NFFA: Nanoscience Foundries and Fine Analysis

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The Nanoscience Foundries and Fine Analysis Project (NFFA) is a FP7-funded Design Study for the definition of a novel European distributed research infrastructure with an advanced standard in modelling, synthesis, characterization and fine analysis facilities. NFFA will provide an advanced platform in nanoscience and nanotechnology by integrating the benefits of advanced fine analysis methods (based on radiation sources at the Large Scale Facilities, LSF) with advanced synthesis and nanofabrication also at the atomic scale. Both academic and industrial users will have access to state-of-the-art instrumentation and methods for designing, synthesis and fabrication in research programs benefiting from access to LSF: Free-Electron-Laser, Synchrotron X-ray and Neutron Beams for advanced fine analysis experiments in a wide energy and time domain range. Conversely, all fine analysis experiments at LSF that require nanoscale or atomic scale precision in sample definition will greatly benefit from prior or simultaneous access to NFFA centres providing synthesis, complementary experiments and adequate metrology. In full agreement with the EU policy in matter of Research Infrastructures, NFFA will operate in open access mode based on scientific merit of proposals and free of charge.

INTRODUCTION

Nanoscience has proven to be of enormous potential in the development of new materials and functional systems, tailored at the nanoscale, which will have significant impacts on many aspects of economy, health and society. Nanoscience and nanotechnology concern the synthesis and functional use of materials, devices, and systems on the basis of the understanding and control of matter at the nanometer length scale (at atomic precision level, at molecular and supermolecular architectural level, at short time scales fs-ns). The need to reach such capabilities is urgent in order to address the grand challenges areas for European competitiveness such as Energy (conversion and saving), Health (diagnostics and therapy) and Environment (toxicology and remediation), as well as strengthening scientific and technologic excellence in research.

The worldwide awareness of this potential has prompted various National Science Plans, International Roadmaps, as well as the GENNESYS exercise (White Paper Jan 2009) [1], the NMP Position Paper 2010-2015 [2], the Productive Nanosystems Roadmap (USA) and others all indicating the urgent need of new infrastructure bridging nanoscience and fine analysis [3]. Radiation sources dedicated to fine analysis (synchrotron radiation sources, free electron lasers, neutron sources, high power or ultrashort laser pulses) play a prime role among the most advanced tools for nanoscale research and characterization, but their effective impact in nanoscience and nanotechnology remains mostly at basic research level, proofs of principle and demonstration experiments.

In fact, most of the fabrication, synthesis and analysis at the nanoscale level are currently performed in laboratories (national or regional, academic or industrial) that do not take full advantage of advanced fine analysis methods. The frontier between the fundamental knowledge of physical, chemical and biological processes or systems and the understanding of their applications in technological contexts is easily crossed in the research at the nanoscale; a high control of the synthesis and nanofabrication is available along with the direct probes of atomic, electronic, magnetic, and dynamical behaviours of nanostructured matter and system. The reproducibility of samples and the scaling of nanosystems (numerous replicas) require an adequate metrology and standard system to be developed based on a organized synergic use of radiation based methods (photon, electron, neutron beams) and in-situ, in-operando studies of synthesis, growth, functionality can be designed and performed again with pulsed radiation beams on the relevant time (10 fs-ms) and energy scales (meV, 100 Kev). Europe operates and developes advanced Large Scale Facilities (LSF) for fine analysis of matter and materials (Synchrotron radiation sources, neutron sources). The analysis power of the methods developed on these LSF have progressed at a much higher pace then the progress of nanotechnology that consistently follows Moore's law. An even sharper increase in brilliance of the short-pulsed free electron laser (FEL) sources is opening the full power of fine analysis at the time scale of chemical synthesis, i.e. fempto-seconds.
All this means that the instruments for learning more about the atomic and nanoscale world than in the recent past are largely in place. However, at the moment this potential is only weakly exploited since the research on synthesis and nanofabrication of functional materials is performed in laboratories (academic or industrial) operating at national or regional level that do not take full advantage of the advanced fine analysis methods available at the LSF.
The NFFA project [4] aims at demonstrating how to overcome the current bottleneck that is preventing the fast development of nanoscience: fine analysis (in particular *in-situ*, *on-growth, in-operando* analysis) of nanostructures is inhibited by the difficulties of sample preparation at the LSF and by the stringent scheduling of beamtime access.

AIMS AND OBJECTIVES OF THE NFFA DESIGN STUDY

The NFFA Design Study is jointly carried on by five European research institutions aiming at establishing the feasibility of a new kind of user infrastructure for nanoscience based on a distribution of Foundry Centres co-located and strongly linked with Analytical LSFs, offering open access. NFFA is developing a scheme of European Distributed Research Infrastructure that will operate a science programme and enforce open access to users whose nanoscience projects require state of the art modelling and numerical simulation methods, material synthesis, nanofabrication, nano-metrology and radiation sources methods of fine analysis or radiation assisted synthesis.
NFFA may adopt the European Research Infrastructure Consortium legal status (ERIC) [5], and a structure consisting of a central hub plus 3 to 6 nanoscience centres each one providing a common platform for design, synthesis, nanofabrication and atomic-scale characterization and its embedding with the co-located LSFs, both from the technical and operational aspects.

The NFFA distributed facility will in fact strengthen the concentrations of research means that are occurring at several science sites in Europe, adding the key glue of synthesis, nanofabrication and metrology among the available or developing radiation sources, microscopy or imaging centers, "omics" and medical science centers. The distributed nature of NFFA will further link the large research sites and will be unique in developing and guaranteeing a common metrology, and ultimately a step towards standardization and certification of data. This last aspect being mandatory for the deployment of an effective interface with industrial research.

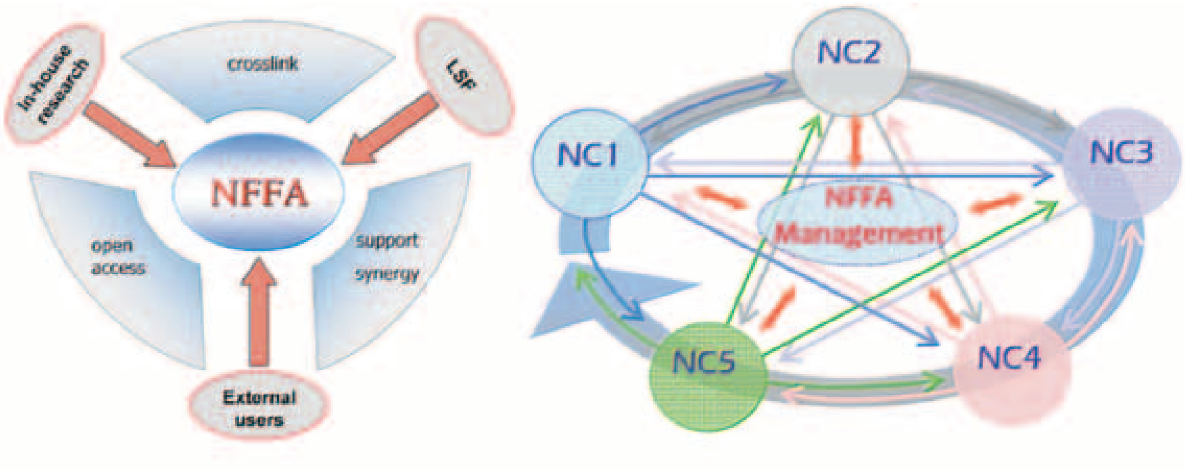

Figure 1. (left panel) Structure of the interplay of external and internal programmes and large scale facilities; (right panel) The interrelationship of NFFA Nanocentres follows the concept of the distributed infrastructure.

NFFA AS A SCIENCE CENTER

The NFFA science centers will carry out fundamental science activity and will be instrumental to the converging character of nanoscience and nanotechnology by also carrying out innovation oriented research and development, including prototyping and technological proofs of principle whenever scientific and technological development merit is met, also allowing for hosting, on medium term contract basis, a quote of private proprietary research.

The science programme is a fundamental building block of NFFA and of each of its individual centres. The NFFA science programme [6] addresses the "main challenges" of energy, health, environment by specific research projects and by identifying the methodological and instrumental platform that will support advanced research to meet them. Users will have special needs of design, simulation, synthesis, and characterisation that must find adequate support in the NFFA centre. Users may also be actually attracted by the NFFA internal research programme and participate to it. The choice of the best suited analytical facilities to be connected to NFFA is crucial in order to provide the best selection of fine analysis means coupled with the NFFA.

The characteristics of specific LSF (low energy X rays, Hard X rays, nanobeams, Ultra short pulses, neutrons) will orient the choice of where to establish the NFFA centres, in order to provide a complete offer of complementary methods.

As a European distributed facility according to ESFRI definition [7], NFFA will be identified by its science programme and its unique access portal.
The individual NFFA centres will develop strong synergy with the local analytical facility that may go beyond the international access programme in establishing possible local partnerships. Each centre should play its own strength and develop its own distinctive science programme. The NFFA central management will provide the coordinating role, to make sure users' needs are met in one NFFA centre or another. NFFA will establish a governance structure and partnership agreement with the LSFs in order to optimize the merit selection of the proposals and the access protocols to both the NFFA infrastructure and the LSF in compliance with the open access criteria.

COMMON METROLOGY AND NFFA DATA REPOSITORY

To guarantee a full reproducibility and traceability of results, NFFA will develop and adopt an "internal" metrology and standard protocol of materials characterisation at the nano and atomic scales, common to all centres such to provide well described methods and data for external users as well as guaranteeing the reproducibility at any NFFA centres of such protocols and data. This will be done with reference to the International System of Units (SI), according to guidelines and standards provided by National Metrology Institutes, where available, and moving beyond wherever it turns out to be needed. Internal reference materials and procedures will be identified so that both academic and industrial users accessing to laboratories located in the different NFFA centres can be ensured that they are investigating precise replica objects with the same resolution. With the aim of offering an open and easily accessible reference for others and to qualify its advanced internal metrology, NFFA will operate and develop the first Nanoscience Repository of molecular data for functional and complex materials and protocols for synthesis and metrology of nanostructured systems.

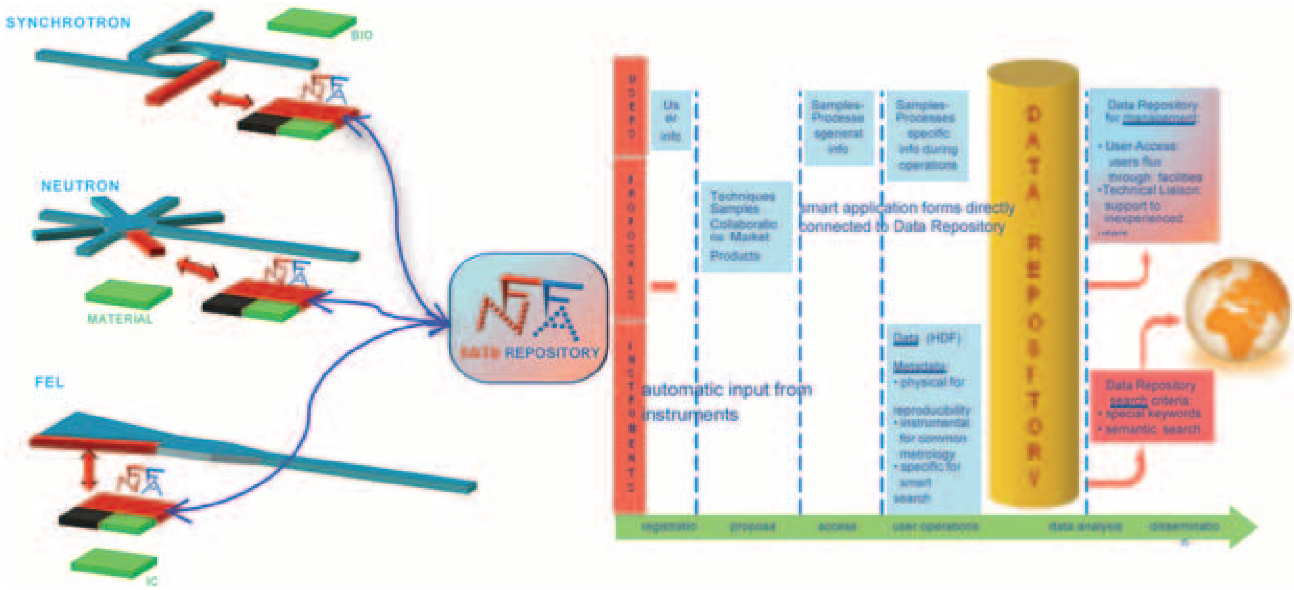

Figure 2. (Schematic drawing of the NFFA infrastructure and of the Data Repository.

All the results, including certification and calibration protocols of nanoscience centers, will be more directly suitable for specific applications developed by technology districts as well as for next generation products manufactured by industries. This will be accomplished by a full exploitation of emerging e-infrastructures to achieve high impact and capillarity in making nanoscience outcome promptly available to society. In Figure 2 a schematic of the NFFA infrastructure and of the Data Repository is shown.
NFFA aims therefore:

- To enhance the use of LSFs by nanoscience and nanotechnology communities with special dedication to *energy*, *health* and *environment* challenges.
- To extend the use of advanced instrumentation for nanotechnology to the scientific and technological communities that are not able or willing to sustain their own medium/large instrumentation. The creation of a metrology-controlled standardized platform with reliable access (from both the technical and bureaucratic point of view) will push towards a research competition based on skill ideas and critical mass collaborations rather than on financial and technical capabilities of individual groups.
- To maximize the impact of LSFs on European science and technology by raising the standard of sample definition and characterization for advanced experiments with ultrafast, nanofocused and high energy resolution probes available at Synchrotrons, FELs and Neutron facilities, and making it available to the largest science community through open access.
- To make scientific data and technology protocols more accessible to communities other than the stakeholders of national nanoscience foundries and LSFs present in the actual European scenario.
- To foster a scientific culture in the converging and interdisciplinary fields, like nanotechnology for Energy, Health and Environment, and extending its benefits to the whole society.
- To create a unique infrastructure capable of advanced training at scientific, technical and managerial level that acts as an interface, possibly with a credit system, to the relevant European academies and research agencies and innovation actors.

The NFFA Design Study will deliver its final results in spring 2011.

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