural marine blueprints for the development and (re)engineering of biological processes and synthesis of bioinspired materials. The development of the Blue biotechnology should be based on a sustainable exploitation of biological resources being crucial to take care about the possible impacts and mitigation measure to prevent irreversible damages in the unique marine life of the Azores. Furthermore, blue biotechnology has an enormous potential for the creation of innovative products and processes of high economic value and environmental and human health impact at a global scale.

Sea organisms can be a valuable source of extremely potent bioactive molecules and may be regarded as a sustainable economic resource for several different industries. Bioprospecting on marine microorganisms through metagenomics characterization and other high throughput strategies constitutes a valuable strategy to identify biotechnologically useful traits and compounds. These may range from antimicrobial biomolecules, enzymes and food additives to anti-inflammatory, anti-ageing or anti-tumor compounds.

- ***Sustainable use of the oceans and blue growth***

To understand and predict the effects and impacts of climate change and human reactions it is first necessary to understand environmental dynamics and natural variability. The Azores Mid-Atlantic Ridge region profits from long-term observations made either at seamounts (Condor) or hydrothermal vent fields (EMSO-Azores observatory), two habitats very likely to be directly and indirectly impacted by human activities. A continuous and improved study and monitoring of these habitats is critical as is the development of new capacities for open-ocean monitoring and will promote best practices for the many baseline and environmental impact assessment studies that cannot obtain long-term observations.

- ***To foster marine technology development***

From a technical point of view, there is a need to further develop systems, sensors, robots and deep-sea observatories, as well as systems for capturing and maintaining deep sea organisms. The Azores provide perfect locations as a test bed for these instruments, namely through the proximity of oceanic harbors to deep sea extreme environments.

Unmanned vehicles are now valuable tools for research, especially for sampling not only small scale ocean processes and the biological environments, but also their diversity over extents which match their speed and endurance. Intelligent and autonomous sampling of ocean properties such as the usual temperature, depth, conductivity (salinity) and O_2 around the island can provide fine-scale oceanographic data. UUV's can also infer currents with ADCP's (acoustic Doppler current profiler) as well as particulates of low concentrations. Side scan sonars and high frequency multibeam echo sounders can provide very high resolution images of the bottom which can be recurrently mapped for changes induced by volcanic activity. Flow cytometers for cellular identification are now being deployed on UUV's which opens many opportunities in biological oceanography. Since this can be very dynamic, simultaneous mapping could be powerful for creating images of the biologic activity.

New technology is being developed rapidly and there is no such place where prototypes from many different fields could be tested and demonstrated to industry development. Also, catalyzing such initiatives would bridge the science needs to technological development suitable for enhanced ocean research, allowing also a strong international collaboration in the co-development of new technologies. Ultimately, this would benefit the capacity building and technology transfer foreseen in many ocean *fora.*

Also, calibration and maintenance of ocean research instruments is key to provide accurate data for scientific purposes. Therefore, the AIR Center could promote public-private partnerships in calibrating and maintaining those equipment, fostering technology transfer by training technical staff on these procedures.

- ***The ocean soundscape around the Azores***

The ocean around Macaronesia regon is an underwater sound scape that is beckoning for research and exploration. The "soundscape" is a combination of natural and anthropogenic sounds that characterize a particular area of the underwater environment. The EU Marine

Strategy Framework Directive (MSFD), which seeks to attain Good Environmental Status in European seas by 2020, mandates that the underwater soundscape be measured and monitored. This would include the EEZ surrounding the Azores. The Azores is strategically located for studying the soundscape of the North-Atlantic. Natural sources of sound include low-frequency signals from seismic activity of the mid-Atlantic Ridge and hydrothermal vents. Certain humpback whale pods are known to migrate through the Atlantic, particularly between Newfoundland and the Azores and may be recognized by their vocalizations. The Azores is close to shipping routes and are exposed to sounds from ships, both far and near. Listening to the sounds in the water surrounding the Azores would be a very cost-effective way to reveal and study such processes and activities.

6. Energy Systems for the Atlantic

6.1. Key Research Challenges

- ***Micro-grid management tool to exploit the use of high penetration of renewable resources, including distributed generation***

The penetration of renewables in the Azores as primary energy represents, in some periods of the year, 40% in electricity generation, mainly coming from geothermal sources, followed by wind, hydroelectric and biomass (residual). In some islands, like São Miguel and also in Flores for some periods of the year, the renewable penetration is beyond 50%; 100% penetration has been observed for several hours without interruptions.

In such isolated grids, to grow from 50 to 70% penetration requires the use of storage systems, but increasing beyond 70% will require the development of a new grid management tool and the enabling technologies to implement it. Thus, a key research challenge is to develop a new set of software for management of the grid operation that must integrate multiple new features: highly accurate demand forecast models depending on weather forecast and occupation forecast (hotels and plane reservations); renewable energy resource (wind and solar) forecast tools; demand response technologies for industrial systems (mainly large heating and cooling systems), buildings air-conditioning systems in hotels and retail) and transportation systems (electric vehicles), while also operating in a fully integrated way, all generation power plants (thermal and renewable), the storage systems (hydro pump-storage, batteries) and the distributed generation (mostly small Photovoltaic (PV) power plants for self-consumption).

- ***Integration of multiple efficient and flexible storage systems***

The grids´ operation under such high renewables penetration requires a storage system that transfers consumption from off-peak periods to peak periods and also contributes to the voltage and frequency regulation of the grid, improving the overall reliability and robustness of the power networks. This includes traditional storage systems like pump-hydro, batteries and flywheels, already available in Azores, but also the use of electric vehicle charge and discharge, together with the demand response in buildings and industry as flexible storage systems. The use of small scale storage systems integrated at the substation level and of distributed storage systems at the residential level to support the distributed generation with

PV for self-consumption can be another factor to be accounted in this context. All these storage technologies are commercially available; however, its full deployment and integration in the networks still requires the development of additional technologies and services.

In addition to serving as a useful testbed for electricity storage from batteries, islands can also be used for other storage approaches, such as compressed air energy storage (CAES), pumped hydro, and thermal storage. Proxies for storage, such as flexible desalination and production of hydrogen or methane with excess wind, can be tested in an island setting as a way to balance the grid and provide other value resources as, for instance, freshwater and fuels.

- ***Establishment of a center to assess/improve the efficiency of the renewable energy resources in the Atlantic***

The integration of in-situ data into models providing more precise and reliable regional predictions will help to improve decisions leading to an effective management of energy resources. Due to the unique conditions of the Azores, different renewable systems can be integrated and the AIR Center can serve as the seed for a deployable system that can be replicated in other similar areas.

- ***Demand response in buildings and large facilities***

Matching the demand of energy at the building level to the availability of renewable energy resources constitutes a major target for the sustainability of an energy system. It requires extensive research in the development of new monitoring, metering and sensing devices, as well as software tools to communicate with intelligent control systems in order to manage energy use while maintaining acceptable environmental conditions within buildings. In particular, it addresses issues on the design of operational control systems to optimize energy use across the urban area, including the scheduling capabilities to enable use of ventilation, lighting and air conditioning to reflect closely the needs of the area while distributing our energy use as optimally as possible.

The full potential of technological excellence is exploited by analyzing in detail specific buildings, which are modeled and instrumented in order to enable the monitoring of human activity as an innovative feature in the formulation of new and advanced energy efficient predictive control strategies that correlate human behavior with the use of energy in the context of dynamic thermal building models.

- ***The electrification of energy systems, in particular in the transportation sector***

The transportation sector is not only one of the largest energy consumers but is the sector where the transition to renewable based technologies is also more challenging. The massive implementation of electric vehicles is definitely a key aspect to achieve the transition. But other technologies are available, mainly the ones associated with the power- to-gas (P2G) paradigm which basically consists of using the excess renewable resources to generate gas fuel, spanning from the traditional electrolysis to generate hydrogen for fuel cell vehicles , but also fuel synthesis. In any case, these technologies need to be coupled with the development of new mobility models, taking advantage of use of information technologies and the shared economy models.

- ***Predictive Asset Failure***

Weather data combined with asset information and analytics can be used to proactively monitor assets and predict failure before it happens. Leverage hyperlocal weather information combined with asset performance information to understand the impact of weather on asset failure. Predictive maintenance analytics can be used to understand the impact of weather on asset performance and provide alerts when assets are at risk to proactively maintain assets before failures perform condition-based maintenance instead of scheduled maintenance and more efficiently allocate capital for asset purchases.

- ***Offshore wind energy***

In the area of renewables, there are also significant contributions from satellite applications that can be another focus of such a center, particularly in islands or continental platforms. For example for offshore wind energy, the current process is to take wind measurements for a number of years (usually 10 at least). UK based research is trying to obtain that information without in situ data from analysing satellite imagery of the sea surface (depending on the refraction, colour, white spots and so on). They can detect number of waves, height, speed in deep sea and by various models estimate the wind speed and direction, without having to install costly platforms (and you can do larger areas at a time, and use past data). This and other similar studies could be a further field of research where an island based center could benefit, by comparing in-situ data at various sites with different depths, currents with estimates from satellite imagery.

7. Data Science for the Atlantic

The successful practice of data science requires finding an effective combination of algorithm, platform and parameters from among thousands of possibilities - hence the requirement for a high level of human skill.

In the domain of data science, solving problems and answering questions through data analysis is standard practice. Often, data scientists construct a model to predict outcomes or discover underlying patterns, with the goal of gaining insights.

There are numerous rapidly evolving technologies for data analysis and building models. In a remarkably short time, they have progressed from desktops to massively parallel warehouses with huge data volumes and in-database analytic functionality in relational databases and Apache Hadoop. Text analytics on unstructured or semi-structured data is becoming increasingly important as a way to incorporate sentiment and other useful information from text into predictive models, often leading to significant improvements in model quality and accuracy.

7.1. Key Research Challenges

- ***Integrating at scale, data collection curation, and storage with advanced computing and analysis***

Regarding the development of an innovative electronic science environment, it is possible to implement a specific cyber-infrastructure deemed essential to the success of the AIR Center: a Research Cloud dedicated to the AIR Center and a portal, iAtlantic, which would be designed and deployed to integrate a comprehensive set of tools and technologies linking the science and engineering relevant to the Azores and the entire Atlantic region. The vision for iAtlantic is that it will become a widely used and indispensable site of reference for the international research community, policy makers and the public in general.

An AIR Center Cloud can support all the thematic areas of the AIR Center as a technological platform and data hub responsible for providing:

- A portal, iAtlantic, for web access to host applications providing data and services for science and engineering applications including a directory for search and browse;
- Real-time data collection from several maritime sensors and information sources (land, sea, air and space) that already exist and also from others to be developed;

- Data correlation and fusion through advanced computational models;
- Data storage and retrieval capabilities enabled by big data distributed databases;
- Open interfaces allowing the research and commercial stakeholders build their own services on top of collected data, core cloud services and third parties hosted services;
- Rapid prototyping environment providing core functionalities such as imagery processing, machine learning and business intelligence;
- Application and services hosting;
- Reliable electronic information exchange between stakeholders (including connection to national and international data exchange networks)

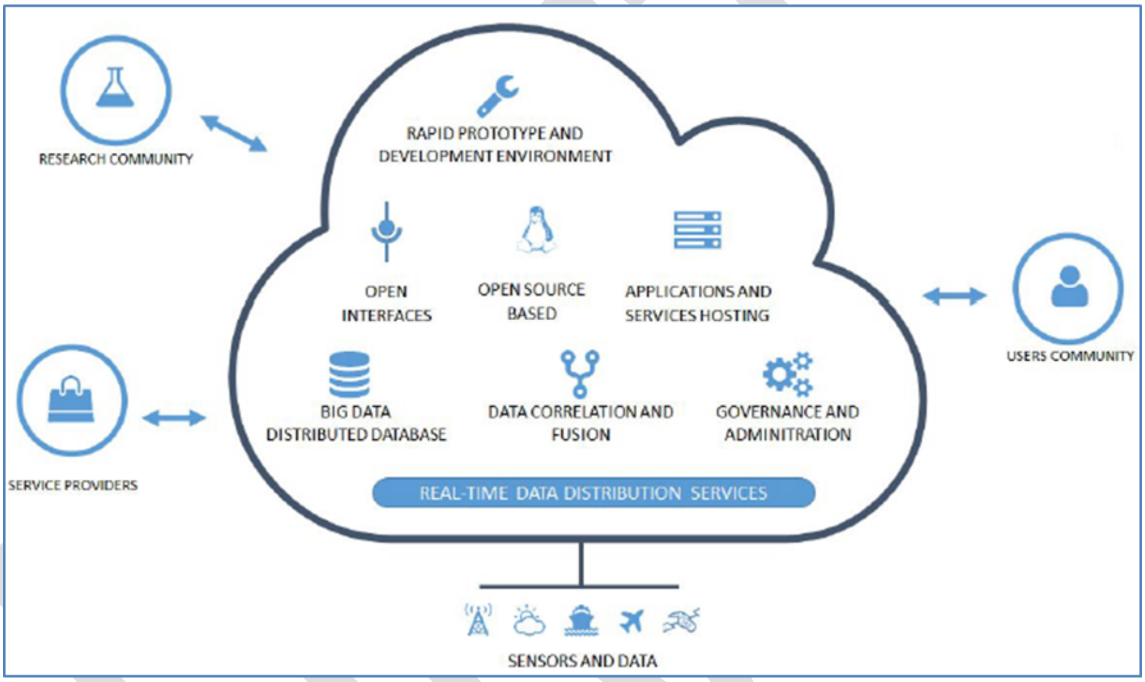

Fig.4 – High-level architecture representation for the AIR Center Cloud

The architecture depicted in Figure 4 above can be efficiently set-up based on existing assets to support Atlantic-related operations such as data collection from several sensors (space, landand sea and), data fusion through advanced computational models, storage and dissemination.

- ***Create a best in class Data Science team to extract value from Data***

The role of the Data Scientist is key to achieve the goals that the AIR Center is aiming for. But the Data Scientist need to rely on a team that should have different roles and the challenge we face is in the articulation of those roles around objectives that should be both scientific and commercial viable.

This team should include Data scientists, Data engineer / Data software developer, Data solutions architect, Data platform administrator, Full-stack developer, Designer, Product manager and Project managers.

- ***Acting as a regional collector of requirements for satellite monitoring systems***

The Air Center could act as a regional collector of requirements for satellite monitoring systems that can be fed into future satellite generations as part of the Constellation of Constellations Initiative of UNOOSA, EU-Copernicus and others.

- ***Design and develop a content analytics platform and methodologies to apply cognitive analytics solutions.***

Applying text analytics driven methodologies of natural language process and text annotation to a search scenario further drives value into the organization by vastly improving findability of content in a business scenario.

Traditional enterprise search solutions are heavily reliant on structured metadata about content being searched to drive faceted navigation, allowing the users to drill down and supplement their query terms with additional filters based on this additional information.

However, many times, that metadata is insufficient or completely missing to allow for accurate and timely searching. Content Analytics provides the analytics-driven search solution that uses natural language processing (NLP) and text analytics to extract and normalize that additional information from the unstructured content.

Content analytics extracts and normalizes that data from the unstructured content and allows for searching. Furthermore, it analyzes the text regarding clustering or classification techniques and correlation or relative co-occurrence, giving users visual clues as to which search elements are important to focus on and possibly drill in on.

- ***Design and develop of cognitive security solutions to manage cybersecurity threads and keep data trustable***

The state of cybersecurity is reaching an inflection point. The number of risks and events is growing exponentially and security operation teams are struggling to keep up with the volume. The threat landscape is changing rapidly, with the sophistication and numbers of threat variants becoming too great to stay abreast of, using traditional approaches. The repercussions of incidents and breaches are increasing, with the financial costs and risks growing rapidly. Finally, data must be kept trustable to be useful for scientific research and commercial usage.

- ***Acting as a regional collector of requirements for satellite monitoring***

Acting as a regional collector of requirements for satellite monitoring systems systems that can be fed into future satellite generations as part of the Constellation of Constellations Initiative of UNOOSA, EU-Copernicus and others.

The data gathered by this Centre could be a valuable contribution to the Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO), established in 1960 as a body with functional autonomy within UNESCO. IOC-UNESCO is the only competent organization for marine science within the United Nations system. Its main purpose is to promote international cooperation and to coordinate programmes in research, services and capacity-building, in order to improve our knowledge of the nature and resources of the ocean and coastal areas and to apply that knowledge for the improvement of the management, sustainable development and protection of the marine environment, as well as for the decision-making processes of its Member States. In addition, IOC is recognized through the United Nations Convention on the Law of the Sea (UNCLOS) as the competent international organization in the fields of Marine Scientific Research (Part XIII) and Transfer of Marine Technology (Part XIV).

7.2. Science Communication and Data Visualization

The development of an all-encompassing research infrastructure calls not only for scientific expertise but also for a communication strategy and the means by which the lay population and journalists can understand the data generated through this international initiative.

Digital media is pertinent and crucial for the AIR Center by providing a roadmap on how science communication, journalism and data visualization can all work together to comprehensively explain and educate the importance of the AIR Centre-driven research to policy makers, researchers and the general public. What is currently described as "big data" includes diverse data sets that can be used by machines to extract knowledge, or else by humans, in different contexts. At least three of these contexts are particularly relevant: data sets to be used by (1) scientists; (2) decision makers and (3) the general public. Although data processing and machine learning techniques are key in this regard, the visualization and interaction aspects play a similarly important role.

Communicating, understanding and visualizing data with interactive tools are key component for the AIR Center. This understanding process could even be extended to areas such as interactive simulations, “serious games” meaning video games currently in use by industry for education, scientific exploration, health care, emergency management, urban planning, and engineering. These can augment and add to the scientific effort of the AIR Center as it relates to the willing participation and involvement of the general public.

Science exploration at the AIR Center will generate complex and extensive data that must be analyzed properly to extract knowledge. As data science is focused on extracting knowledge or insights from data in various forms, either structured or unstructured, this endeavor is simultaneous processing of this data, towards its understanding by the scientists and broad public constituencies.

Part III – Promoting International North-South cooperation for knowledge, research and business across the Atlantic

8. Towards an Intergovernmental Organization, fostering North-South cooperation

As an integrative and distributed research platform, the AIR Center can provide a shared and international environment to support and foster new space, climate, earth and marine research activities benefiting decision makers, public users, universities and industry, as well as contributing to retain highly skilled human resources and stimulate regional growth.

In particular, the AIR Center may provide a unique opportunity to drive multilateral cooperation in complex systems engineering and science through an integrative approach to space, climate and energy, earth and ocean research and development in the Atlantic.

The AIR Center, through a flexible international governance model with international statute and international legal status (i.e., emulating the CERN experience in Geneva or that of INL in Braga, Portugal, among others), would provide a solid legal context to overcome potential national constraints, as well as an appropriate regulatory framework to efficiently and effectively address operational issues such as staff regulations, financial contributions and definition of the several scientific programs.

Potential advantages of an intergovernmental research center in the Azores:

- It can offer a global-scale research site, capable to attact scientists and technology developers around the world, stimulate different forms of collaboration with other countries , being public or private entities, in a wide range of areas associated with research, education or commercial applications.
- It can be exempted from direct and indirect taxes for its facilities and also movable goods and from customs duties for imports.
- Member states delegations can have diplomatic status.

9. Towards a new North-South Atlantic Research & Technology Agenda

9.1 Extend Atlantic Cooperation to the South

The AIR Center will act in terms of an international organization that will foster new horizons for Atlantic research through multilateral cooperation and will promote a network of research centers and technology-based businesses in both the North and South Atlantic. It will take advantage of a new cooperative agenda to be established between Europe, USA and Canada with South Atlantic countries contributing for linking the expansion of the Galway Declaration scientific goals to thosee defined for the South Atlantic.

As an example, AIR could complement and extend the AtlantOS initiative through a new multi- and inter-disciplinary approach for research in the Atlantic. The AtlantOS project (Optimizing and Enhancing the Integrated Atlantic Ocean Observing System; 2015-2019) has been recently funded under the EU H2020 program with the overarching goal to integrate existing ocean observing activities to a more sustainable, more efficient and tailored integrated Atlantic Ocean Observing System in terms of the "Framework of Ocean Observing" (FOO). It contributes to achieving the aims of the Galway Statement on Atlantic Ocean Cooperation signed in 2013 by the EU, Canada and the US, launching an Atlantic Ocean Research Alliance to enhance collaboration to better understand the Atlantic Ocean and sustainably manage its resources. The AtlantOS project joins the efforts of 57 European and 5 non-European partners (research institutes, universities, marine service providers, multi-institutional organizations).

9.2 Opportunity for a new Research Infrastructure of pan-European interest

The AIR Center is envisaged as a major hub of an international network of Atlantic research centers, which needs to consider with particular attention the landscape of European-scale Research Infrastructures (ERIs), namely those that are part of the ESFRI Roadmap, as well as the transnational Projects for new ERIs currently funded by Horizon 2020 (or FP7). (Fig.6)

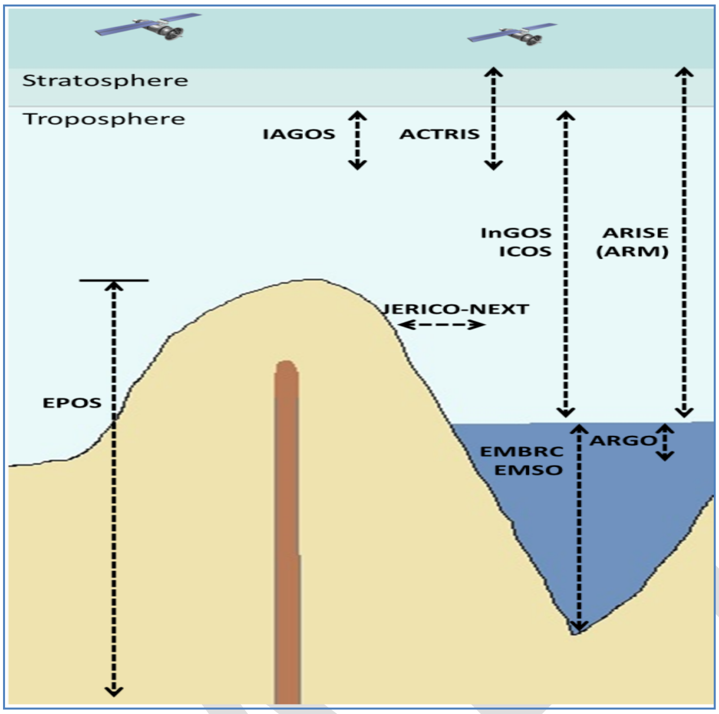

Fig.6 – Illustration of the existing European Infrastructures[1] within the AIR Center thematic areas

This landscape illustrates a comprehensive coverage of specific topics in dedicated research infrastructures, and allows the identification of gaps that may be filled by new research infrastructure, such as:

I. Research infrastructure on Sustainable Energy Systems;
II. North-South Atlantic Interdisciplinary Research Infrastructure.

These potential initiatives are described in the next paragraphs.

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[1] **EMBRC** – European Marine Biological Resource Centre: a distributed research infrastructure that aims to provide a strategic delivery mechanism for excellent and large-scale marine science in Europe.
EMSO – European Multidisciplinary Seafloor and water column Observatory: main scientific objective of long-term monitoring, mainly in real-time, of environmental processes related to the interaction between the geosphere, biosphere, and hydrosphere.
ACTRIS – Aerosols, Clouds, and Trace gases Research Infrastructure Network**:** Atlantic circulation of Aerosols and trace gases; study shallow marine clouds.
IAGOS – IAGOS is a new European Research Infrastructure conducting long-term observations of atmospheric composition, aerosol and cloud particles on a global scale from commercial aircraft of internationally operating airlines
InGOS – InGOS is an EU FP7 funded Integrating Activity (IA) project targeted at improving and extending the European observation capacity for non-CO2 greenhouse gases.
ICOS – The Integrated Carbon Observing System (ICOS) is a pan-European Research Infrastructure which provides harmonized and high precision scientific data on Carbon Cycle and Greenhouse Gas budget and perturbations.
ARISE –The aim of ARISE is to provide observations and models for future assimilation of data by operational weather forecasting models in the perspective of improving weather forecasting to monthly or seasonal timescales.
JERICO-Next – The vision of JERICO-Next is to improve and innovate the cooperation in coastal observatories in Europe by implementing the coastal part of a European Ocean Observing System, to cooperate with other European initiatives.
EPOS – European Plate Observing System: The activities of the European Plate Observing System span a wide range of themes related to Solid Earth Science, such as Near-Fault and Geomagnetic Observations, Seismology, Geological Modeling, Volcanology, GNSS and Satellite data, among others.
EURO-ARGO – active coordination and strengthening of the European contribution to the international Argo program.

9.2.1. Research Infrastructure on Sustainable Energy Systems

The "ESFRI 2016 landscape analysis" identifies the need for a new Centre of Excellence for energy-related topics, working closely with associated experimental and industrial groups, and is expected to have a multiscale integrating character.

The AIR Center provides significant opportunities starting from access to a comprehensive set of renewable energies (i.e.: wind, hydro, geothermal, complex and diversified storage systems), satellite measurements for sustainable energy systems and a 15m antenna to be installed in the Azores, that will collect large flows of relevant data from different satellites.

The main goal would be to develop an array of satellite based techniques that will provide spatial and time-resolved information on renewable energy resources, namely solar and wind and combine this information with energy systems modeling models that could provide a globally applicable method to design sustainable energy solutions. The research infrastructure will include different sets of local measurements and sensors that will enable the calibration of the satellite based data sets.

09.2.2. North-South Atlantic Interdisciplinary Research Infrastructure

The development of a new interdisciplinary research platform could be considered in order to extend the capabilities of research centers around Europe and North Atlantic Nations to the South Atlantic in addressing the synergies between **Space Sciences, Energy, Climate Change and Ocean.**

This research infrastructure will act as a catalyst for research and innovation in multiple domains ranging from space, satellites for observation, renewable energies, to the interactions of the Ocean with the Atmosphere and global climate phenomena, the impacts of global changes on the open Ocean and the deep sea, including their biodiversity, as well as blue biotechnologies.

A new infrastructure based at the AIR Center, given the central geographical position of the Azores in the Atlantic, would be a complementary capability to the already existing European Research Insfrastructures (RIs) in the domains of space sciences, atmospheric sciences, climate change, ocean sciences, and energy (especially renewable energies). This new Global RI would focus on disciplines that combine more than one of these scientific areas, or else the application of enhanced Earth Observation (EO) systems to those areas. Some examples would be:

- Ocean-Atmosphere interactions and Climate (species that provide natural carbon sequestration, model and simulations of Air and Ocean currents);
- Collaborate and enhance Earth System Models;
- Ocean technologies in response to scientific needs;
- Capacity building and transfer of technology
- Study the Atlantic Meridional Overturning Circulation (AMOC);
- Offshore wind farms, and tidal / wave energy systems;
- Ocean thermal energy (study of gulf stream), on-shore wind; geothermal;
- Study the effect of climate change in hydropower, energy demand;
- Develop and implement weather models and the algorithms that convert weather predictions into power forecasts;
- Research satellites for targeted Climate applications/ studies;
- GNSS measurements of atmospheric properties over the North Atlantic;
- Pollutants circulation over the Atlantic and their impact on climate;
- Inland carbon sequestration.

The AIR Center would take advantage of the existing Infrastructures in the different Azores Islands and of the coast of Azores, as well as other Atlantic islands, for the multiple thematic areas involved, and would be expected to provide a global context by having among its Members Atlantic Countries that can provide access to their national infrastructures dedicated to Atlantic research as represented in Figure 7.

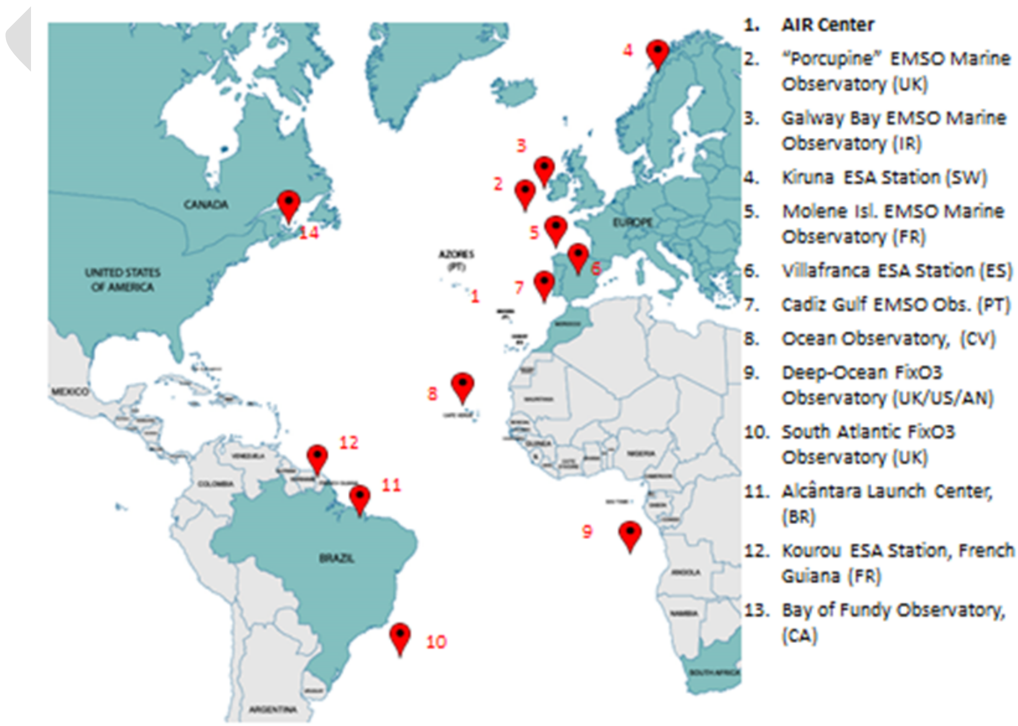

Fig.7 – Illustration of research stations identified as potential partners in the new Atlantic North-South research infrastructure

10. Knowledge for Space – Space for Knowledge: an opportunity for cooperation

The AIR Center Agenda will include and foster an education and knowledge agenda aimed to promote "Knowledge for Space" and its integration with ocean, earth and climate education in a fully holistic approach, but it will also extend traditional education and science awareness programs to consider new horizons of space technologies to foster the access to education for all. This will be achieved by involving telecom operators, broadcast services and space providers in a "Space for Knowledge" network.

Although "star wars" program days are gone, in today's world space activities are still very much perceived by the general public as a dispute for outer space conquests of "rocket" scientists. The majority of the world's population is unaware of the importance of space activities in our daily lives.

This is a highly relevant theme in today's societies because space science involves a series of disciplines that provide new insights on the Universe (physics; astronomy), allows perceiving earth dynamics which helps in the prediction and preparation for emerging threats; foster new advancements in satellites and robotic engineering, as well as in related technology allowing the exploration of outer space and find new materials and new knowledge of the Universe.

It is under this context that several major initiatives have been launched worldwide in the last decades to foster education for space in an effort to bridging the knowledge gap between people and space science. For example, in 2002, UNESCO launched a Space Education program following recommendations from the 1999 World Conference on Science and the Third United Nations Conference on the Peaceful Uses of Outer Space. It is aimed to enhance space subjects and disciplines in schools and university curricula, the improvement of teaching methodologies to raise awareness about the importance of space and space related activities to human development. Three disciplines are mainly addressed:

- Astronomy;
- Aeronautic engineering, satellite design, robotic engineering; and
- Space technology applications;

To carry out these objectives, UNESCO develops space education workshops and other initiatives that show the importance of the peaceful uses of outer space and the role played by space uses and technology in protecting, monitoring, documenting, and sharing our common heritage, both cultural and natural.

In a related action, ESA launched the ESERO initiative (European Space Education Resource Office) with several nations, including activities to help teachers introducing space in the classroom and raising awareness in schools of the importance of space science and technology. Among other initiatives, it has provided teacher-training courses, with special emphasis to primary level education and the reinforcement of the communication between the scientific community, enterprises and schools.

The United Nations Office for Outer Space Affairs (UNOOSA) is the United Nations office responsible for promoting international cooperation in the peaceful uses of outer space and has an extensive capacity-building role achieved through different programmes and initiatives. The AIR Center could complement and partner with UNOOSA to deliver capacity-building efforts to developing countries."

By using space as an engaging multidisciplinary challenge, these initiatives are contributing to promote the interest and mobilization of younger generations for science and technology.

Through the initiative "Knowledge for Space – Space for knowledge", the AIR Center will aim to expand and complement existing activities at UNESCO, ESA, NASA and other major players worldwide to raise awareness for the natural, physical and engineering sciences among all children, but also to deliver new educational and cultural contents in developing countries through space technologies. Specific activities will be aimed to promote the diffusion of endogenous knowledge of local cultural and natural heritages, and contributing for educating more children everywhere, all the time.

A sustainable future requires more knowledge and more scientific culture, ensuring the access to science and education as an inalienable right of all.

Part IV – International Infrastructures

11. Exploring synergies with North-South Atlantic Research Infrastructures

11.1 Portugal

11.1.1 Infrastructures and other resources

The text table below presents existing research infrastructures in the Azores as well as the specific island on which they are located. Most of these will be part of the development and implementation of the AIR Center.

	Existing Infrastructures	Island
Space Science and Technology	European Space Agency (ESA) Tracking Station	Santa Maria Island
	Galileo Sensor Station	
	Copernicus Collaborative station	
	Earth Observation (EO) station	
	Atlantic Network of Geodynamical and Space stations	
	NAV Portugal Air Traffic Control Center	
Atmospheric Science and Climate Change	Eastern North Atlantic (ENA) Atmospheric Radiation Measurement (ARM) facility, U.S. Department of Energy & University of Azores	Graciosa
	Pico Mountain Air Pollution Observatory - North Atlantic Regional Experiment, University of Azores	Pico
	Center for Volcanology and Geological Risk Assessment , University of Azores	São Miguel
	Center for Climate, Meteorology and Global Change - Center for Agriculture Research and Technology, University of Azores	Terceira
	System of hybrid power (wind and solar), supported by an innovative battery	

	Existing Infrastructures	Island
	system, that will enable uninterrupted power supply, to be constructed in Graciosa.	
Ocean Science and Technology	Highly skilled human resources at the institute of Marine Research based at the Department of Oceanography and Fisheries (DOP)	Faial
	Oceanic harbor of Horta	Faial
	DeepSeaLab facility designed to maintain and experiment on deep sea fauna (e.g. from hydrothermal vents and seamounts), under simulated hydrothermal vent (sulphide, methane) and climate change (pH, temperature) scenario conditions	
	Experimental laboratory to research scenarios of climate change on deep sea organisms	
	Experimental high pressure vessel (up to 4000m), to conduct experiments with deep-sea fauna under natural and extreme pressure conditions on the effect of scenarios under pressure.	
	Multi-instrumented permanent deep sea observatories – EMSO: Azores Hydrothermal vent observatory, currently maintained by IFREMER	
	Hydrothermal vent observatory	
	Condor observatory located in the first seamount marine reserve for scientific purposes	
	Deep sea moored array of acoustic receivers for the tracking and monitoring of marine animals	
Energy Systems	A wave energy pilot plant run by WavEC: OWC Pico Power Plant (www.pico-owc.net)	Pico
	High penetration of geothermal and wind energy, with pump storage: "Central Geotérmica do Pico Vermelho" and "Central Geotérmica da Ribeira Grande" in São Miguel	São Miguel
	The "Most" Hydro Flywheels on Flores: "Central Hidroeléctrica da Ribeira	Flores

	Existing Infrastructures	Island
	Grande" and "Central Hidroeléctrica de Além Fazenda"	
	Flores PowerStore Flywheel Project	
	Graciosa PowerStore Flywheel Project	Graciosa
	System of hybrid power (wind and solar), supported by an innovative battery system, that will enable uninterrupted power supply, to be constructed in Graciosa.	

11.1.2 Potential additional resources

i. Space Science and Technology

In addition to the existing space-related infrastructure, there are resources that could be potentially complementary throughout the Azores archipelago. For instance, an Atlantic spaceport for low cost access to could be situated on the islands of Terceira or Santa Maria. Likewise, Santa Maria could host an Atlantic surveillance center, space surveillance and tracking program, or a high data rate direct broadcast reception facility, and any of the islands could serve as the location of an ESA /Azores launchpad technology incubation facility.

Potential Resources	Island
Atlantic Spaceport for low cost access to Space	Terceira or Santa Maria
Atlantic Surveillance Center	Santa Maria
Space Surveillance and Tracking program	Santa Maria
ESA /Azores Launchpad Technology Incubation facility	All

ii. Atmospheric Science and Climate Change for the Atlantic

In addition to institutional resources, the Azores have numerous non-institutional resources that can potentially be used in the context of the AIR Center. For example, there is the need for a robust cyber-infrastructure that allows accelerating the pace of scientific discovery in climate change research and large scale monitoring, modeling and simulation of Earth phenomena. The proliferation of datasets, modeling tools and the convergence of diverse disciplinary expertise calls for an integrated and efficient approach to data curating, analysis and visualization.

Furthermore, there are relationships (existing and future) that will or could be associated with the AIR Center, such as integration into the European and Global Research Infrastructure landscape, namely, the integration of PICO-NARE in the World Meteorological Organization - Global Atmospheric Watch, and the possible integration of existing infrastructures in Azores for atmosphere science and climate in European infrastructures such as ACTRIS (observation of aerosol, clouds, and trace gases), IAGOS (long-term observations of atmospheric composition, aerosol and cloud particles), ICOS (carbon cycle and greenhouse gas budget and perturbations), and InGOS (improving observation of non-CO_2 greenhouse gases). Additional resources will be required in climate modeling, land surface modeling, observations (from space), computing and data science, and mass data storage to provide the AIR Center's specialized human resources with the optimal research environment.

The AIR Center will be a privileged platform to couple observations and model developments in the North Atlantic climate. Together with a strong involvement in the global ESM development, which is already in place, a regional modeling facility focused on specific processes that can be assessed in the North or South Atlantic region will increase the impact of research based in the AIR Centre on the global research agenda. Improved infrastructures for observation and monitoring will increase the potential impact of the AIR Center climate studies.

Potential resources
A robust cyber-infrastructure that allows accelerating the pace of scientific discovery in climate change research and large scale monitoring, modeling and simulation of Earth phenomena. The proliferation of datasets, modeling tools and the convergence of diverse disciplinary expertise calls for an integrated and efficient approach to data curating, analysis and visualization.
Integration in the European and Global Research Infrastructure Landscape, namely: - PICO-NARE in the World Meteorological Organization - Global Atmospheric Watch; - existing infrastructures in Azores for Atmosphere Science and Climate in the European Infrastructures ACTRIS (Aerosols, Clouds, and Trace gases), IAGOS (In-Service Aircrat for a Global Observing System), ICOS (Integrated Carbon Observing System) and InGOS (Integrated non-CO_2Greenhouse GAs Observing System).
Specialized human resources

Laboratory for detailed measurement of over 40 greenhouse gases, at high altitude (over 2000 m) at the Pico Island
Multiparametric stations (mooring buoys, eddy correlation towers) for land-atmosphere -ocean fluxes
Surveys for physical and biogeochemical upper ocean sampling
Laboratory for physical and biogeochemical interface processes (Gas Chromatography / Mass Spectrometry, etc.)
High performance computational facilities for data analysis, image processing; numerical modeling

iii. Ocean Science and Technology

There are several potential resources that include land-based facilities (e.g., laboratories, experimentation stations, and monitoring stations) and remote platforms (e.g., vessels, satellites, drifting floats, autonomous underwater vehicles, gliders, underwater robots, receiving devices (and sources) for passive (and/or active) ocean acoustic tomography/thermometry, cabled seabed observatories, instrumented marine mammals. Finally, there are deep-sea and open-ocean long-term fixed point observatories for such targeted contributions as the European Union Horizon 2020 project *AtlantOS* (Optimizing and Enhancing the Integrated Atlantic Ocean Observing Systems).

Potential resources
Land based facilities : laboratories, experimental stations and monitoring stations
Remote platforms: vessels, satellites and underwater robots
Deep sea and open ocean long term fixed point observatories
Equipment: sensors, vehicles and sensors that can operate below 200m
Secure and reinforce high skilled critical mass of researchers through international collaboration

iv. Energy Systems

The Azores also have a range of resources that can be leveraged for experimentation and analysis. As set forth below, some of these resources can be integrated for unique solutions.

Potential resources	Island
Geothermal exploration on Terceira: "Central Geotérmica do Pico Alto" planned for 2017	Terceira

Potential resources	Island
Electric Vehicle Deployment Demonstration	
Flexible, efficient and resilient storage systems (i.e. Integration of power grids hardware to be efficient and resilient; grids that are able to cope with the erratic nature of wind and solar power)	All
Renewable energy technologies deployment demonstration in a confined environment; possible interactions to be established with the Marinerg-i project	All
Full scale smart grid management of full scale laboratory aiming at 100% renewable energy	Corvo, Flores e Graciosa
Integration of renewable energy with desalination technologies for simultaneously balancing the grid and providing freshwater.	
Integration of renewable energy with hydrogen production (via electrolysis) or methane production (via methanation) for simultaneously balancing the grid and providing domestic fuels.	All
Ocean thermal energy conversion (OTEC), which uses temperature differences between the ocean surface and depths to generate electricity.	All
Osmotic power, which uses salinity gradients between freshwater onshore with saltwater offshore to generate electricity.	All

v. Data Science

The research community engaged in climate change research and large scale monitoring, modeling and simulation of earth phenomena is keenly aware of the need for a robust cyber-infrastructure in order to accelerate the pace of scientific discovery. In particular, the proliferation of datasets, modeling tools and the convergence of diverse disciplinary expertise calls for an integrated and efficient approach to collecting, curating, analyzing and visualizing data.

The ultimate goal and objective of a robust cyber-infrastructure is to support the mission of the Atlantic International Research Center and to provide enabling tools to researchers in order to maximize their ability to navigate across data sets, computational models and a variety of disciplines. Ideally, the tools should be components that are accessible and of demonstrated value to both policy makers and non-experts in the general public.

11.2 Brazil

The workshop held in Brazil allowed the identification of synergies that fully exemplify the type of cooperation that can be established through the AIR Center, combining national research priorities and the research opportunities presented by international interdisciplinary cooperation for attaining better and more comprehensive datasets for innovative research (Table 1).

	Synergies with Brazil		
Space Science and Technology	Satellite launch and operation	Satellite data collection and processing	Interoperability between different computational systems
Atmospheric Science	Cloud formation identification mechanisms and modeling	Monitoring of the atmospheric transport of pollutants emitted in the South American and South African continents	
Ocean Science and Technology	Ocean and ocean-atmosphere interaction monitoring programs	Satellite based Oceanography	Ocean technologies and renewable energy
Climate Change	Biogeochemical variability at the tropics and CO_2 flows quantification	Global climate change models development and calibration	Climate change scenarios analysis: Project PNUD and Project PROBIO
Energy Systems	Data sets to model and design sustainable energy systems: Project SONDA; Project SWERA	Wind forecasting: Project PREVENTO	Public disclosure of renewable energy availability data

Table 1 – Potential Synergies of the Atlantic Research Center with Brazil

In addition, the development of a cooperative agenda between the AIR Center and INPE for capacity building of young undergraduate and graduate students is an imperative for a long-term perspective of scientific and technological aspirations of tackling global issues in areas of space and oceans. Moreover, the possibility of applying technology transfer mechanisms, as foreseen by the "IOC Criteria and Guidelines on Transfer of Marine Technology", would be key to enhance cooperation North to South.

After the meeting in Brazil specifical points of cooperation with the State of Ceará were also identified:

Area of cooperation	Objectieve	Organization
Ocean Science and Technology	Understanding and determination of impacts suffered by the Oceans and coastal areas as a consequence of economic exploitation of renewable and non-renewable resources.	UFC (LABOMAR), UECE
Climate Change	Use of climate information as a support for public policy and decision making processes for Ceara economic setors of interest such as agriculture, industry, environment and energy	FUNCEME, UECE e UFC
Energy Systems	Development of technologies of energetic efficiency	IFCE, UNILAB, SINDENERGIA, SECITECE e SEBRAE
Data Scence	Development of a platform for Ocean monitoring (internet of things) – development of specific sensors interconnected used for identification and prediction of phenomena	IFCE, ITIC, UFC (LSDB), UECE (NPTEC), CTI-Ne UFC (LSDB); CTI-Ne; UECE (NPTEC), ITIC
Space Science and Technology	Development of sensors for space aplications	CTI-Ne, ITIC, UECE, IFCE

Table 2 – Potential Synergies of the Atlantic Research Center with Brazilian State of ceará

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11.3 Other Countries (to be developed)

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