Thematics

ARCHERS addresses both the education and training of young scientists in cutting edge technologies and the sustaining of early stage researchers in the areas of preservation of cultural heritage and the tackling of societal challenges, like energy, environment and health, as well as the social preconditions of innovation and the stimulation of young researchers in the direction of entrepreneurship.

1. Cultural Heritage Science and Technology

The preservation, protection and promotion of Cultural Heritage (CH), its content and its concepts, is an issue of prime importance for human development and well being as well as a dynamic contributor to sustainable growth of society.[1,2] Indicators of socio-economic development, such as tourism,[3] employment, small businesses and trade, construction and city growth, education and training are strongly linked to the Cultural Heritage assets of a country and this is of particular relevance to Greece where archaeological and historical treasures have the potential of becoming a national "heavy industry".

In parallel, high-level scientific research, technological development and innovation are key ingredients to supporting and enhancing our Cultural Heritage via highly cross-disciplinary activities including: (a) scientific investigations for understanding and interpreting Cultural Heritage, (b) conservation and preservation of material and immaterial Cultural Heritage safeguarding it for future generations, and (c) use of enhanced tools for presentation of the cultural content and efficient access to it including education and training.

The Institutes of FORTH pursue internationally recognized research, serving several aspects of Cultural Heritage science and maintain highly competitive facilities to support such research and services. In fact, recently IPERION-CH.gr, a network of laboratories based largely at FORTH, has been included in the National Roadmap for Research Infrastructures.[4,5] The vision and the mission of this cross-disciplinary initiative is to advance the state-of-the-art of scientific methods and techniques, including key information technologies, so as to develop and offer innovative, reliable and efficient tools that will enable users to address demanding research challenges in the field of Cultural Heritage science.

In the work package on Cultural Heritage science and technology, scientists at FORTH will collaborate with the partial support of the Stavros Niarchos Foundation to address demanding research and technological challenges that include:

- Use of innovative methodologies based on the combination of geophysical surveys, satellite imaging, acoustic sensing technologies and modeling tools for an integral approach to archaeological landscape mapping both on the ground and underwater;
- Development of versatile photonic tools for materials analysis and conservation in museums and in field campaigns;
- Application of smart laboratory tests for assessing the mechanisms underlying monument damage and development of specific methodologies for optimizing materials selection in monuments undergoing conservation;
- Establishing of advanced genomic methods and protocols for the detailed characterization of ancient genetic material from human, animal or plant remains;
- Development of interoperability standards across all sorts of data relevant to answer a museums and cultural heritage research question;
- Design and development of ambient interactive systems providing multi-user natural interaction for the ubiquitous social fruition of cultural heritage assets.

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1 "Culture and Development" United Nations, A/C.2/65/L.50, (2010)

2 "Culture for Development Indicators Suite" UNESCO initiative: http://www.unesco.org/new/en/culture/themes/cultural-diversity/diversity-of-cultural-expressions/programmes/%20culture-for-development-indicators/

3 "The Impact of Culture on Tourism" – ISBN- 978-92-64-05648-0 © OECD 2009

4 http://www.gsrt.gr/News/Files/New987/road-map-web_version_final.pdf, page 58

5 Two relevant projects on Research Infrastructures (IPERION-CH and PARTHENOS) with involvement of FORTH (IESL, ICS, IMBB) are funded by the EU Horizon-2020 Research Infrastructures programme.

2. Clean Energy

The Energy sector worldwide is in a transition stage from fossil-based sources to renewable ones in response to the need for clean, low-cost and reliable energy supply. Considering that the world energy consumption will increase by 53 percent between 2008 and 2035[6] and the environmental concerns regarding the use of fossil fuels, renewables are currently the fastest-growing source of world energy, with consumption increasing by 2.8% per year, offering a green energy alternative to fossil fuels.

The challenges in the international energy sector are basically threefold:[7] *Energy Independence*, i.e., moving away from the dependence on oil imports (in the E.U., almost 50% of the energy requirements were fulfilled by oil imports in 2006); *Environmental Sustainability*, i.e., reduction in the emissions of carbon dioxide and other greenhouse gases, whose primary source is fossil fuel; *Economic Opportunity*, i.e., reduction in the high cost of imported energy by creating the next-generation of clean energy technologies. Meeting the challenges will require new technologies for producing, storing and using energy with performance levels far beyond what is possible now; such technologies will spring from scientific breakthroughs in new materials and chemical processes that govern the transfer of energy between light, electricity and chemical fuels.

The realization of the new energy landscape will, therefore, be based on the development of new/improved energy conversion technologies and adoption of new energy carriers, as well as on energy storage and management concepts. Research activities in the field of Energy aim at designing and developing technologies and processes in the context of renewable sources. At FORTH, taking also into account the national needs, the adopted approach involves enabling (nano)materials and their optimal incorporation in units and systems. Current projects in the field of energy materials and technologies with funding from national and EU sources include the development of fuel cell systems for earth transportation and space applications, efficient use of resources in energy converting applications, innovative materials for solar cell design and demonstration, fractionation of lignocellulosic biomass for hydrogen and methane production, development of nanostructured materials for Li-ion batteries. In addition, FORTH has been providing technology awareness reports concerning the energy sector to the Hellenic Federation of Enterprises for the last four years. Moreover, recently INNOVATION.EL and HELLAS, networks of laboratories based largely at FORTH (IESL, ICE-HT), have been included in the National Roadmap for Research Infrastructures.[8,9,10]

Three axes are especially important, if not necessary, for the achievement of real leaps and simple steps towards achieving the safe and sustainable energy future: new advanced materials allowing the complete control of the chemical changes, advanced instrumentation for the characterization of the structure and dynamics in the nanoscale and over extended time scales, and advanced theory and computer simulations for the understanding of the behavior and for the knowledge-based design of processes and devices.

The Energy Workpackage is organized in a way that it lends itself to opportunities for both supporting early stage researchers already employed by FORTH as well as for training and education of young scientists at different levels from design to implementation. The approach, that is followed, offers strong prospects for future exploitation of the devices to be produced. Representative research activities to be partially supported by the Stavros Niarchos Foundation in this Workpackage include:

- Fuel and photoelectrochemical cells: for improvement of efficiency and durability through novel electrolytes and for efficient production of hydrogen from organic wastes.
- Li-ion batteries and supercapacitors. Energy storage devices, such as Li-ion batteries (including polymer electrolyte batteries) and supercapacitors, will play a key role in future energy networks relying on renewables and also for energy storage in electric vehicles.
- Incorporation of nanomaterials in energy intensive processes: membrane separation, desalination; and production of biofuels using biological and thermochemical methods.

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6 *International Energy Outlook 2011*, U.S. Energy Information Administration, DOE/EIA-0484(2011), September 2011, http://205.254.135.7/forecasts/ieo/pdf/0484(2011).pdf

7 *New Science for a Secure and Sustainable Energy Future*, Basic Energy Sciences Advisory Committee (BESAC) Report, 12/2008, http://science.energy.gov/~/media/bes/pdf/reports/files/nsssef_rpt.pdf

8 http://www.gsrt.gr/News/Files/New987/road-map-web_version_final.pdf, pages 58 and 59

9 A relevant project on Research Infrastructures (NFFA) with involvement of FORTH (IESL) is funded by the EU Horizon-2020 Research Infrastructures programme.

10 A relevant project on Research Infrastructures (LASERLAB Europe) with involvement of FORTH (IESL) is funded by the EU Horizon-2020 Research Infrastructures programme.

- Computer-aided simulation of hybrid processes for the reduction of energy load in water treatment processes. This activity is ideal for knowledge-based design, software development and attraction of young, talented scientists for coding and exploitation.
- Materials/thin films to be utilized in smart windows (thermochromics, eectrochromics, self-cleaning) for energy efficient buildings
- Materials for photovoltaic systems and solar inverters: organic photovoltaics; third generation photovoltaics based on micro/nanoelectronic devices based on III-V semiconductors, SiC and 4G nanowire-based materials; metamaterials
- Carbon-based materials (graphene, carbon nanotubes) and other 2D structures for thermoelectric energy harvesting for zero consumption electronics

3. Environment

The Greek natural environment is very rich in flora, fauna, habitats and ecosystems. This is a result of the country's geographical location, which entails great variety of climate conditions and geomorphology.

In the last decades the intensification of transport, industrial and agricultural activities has led to extended pollution (chemical, physical, acoustical, etc.) of air, sea, soil, surface and underground waters. Further, the continuing urbanization in unorganized and constantly expanding cities has caused considerable environmental problems, both in the built environment and the neighboring areas, e.g., expansion of road networks, increasing litter volumes, forest fires, etc. Climate change intensifies many of the above problems and creates additional ones, e.g., global warming, sea-level rise, intensification of extreme weather events and associated natural disasters, and the Eastern Mediterranean is among the areas most affected. The location of Greece in a seismically active area further increases the natural hazard potential, but at the same time offers an opportunity for developing passive and environment-friendly exploration methods using ambient microseism activity.

The sustainable exploitation of natural, biological and mineral resources is of vital importance for the Greek economy. The design and development of eco-efficient exploration and exploitation methods with minimal environmental footprint should be at the center of the strategy for a sustainable future. Eco-efficiency stands for doing more – or the same – with less, and includes resource efficiency (using and reusing resources more efficiently throughout economy) and eco-innovation (developing and using products, processes and other solutions that contribute to environmental protection or efficient use of resources).

This Workpackage aims at providing education to young researchers as well as support to existing researchers of FORTH in the development of methods and tools for monitoring, analysis and efficient management of the terrestrial (both urban and non-urban) atmospheric and marine environment. The actions to be partially supported by the Stavros Niarchos Foundation will address the following topics:

- Numerical simulations of pollutant spreading in the atmosphere and the subsurface
- Testing and optimization of sustainable, eco-innovative and cost-effective technologies (e.g. non-thermal plasma) for the remediation of soil and water from persistent contaminants
- Analysis of satellite remote sensing data and modelling for natural disaster management, urban planning and management
- Methods of analysis of seismic data and imaging methods based on cross-correlation of seismic time series
- Methods for the prediction of ambient noise levels in the sea due to shipping and changes in the underwater acoustic environment
- Monitoring of the coastal zone in combination with environmental models and estimation of socioeconomic indicators
- Recovery of valuable chemical compounds from waste

4. Systems Biology Approaches and Personal Genomics for Health and Disease Treatment

Systems biology is an integrated quantitative analysis of the manner in which all components of a biological system interact functionally over space and time. The holistic claim of systems biology is progressively influencing science and leading to the emergence of previously largely separated fields of experimental investigation and mathematical-computational modeling. Systems biology requires interdisciplinary approaches that are also capable of developing new technologies and computational tools. In turn this new technology is transformed into infrastructure that revolutionizes biology.

The comprehensive understanding of complex biological system functions requires holistic and detailed data collection, using post-genomic technologies relating to the analysis of all constituent levels of organisms. The recording and processing of all data and the comparison of various levels of living matter organization (from genes to transcripts, proteins, the molecular complexes and their metabolites) provide the ability to identify relationships between components involved in various mechanisms (molecular pathways, interaction networks, regulatory changes) that are responsible for particularly complex states and behaviors of biological systems, including those relevant to pathology.

The systems concept is the one that leads today to the rationally designed genetic medicine and personalized medical care. Delivering personalized therapeutic options to patients based on the genetic and molecular profiles of the various diseases offers great promise to improve the outcomes of therapy. The main requirement to realize genomic-based personalized medicine is to collect and include genomic information into the medical record of the patients where physicians will have ready access to it. Today genomic information in patients' medical records is still limited to results from targeted genetic testing. However, as soon as whole exome or genome sequencing are becoming readily accessible and affordable to the average person, it will be more cost-effective for patients to have their whole exome (or genome) sequenced than to undergo targeted genetic testing. The development of other high throughput methodologies provides today tens of thousands of "omic" data points across multiple levels (DNA, RNA protein, small molecules-metabolites, (oligo)peptides) in a reasonable time frame for making clinical decisions. With this data in hand, the challenge from the bioinformatics and systems biology point of view is how one can convert data into information and knowledge that can improve the delivery of personalized therapy to the patient.

To this end, a variety of methodological approaches are used: (a) novel clustering, classification and feature selection algorithms, (b) machine learning algorithms such as artificial neural networks, hidden Markov models etc, (c) detailed biophysical and/or simplified models of cells and tissues, d) theoretical analysis and abstract mathematical modeling, (e) meta-databases and software for protein interaction and metabolic network reconstruction and analysis, (f) hierarchical simulation methodologies for studying biomolecular systems across spatial and temporal scales, (g) tools for the visualization, analysis and integration of -omic data at different levels of cellular function, (h) workflows for the efficient annotation and clinical interpretation of whole genome analysis, and (i) methods for computationally intensive whole genome-wide association studies.

Research interests in the field of computational biology focus mainly on the discrimination of different disease subtypes for more accurate and detailed diagnosis, the identification of molecular markers for disease prognosis and prediction of therapy, and the development of *in computo* modelling techniques for the investigation of cellular and gene functions at multiple length and time scales. The Stavros Niarchos Foundation will partially support computational methods and tools developed for:

- analyzing large-scale gene expression data related to various disease in search for gene markers and disease sub-categories,
- building theoretical models of gene regulatory networks, reconstructing and integrating the active protein interaction and metabolic networks in human and animal models of disease,
- studying disease-associated self-organized structures at the molecular level, and
- planning medication by modeling pharmacodynamics (drug action at target) and pharmacokinetics (drug fate in body) parameters.

5. The Societal Challenges in the Innovation Process

The importance of innovation to securing sustainable and viable economic growth is widely accepted. With the Lisbon Strategy of March 2000, the European Council set as a strategic goal for the next decade to make

the European Union "the most competitive and dynamic knowledge-based economy in the world" through innovation and knowledge. The acknowledgement by EU authorities that the Lisbon Strategy's goals had not been met and their reformulation and greater specification in the Europe 2020 strategy as "smart, sustainable, inclusive growth" demonstrates that the introduction of innovation into the economy and its translation into greater development do not depend so much on decisions taken at the top but instead presuppose the existence of a series of societal factors. It is precisely these factors that are difficult to conceptualize using the quantitative indicators with which, as a rule, the performance in innovation of an economy and its society are measured.

In Greece, too, the difficult times, through which the local economy has gone in the past few years, have often brought to the forefront of discussions proposals for technological research and innovation. Even so, although offhand "historical" and "sociological" interpretations are often given of the insufficient research funding or the supposed failure of research to contribute to economic growth and proposals are made that range from increasing funding to abandoning scientific research, a proper consideration of the deeper causes of the state of research and innovation in Greece today is missing, as though they did not have a history. This circumstance affects adversely the effectiveness of the policies implemented in the field of innovation, by both European and national authorities.

The Institutes of FORTH have already devoted an important part of research activities to fill this lacuna by studying crucial aspects of the history of innovation in Greece and in the Mediterranean ambit (ELISTOKAINO project). During the implementation of this project, special attention has been paid to bottom up initiatives in the various sectors of the economy. In the workpackage on the societal challenges in the innovation process, specialists in the technology history and in industrial relations will be partially supported by the Stavros Niarchos Foundation on:

- Policies for the protection of intellectual property
- R&D record of selected Greek industries
- Innovation in the agricultural sector
- The effects of technological change and globalization on the shipbuilding and ship-repairing industry
- Industrial relations in a changing institutional and technological environment

6. Innovation and Entrepreneurship

It is FORTH´s constitutional mission to serve the world of knowledge and the associated economic and societal needs at national and European level, by conducting fundamental and applied research in a broad spectrum of sciences: the *study* of matter and materials (at nano, micro and macro level) and their interaction with light, the *exploration* of the bio-world, the *investigation* of the informatics highways, the mathematical *leveraging of life* are employed as critical tools for growth, development and solutions for key societal priorities: health, energy, environment, culture, entrepreneurship.

The sequence *research, innovation, growth* can only be served by ensuring and building the skills of young researchers, on one hand, and by strengthening the capacity of established Centers of Excellence, on the other. The support of a training and educational program, particularly in a period of sparseness of resources, has a *multi-fold effect*:

- Support the "locomotives" of middle and long term growth in the country
- Build innovation prospects by cultivating entrepreneurial spirit in the research community
- Introduce skillful young scientists to the job market and the national economy
- Provide leadership training to skillful young scientists
- Provide business mentorship to your researchers

The mid-term goal of this part of the project is to inspire concrete initiatives and stimulate young researchers in the direction of entrepreneurship, building upon the know-how to be developed. It must be mentioned at this point that the selection of the project topics is ideal for this approach, considering their societal impact and the concomitant expansion of market opportunities in the near future.