FINAL PUBLISHABLE SUMMARY REPORT

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Contents

1. NFFA FINAL PUBLISHABLE SUMMARY REPORT ... 3

1.1 EXECUTIVE SUMMARY ... 3

1.2 PROJECT CONTEXT AND OBJECTIVES ... 4

1.3 MAIN S&T RESULTS/FOREGROUNDS ... 8

NFFA-Distributed Research Infrastructure Description ... 8
NFFA-Distributed Research Infrastructure Technical Layout ... 15
NFFA-Distributed Research Infrastructure Management Structure ... 22
NFFA-Distributed Research Infrastructure in the ERA ... 27

1.4 POTENTIAL IMPACT ... 28

1. NFFA FINAL PUBLISHABLE SUMMARY REPORT

1.1 EXECUTIVE SUMMARY

Nanoscience and nanotechnology are broad domains of research bearing great innovation potential in the fields of health, environment, energy and communication. Direct sensitivity to the atomic scale and to the fundamental time scale of the processes ruling the assembly of matter and the response of materials, as well as the direct exploitation of quantum phenomena, are requested for acquiring the knowledge to enable the design of new generation products and sustainable technologies.

Nanotechnology requires special infrastructures with "atomically clean environments" for the assembling of nanosystems, whereas nanoscience needs adequate probes that include radiation sources (Large Scale Facilities for fine analysis of matter, LSF) for the direct control of the functionalities at the relevant space and time scale of the fundamental processes. These infrastructures, which require substantial human and financial investments, are most often not co-located and not operated in close synergy with the LSFs, offering a unique integrated environment for advanced research open to the access of European and international scientists. NFFA will be characterized by:

*A single portal for open access to up to six centres characterized by specific fields of interest and local synergies with complementary nearby Large Scale Facilities (LSFs), with a central management based on a project oriented structure tailored by the scientific programme, but well suited to establish local relationships at national and regional level that satisfy both a European vision of modern research infrastructures as well as local needs and sustainability. The distributed infrastructure will adopt the legal framework of the European Research Infrastructure Consortium (ERIC).

*A strategic access to LSFs to a wider nano-oriented community of users by raising the standard in sample definition. Advanced beam lines on radiation sources generally lack adequate levels of sample preparation and delivery tools, or atomic resolution microscopy. Such severe limitations to the optimal development of nanoscience and consequently of nanotechnologies (that become a limiting factor for the full scientific return from the LSFs) will be overcome by co-locating advanced synthesis facilities equipped with controlled sample transfer and by developing dedicated beam lines and full characterization lines all connected by a well suited metrology. *In-operando* experiments will be also developed and will provide a more reliable feedback to the assembly and functionalisation protocols.

*A common platform of standards and metrology enabling the comparability and transferability of synthesis protocols and analytical results obtained in complementary radiation sources. To achieve this it is fundamental to join nanofabrication and synthesis with fine analysis at the LSFs as well as to make the several NFFA centres act as a single-site infrastructure with several virtual *in-situ* and *in-operando* capabilities (in the frame of the reproducibility certified by the common standards). A quality management system approach has been planned to account for a reliable implementation of such a platform, including data and competence management achieved by means of a Technical Liaison activity carried out by staff members and consisting in common practices and in the development of an activity pointing to the full reproducibility and transferability of nanoscience results and nanotechnology products capable to face the challenge of atomic precision manufacturing.

*A first Data Repository of molecular data for functional and complex materials and protocols for the synthesis and the metrology of nanostructured systems. The format of the data and the metadata (the set of all the relevant information aiming at the reproducibility and the transferability of the data) will be devised so as to ensure full exploitation of the results by a broad science community.

*The indicative overall construction cost of NFFA for 3-6 centres is 200-400 M€ in case of green-field construction (co-located next to LSF) and an operation cost of about 15% of the investment cost per year. The construction time is 3 years per centre with several centres being built in parallel. Based on the DOE experience 5 years are necessary for full regime operation. These goals are pursued by involving national institutes and research agencies as well as the European Commission in a strategic planning. Whenever an update of the ESFRI Roadmap will consider the inclusion of nanoscience and nanotechnology, NFFA could represent a valuable option.

*The development of the concept of a NFFA demonstrator phase to be started quickly with the initial support of all the Institutions that participated in the NFFA Design Study and to be extended also to other relevant institutions in the EU and Associated States within the framework of FP7, WP2012 funding schemes. The NFFA Demonstrator Phase will enforce and develop the NFFA concept within a limited programme that will integrate the existing nanoscience infrastructures co-located next to LSFs for Fine Analysis that do have some infrastructural capacity for supporting a users programme if funded for the extra costs that are involved.

While the European offer of LSFs is adequate, the availability of open access nanoscience centres is overall undersized, and the link to LSF is weak. NFFA can therefore play a key role in the construction of the European Research Area creating a unique environment to support leading research by users from academy and institutes, offering advanced training to young researchers and engineers, providing an effective support to innovation projects by diverse stakeholders.

1.2 PROJECT CONTEXT AND OBJECTIVES

Perspectives on Research in Nanoscience and Nanotechnology

Exploring the frontier of nanotechnology is an unavoidable challenge for addressing the key problems of sustainability of our civilization. We need to understand the properties of matter at the nanoscale and to seek control of functionalities based on nano-systems because the cost in terms of energy, raw materials and waste of large scale “classical” devices is too high to sustain further expansion of civilization on earth. Nanoscience attempts to discover and understand the quantum phenomena that may lead simultaneously to downsizing products and processes and to improve their performances and specificities therefore enabling technologies of low energy content (i.e. low cost and highly efficient) in the fields of energy, health, food and environment. All these developments rely on the understanding of the properties of matter at the nanoscale, on the synthesis of materials with properties suitable to realize functional systems, and on the observation and control of their behaviour.

First principles analysis of model systems, synthesis of materials, nanofabrication with top-down and bottom-up methods, atomic precision manufacturing, atomic resolution microscopy, atom specific spectroscopy and magnetometry, high resolution diffraction, time resolution probes from 10^{-14}s to 10^{1}s, single molecule manipulation, spectroscopy and transport measurements are recent developments of research that need to become available as reliable methods in order to advance in an effective way towards new knowledge and new capabilities in synthesis and fabrication of novel materials and devices that are needed to address the grand societal challenges of this time.

Motivation and aim of the Nano Foundries and Fine Analysis Research Infrastructure (NFFA-RI) is to realize and operate such an integrated research environment for nanoscience.

The infrastructure for fine analysis of matter is strong in Europe: 13 synchrotron radiation centres, 8 neutron spectroscopy laboratories, the fast development of free-electron-laser sources extending to soft and hard X-rays with very high brilliance and *femtosecond* scale pulses, the development of *exawatt* laser prototypes and *attosecond* optical pulse sources.

Large clean-room based nanofabrication laboratories exist as well in several EU countries and are operated by universities, national research centres and public-private institutions. Still most of the research in nanoscience is carried out at university laboratories or public research laboratories that have no or very limited access to the relevant large scale infrastructures, and often produce “demonstration experiments” of high scientific value but of limited technological impact, due to lack of scalability and reproducibility.

High societal and economic impact advances in science and technology at the nanoscale require systematic work in which well-established advanced probes are applied on materials grown in controlled conditions, or subjected to reliable external perturbations, *in-situ* and *in-operando*. This activity requires the development of a common platform with protocols, metrology and data structure, as well as a working environment and organization capable of creating the conditions for the reproducibility of results and the effective transfer of knowledge. Nanometrology and the complementarity of a large set of experimental data on the same sample or on very reliable replicas, as well as modelling on the proper length and time scale, are prerequisites for the advancement of nanoscience. To accomplish this, a step forward in data management and data repository is required. In particular metadata on synthesis and fine analysis protocols must be streamlined in an integrated data management system in order to supply the first repository of nanoscience data that will set the reference basis for standardization and for related research and certification issues, like nano-toxicity. Reproducibility is a frontier of nanoscience that must be addressed with adequate infrastructure to allow a large number of European and international researchers to develop and use protocols and to perform research in nanoscience taking full advantage of the methods and capabilities available at the Large Scale Facilities for fine analysis of matter.

The worldwide awareness of nanoscience potentials has prompted the EC and research infrastructures dedicated to nanoscience and nanotechnology to work out various supporting programmes and schemes, all aiming at bridging the gap between fundamental research and industry-oriented research. Europe has a great potential in impacting on nanoscience and nanotechnology thanks to its remarkable infrastructural heritage of Large Scale Facilities (LSFs). Nevertheless, at present, the effective impact of LSFs on nanoscience and nanotechnology is achieved mostly at the level of basic research, 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 and regional, academic and industrial) that do not take full advantage of the advanced fine analysis methods.

Large Scale Facilities, as they are operated nowadays, are very well suited for advanced science experiments that often demonstrate new phenomena by exploiting extreme conditions of sources and sample environment, and result in articles that are generally published in high impact journals. The dissemination of scientific results via articles further stimulates researchers to go and search for new understanding at the phenomenological level. Science development programmes, for instance on materials science, are greatly tributary to systematic work since the well-established and advanced probes are applied systematically on materials grown in modified conditions, or subject to thermal, pressure, or field treatments, and possibly with in-situ and in-operando conditions.

The further development of this science however is strongly dependent on the development of an advanced and reliable metrology. The measurements campaigns must be compared with each other and this requires that the absolute values of key parameters (radiation intensity, degree of polarization, focus dimension, degree of coherence, monochromaticity etc.) are known within well-established and routinely verified error bars. Also sample preparation, characterisation and parameters of sample environment must be certified by an appropriate reliable metrology. Similarly, data is to be obtained on comparable samples in quantitatively comparable conditions and with enough quantitative information to feed information and constraints directly into the overall data analysis and finally into the interpretation work.

ESFRI and EC Infrastructure Programmes

The European Strategy Forum for Research Infrastructures (ESFRI) periodically brings up-to-date the roadmap for analytical facilities that covers presently the upgrade of the operating international sources of Grenoble (ESRF and ILL) as well as the construction of the new infrastructures for ultrafast X-ray pulses (X-FEL, EuroFEL), intense laser pulses (ELI) and long-pulse spallation source of neutrons (ESS). These European laboratories and the ensemble of large scale national facilities (synchrotrons, neutron sources, FELs) offer unique radiation beams for advanced experimental research in all fields converging with nanoscience, from materials science to medicine, from analysis and conservation of cultural heritage to conversion and storage of energy. Most of the analytical facilities of the ESFRI roadmap are in the implementation or pre-construction phase and correspond to an overall new investment of 4 G€ in the next 10 years, adding to the current multi billion spending for operating European and national facilities, and for the construction of new national facilities (PSI-FEL, FERMI@Elettra, ALBA, Max-IV, SOLARIS, etc.).

On the side of materials synthesis and nanofabrication however the ESFRI roadmap does not include projects of pan-European infrastructures based on the open access mode. **NFFA addresses this weakness of the European Research Area by defining a new kind of Distributed European Infrastructure that will have laboratories (Centres) co-located next to the analytical large scale facilities.**

DoE experience and the GENNESYS exercise

The Department of Energy (DoE) of the United States realized a network of 5 Nanoscale Science Research Centers (NSRC-DOE) co-located next to synchrotrons and neutron spallation sources that operate under own science programmes and offer public access to researchers whose proposals are selected and ranked by peer-review. The centres started operating in 2006. The number of projects per centre is of the order of 150-200 per year involving a substantial users flow in each centre. The access to the co-located LSFs consists in either using own instruments (beam lines) or in sharing instruments co-operated with the LSF. Users of the DoE centres are trained and introduced to the advantages of the LSF-based techniques by the scientific staff of the DoE centres. All centres include theory, synthesis, biology, nanofabrication and spectroscopy/microscopy facilities.

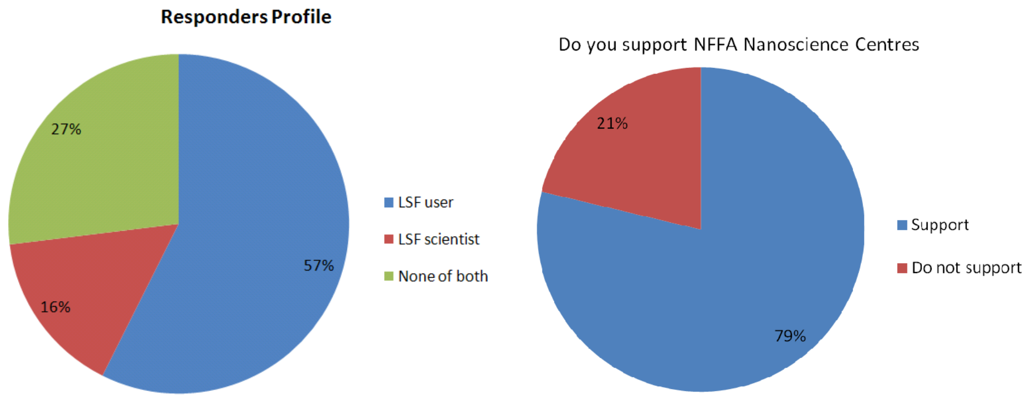
In 2009 the GENNESYS White Paper summarized a five-year exercise of analysis and forecasting of the research needs for the development of nanoscience in Europe. In all relevant fields of research the goals and methods of nanoscience and nanotechnology were discussed in view of the relevant contributions that neutron and X-ray spectroscopies could make. Strategies were proposed for “bridging” the science carried out at Large Scale Facilities with the industrial research and development relying on nanotechnology. GENNESYS suggests creating new European Science and Technology centres focussing on materials, nanofood, nano/bio applications, energy and cultural heritage.

The NFFA User Survey

The NFFA Design Study started with a web survey designed to analyse the European context of nanoscience facility users and their perspective expectations in the next 10 years, and to test their potential support for a Research Infrastructure with the general characteristic of the NFFA Design Study.

The survey population included groups that are already users, or who are clearly potential users, of Fine Analysis Infrastructures (synchrotrons, high power lasers, FELs and neutron sources) for experiments in the domain of nanoscience, and groups that have not yet considered these methods. The main goal of the survey was in fact to question the nanoscience community that **does not** integrate the access to LSFs in their current research programme. This includes research on functional materials and systems, nano-bio, nano- metrology, nano-toxicology, certification.

The outcome of the survey was detailed in the relevant deliverable and discussed at the mid-term review. The main result was that 80% of the respondents were in favour of the NFFA concept. Those who were against the concept expressed fears such as: “a centralised facility is a diversion of national/European funds”; “will become a local facility”; “only a minority of users would benefit from the centres”; “complex organization”; “each experiment is unique, can’t have fit-all-purposes facility.”



Respondent profile and degree of support of the NFFA concept

Project objectives

The objectives of the NFFA-DS are a thorough analysis of the European context in which a novel Distributed Infrastructure for nanoscience could be built, and a detailed technical and strategic study on the characteristics that such Distributed Infrastructure should have in order to address the needs of European science, technology and education in the field of nanoscience and nanotechnology.

The Design Study is the joint effort of five European research institutions to investigate the feasibility of a new kind of user infrastructure for nanoscience consisting in a cluster of 3 up to 6 Foundry Centres in close connection with LSFs which purpose is to:

a) carry out advanced nanoscience research in an integrated environment that requires state of the art modelling and simulation methods, material synthesis, nanofabrication, nano-characterisation, including the use of radiation sources suitable for fine analysis as well as for material and system synthesis;
b) provide European researchers with a substantial access to state-of-the-art nanoscience instruments and methods and fine analysis therefore increasing the competitiveness of European research by structuring the ERA and creating an ideal environment for advanced training of researchers;
c) raise the standards of sample definition and characterization for advanced experiments with ultrafast, nanofocused, high energy resolution probes available at Synchrotrons, FELs and Neutron facilities in order to maximise the impact of LSFs on European science and technology, thus providing European users with a well defined metrology for synthesis and nanofabrication protocols, atomic resolution analysis, modelling and simulation methods;
d) implement a repository-type data bank for nanoscience data and protocols, with wide regulated access by the research community.

To achieve all these aims the objectives of the NFFA project are:

WP2 a) to map the existing competencies in nanoscience that already operate synergies with LSFs; b) to estimate range and size of the overall nanoscience community that may benefit from NFFA-Research Infrastructure as both active users and users of the data repository of results, nanofabrication/synthesis protocols, remote access; c) to define the science programme and d) to develop the NFFA roadmap;

WP3 to define the technical layout of the NFFA Centres, the common configuration of the infrastructure (clean rooms specifications, particle beam lithographies and nanofabrication, characterisation and nanometrology tools) and the domains of specialization at the different Centres (e.g. atomic resolution microscopies and spectromicroscopies based on electron beams TEM, SEM, LEEM and complementary nanometer resolution microscopies and spectromicroscopies based on X-ray beams);

WP4 to define the mission and general structure of the NFFA- Research Infrastructure, including the general management of the central and the local facilities; b) to develop schemes for implementing the NFFA-RI repository of data and protocols and to make it available to general users; c) to develop schemes for remote use of NFFA-RI; d) to set quality standards of production and e) to define an efficient users' access scheme;

WP5 to develop actions aimed at increasing the amount of competences in nanoscience methods: a) training of NFFA-RI staff; b) scientific and technological training of potential users involved in NFFA-RI activities and advanced training for nanoscience and nanotechnology operators and researchers; c) organisation of schools and public conferences, circulation of dissemination material and release of the NFFA book.

The long term objective is to actually build such infrastructure and to realize a novel user programme based on access to facilities, remote access to experiments, access to data repository and full integration of the fine analysis in the nanoscience protocols for nanofabrication, for system functionalization, and for advanced research on matter at the nanoscale, with a multidisciplinary approach and multi-application fields, from energy to health, from basic science to prototyping.

1.3 MAIN S&T RESULTS/FOREGROUNDS

The main achievements of NFFA-DS consist in the description of the distributed infrastructure from a technical point of view and its integration with the co-located large Scale Facilities for Fine Analysis, of the operation mode, the users access conventional and advanced modes, the construction of the data system and repository, the potential role in the nano-metrology domain and the governance of the Distributed Infrastructure.

NFFA-Distributed Research Infrastructure Description

Open Access Research

NFFA will provide effective open access to academic and industrial researchers to a state of the art and flexible infrastructure with direct support of highly qualified scientific and technical staff. NFFA will primarily perform and support top-level non-proprietary research in the open access mode, in the form of both short and long-term nanoscience proposals regulated by a peer review system taking into account the scientific/technological merit of the proposals.

The **access steps for a user group** will be the following:

1. Idea submission (optional, addressed to the Technical Liaison)
2. Proposal submission (this opens the Work-Place in the NFFA Data Management)
3. Technical feasibility check (quick in-house response)
4. Scientific review (periodical, external, a few calls per year)
5. NFFA decision on acceptance (preparation of a work flow and schedule)
6. User acceptance of workflow and scheduling

NFFA will have one **single entry portal for proposals**. The final allocation of the proposals will take into account firstly the thematic alignment with the distinct science programmes of the NFFA sites and the specificity of the tools available at particular NFFA/LSF environments; and secondly, other technicalities such as the current availability of NFFA resources at the different sites and the geographical proximity of the applicants to the facility considered. The need to access the LSF instrumentation and beam time will be ruled under specific agreements. LSF experts will be present in the proposal review panels.
In the context of proposal **submission and reviewing**, several time-entry points and a fast reviewing process will be favoured. Short forms, with just enough description to evaluate feasibility and scientific merit, will be favoured. Confidentiality issues regarding reviewers and NFFA staff will be taken care of. For the sake of flexibility, a **swift access mode** shortcutting the above procedure may be envisaged for a very limited quota of urgent proposals, which will be evaluated *a posteriori*.
A report should be filled by the user at the end of the project. Reports will work both ways: the user will be asked about his/her satisfaction, and conversely NFFA will check that the user team has made proper and efficient use of the resources made available to the team. Long term projects may be submitted to intermediate reporting. The primary purpose of such process is to improve NFFA operation and to assure that the resources are used profitably.

Different **access modes** will be possible in relation to the personal involvement of the users. Users may be direct operators, clients, or trainees at the facilities, according to expertise and effective need/possibility. The different working modes considered are the following:

- [Presential] Generally, the users will be present in NFFA premises when their projects are being developed. However they will have a 'hands off' access in case the machines that are being used are considered too critical for being operated under a self-service mode. When the machines allow a certain degree of self-service, the user will follow a 'hands on' approach.
- [Non-presential/remote] In this type of access, the user does not need to travel to the NFFA Centre. The user defines a sequence of standard steps from an established set available at the NFFA site and NFFA staff does the work.
- [e-access] it refers to the on-line access to computer based tools (simulation, modelling…) and resources (data repository) that will be progressively developed at the NFFA Centres.

The final implementation of the access of users will impact other managerial aspects such as the user agreements to be prepared and to fulfil the repository feeding obligations and the training schemes for users, ranging from mere information about techniques/processes to in depth training/qualification.
The NFFA operation rules will have enough built-in flexibility to allow quick decisions on all aspects of the operation and service to users, under the responsibility of the local management and subject to *a posteriori* verification by the relevant boards.

In-house Research

The NFFA science Centres staff will include scientists, research-engineers, and laboratory technicians devoted to the in-house and users programme as well as to the facility operation and development. The scientist staff positions will involve 50% duty towards the users programme and 50% dedication to the in-house research. The NFFA in-house science programme, coordinated at the level of the NFFA Centre and of the NFFA RI, will be carried out by exploiting all the relevant facilities, from theory to nanofabrication and fine analysis, with a multidisciplinary approach, addressing:

Fundamental nanoscale phenomena and processes: discovery and development of fundamental knowledge pertaining to new phenomena in physical, biological and engineering sciences that occur at the nanoscale. Elucidation of scientific and engineering principles related to nanoscale structures, processes and mechanisms.
Nanomaterials: research aimed at the discovery of novel nanoscale and nanostructured materials and at a comprehensive understanding of the properties of nanomaterials (ranging across length scales, and including interface interactions). R&D leading to the ability to design and synthesise, in a controlled manner, nanostructured materials with targeted properties.
Nanoscale devices and systems: R&D that applies the principles of nanoscale science and engineering to create novel, or to improve existing, devices and systems, including the incorporation of nanoscale or nanostructured materials to achieve improved performance or new functionality. Though the devices or systems may not be restricted to nanoscale, the enabling science and technology must be at the nanoscale.
Instrumentation research: next generation techniques and technical solutions for extending the direct benefits of fine analysis to complex nano-synthesis or real environments.

Common metrology and standards: research on nanometrology is a prerequisite to most activities of NFFA and is needed to develop nanotechnology standards and to advance nanotechnology research and commercialization. Round robin activities will be established to compare protocols for both metrology and synthesis of nanostructured materials.
Nanomanufacturing: R&D aimed at enabling scaled-up reliable and cost effective manufacturing of nanoscale materials, structures, devices and systems.
Environment, health and safety: directed at understanding the environmental, health and safety impacts of nanotechnology development and corresponding risk assessment, risk management and methods for risk mitigation.
Atomic precision: is potentially the new paradigm for exploiting quantum effects to produce functional systems, moving beyond the current definition of nanoscience methods and techniques. NFFA will provide the most adequate environment for developing atomic precision metrology and fabrication.

Development of the Data Repository: aiming to become the most relevant and effective instrument for a science centre to make nanoscience outcome promptly available to the broadest share of stakeholders.
The NFFA Centres will carry out the whole in-house research programme of the NFFA RI, with local specialization according to the characteristics of the co-located LSF and other research institutions. The NFFA science Centres will also carry out application oriented research and development, including prototyping and technology proofs of principle when considered of high scientific/technological merit.

Innovation and Industrial Research

The NFFA-RI will work mostly with public and private institutions in their nanoscience/nanotechnology non-proprietary research. This means that industry has no limitation in accessing the NFFA-RI for the open access research, via a peer review competition and results are subjected to non-proprietary research intellectual property rights (IPR) regulation, which could be well suited for pioneering industrial research. Much innovation is expected in this domain of activity, addressing the metrology and certification and standardization issues that are preliminary to high impact applications.
For precompetitive developments, there will be a special access time quota available for industrial proprietary research. Arrangements in this sense have been formulated in the Design Study, including assistance to inexperienced users and IPR issues.
Industrial Liaison Offices (ILOs) will be set-up in each NFFA Centre and will act as the initial point of contact for industrial companies and provide help and assistance, as required. The technical-scientific support to industrial users will be provided mainly by the Technical Liaison (described in the next section), with the role of ILO being to accept the initial request and to deal with legal and economic issues leading to the eventual contracts, including intellectual property issues.
Industrial users are likely to be more demanding in terms of formal operating procedures and so the ILO may also be appointed to set up quality standard for the management of customer commitments (ISO 9000-9001 standard).

The Technical Liaison

The objective to create and operate a user friendly common platform of standardized protocols, metrology and data, in particular among Centres located at different sites, will require an adequate effort in terms of personnel and coordination. To this aim a Technical Liaison (TL), made up of personnel across the NFFA Centres, will operate under a defined set of rules and procedures and manage the technical competences of NFFA. It will be an extension of the concept of Technical Liaison developed for the National Nanotechnology Infrastructure Network (NNIN) initiative in USA.

The NFFA **Technical Liaison** (TL) is a coordinated management of technical competences inside and among the several NFFA Centres in the following areas:

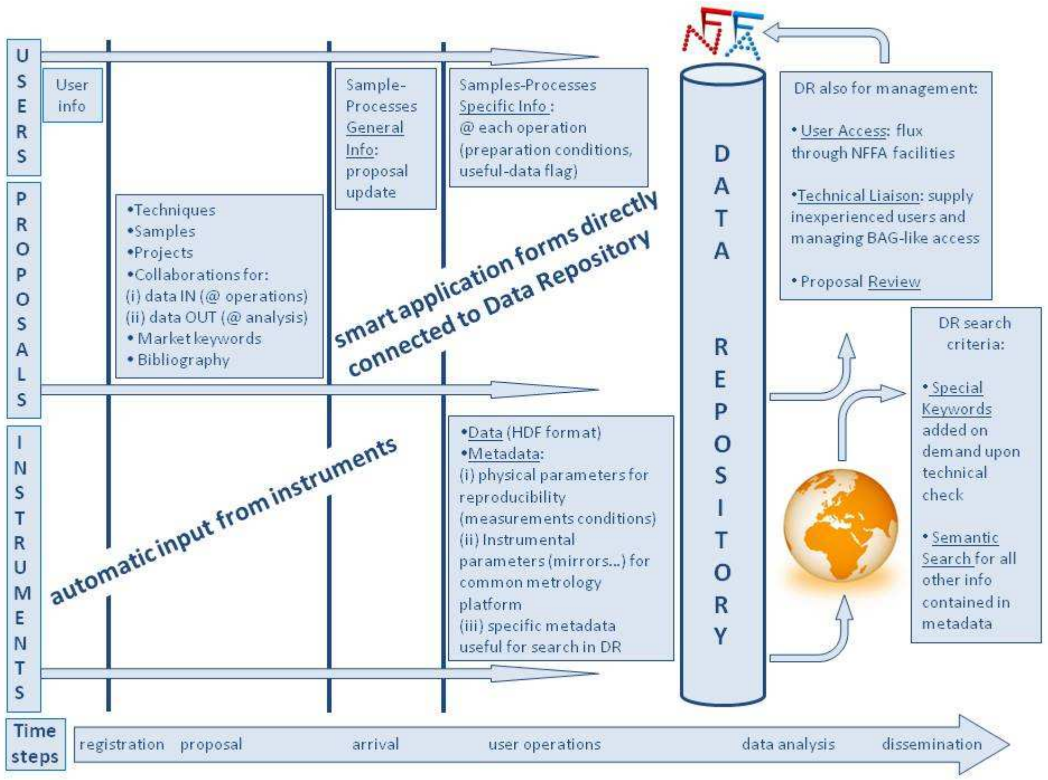
- Users consultancy (scientific and technological support to inexperienced users also including activities promoted by the ILO and addressed to industrial potential users)
- Common metrology and protocol standard development and maintenance
- Data Repository management
- Local Desk Services – set-up to provide support for quick characterisations by means of the well-established common metrology platform available at the NFFA Centres as well as rapid fabrication or synthesis by means of standardised protocols.
- Characterization of associated LSF methods and development of technical solutions to link analytical methods at the associated LSFs with nanoscience instrumentation running at the NFFA Centres.

An editorial-like approach will provide the connection between the NFFA-TL and the scientists who may have the specific competences for developing a given idea by a user. For instance the TL staff, when implementing a common protocol, can call for a review involving the widest Scientific Community of the NFFA Centres, i.e. the scientific staff and specially qualified users, acting as referees. In such a way a peer review-like method will account for the technical evaluation and competence management.

Integrated Data management and Data Repository

A second level of open access will be provided by NFFA by means of the first Data Repository for nanoscience. It will archive and make available, under fair rules, the data and protocols developed at NFFA as a basic resource for

reproducible preparations and analytical results to the broadest community of scientists and developers. The impact of research on society is mediated by the actual access to data by the various operators of innovation, being development laboratories, industry, test facilities, services, certification bodies, researchers and higher education institutions. Effective archiving, or open-access scientific Data Repositories (DR) are a challenge that can be met more easily by research infrastructures that can develop advanced data management methods building in the intrinsic need to make collected data available to the users for the medium-long time required for data analysis. Suitable **data** formats for transferability, analysis, archiving, and possibly interoperability are mandatory as well as an effective link to **metadata** completing the relevant information on the protocols followed in the sample definition and in the measurements.
NFFA has addressed the creation of the first Data Repository (DR) in nanoscience, including the relevant information for data analysis and, most important, for the full reproducibility of preparations and experiments in order to enable the exploitation of truly complementary data as obtained with different methods on true replica samples and environment conditions.



Flux of data in the NFFA Data Repository

Beyond the focus on data storage, data retrieval and interactive analysis (availability of significant intermediate analysis steps for others to continue), data format conversion and management of the data dictionary have been considered as essential building blocks of the NFFA DR.
The DR should be a key item monitored and developed by the NFFA infrastructure which will be operated by users who generate the data and "**third-users**" who access the NFFA-DR according to suitable rules. An integrated data management system has been sketched for the NFFA Research Infrastructure in which a new entry is added when a new proposal is received, generating a work-place where all relevant information on users, samples, previously acquired results, and related literature is uploaded or linked and where all proposal evaluation steps and scheduling of access to the NFFA facilities are recorded. The Data Management system will acquire actual data from the NFFA facilities, as often as possible in automated way, providing an on-line recording of the relevant data and metadata as the research work progresses. Text entries by the users will be necessary, but limited to an overall lower effort than conventional logbooking. The access to the experiment work-place will be extended to the users and to their collaborators in e-access/remote mode, so that remote data analysis or complementary work (simulations, calculations, other) can be performed in an interactive mode in real time. The system will support some degree of remote-operation of NFFA facilities allowing complex experiments to be conducted by one-two users on site (with NFFA assistance) and more at the remote home institutions, but effectively on-line.
Once the research project is completed and the users (or the NFFA scientists) publish their results (scientific papers, thesis, reports, presentations) a "**useful data and metadata**" subset of all the content of the proposal "work-place" will be archived in the open-access NFFA-DR, after a suitable and agreed-upon embargo period. This information will be open to all qualified interested people after acceptance of adequate rules of access implying

some limitations on the use of the data, mandatory acknowledgement of the source of the data and metadata including the scientists and institutions who did the work and who should agree in its further use by the “third users”.

The most important technical guidelines of the **NFFA-Data Repository** are:

- The data reside in file archives. The metadata are managed using a database.
- Metadata management and search criteria will be performed by using both keywords and semantic search
- Extensive support for metadata management and data processing
- A flexible architecture that can be adapted to multiple scenarios (transparently extendible to other e-infrastructure).

The NFFA relational database will have basic tables organized in three levels.

1. Parameters characterising the object of the research which will be useful for third users external access: Sample, Experimental technique
2. Parameters characterizing the user access: Proposal ID, Description, Users
3. The single experiment (measure, synthesis, fabrication or simulation): Data address, Data description, Metadata (made of keywords and free text which will be handled with semantic search), Useful data flag (labelling final useful data with respect to preliminary ones carried out in order to optimise the experiment)

All the input parameters for these tables will be **keywords** easily recognisable in the search operation. Special keywords will be used also in the metadata description in order to make it as standardized as possible. The keywords sets will be managed by the Technical Liaison, taking into account the requests by the users as well as the need to simplify the metadata input forms.
NFFA, within the scope of the Design Study, has developed a **DR-prototype** built, after evaluation of the recent advances in e-infrastructures and scientific data repositories, on the I-CAT system and on the existing e-infrastructure operating at the Elettra synchrotron.
The prototype was connected to three different experimental facilities: a SEM instrument, a synchrotron radiation beam line for spectroscopy, and an open code for first principle simulation (Quantum Expresso) being representative facilities of a NFFA Centre. The overall system is available on line at https://nffa.grid.elettra.trieste.it for demo purpose. The design of the NFFA-DR and the deployment of the demonstrator have shown that the integrated data management and repository is a key element of the research infrastructure that implies requirements not accomplished by simply assembling available e-science tools. A major effort is needed by nevertheless maintaining an open approach based on maximum integration of valuable and popular data formats and protocols.

Quality Standard

The NFFA-Research Infrastructure aims to create a common metrology and protocols platform, open to external users and third-users; consequently it will be faced with “quality” and “standard” issues.
The “**quality**” management system (QMS), as treated by the ISO 9000 prescriptions, is based on the continuous improvement of the system and of assurance of conformity to customer and applicable statutory and regulatory requirements. In this framework, the users policy plays a fundamental role, and quality rules will need to be implemented mainly for the following three objectives:

- a more flexible access with respect to existing infrastructures, including a strategic access to the analytical LSFs,
- actions to foster access of new users communities,
- implementation of an effective data management.

The latter issue brings about a newer concept of quality aspects that mainly concern:

- the data format and the metadata structure,
- IPR issues,

- the effects on users and third-users (users only accessing the Data Repository).

Industrial users will be concerned with QMS and it will be the duty of the ILO (Industrial Liaison office) to monitor the quality, to organise the users community audit and implement the feedback.
A "**standard**" provides rules and/or characteristics for activities or for ensuing results aiming at common and repeated use. As the nanoscience competence core is still mainly shared among scientific institutions which, unlike manufactures and entrepreneurs, have little involvement/interest in the normative activity, an effort towards establishing more common practices and round robin activities aiming at comparing processes and results at the atomic scale among scientific research groups, will introduce standardization practices much needed in the nanosciences.

Measurements must be compared with each other and this requires that absolute values of reference parameters are known, within well-understood and constantly verified error bars. The sample preparation, characterization and the parameters of the sample environment must be certified by an appropriate reliable metrology. This is also a strategic issue for the best use of LSFs to overcome the "on-line" time-consuming sample preparations, the difficulties in quantitative comparison of data from different sites, and the criticalities in performing *in-situ* or *in-operando* measurements.

The **NFFA standard** will involve few actions of "common" practice.

- an internal common standard of metrology, aiming at establishing reliable references and constant calibration of instruments of all NFFA centres, extended at the atomic scale where relevant and exploiting the access to fine analysis in order to guarantee that the overall NFFA research is performed with all the physical, chemical and morphological parameters under full quantitative control with certified error bars.
- an internal common standard of protocols to optimize time-consuming clean-room practices as well as sample preparation for measurements at analytical beam lines: for instance sample transfer under UHV/cryogenic conditions to the beam lines or direct connection of synthesis chambers to the beam lines for in-operando studies, or implementing EM-field manipulators for cells or macromolecular assemblies, with known applied pressure.
- the standard of data (format, access, transferability), will be instrumental in making protocols and metrology standards effective and exportable.

The implementation of common standards will require technical as well as organizational solutions like the correct estimate of duty cycles in the equipment time, an adequate involvement of the staff personnel and data-metadata management fitting specific requests concerning metrology and protocols (e.g. the reference to calibration operations). For such a purpose, the NFFA Technical Liaison (TL) will act both in the common platform of metrology and protocols and in the Data Management, in order to guarantee an adequate level of round robin activity for establishing internal standards and for performing quality checks and calibrations and the proper level of control/coordination of the quality data management.

Staff Training

In the NFFA scenario two communities come together - staff researchers/technicians and external users - with the appointed objective of extracting maximum profit from the available technical infrastructure and shared brainpower. To accomplish this goal a certain degree of preparation and training is needed for both groups. Non-surprisingly, both, staff and external users will share common training topics in some cases. The basic difference between them will be the periodicity of such courses and the degree of detail attained. Certainly for any common topic NFFA staff will be trained to a deeper level (at least as deep as to become good trainers themselves when interacting with external users).
The objective of **internal training actions** is to assure a safe and flexible operation of the facilities.

Specific **internal training** to assure safe and professional NFFA operation will address the following topics:

- NFFA generic concept, mode of operation and scientific/technical offer of the NFFA site, associated LSF, and possible associated nano-labs
- Safety training: civil building and lab operation
- Clean Room operation protocols
- In-depth technical training about in-house processes/equipment
- Resolution of conflict of interests. Degree of involvement with users. User agreement clauses.
- Data management and repository maintenance and use guidelines

With the exception of the in-depth technical training, the above training actions may be short (briefing type) or document based. All the mentioned actions will be rather punctual in time, only to be repeated for new recruitments or when changes in internal policies/protocols occur.

Additionally, **periodic training** to keep the staff technical/scientific proficiency will take the following form:

- Technical workshops about current and future techniques associated to NFFA operation.
- Science seminars programme.

Users Training

The external training schemes are divided into **focused short-term** implementations and **long term far-reaching** schemes. Among these, the collaboration with academia in general and the contribution to post-graduate masters in particular are probably the most strategic and effective schemes in preserving the integrity of the NFFA approach and guaranteeing its long term sustainability.

The **focused training** is the training scheme intended to make the potential users proficient in applying for proposals and in developing them at the NFFA sites when approved. Therefore two distinct stages can be distinguished: a pre-proposal and a post-proposal stage with different needs in terms of training.

In the **pre-proposal stage** the training goal is double: to promote the NFFA concept in the community of potentially interested users, and to train the potential user in the application procedure. The material to be communicated in order to fulfil such goal should cover the following issues:

- NFFA concept and mission as an open access nano-oriented distributed infrastructure
- NFFA portfolio: both scientific and technological capacities
- The different type of users, type of projects expected and different access modes
- The application procedure (calls, form filling, review process)
- NFFA Repository issues
- Rights and duties of users when performing a project in a NFFA site.

In the **post-proposal stage** a granted user will perform personally some work at a NFFA site for a certain period of time, or will have some work done for him by the NFFA staff. The degree of training needed in relation to the operation of NFFA equipment will vary accordingly. In the more generic case the external training at this stage will comprise the following issues:

- Safety training
- Specific Clean Room / nano-labs operation protocols
- Hands off / hands on training, going from thorough theoretical knowledge of the capabilities of the available equipment to deep practical training of the set of equipments that could be used under a self-service approach.
- Training on the repository access and feed

NFFA sites will have special traits (international environment, state of the art facilities, local connection with LSFs etc.) that will make them privileged places to perform **far reaching external dissemination and training** activities for the benefit of future users themselves, but also for students, young researchers and technicians.
The NFFA **distributed** sites throughout Europe will offer their capacities to contribute to raise a **nano educated scientific/engineering workforce** and to the **nano literacy of general public**, thus complementing any other initiative that European authorities may devise within or in parallel to the EU Nanoscience and Nanotechnology Action Plan.

Some of the **far-reaching training** actions envisaged are:

- A science seminar programme taking advantage of the NFFA environment and to be addressed to the NFFA community, thus involving external users, as well as visiting experts and guest speakers.
- The extensive NFFA infrastructure and technical expertise, as well as groundbreaking scientific labour, should be put into use in the form of summer schools and specialised courses. The fact of having a common infrastructure at the different NFFA sites makes it possible to run courses in an itinerant way in the different European regions.
- Collaboration with academia to rearrange in a structured way whatever training content may be found useful to be included as formative credits in masters and/or doctor programmes.
- Common open days with the neighbouring LSFs addressed to the general public and schools to make the societal impact of ‘Nano’ understood, as well as its economic impact (and entrepreneurial opportunities).

NFFA-Distributed Research Infrastructure Technical Layout

Overall Infrastructure

The planned NFFA-RI, distributed in three to six Centres, will be capable of combining open access to both state of the art nanofabrication and complementary analysis methods with the full exploitation of fine analysis enabled by radiation sources methods offered by large scale facilities (LSFs). This combination, not yet present among the available European public research infrastructures, will bring the added value to overcome barriers for the emerging of a more mature stage of development of nanoscience and to remove bottlenecks in the European competitiveness in medium-long term research programmes on nano-functional materials and nano-systems with special implications on energy, health and environmental issues. The infrastructure will offer European scientists a unique access to advanced instrumentation covering the synthesis and fabrication of nano-materials and nanostructures, the advanced nano-metrology and characterization, and all relevant fine analysis methods (SR, FEL, lasers, neutrons) by co-locating the NFFA Centres with the most relevant radiation sources at Large Scale Facilities. This choice guarantees short iteration cycles with frequent and direct interaction among persons involved in sample preparation and in fine analysis, thus widening the opportunities of exploiting materials definition and nanoscale properties. It is the aim of NFFA to provide mature, standardized micro- and nano-technological processes in the broadest sense with unrivalled levels of reliability and reproducibility. Each Centre shall present common characteristics in terms of basic instrumentation platform and organization, such as the division into a set of internal facilities: nanolitography, material synthesis, advanced analysis and metrology, nanomanipulation, nano-bio, theoretical modelling. In addition, the centres will differentiate themselves in conformity with peculiarities connected to the type of radiation source operating on the same site, other complementary existing infrastructures and special regional competences and users' needs, which may be for instance more in the Bio- or in the IT area. NFFA Centres aim to provide European scientists with a novel infrastructure that can support basic science at the nanoscale in combination with atomic precision manufacturing and engineering, along with innovative applications that explore beyond the short to medium term issues of electronics industry and current nano-bio applications.

The basic experimental infrastructure in each Centre will be the same, in order to safeguard compatibility between the centres and an optimal level of redundancy. A very important aspect of the NFFA centres is a standardized metrology adequate for all relevant physical, chemical or biological parameters of the user's samples to be processed.

Typical NFFA Centres should have an approximate total size of 6300 m^2 plus access to a guesthouse (~1000 m^2) for users who may have to stay several weeks or even months, compared to the usually short sojourns of users of LSFs. Each Centre will include a state of the art clean room of about 700 m^2 with various classes of cleanliness. The layout will be "finger-type" which has proven to be most effective and flexible. About 5000 m^2 are necessary for conventional labs, workshops, offices, meeting rooms etc.

Nanolithography Facility

In a near future the production of the most technologically advanced materials will not only be ensured by the methods of chemical/physical synthesis. New functional materials may be produced by contribution of top-down nanofabrication technologies. Thanks to the maturity of the present technology, nanofabrication enables the structuring of materials at scales comparable to some intrinsic physical dimensions (e.g. the mean free path of the charge carriers, the wavelength of optical, acoustical, plasmonic or excitonic modes). Very frequently, these dimensions are on the scale between a few nanometres and a few tens of nanometres.

The possibility to reach, with lithographic capabilities, the scale at which some physical phenomena take place in materials, will allow the exploitation of nanofabrication as a material synthesis technique, conferring to materials new properties departing from those inherited from the chemical/physical synthesis.

Among those new artificial materials, engineered by means of nanofabrication, we find for example photonic crystals, metamaterials, nanomagnets of a single domain, superhydrophobic surfaces, and special optical materials able to alter the polarization and the orbital angular momentum of the electromagnetic radiation.

In addition to the nanopatterning of materials to investigate the above-mentioned changes in their physical/chemical behaviour, nanolithography can also be of importance to NFFA in more indirect ways:

- When the materials under study cannot be patterned directly, top-down nanolithography can be combined with bottom-up approaches. Nanometer sized templates have been used for the guided self-assembly e.g. of block-copolymer structures, colloids or for the growth of semiconductor nanowires and nanodots.
- Nanolithography can enable researchers at LSFs to perform fine analysis on systems of increasing complexity that include working nano-devices. These devices range from very simple ones such as local electrical heaters or thermocouples, to more complex structures like micro-coils for fast magnetic switching.
- An additional close link between nanolithography and a synchrotron LSF is given by the fact, that x-rays are not merely used for analysis, but also for nanofabrication itself. The short wavelengths applied in x-ray lithography or EUV interference lithography offers the potential of high resolution, while the high brilliance is favourable in terms of throughput.
- Nanolithography techniques can contribute significantly to improving the performance of fine analysis at LSFs. These applications include the fabrication of test objects with well-defined nanostructures for benchmarking and calibration of x-ray microprobes. In addition, advanced electron-beam writing techniques are applied to produce high resolution x-ray lenses

To enable a research programme on the wide range of advanced topics in nanoscience, **NFFA Nanolithography facilities** will host the following instrumentations:

- high-end Gaussian beam systems,
- Nanoimprint Lithography systems,
- Dual Beam (FIB+SEM) with pattern generator,
- different scanning probe lithography (STM, AFM and Dip Pen),
- photolithography (mask aligners),
- spin-coaters.

In addition, one X-ray Interference Lithography, one X-ray (proximity) Lithography and one Injection Molding system should be available in the NFFA infrastructure.
Glove boxes, electroplating station, UHV evaporators and sputtering are other equipment that the nanolithography laboratories in the NFFA centres will include.
A range of **pattern transfer techniques**, based on reactive plasmas will be available, such as *Inductive Coupled Plasma (ICP) etchers* for silicon as well as for III-V semiconductors, *Deep Reactive Ion Etching*, *chromium etchers* and an *Ion milling system*. Finally, an area of the facility will be equipped for *Soft lithography methods*.

Considering the different specifications and access regulations of different equipment, the cleanroom should be divided into two main areas, Nanolith I and Nanolith II.
Nanolith I will contain EBL (High-end Gaussian beam system), UV-Nanoimprinting, laminar flow hood with spin-coater and hot plate, and will have tight specifications for cleanliness (ISO4), Thermal control (21± 0.1 °C), antivibration floor and shielding for electromagnetic and stray magnetic field. The use of EBL and UV-NIL will be restricted to scientific/technical staff.
Nanolith II will contain all other instrumentations and will be open to users after proper training.

Material Synthesis Facility

Within the European Scientific Community a strong request for materials growth and nanostructures synthesis emerged in the NFFA survey as basic tools for a nanoscience centre.

Nanostructured materials are becoming increasingly important in many areas as energy storage, environment, detectors and biochemistry, and important advance in microelectronics is perhaps one of the most relevant examples. The actual needs are to tailor novel nanostructures with new geometries and functions (e.g. “functional interfaces”) and to explore new combinations of different materials (“hybrid materials”) paying special attention to the interface with biological materials. NFFA Centres will meet these needs as their major goals.

The NFFA strategy for the wide range of synthesis activities will pursue the following objectives:

- explore the possibility to create **new nano-materials** with **new functionalities**,
- **improve the in-situ monitor of the synthesis processes** in order to better correlate the synthesis parameters to the structure of the growing material,
- take **advantage of the unique co-location with LSFs**, by using fine analysis techniques as advanced tools to investigate the atomic structure of the grown materials,
- foster the **collaboration between nano-synthesis experimentalists and material science theoreticians**.

There is an increasing need to identify well-defined and standardized processes for the synthesis of materials so that they can be reliably reproduced in any laboratory. To increase the reproducibility and to control at the nanometre level all the structural parameters of material growth, which is a basic issue to correlate the synthesis parameters with the nano-material structure and function, it is fundamental to improve ***in-situ*** and ***in-operando*** characterization of all the relevant synthesis steps by using non-destructive and high-resolution techniques. In this respect, an important goal of the NFFA infrastructure will be to optimize the **exploitation of LSFs**. A known problem when accessing synchrotron radiation facilities is the limited time available for sample preparation, a preparation that has to be usually performed during beam time and with a limited number of synthesis and characterization techniques. This is in general a serious drawback and a waste of precious beam time. Ideally one should be able to prepare and characterize samples close to LSFs prior to the measurements. This is a critical point that is not being adequately addressed in most cases and dedicated NFFA Centres close to LSFs would offer consistent solutions like a NFFA end-station or beam line managed by the NFFA Centre dedicated to the *in-situ* study of synthesis processes, or a battery of selected synthesis chambers very close to the beam lines with the possibility to transfer the grown sample from the reactors to the fine analysis end-stations under controlled UHV conditions.

Another original interconnection between the NFFA material synthesis and the collocated LSFs, well suited to improve a systematic understanding of complex compounds, is that of implementing sample libraries, e.g. alloys or metal oxide compounds as obtained by cross wedge depositions on a substrate or other gradient concentration systems that will produce a continuous variation of composition, crystalline, stress and strain properties of a class of samples all grown on a common substrate and separated laterally by tens of micrometers. An automated scan of these properties will quickly identify the “regions” of interest for further investigation and speed up considerably the material science/nanoscience analysis.

A final important challenge for NFFA material synthesis is the dialogue between material synthesis experts and **material science theoreticians**: the systematic availability of experimental results about *in-situ* characterisation of the synthesis steps will serve as effective input for testing new theoretical models on growth and assembly processes and vice versa, easily accessible simulations will act as quantitative data analysis of spectroscopic and imaging data.

The rather broad definition of materials considered in NFFA **Material Synthesis facilities** includes all different forms in which materials can be prepared, spanning from single crystals, thin films and nanostructured materials, to nanoparticles and supramolecular aggregates. An arsenal of both conventional and cutting edge preparation techniques as well as the ability to develop new techniques will be therefore included, pointing to make NFFA material synthesis facilities excel over more conventional ones.

Advanced Analysis and Metrology Facility

One of the major bottlenecks for the development of new nanoscale science and applications is the limited reproducibility of both sample fabrication protocols and experimental results. NFFA will fill this gap by developing the Advanced Analysis and Metrology facility providing full traceability of results and therefore opening new perspectives in sample definition and new certification criteria.

A reliable sample definition is crucial for accessing the Large Scale Facilities (LSFs) in order to optimise the use of beam time and to achieve the research goals. The Advanced Analysis and Metrology facility of each NFFA Centre will warrant the consistency of the results of all preparation and characterization processes.

Besides the well-established techniques for the physical, chemical, magnetic, transport and mechanical characterization of nanostructured systems, NFFA will open the access to state of the art tools that are typically available only in specialized laboratories.

The Advanced Analysis and Metrology facilities will be partially located in the cleanroom and/or organized with modular set-ups that could be physically connected to any other equipment for *in-situ* metrological analysis. The staff of the facility will be constantly updated on developments and potentials needs of developing new tools, with the underlying philosophy of putting on the metrology bench every new atomic/nano scale probe that appears suitable for a broader use.

The facility will extend inside the partner LSF, with NFFA staff personnel working in collaboration with LSF scientists to fully characterize the source and experimental stations, i.e. the accurate determination of the degree of polarization, of the radiation spot size, timing etc.

The instrumentation inside the facility will be divided into a **basic tool set**, i.e. a common platform for all Centres, which will be the skeleton of the NFFA *common metrology*, and an **advanced tool set**, composed of very specialised tools or state of the art instruments, diversified among the Centres according to the scientific specialisation of the single location, linked to the other NFFA facilities, the co-located LSF, the scientific environment, and the local competences at the given NFFA site.

The technical layout of NFFA **Advanced Analysis and Metrology facilities** includes sections and, when deemed appropriate, sub-sections (in brackets):

- Microscopy Section (Electron Microscopy, Scanning Probe Microscopy, Emerging Microscopes)
- Structural, Optical & Elemental Analysis (X-Ray Laboratory, Optics Laboratory, Surface Analysis, Composition Analysis)
- Magnetic Characterisation
- Thermal & Mechanical Characterisation
- Transport Properties
- Advanced Radiation Sources Section located at the LSF

In addition, a Total Characterisation Line should be developed as a fully automated system with a batch of samples moving inside a UHV pipeline through consecutive measurement stations, each equipped for a different analytical technique, providing complementary information for the sample definition standard. The line will be well connected to the data repository for automated data storing. It will be offered as a fast means for fully traceable characterisation of a wide range of basic properties, complementary to the standard, human-controlled activity dedicated to more specific and/or more challenging scientific questions.

The advanced tool set will also include new tools or new applications of existing techniques developed directly inside the NFFA Advanced Analysis and Metrology facilities: once successfully implemented and tested by NFFA staff, these new tools will be made available to users. The choice of the advanced instrumentation, both commercial and in-house developed, has to be guided by the NFFA scientific programme along the directions of foreseen scientific needs, with particular attention towards dynamic, real-time measurements. Possible suggestions include tools capable of working in specific environments, e.g. in-operando, high fields, high pressures, liquids or *in-vivo*.

Nano-Manipulation Facility

Nanomanipulation, or positional and/or force control at the nanometre scale, is an enabling technology filling the gap between top-down and bottom-up strategies. Presently, nanomanipulation is applied to mesoscopic physical phenomena and to the investigation of biological matter. Sample handling and manipulation of bio-materials, specifically for experiments at the LSFs, require nano-manipulation techniques, both for positioning of nano-objects and for applying controlled forces also by exploiting tactile feedback technology (Haptics). The link of the macroscopic world to the nano-world of single molecules, nanoparticle and functional nanostructures in devices which operate under the LSFs beam lines constraints (e.g. microbeam, limited space and time) represents a technological challenge that will be addressed by combining multiple nanomanipulation approaches.

The manipulation techniques (MTs) can be classified as “contact” and “contact-less”, both offering a wide range of possibilities for assembling nanosystems, for positioning and orienting nano-objects in front of a beam for fine analysis experiments, as well as for applying forces to reactive systems like living cells. The entire range of manipulation techniques will be implemented at NFFA. A special regard will be given to contact-less techniques, which provide high flexibility in terms of the manipulation degrees of freedom and of the environment in which they can be implemented.

Both contact-less and contact **manipulation techniques** will be available in NFFA Nano-Manipulation facilities. The offer will include:

- Optical manipulation techniques (optical tweezers, optical levitation)
- Magnetic tweezers
- Dielectrophoretic tweezers
- Scanning Probe Microscopy manipulation (with both STM and AFM)
- Microgripper
- Haptic feedback manipulation

Nano-Bio Facility

The facilities for biological research will be equipped according to the specialization and research focus of each NFFA Centre. The offered infrastructure will include a Biolab user facility with basic equipment (CO_2 incubator, sterile working bench, cryo-microtome) for sample preparation and storage and provide access to special characterization techniques, i.e. a state of the art NanoBio facility supporting ambitious scientific programmes. The nano-bio facility will be developed in full synergy with the other NFFA facilities (material synthesis, nanopatterning, imaging, theory) and will establish common programmes with the co-located LSF and other institutions. Nanobiological research themes addressed by NFFA are: Biointerfaces, Biomimetics, Biosensor devices, Nanomedicine, Toxicology, Proteomics, Protein crystallography.

A NFFA **Nano-Bio facility** will need access to support labs that will to some extent also be necessary or useful for other facilities:

- Chemistry lab: standard equipment and a chemical synthesis facility (fume hood, pH-meters, heating/stirring plates, microcentrifuges, ultrasonic processor, and microscope with CCD camera, glove box with controlled atmosphere, precision balance, and standard chemical lab supply) will be available at every NFFA site.
- Microfluidics lab**:** including stopped-flow / rapid mixing equipment, and automated high-throughput facilities for biological samples. Recent practical experience suggests also considering the need for the presence of a clean area for microdevices assembly.
- Bio-lab: standard equipment includes a biological safety cabinet, laminar-flow box, CO_2-Incubator with inverse microscope with CCD camera and an autoclave. The basic layout of the Biolab should provide sufficient space/infrastructure to allow further upgrades.

Many characterization tools that will be provided by the Advanced Analysis and Metrology facility for other research areas will require only some adaptability, precautions and suitable environmental conditions to be also useable for biological tasks. At specialised NanoBio-facilities, analytical techniques that are most frequently used by this facility will be installed directly inside the BioNano lab area. Duplication of basic tools will only be necessary whenever the danger of (mutual) contamination is present or to handle an overload.
Instrumentation of general use, which will be very frequently used for NanoBio research and should be located inside the biolab: *Spectroscopy (μ-Raman, UV-VIS, IR,) (Fluorescence) Microscopy and Imaging Environmental Scanning Electron Microscopy (FE-SEM) Mass spectrometry, HPLC.*
Methods that are also of interest for other facilities and that shall profit from further development by dedicated research groups: *Cryo- Electron microscopy / -tomography NMR spectroscopy Optical tweezers, Single particle chemistry on biological macromolecules*
A specialised NanoBio facility could also be installed to do research at the S3 safety level, requiring infrastructure for storage, handling and disposal of highly infectious or biohazardous material. This would require a strong interest also from the associated LSF, because it would require investment and safety adaptation also from this side. The most probable location for such a facility would be at a LSF that is already involved in such research.

Theory Facility

Nanoscience is born out of atomic precision measurements of small objects and is addressing, thanks to the availability of short-pulsed sources, the dynamics at the nanoscale. On this ground, the direct interplay of theory and experiment is taking place at a much more direct level than even in condensed matter science, due to the capability of modelling and simulating the exact quantum behaviour of small size systems and the femtosecond-picosecond dynamics. NFFA does therefore include a theory facility aimed at developing a fully integrated approach to the challenges of nanoscience. The NFFA theory facility for materials modelling and simulation will provide numerical and theoretical support to the users in conjunction with experimental activities carried out in the NFFA Centres. It will cover a large spectrum of competences ranging from phenomenology, nanobiology, theoretical materials science, physics and chemistry, down to algorithmic and software engineering. The general goal of the theoretical facility is to provide the detailed and fundamental atomistic insight into materials' properties that allows for optimising their functional properties and for guiding a more efficient and controlled synthesis. The NFFA theoretical facility will develop and apply multi-scale computational techniques for the numerical materials' simulation.

The NFFA facility should be organized around a **multidisciplinary research group** with diverse expertise and background covering nanoscale materials science and engineering / solid state physics / surface science; method development/ computational spectroscopy / many body theoretical physics; quantum chemistry / computational chemical physics; soft matter/statistical and biological physics/polymer theory; scientific software engineering.

The **general methodology approach** of the computational facility will be multi-scale and multi-level, with a particular emphasis on the atomic level. The methods will be optimized for quantitative predictions of materials' properties at time and length scales as different as i) the optical electronic transitions in photo-excited heterogeneous nanostructures (requiring many-body perturbation theories), ii) the electronic ground states of large collections of atoms from several tens up to hundreds (requiring Density Functional Theory approaches), iii) the kinetic and dynamical properties of materials such as molecular self-assembly (involving molecular dynamics with DFT or empirical forces), iv) rare events such as thermally activated processes and chemical reactions (requiring the use of accelerated dynamics), etc. In particular, **computational techniques** based on DFT, in combination with the Car-Parrinello (CP) first-principles molecular dynamics (MD), will be the central computational techniques of the NFFA theory facility.

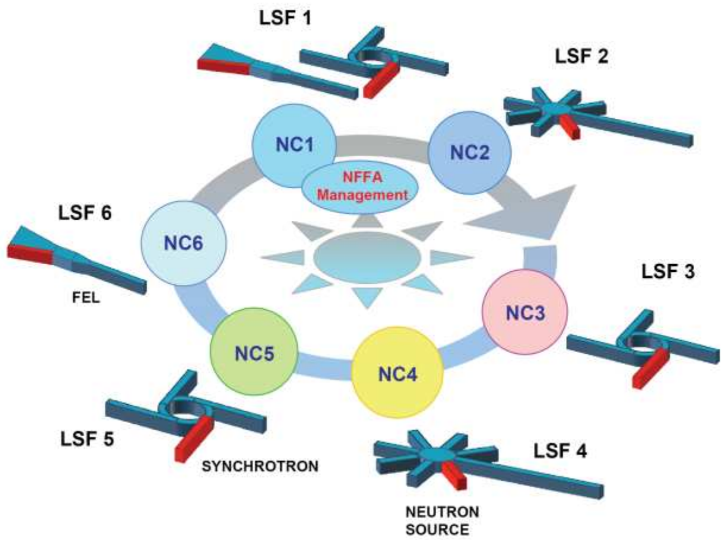
The main objectives of the **Theory Facility** include:

- providing theoretical support to the NFFA users. This can be achieved by the research staff, who will perform quantitative numerical simulations necessary to complement the selected experimental analysis, as well as theory work by external theory users;
- providing computational resources (scientific software, in house computing cluster, and access to massively parallelized external computing resources, including PRACE) necessary to carry out the numerical calculations of relevance, both in presential and remote mode.
- providing training and assistance to the users who request access to the computational resources;
- developing novel theoretical approaches and methodologies as well as optimizing the available implementations. NFFA should become a reference point for the development of new theoretical, numerical, and computational methods for the more efficient and accurate calculation of the spectroscopies and microscopies available in the NFFA Centres. The most challenging and urgent issues on which the theory facility should focus include the accurate description of the excited states of molecular compounds or of complex nanostructured systems (starting from the gas phase but aiming at the complexity of liquid solutions), ultrafast spectroscopies, multiscale simulations with embedding or for accelerating rare events, and molecular dynamics of excited states.

NFFA-Distributed Research Infrastructure Management Structure

Governance of NFFA

The NFFA Research Infrastructure will be a "distributed facility": i.e. a facility with one unique name and legal status, one management structure, one strategy and development plan, and having one annual report and fiscal address although its research facilities are located in different sites and different countries.



NFFA Distributed Research Infrastructure

NFFA's unique portal and central management will be hosted at one of the NFFA Centres. The legal entity has been designed making reference to the ERIC CE Regulation N. 723/200 and accordingly the NFFA prototype statutes have been drafted. The organization model has a central hub, responsible for the coordinated operation of the distributed nodes (NFFA Centres), supported by specific councils with different responsibilities and competences ranging from the overall strategy to the central administration accounting and reporting to the CE and stakeholders.

At the **central level** the Governance structure of NFFA-RI consists of three main bodies:

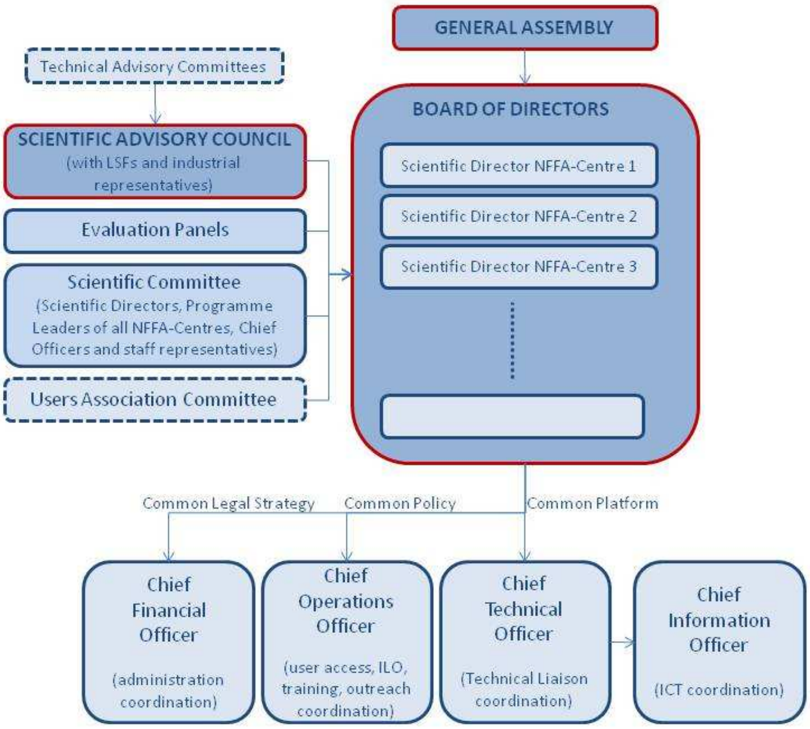
1. The General Assembly (GA**)** is the top decisional body representing all its members (Member States, Associated Countries, Third Countries, and Intergovernmental Organisations). Each Member State may nominate a delegation composed of as many delegates as Representing Entities. The General Assembly is constituted by the delegations of the Members. Each Member has one single vote in the General Assembly that is the full power decision-making body.
2. The Board of Directors (BoD) is the top executive body appointed by the General Assembly and constitutes the legal representative of NFFA-RI. The Board of Directors shall consist of up to 9 components: the Scientific Directors of the 6 Centres plus 3 other members not directly involved with the Centres operation. The Board of Directors implements the decisions of the General Assembly by directing and co-ordinating all the activities of NFFA-RI and is accountable for the RI's finances and management.
3. The Scientific Advisory Council (SAC**)** is an external consultancy body appointed by the General Assembly. It is composed by experts in the field of Nanoscience research, and by experts of Fine Analysis methods, also representing the user community. Its task is to advise the Board of Directors and the General Assembly on the scientific and technical activities carried out at NFFA-RI.

Other ad hoc committees (e.g. Technical Advisory Committee, Evaluation Panels, and Users Association Committee) may be established for the implementation of specific activities and are also consultancy bodies.
At the NFFA Centre **local level** operates a Local Executive Board (LEB) composed of:

- The Centre Scientific Director, i.e. the body having decision-making powers. He/she is appointed by the General Assembly and also sits in the central Board of Directors.

- The Managing Director who is responsible locally for Administration, general Services, Safety Issues, Industrial Liaison Office, User Office and Desk Service.
- Science Programme Leaders, as many as there are scientific programmes. They are responsible for the implementation and results of the scientific programme.

A Local Advisory Committee (LAC) will involve all the local/national stakeholders of each Centre in a support role towards optimizing the local impact and the synergies with the co-located facilities for research and teaching/training.
A flexible **funding scheme** will allow to pool together financial resources available from the different channels: European Commission, Members of the ERIC, European Investment Bank and revenues from limited economic activities. In-kind contributions are likely to be a consistent part of the initial dowry of NFFA and those can be essentially premises (land, new/refurbished buildings), equipment and seconded personnel. In-kind contributions will be evaluated and accepted through strict quality and cost criteria.
The Members must assure a cash flow in order to support the basic operation of the NFFA. The cost of the Distributed Facility Management and Coordination must be overcompensated by the higher capacity of the Distributed Infrastructure to obtain financial means from the future Framework Programmes and from international competitive research projects. NFFA will pursue the goal of a positive balance with respect to the sum of the national cash contributions to the individual Centres.

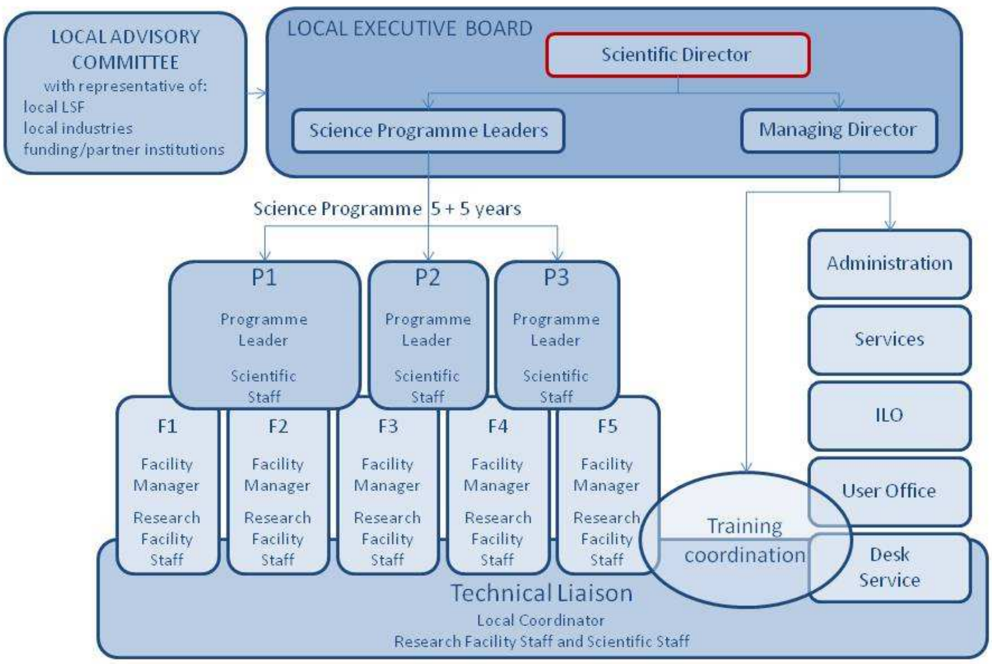


The NFFA-RI central management structure. In bold characters the governance bodies are evidenced, while in dashed contour optional structures are specified

Scientific Management

The scientific management shall be able to follow the rapid evolution of nanoscience and nanotechnology as well as emerging techniques pointing to atomic scale control.
The scientific management of the NFFA distributed infrastructure will be tiered such that two levels are relevant: the NFFA interface to the European researchers as a recognizable element of ERA and, equally important, the local (national) level representing the actual environment of operation of each NFFA Centre. Thus the Centres will operate autonomously at the local level, within the framework of the NFFA distributed infrastructure mission and science programme, therefore optimizing their activity through full integration of skills and techniques and internal (inter-Centre) mobility of personnel. Advisory Committees, invited from academia and industry as well as representatives from the local Large Scale Facilities (LSFs), will cooperate with the management to ensure that research follows the correct direction and is updated as time progresses.

The **local management** structure of each NFFA-Centre will be project-driven-like, that is, the main scientific responsibility will be channelled into the Scientific Programmes. This will be better suited, with respect to competence driven management, to address scientific challenges and better guarantee the proper level of interdisciplinary research. In parallel, Facility Managers (FMs) will operate the laboratories and run work-plans for users. The NFFA-Centre Scientific Director, a Managing Director and the Programme Leaders will constitute the Local Executive Board (LEB). A Local Advisory Committee (LAC) will be formed from representatives of local (national) academic institutions, industries and LSFs to give a voice to their needs and opinions. Finally, with the main target to make two of the NFFA key objectives (the common platform of metrology and protocols and the data repository) effective and reliable, a NFFA Technical Liaison (TL), made up of personnel operating under a set of rules and coordination procedures, will manage the technical competences inside and among the NFFA Centres.
The **central management** structure of the NFFA-RI, will operate with reference to the governance structure of the ERIC (or similar international legal entity). Top level management will consist of a General Assembly (GA, decisional body) and the Board of Directors (BD, executive body). They will be advised and assisted by the Scientific Advisory Council (SAC, consultancy body) and the Evaluation Panels. Financial, Operations and Technical Chief Officers will be appointed to coordinate responses on local demands and needs in such a way that common strategies, policies and technical platforms will be found across the distributed infrastructure. A Scientific Committee (SC, which may include a number of staff-elected representatives) will operate to have an internal inter-Centre consultancy.
One NFFA-Centre will act as Headquarters, that is legal seat, central Administration, secretariat supporting the Board of Directors and central User Office. It will host items and activities which cover the whole NFFA-RI (e.g. Data Repository hardware and maintenance and ICT platform, as well as administration functions, organization of periodic reviews, media and public awareness, programme assessments and reporting).
The overall research time at the Centres should be 70% user programme 30% in-house research (NFFA scientific programme). To this effect, scientific research **staff** will work 50% of time in support of the users and 50% in carrying out the NFFA in-house research programme. The facility staff engineers, on the other hand, will be mainly dedicated to the user programme with the option to dedicate up to 15% of work-time to the original development of specific in-house research projects. NFFA personnel will be either hired directly by NFFA or seconded (full time or part-time) to NFFA by other institutions for a given number of years (possibly reiterated) as well as visiting scientists in sabbatical leave from universities or other institutions.



The local management structure for a typical NFFA-Centre

Access and Partnership with Large Scale Facilities for Fine Analysis

The NFFA concept is based on a close collaboration with the LSF for Fine Analysis both in terms of science programme and user programme, i.e. access rules integrated within the NFFA proposal scheme. Different options are valuable and a variable geometry scheme of integration shall be adopted. The general philosophy of NFFA is that most or all the advanced methods based on radiation sources (SR, FEL, neutrons) are relevant for nanoscience and should be supported when integrated in the nanoscience proposals submitted to NFFA. This implies a framework agreement with the LSFs in general and to those co-located with NFFA centres in particular for optimized access to the facilities. One explored possibility is to establish a BAG (Block Allocation Group) system that, while undergoing the periodic peer review process by the LSF, does allow direct management of the access, within the BAG quota, by NFFA. Such scheme is operating successfully at several European facilities for the structural biology community that needs quick access when new protein crystals become available and act as consortia of users. NFFA could, under such scheme, warrant the optimal access to NFFA proposals including work at the LSF to be done on “fresh” samples or urgent studies, whilst the LSF would maintain peer-review control *a-priori* and *a-posteriori* on the science. The BAG could extend to all or some of the beam lines and instruments. Alternatively, or complementarily, some specific beam lines or instruments on high demand by the NFFA users could be built and operated jointly with the LSF or could be entirely owned and operated by the NFFA co-located centre. These options may apply differently in different centres and with different LSFs, but will always represent a substantial optimization of access to fine analysis by nanoscience research and, vice-versa, a substantial improvement of sample preparations and metrology control for the LSF experiments. Part of the collaboration with the LSF will be on development of instrumentation based on nanotechnology and nanometrology, so that a scale economy will result from the framework agreements.

IPR

Intellectual Property Rights (IPR) issues require a no-nonsense policy to be established in order to make the open access as effective as possible, avoiding the bottleneck of heavy paperwork even for industrial users. Both for non-proprietary and proprietary research a Non Disclosure Agreement (NDA) will be issued by the NFFA structures (User Administration, Advisory Panels, Technical Liaison, facility research staff, etc.) involved in the idea/proposal processing and the proposal will be tracked by a temporal mark testifying the temporal allocation of the specific idea, as it enters the NFFA Data Management at the proposal submission time. Afterward, the main IPR criterion is based on a user request basis, in case evaluated ex-post, trying to avoid stringent fixed rules which may turn out to be annoying bottlenecks with little positive effect.

The proposed user-request-based option for non-proprietary data is that the IPR could be handled in three stages:

1. For an agreed time window (expected no longer than 3 years) the data work-space will be accessible only to the “parent” users and their authorized collaborators. After the embargo time, the work-place will be reduced in the useful data to be archived in the Data Repository, therefore becoming available to open access by “third-users”. If, within the embargo time, a patent pending or intent is addressed, additional Non Disclosure time windows will be provided, via ex-post evaluation on the previous window. The evaluation will account for actions made by the users (patent filing, contracts with other institutions, etc.) and prior art reports.
2. The Data Repository will be open for a “read only” external access; the use of the data for further analysis by third-users will be subject to permission by the parent user. This can stimulate collaborations and the exploitation of non-published or marginal data.
3. After a longer time (say ten years) the data will become completely free access with a caveat that there is always an explicit reference indicating the sources. Therefore, from the third-user point of view, whenever an access request is submitted to read or download data or protocols from the NFFA data repository, he/she will be asked to formally accept the rules and conditions set by the NFFA DR.

Industrial property and in general IPR concerning private institutions, will be properly managed in order to avoid even non controlled internal leak among the NFFA staff, that can eventually translate in an external leak of protected information. Only authorized NFFA staff will have access to sensitive information regarding proprietary research and industrial property.

In order to satisfy an adequate level of quality data management, any operation on the data repository, data entry or output request, will be recorded on the data repository and the user will be identified.

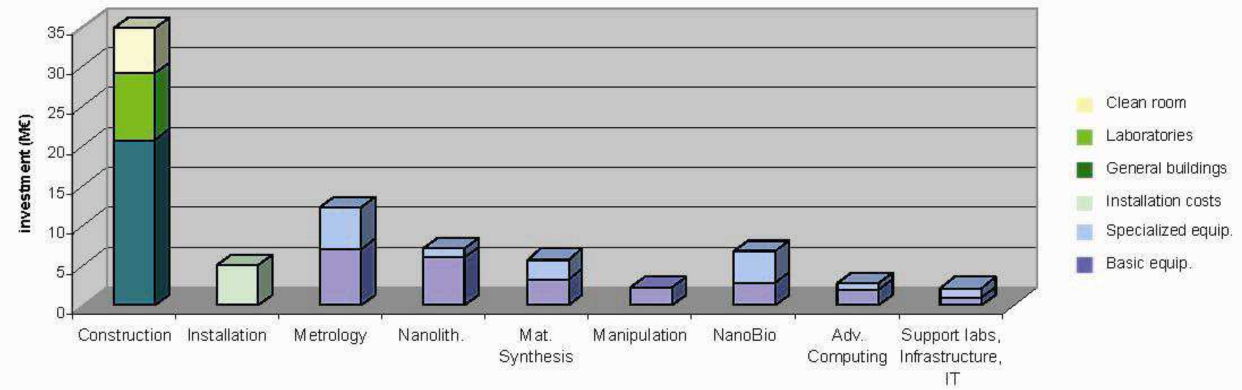
Construction Costs

The financial issues relate to NFFA-RI construction and exploitation. According to the NFFA roadmap, the implementation of the NFFA-RI will take place in two phases – firstly, three Centres will be funded and set-up, while additional sites will be installed later and will profit from the experiences of the phase 1 Centres.

The preliminary construction layout includes a total area of 6300 m², of which 700 m² will be reserved for cleanrooms. Additional 1000 m² should be available for a guesthouse for the users. Current construction costs of cleanroom area are about 8 k€/m2; building costs for "general use area" and standard laboratories are around 4-6 k€/m² (€ value 2010). According to these numbers the investment for construction of one NFFA Centre in a green field would be about 35 M€.

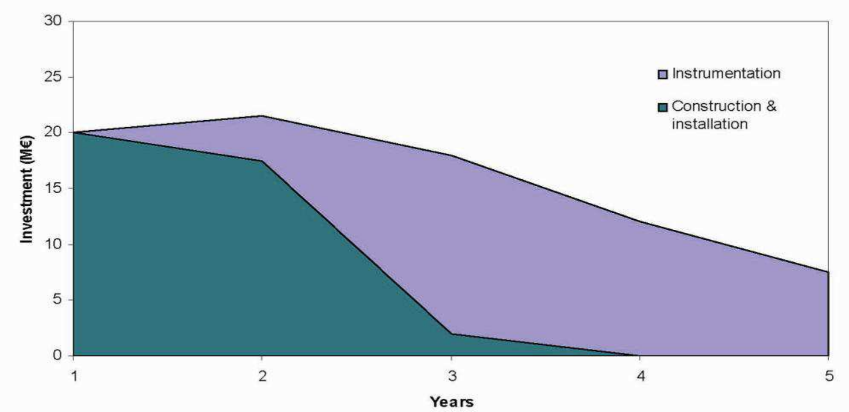
Besides the construction costs, additional 22 M€ for common infrastructure including support labs, technical infrastructure, basic scientific equipment should be considered. A sum of 5 M€ must be budgeted for additional costs during the installation phase of equipment.

Costs for specialized computing and for the whole IT infrastructure at one NFFA Centre are estimated around 2 M€. All Centres will have similar basic activities but they will differ in their particular specialisation. The average investment cost for advanced instrumentation, related to the specialisation of the particular Centre, is estimated to be 6 – 8 M€. The overall reference cost figure for a fully equipped and operational NFFA Centre is of 70 M€.



Graphical representation of the investment averaged costs for facilities and supplementary infrastructure for one NFFA Centre

The specialisations are likely to be driven by activities of already existing facilities and by national and regional interests. Duplication should be avoided to ensure that the NFFA distributed infrastructure covers the best possible range of techniques, and acts as an effective distributed infrastructure scheduling different parts of a given proposal in different NFFA centres where needed.



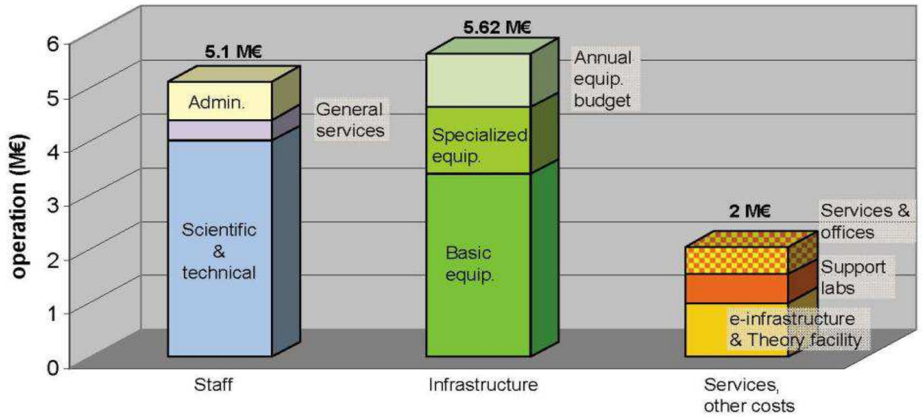
Development of investment costs for one NFFA Centre during the first five years (Development/Construction/ Investment for primary infrastructure)

Operation Costs

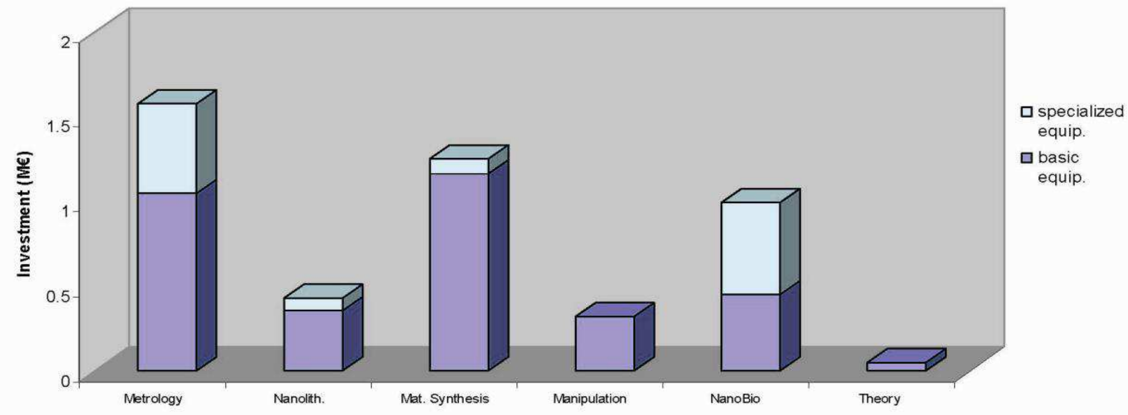
The layout of a **Prototypical Reference Centre** has been used as the basis for addressing running costs specific to the operation of the NFFA infrastructure, without taking into account possible synergies with existing institutions or facilities on the same sites. Therefore the Prototypical Reference Centre is introduced as a newly constructed facility *on a green-field* including all basic infrastructure and equipped with instrumentation for basic activities as well as advanced instrumentation in the specialized research areas as Metrology and Advanced Analysis Facility, Nanolithography, Material synthesis, Molecular and nano-particle manipulation, Nano-bio laboratory, Computing, but not including general urban services.

Provisional costs for the employed staff have been estimated to be about 5.1 M€ for ~65 people. An annual budget of ~1 M€ for the renewal of the Centre's equipment was estimated; additional costs directly related to the number of users and the users' activity were also considered. These costs are actually very variable since the wages and taxes are not at all uniform in Europe. A reference value has nevertheless been taken into account.

The total running costs for basic instrumentation were estimated to be about 3.4 M€; additionally, 1.24 M€ for advanced equipment were considered.
In this exercise we do not take into account the travel expenditures of users to come to the NFFA Centres. In the current framework programme (FP7) I3-type contracts support the users access to European research infrastructures. Our hypothesis is that in the next European research and innovation common strategic framework a direct support of the UE towards the running costs of the facilities enabling the open access will be in place. Accordingly the issue of users travelling costs will be redefined.
Overall a yearly budget of 13 M€ has been estimated, which also contains the sufficient provisions for maintaining the state-of-the-art level of the nanofoundry.



Composition of the running cost for personnel, scientific and general infrastructure for one NFFA Centre



Expected running cost for each facility of a prototypical NFFA Centre. Costs for basic and specialized instrumentation.

NFFA-Distributed Research Infrastructure in the ERA

The NFFA Distributed Research Infrastructure will play a key role in the European Research Area as it will in fact provide unique services to the scientific community and optimize the use of the large scale facilities for fine analysis in the strategic domain of nanoscience and nanotechnology. The NFFA centres will provide a reference for nano-metrology, standardization of protocols, potential certification and open-access to relevant data that will support both the basic science by European researchers that do not have access to advanced nanofoundry labs in their home institution, and by nanoscience centres that do not have the possibility of reproducing their protocols in an integrated environment including synchrotron or neutron or FEL measurement stations and advanced experiments. Likewise a structured open access to numerical analysis and theory of matter at the nanoscale and mesoscale will be offered integrated with the relevant experimental programmes. The expectation of build up of the users community is very high. New nanocentres are planned in the large concentrations of science laboratories, like Lund and Hamburg. These have the option of developing in the context of a European distributed infrastructure, optimizing the offer to the science community, and possibly realizing scale economies (procurement) and standardization of protocols and metrology such to create an attractive offer also for the industrial development sector, at the precompetitive innovation level.

1.4 POTENTIAL IMPACT

Expected impacts listed in the work programme

The concept of a cluster of nanoscience facilities attached to LSFs, which aims at raising the standards of nanoscience experiments and offering access to state-of-the-art synthesis and nanofabrication to a wide research user's community, has been included in the 2006 ESFRI roadmap by one of the specific Emerging Proposals named NANOSCIENCE. Thus, the NFFA proposal fully enters in the structuring project for the ERA, with the support of the EC under FP7.

The European potential users of NFFA belong to diverse areas: materials science, physics, chemistry, life-sciences, various branches of engineering, bio-medical application, etc., and come from academia, national research institutions, and industry. Currently there are no open facilities for supporting full nanoscience projects involving design and nanofabrication of samples and functional systems. The research is done via collaborations between different institutions, with a generally low pace when complex processes are involved at far away institutions (like growth, lithography, electrical characterization, protection of samples, acquisition of beam time at a LSF).
For this reasons, a strategic plan for a scaled implementation of Centres and their locations in Europe both in close connection and synergy with specific LSFs is needed at European level. This action will provide effective services also to nanoscience users from Countries that do not host LSFs.

The NFFA-Distributed Research Infrastructure will ***greatly empower the European Research Area by providing unique Nanoscience and Nanotechnology research and innovation instruments.*** NFFA will help to ***overcome the fragmentation of the European research landscape*** and foster competitive research excellence by ***a)*** providing nano-foundry activities and ***state-of-the-art facilities for nanoscience and fine analysis*** to a large European and international research community operating basic science, ***b)*** building a fully ***synergetic infrastructure of nanocentres*** and the co-located ALSFs for fine analysis, ***c) integrating the most relevant fine analysis methods*** in nanoscience research protocols. NFFA-DRI will effectively increase the potential for innovation and contribute to the development of an ***open and competitive European Research Area*** (ERA). The communication and transfer of knowledge will be implemented with a new data management system, the free circulation of researchers from academic and industrial laboratories will be supported and an advanced training programme with academic relevance as well as for the requalification of engineers and technicians operating innovation in industry and services will be implemented.

NFFA aims at filling a gap in the ERA concerning the nanoscience and nanotechnology research infrastructure. No large European Infrastructure for nanoscience is currently in the ESFRI roadmap, although the NFFA project has been included in the emerging projects in the 2006 Roadmap and in the landscape in the 2010 Roadmap update (that was restricted to Energy, Food and Biotechnologies projects).

Strategic Impact: structuring effects on quality and operation of European nanoscience laboratories and ALSFs enabling advances in science and in innovation
The NFFA Design Study has addressed the need and opportunities to build a European Distributed Research Infrastructure on Nanoscience integrating the relevant methods of Analytical pan-European and national/regional RIs.
A first impact has been the inclusion in WP2012 of FP7 of a topic on nanoscience infrastructures (Topic 21).
Europe makes large investments in nanoscience and nanotechnology research as well as in analytical research infrastructures. The NFFA expected impact is in increasing the volume of world leading research in the field of nanoscience taking fuller advantage of the existing facilities, and contributing to attract and train a new generation of scientists capable of exploiting the ERA in the domain of nanoscience and to establish direct links and synergies with the relevant industrial developments and new services.

Impact of realizing a European common advanced baseline for Nanoscience research with full integration of the Analytical Large Scale Facility methods
The NFFA-DS has set the basis for advancing the common baseline of methodological, metrological, data management and user interface of the consortium that represents a significant fraction of the whole effort in European nanoscience. NFFA has addressed directly the innovation issues, the improvement of effective access by industry and services to basic science infrastructure, and may develop further synergies with Joint programming and other EU and national and international undertakings in nanoscience and nanotechnology. The development of

a data repository for such multidisciplinary and complex research will potentially impact also a broader access to the knowledge and the know-how developed by nanoscience projects.

Innovation based on research is expected to be a key asset for recovery and sustainable development. Innovation contributions from the NFFA-DRI shall come from high priority actions in know-how transfer, data/metadata public availability, and involvement of industry/service operators in training by experimental development activities, stimulus towards productive enterprises based on research results.

A specific training activity will be addressed to boost access of industry. The chance where industry meets “hands-on” activities carried out in research laboratories must be increased, most likely starting from desk-service where typically characterization is the dominant request. Hands-on is the definition adopted in the NFFA Design Study where people, in this case employed in the industry, will spend a bit of time in carrying out some experimental development in the laboratories, in alternative or complementing colloquial contacts

Impact on future European Distributed Research Infrastructures

The NFFA-DRI will be an asset for the EU and the ERA. NFFA-DS has a direct impact to the ERA since, at least, two co-located projects are underway implying several tens of M€ investments: the nanocentre at DESY (Hamburg) and the nanocentre LINXS at Lund represented by ESS.

Impact of Joint Research on key enabling tools for advanced nanoscience research and innovation, in a fully integrated effort of nanofoundries and fine analysis ESFRI-class RIs

Innovation will be relevant both in the direct domain of research infrastructures for nanoscience, their operation, their ability to exchange protocols and to have absolute metrology, and in the direct collaboration with industry. The Integrated Access concept of NFFA-DS addresses a barrier that has been indicated as a key bottleneck of knowledge and know-how transfer from research to industry.

The training and mobility of researchers, engineers and general users is another prerequisite to produce innovation by creating a distributed interface (the trainees) between their employer companies / public services and the research infrastructure and data repositories.

Exploitation

The main effort of NFFA is to improve the overall return of the investments in nanoscience, and the related quota of investment in the relevant ALSFs, by offering integrated access and developing integrated joint research to optimally exploit the existing facilities, either national, regional or pan-European to the benefit of research and innovation activities. Introduction of an accepted advanced data/metadata management and of the first repository of nanoscience data and protocols will create an all new method of work for a broad community and establish, in the field of nanoscience a novel knowledge management protocol.

The NFFA activity will directly impact on European nanoscience by monitoring the effective response to users' needs, qualitative and quantitative, contributing to the development of a RI integrated science policy.

The expensive equipment for nanofabrication will be better procured and exploited in NFFA user Centres allowing also for a faster update. E-beam lithography machines or TEMs, as examples, are multi-million Euro instruments with a 5-6 year life at the edge of technology. Intensive use at NFFA Centres will make overall financially possible to stay at the state-of-the-art by replacing and upgrading even the top equipment. This is hardly affordable by typical nanoscience national laboratories in Europe, and simply not available to most of the academic research groups, or to entire national research communities within Europe.

Routine technical cross checking of the nanofabrication and nanoprobing capabilities of the NFFA Centres will provide the metrology for establishing a NFFA standard that should result in great benefits for European research in nanoscience.

Just one example of research that will take advantage of the NFFA paradigm is the wide effort in the study, design, fabrication and experimentation in vitro and in vivo of nanostructured devices and micro systems of biomedical interest for in *situ* release of drugs (e.g., oncological cures, pharmacological treatment of tumours). The world-wide research is aiming to the development of smart systems that allow driving in time and space the release of drugs inside the human body by means of an in-out interactive communication, leading to an in *situ* controlled drug release. NFFA Centres would be excellent faculties for the materials synthesis and nanofabrication stages of this research, and for designing and performing innovative experiments using diagnostics of the LSF sources.

Integration. Researchers joining the project will be part of a truly European cluster, with co-ordinated science planning and with geographically distributed Centres sharing common facilities as well as specialised methods and tools. This implies that NFFA researchers will be certainly mobile within the NFFA Centres, as a key feature of NFFA, which will be able to enforce effectively the uniformity of quality standard.

The NFFA researchers will be exposed to a high flux of international users bringing in their advanced research projects (selected by international review) and the related challenges that will often push forward the state-of-the-art of nanoscience, and the standard of NFFA. The NFFA researchers will be in close contact with the scientific and technical staff, as well as with the users groups operating at the neighbouring LSF, making the overall environment extremely rich and multidisciplinary. Mutual benefits of seminar and conference activities at the NFFA and LSF are easily foreseen. The NFFA researchers and associated personnel will also carry out in-house research programs with full access to the advanced facilities, i.e. in a unique environment for Europe. We expect NFFA researchers to be, after a 3-5 year working term, extremely qualified to contribute at the highest level to industrial research and development, or to start own activities, perhaps with NFFA spin-off or start-up schemes to be analysed at a later stage of structuring of NFFA.

Users' serving or coaching as well as teaching and training in nanoscience will also be an opportunity for NFFA researchers to develop communication skills that will develop their attitudes to co-ordinate research in nanoscience and in general, helping the formation of a much needed technically and scientifically aware European leadership.

We believe that NFFA will increase the level of cultural uniformity in research at the highest level, so **it will favour integration in its broad sense**. We also believe that the project itself will take advantage from the melting of different points of view and cultural roots.

Finalizing dispersed high quality research. European research in nanosciences has strength and weaknesses typical of the large number of good level scientists, but the relatively small number of "critical mass" groups and centres capable to fully support the exploitation of new ideas and the reproducibility of results such to help in quickly translating into nanotechnology the nanoscience findings that bear that potentiality. NFFA can fill in part this lack of infrastructures by making a top-quality one open to the users. Active groups will be supported and best projects by sub-critical groups may become joint projects involving some in-house effort. All these effects should be greatly beneficial to European science and to integration of research efforts.

The NFFA project will strongly contribute in optimizing the activity of the European research community in the very important field of nanoscience and nanotechnology. Synergies with the e-infrastructures and with other distributed RIs will be developed on many relevant aspects in the formation of the ERA, including access modes, interoperability of data, open information and reference standards and protocols.

Socio-economic Impact

The socio-economic impact of NFFA will be measured in terms of "increase of amount and quality" of European nanoscience research. The indicators will be multiple, from the more easily measures, like publications with high impact factor, patents with exploitation agreements, number of advanced trainees (Ph-D- thesis, specialization of engineers, technicians, managers), spin off activities with commercial aims. Local socio economic impact at the NFFA sites will reach beyond the usual employment, procurement and operation contracts (utilities, services) since it will contribute to the establishment of science parks with nanotechnology/nanomedicine mission providing advanced services to large, medium and small enterprises. Local universities will also greatly benefit from the presence of NFFA for engineering, materials science, biology, physics, medicine and more, improving their competiveness on the global level and attracting best students from all Europe and abroad.

NFFA will also contribute to improving the science awareness of Europeans with specific outreach activities.