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Big science and big administration

Confronting the governance, financial and legal challenges of FuturICT

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Abstract. This paper considers the issues around managing large scientific projects, and draws conclusions for the governance and management of FuturICT, based on previous experience of Big Science projects, such as CERN and ATLAS. We also consider the legal and ethical issues of the FuturICT project as the funding instrument moves from the Seventh Framework Programme to Horizon 2020.

1 Vision, goals and opportunities

The goals of the governance and legal structures of the FuturICT project are:

- to support the scientific endeavours of FuturICT and ensure that its goals are realized,
- to enable and encourage the opportunities for innovation and collaboration within the FuturICT community,
- to ensure that the outcomes of the research work make the most effective contribution to the creation of wealth and social benefit within Europe, and
- to do so in a way that is demonstrably fair, legal and ethical.

The scientific research will be driven forwards by the Innovation Accelerator [10,18], the Living Earth Simulator [15], the Exploratories [5,19], the Global Participatory Platform [4] and the Planetary Nervous Systems [9]. The work of the FuturICT Foundation will ensure that the research outcomes will be developed and exploited, and will support a stream of income that will continue to fund the work of FuturICT beyond the initial tranche of EU funding. To ensure integrity and

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best practice within the FuturICT community, due care will be paid to the structure of decision-making and responsibilities within the wider network of FuturICT stakeholders.

In setting up the governance and legal structures described later in this document, we have taken care to keep in mind four key opportunities. These are explained below.

Facilitate a true ‘man on the moon’ scale initiative with a modern, effective management structure.

There are, necessarily, very few science projects of the scale of the FET Flagship projects. Some mega-projects exist, such as very large construction projects, railway networks or sporting events, which cost of the order of billions of Euros and may take more than ten years from project approval to completion and delivery. However, the management practices that are appropriate for corporate or engineering environments do not transfer readily to academic, research environments. Therefore, we will re-think some of the notions from the traditional project management communities, and integrate with best practice from current large science projects to develop a governance and legal structure that will best serve the FuturICT research community, its funding organizations and other stakeholders. We will draw upon the ideas from complexity science to develop new approaches to the encouragement and development of multi-modal, networked scientific collaboration, while maintaining accountability and ethical behaviour.

Support the European Research Area, enabling links between countries and between different types of research actors.

The FET Flagships are presented with the challenge of integrating the work of researchers from many different nationalities and research cultures, and at different stages of their careers. In addition, FuturICT will integrate the work of three academic disciplines – ICT, Complexity Science, and Social Science. These three communities of scientists have been drawing together for many years, through transfer of scientists from one discipline to another, and through shared conferences and workshops. In particular, Complexity Science has been effective in bridging the gap between the ICT and the social sciences, with many multi-disciplinary research teams already operating successfully within Europe. For example, the Cabdyn research group (www.cabdyn.ox.ac.uk), based in the Saïd Business School, consists of researchers with backgrounds in engineering, physics and mathematics, but with strong links to sociologists, biologists, anthropologists and economists elsewhere in the University of Oxford and beyond. Building on this multi-disciplinary history and culture, the next challenge for Complexity Science is to link the communities and scientific disciplines of social sciences and ICT.

Collaboration between countries will be made explicit in the FuturICT governance structure by making the workpackages the focus of the governance and project management operational activities, while providing other structures and resources to enable the formation of communities based on national and regional groupings and competencies. By bringing together the expertise of researchers in many nations, the leadership teams of the Focus Areas and Work Packages will enable integration and research development between countries and research actors.

Improve European innovation and competitiveness using the outputs of FuturICT and promote links to business.

The outputs of FuturICT will make a profound and lasting contribution to European competitiveness and innovation, through the Innovation Accelerator and contributions to the formulation of policy, for example. These and other

exploitation activities will be supported by clear policies on the protection and sharing of Intellectual Property Rights; policies on the flow of any earned income back to FuturICT in order to support further research; the encouragement of links to innovation and mentoring support; and the creation of the FuturICT Foundation that will support new start-up and spin-out firms.

Create a management structure that has clear responsibilities, yet is decentralized and adaptive.

The FET Flagship projects are attempting a scale of decentralized scientific collaboration that has rarely been seen before. The governance of FuturICT will need to enable and support multi-disciplinary, multinational collaboration and research, yet simultaneously it should make clear the lines of responsibility and accountability, never forgetting our responsibilities to the citizens and tax-payers of Europe who are funding and supporting this research. We recognize that the governance structure that will be put in place to manage and oversee the FuturICT project, although based on that of successful Big Science projects, may need to be adapted as the project itself evolves over time, within the context of a rapidly-changing technical, legal and ethical environment. Hence, it is unlikely that the initial governance structure will endure unaltered for the first 10 years and beyond. The framework will therefore contain mechanisms to review the performance of the governance structure and committees, and to enable their revision periodically.

Furthermore, the legal structure that is set up under the EU's Seventh Framework Programme funding instrument for the early years will also need to support and enable the four goals considered above, while enabling as smooth as possible a transition to the new legal structures that will be available in the post-FP7 period, under Horizon 2020.

2 The challenges of big science

Regardless of the problem encountered, when dealing with projects in Big Science, there are several different considerations that must be taken into account right from the beginning, which are not encountered in everyday research problems. Programmes that cost billions and extend over years, involving national and European Community interests and multiple agencies, are distinctly different in that they require almost perfect coordination, agreement by all stakeholders, and well designed methodologies and approaches to carry them out. In consideration of this we propose a list of six points which should be clearly considered and emphasized during the course of the project in order to minimize hurdles and increase the probability of success [12]. Of course, this list is not exhaustive at all, but it should certainly include the items below as minimum criteria.

- (a) Set a clear and focused goal or target. One needs to know clearly, and well in advance, the goals that are to be attained in the project. These goals must be selected in concord by all stakeholders, and must be widely agreed upon. Coordination is always difficult where many agents with different stakes in a large enterprise are involved. Ambiguous goals without the means to measure their attainment exacerbate confusion and conflict. The more focused the goals are, the better the chances for a smooth solution to the problem the project is intended to address.
- (b) Emphasize common interests. A key interest that should be promoted in most science and technology endeavours is an increase to the level of funding for the project's research areas. Funding agencies and other stakeholders need a positive

incentive to cooperate, and obtaining more resources to support the project can provide that mutually beneficial activity and goal. To obtain the resources and put them to proper use, collaborating partners in the consortium must cooperate fully. Thus, the better the cooperation between the agencies, the higher is the probability to receive the maximum possible support. However, there are other non-financial interests that can increase cohesion, such as highlighting a project's contribution to foreign policy, economic development, health, or even a general sense of pride of accomplishment.

- (c) Attract political support. These larger interests help attract political support. If the technical agencies exert a push, the politicians (and their surrogates) constitute a policy pull. For domestic and international programmes, what the key leaders can seek is the status of a governmental initiative. Thus, the government must be convinced first that the goals sought are for the benefit of the country or international grouping in the long run. In addition, legislation underpinning a collective inter-agency activity can serve to sustain the programme across governmental transitions, and should therefore be sought.
- (d) Employ strong but diplomatic leadership. The leaders of Big Science endeavours should be proactive, but understand the limits of power. In this context, “leaders” may be the Chair of the Flagship Strategy Board, the Chair of the Executive Board, or the Principal Investigator, or the Chair of a host institution. Whichever role is fulfilled by a leader, their power and position will be negotiated over time with the wider collaborating team. Separate agencies or stakeholders (as separate nations) have power bases independent of the would-be coordinator, who is therefore more likely to get joint action through consensual tactics than coercion. History has shown that when there is no prior agreement or a general consensus between the different stakeholders, then the project may get started, but may subsequently crumble into pieces and result in total failure to achieve the stated goals.
- (e) Retain staff support. There is an “overhead” inherent to joint activities, which may involve considerable time and effort beyond what individuals do in their home institutions. Leaders need the help of secretariats (or their equivalents) and of staff devoted to facilitating joint activity, such as meetings and the preparation of interagency documents. Good coordination between staff from different agencies is a vital requirement, and here the ability of the Coordinator to inspire and lead his or her staff in unison toward the common goal is critical.
- (f) Hold to the end, but be flexible as to the means. Achieving the goal of a Big Science endeavour can take many years. The leader helps the enterprise to adapt whilst always keeping the intended end goals in sight. The successful leader maintains an overarching strategy, but remains flexible as to the specific tactics used to fulfill it. It is useful to think of the joint activity as an exercise in coalition building. The leader adapts the coalition to changing conditions, stressing interdependence, and holds to the goal through mutually acceptable adjustments over time. The leader needs attainable interim goals to provide morale-building victories and reasons for the participants to stay in alliance. The abilities of the leader to address all these challenges together in a convincing and successful manner will largely determine the overall success of the project.

3 What are the big challenges today facing FuturICT?

In this section, we identify the specific challenges related to the management of FuturICT, within the framework of Big Science.

3.1 Is social science accepted as a science?

Social Science is named as the “The next big thing?” in the cover page of *Nature* (Feb, 1, 2007), but in many scientific environments it is not yet even considered as a legitimate scientific field. In particular, within the community of practitioners of “hard sciences” it is still often seen as mere intellectual entertainment and, for instance, physicists that decide to embark on the challenge of contributing to social science problems are often regarded with suspicion. This feeling is shared to a great extent by society at large, a paradigmatic example being that US Senator Kay Bailey Hutchinson’s proposal to the US Congress in 2006 to cut the entire Social and Behavioural Sciences budget of the National Science Foundation. The story is discussed from this perspective by D. Watts in his book addressing the question of why attempts to predict and manage socio-economic systems often completely fail [20]. It is then clear that a first policy challenge is to provide compelling arguments that social problems can be approached and investigated from established scientific protocols and that answers can be provided to well posed social questions. The second challenge is the dissemination of these arguments to the general scientific community and in appropriate media in order to reach the general public.

3.2 Defining priorities: Basic and applied research

The basic/applied dichotomy is in many aspects an old-fashioned and administrative differentiation. Priority should be given, as a scientific policy, to strategic research; i.e. focusing on advanced studies in fields with strong future potential while avoiding incremental research in well-established fields. The intersection of ICT, Social Sciences and Complexity Sciences at the core of FuturICT is a perfect example of strategic research. This research is full of extraordinary intellectual challenges addressing very new fundamental unsolved scientific questions, whilst having tremendous impact on issues of immediate and very important social relevance. The two ingredients define the project’s strong future potential impact.

3.3 Building a community

Enhancing transnational governance and co-learning processes across geographical and administrative boundaries is an important issue in any big scientific undertaking. This is even more the case in FuturICT in which there is the need to create the community of scholars working in this new field, with researchers coming from very different backgrounds. To integrate these groups in a community that can speak with a unified message to the central European political actors, including feedback processes with the definition of new national research priorities, is an important task. It can be demonstrated that the activities of the initial FuturICT pilot project have already achieved important results in this direction.

3.4 The need for public and open research

Privacy issues and concerns about scrutiny of our activities on the internet is a primary public concern. When an uninformed Google Mail user is told to observe how the advertisements on the Gmail web page change depending on what he or she writes or reads in a message, he or she normally becomes alarmed. There will

be, for sure, reactions within the media and in different public forums (including parliaments) against a project that, if interpreted wrongly, could be understood to be attempting control citizens' lives through accumulation, scrutiny and management of the various footprints left online. It is then an urgent and important challenge to convey to the public and political actors that what FuturICT intends to do is already being done on a considerable scale by private companies that operate in telecommunications or the internet, and that these companies will continue to do it regardless of public opinion. FuturICT is the European-level alternative to these activities with the goal of having open and public research in this area that can be democratically controlled in line with strict ethical protocols and with databases accessible to all interested parties. The equivalent of the present situation in meteorology would be that databases for meteorological prediction would only be owned by private companies. Public debate on these issues in the European media is needed.

We shall show in the remainder of this paper how these, and more, significant challenges are being addressed by FuturICT through a carefully designed governance model, alongside initiatives for the appropriate processes for managing issues within the project as they arise.

4 State of the art

In this section, we will review briefly some of the project and programme management ideologies and methodologies, and consider briefly the extent to which they are applicable to the FuturICT endeavour. We will consider the management and governance of an existing large science project, i.e. the ATLAS Experiment at CERN, and identify how FuturICT may draw lessons from this undertaking.

4.1 FuturICT: Project or programme?

An important question is whether FuturICT should be considered as a programme or a project overall. There are several possible definitions of a project, and a few examples are given below.

An endeavour in which human, material and financial resources are organized in a novel way, to undertake a unique scope of work of given specification, within constraints of cost and time, so as to achieve unitary, beneficial change, through the delivery of quantified and qualitative objectives [16].

A set of human and non-human resources pulled together in a temporary organization to achieve a specific purpose [6].

Are unique and frequently take place over an extended period of time and demand the engagement of a wide range of resources, including people, finance, facilities, materials and intellectual property. In most circumstances, projects have defined objectives or an end-state that provides those involved in the project with a clear vision and specification of their goal [7].

The conclusion we draw from these definitions are that a project is a well-bounded piece of work, with (more or less) clearly defined objectives to be delivered, and with defined constraints on budget and delivery date. But a project is more than simply a set of coordinated tasks, it may also be an organization in its own right, with all of the complexities and issues that are typical of any organization.

Consider now a programme, which may be defined as:

A programme is defined as a temporary, flexible organization created to coordinate, direct and oversee the implementation of a set of related projects and activities in order to deliver outcomes and benefits related to the organization's strategic objectives [14].

Programme management is the coordinated management of related projects, which may include related business-as-usual activities that together achieve a beneficial change of a strategic nature for an organization [1].

A programme is an organization created to coordinate, direct and oversee the implementation of a dossier of several projects and transformation activities that deliver benefits related to key strategic objectives [3].

Programmes are also **organizations**, which manage a portfolio of interrelated projects. We see too that programmes are **transformational** in their scale and intent. They intend to transform the way in which an organization, or a nation, operates. Whilst a new bridge that crosses a river might change the volume and balance of traffic that uses different routes, this undertaking would be categorized as a project rather than a programme. The introduction of a new technology for harvesting and distributing renewable energy would be a programme, because of its far-reaching impact that displaces current energy generation and distribution technologies, and with possibly far-reaching consequences on the way that energy is used, measured and paid for by consumers. All of these transformational changes would be translated into the specific goals of a series of linked projects.

Let us compare projects and programmes:

In principle, projects exist and thrive on certainty of outcome, whereas programmes exist and evolve in more ambiguous environments [13].

To paraphrase, a programme's success is based on the realization of *benefits*, whereas a project's success is determined upon the delivery of a well-defined *output* within constraints of *time* and *cost*.

Based on these characteristics of projects and programmes, we may conclude that FuturICT has the characteristics of a programme, as defined by the UK's Office of Government Commerce (UK OGC) and other organizations, and should therefore be managed as such. As such, the FuturICT management team should consider adopting, and adapting, some of the principles of the UK OGC 'Managing Successful Programmes' approach or a similar programme management methodology.

In the next section, we review existing best practices that are available as standard textbook guidance on the management of major projects and programmes (i.e. Managing Successful Programmes) and an example of a successful Big Science project, the ATLAS project at CERN, a project that has many features similar to FuturICT.

5 Project and programme management methodologies

In this section, we will discuss a well-known and established standardised project management methodology, the UK OGC's 'Projects in Controlled Environments' (PRINCE2) [13]. In the next section, we will describe briefly some of the

management practices of the ATLAS Experiment, one of the largest science projects currently underway in Europe.

5.1 PRINCE2: Projects in controlled environments

PRINCE2 (Projects in a Controlled Environment) [13] is a structured project management methodology that is used extensively around the world by 20,000 organizations in 150 countries. PRINCE2 was developed by the UK Office of Government Commerce (OGC), and it has undergone several revisions following a continuous process of benchmarking and stakeholder feedback. The methodology covers the full project life cycle, including project governance, and provides tool-kits for risk and quality management. It purports to be fully customizable, and is designed in a way that allows it to be tailored to any number of different projects and project environments. According to the OGC, the organizational context of projects is becoming more and more complex, requiring a more comprehensive and customizable approach to the management of such large, far-reaching and complex programmes. Given PRINCE2's track record in improving the management of projects via a comprehensive structured approach, it could be considered as a possible methodology around which to structure the management of the FuturICT flagship project.

FuturICT, rather than being based on a simple customer/supplier relationship involving two organizations, is a venture that involves a large number of heterogeneous organizations working in collaboration. Although the European Commission can be considered to be the authority commissioning the project, in a very real sense the project will be 'multi-owned', with participating stakeholders ranging from national ministries to businesses, as well as the individual scientists and their institutions. Therefore, unlike PRINCE2 projects where one organization has ultimate control over the decision-making process, FuturICT will be obliged to operate within a wide, democratic consensus. PRINCE2, therefore, is not a suitable methodology for the governance of the FuturICT project, as the necessary single origin of authority cannot be established. For this reason, the OGC suggests the adoption of organizational structures of programme management to assist with benefits realization and stakeholder engagement in large collaborative projects [13]. Therefore, although PRINCE2 may be useful in application to certain aspects or sub-divisions of the FuturICT project, it becomes apparent that it cannot usefully be applied to the totality of the project effort.

5.2 The ATLAS experiment

The ATLAS Experiment is an example of a large, multi-institutional research project, which has had twenty years of development and reflection during which to develop its governance structure. We review below the structure of the governance of ATLAS to identify the lessons that we may learn from their experience.

The ATLAS Experiment is one of the four detectors of the Large Hadron Collider (LHC) of CERN. The LHC is an underground ring in which two counter-rotating beams of particles are accelerated to speeds approaching the speed of light. At four points in the ring, the beams collide and the fragments of subatomic particles that emerge are detected by the instruments placed around the collision points. ATLAS is one of these four detectors.

ATLAS consists of around 20 million separate components. It was assembled in an underground cavern on the beam-line of the LHC over a period of about four years, although it took about twenty years to design, simulate and construct the instrument.

The team that is building ATLAS is a collaboration of about 3,000 research physicists, supported by a small team of administrators and secretarial support based on the CERN campus.

CERN is the European Organization for Nuclear Research, and is based outside Geneva on the French-Swiss border. The CERN Convention in 1953 established CERN, with 12 countries signing up to “assist and encourage the formation of regional research laboratories in order to increase international scientific collaboration”. Now, CERN is run by 20 European member states, but with many other countries and organizations holding Observer status. Scientists from 608 research institutes around the world use CERN’s facilities. CERN provides the LHC and the beams of particles, as well as on-site infrastructure. ATLAS is responsible for designing, building and operating the ATLAS detector which detects the particles that appear during the collisions on the LHC.

In this section, we will review briefly some aspects of the governance and project management of ATLAS which have enabled this uniquely complex instrument to be developed and operated.

5.3 The management team of ATLAS

According to the ATLAS website:

ATLAS is a virtual United Nations of 38 countries. In this troubled world, it is inspiring to see people from many lands working together in harmony. International collaboration has been essential to this success. These physicists come from more than 174 universities and laboratories and include 1000 students. ATLAS is one of the largest collaborative efforts ever attempted in the physical sciences.

The ATLAS management team consists of five people:

- Spokesperson
- Two deputy spokespersons
- Technical Coordinator
- Resources Coordinator.

Their responsibilities are as below:

- The Spokesperson and Deputy Spokespersons have the responsibility to globally overview all aspects of the ATLAS project, and to react appropriately. The Spokesperson represents ATLAS with respect to CERN, funding agencies and other outside bodies. [outward looking]
- The Technical Coordinator is responsible for the common project construction and the technical integration of all ATLAS components. He or she should also overview the implementation of ATLAS engineering standards and procedures, and also monitor the detector construction. He or she is assisted by activity managers. [technical & project focused]
- The Resources Coordinator is responsible for the overall resource planning, and to ensure that the ATLAS resource needs are consistent with the different local national planning. The Resources Coordinator is also directly responsible for the administration of the ATLAS common fund.

Spokespersons are elected by secret ballot from within the Collaboration Board for a period of two years, with the possibility of extension of that term by a further two years. The Spokesperson may nominate their deputies, but these choices are ratified by the Collaboration Board (see Fig. 1).

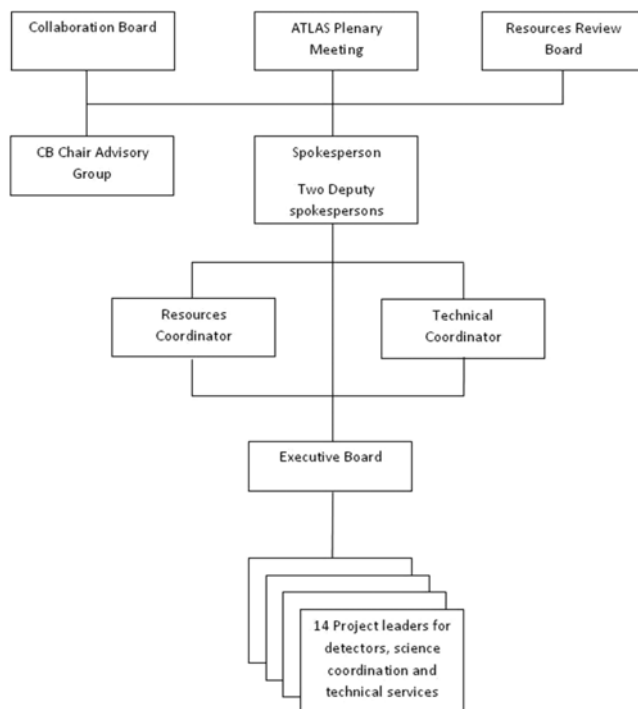


Fig. 1. The ATLAS governance structure.

What is remarkable about this structure is how few people are required to manage such a huge, widely distributed team. In some ways, the task is made easier by the fact that the team is mono-disciplinary, i.e. they are all physicists and all understand the common goal to which they are all contributing. Furthermore, the focus is further tightened by the fact that the builders of the instrument will also be the users, which means that rapid feedback loops may be set up so that potential use problems are detected quickly and fed back to the project team(s) that can address them. The budget for ATLAS covers only the materials that are used to construct the machine, while the salaries of most of the scientists and students who work on the project are covered by their host institutions. Although this simplifies the budget negotiations, it means that the ATLAS management team cannot use the usual procedures of hiring and firing team members. One of the other remarkable features of ATLAS is the large number of meetings that occur every day. There are informal meetings and seminars taking place on site on the CERN campus, but many video-conferences go on every day, enabling scientists from different locations around the world to view and share their results.

5.4 Organizational structure of ATLAS

The organigram of ATLAS is shown in Fig. 1. There is a clear distinction between policy setting and operations, with the management team (above) as the body responsible for translating agreed policy into action. Every year, there are a number of ATLAS Weeks, when the entire community meets together with the stakeholders (i.e. the funding organizations and CERN) to share the findings of the past year's research, plan the year to come, look further ahead to the next generation and instruments, and make challenging and far-reaching decisions involving strategy.

6 Governance challenges

In this section, we will review and discuss the governance challenges that affect major collaborative, academic projects and indicate how they are being addressed within the FuturICT project.

As indicated in Sect. 2, the governance of FuturICT must combine ethical, accountable practices and behaviour, combined with frictionless collaboration between and within many nations, institutions, and disciplines. The structures we propose will attempt to address this tension.

Since global problems necessarily require the involvement of a large number of scientists, it is imperative that they have all agreed to a certain common way of operating, which will eliminate or reduce the impact of the differences in their approaches. In other words, it pays to have a certain number of guidelines to which all participants agree to abide. Such guidelines include the following points (see Sect. 2):

- Setting a clear and focused goal or target,
- Emphasizing all common interests,
- Attracting political support to the their cause,
- Employing strong but diplomatic leadership,
- Retaining staff support,
- Using external competition for internal cohesion,
- Holding to the end, but being flexible as to means.

This list is not exhaustive but it is indicative of the central requirements to be considered upon embarking on a large-scale, or ‘Big Science’, project.

FuturICT is based on the three disciplines of ICT, Complexity, and Social Science, so the governance and management approaches should build on current practices that are acceptable within the cultural and legal norms of the institutions, but they should equip and enable the scientists to achieve the maximum interaction, collaboration and dissemination. This will lead to greater impact and penetration of the research outcomes.

A challenge for major academic projects is therefore to create a management structure that:

- Enables and supports the stated goals and deliverables of the project’s contract,
- Is consistent with the contractual obligations of the project scientists who are employed at host institutions across a number of countries,
- Recognizes the working methods of scientists and scientific teams,
- Is clearly understood,
- Provides a clear distinction between policy setting and operational management,
- Ensures transparency,
- Satisfies the many stakeholder organizations.

Within individual research institutions, scientists tend to work in small to medium-sized teams, but meet to share their findings at national or international workshops and conferences. This mode of distributed team working has been marshaled effectively by large collaborations, such as the ATLAS project, which has regular short-term visits by scientists working on the project, longer placements of a year or more for scientists and students, and salaried scientists who work full-time and permanently on the project. Thus, the ATLAS project combines a distributed network of small teams working around the world, with a management structure to support the central integration, sharing and distribution of ideas, findings and results. In the ATLAS project, this loosely coupled structure of distributed teams is supported by a small, central team of executive officers, who are overseen by a Flagship Strategy

Board. This model has been used to inspire the proposed management structure for FuturICT.

FuturICT has (at least) five additional challenges that are *not* faced by the ATLAS project -

- The designers and builders of the outcomes of the FuturICT project will not be its only users, as FuturICT's users will also be citizens, policymakers, scientists and businesspeople. In contrast, the scientists who designed and built ATLAS remain its users.
- The ATLAS project has been twenty years since conception to delivery, whereas FuturICT will have a shorter initiation and delivery timescale of about 12-24 months in the specification phase and ten years in the development and delivery phases.
- The ATLAS Experiment has a single "boundary object", i.e. the ATLAS detector, which serves as a focus for the community, as well as providing a single tangible deliverable of the project. FuturICT will have a number of deliverables, inter alia the Observatories, distributed around Europe.
- FuturICT will aim to exploit effectively the research outcomes of the project in collaboration with business, whereas CERN and ATLAS deliberately hold very few patents on their work.
- The FuturICT community will be made up of scientists from three communities: complexity science, ICT and social sciences. These have separate cultures, social norms, frameworks of ideas and vocabularies of concepts, rather than a "mono-culture" of physics supported by engineers.

The ATLAS project is built by a large, international team of physicists who are using the instrument to detect the presence or otherwise of sub-atomic fragments. They are committing their careers to the development and design of this instrument so that they may eventually use it to test theories of the structure and nature of matter. The ATLAS project grew from a team of physicists who had already been working together on related projects, so a collaborative culture and modus operandi were already well-established. CERN holds only a small number of patents on its many technical innovations, but none on its most famous innovation – the World Wide Web. CERN believes in the free and open dissemination of knowledge for peaceful purposes, so has no obligation to exploit the outcomes of its work or to protect its IP.

While many of these goals, and the supporting culture, would be shared by the scientists and researchers of FuturICT, we will have to include extra arrangements to support and enable the inclusion of external stakeholders in the specification of the deliverables of FuturICT, and the exploitation of FuturICT's research outcomes. In this section, we shall consider four broad classes of challenge that will be faced by FuturICT. Although many of these challenges will be faced by other large FET Flagship projects, FuturICT has the additional challenge of forming a multi-site, multi-national, multi-disciplinary team.

6.1 Multi-site, multi-national, multi-disciplinary challenges

Although the ATLAS Experiment consists of a very large number of scientists, they do have the advantage that these are mostly physicists, who are working within a community that has been in place since the early 1950s, giving time for cultural norms to become established, and the organization to have developed a deep understanding of the processes and procedures that are required for the operational activities to run smoothly and efficiently. In practice, this means that the rights and responsibilities that must be accepted, for example to have the right to be included as an author on a

publication, have been addressed and a policy has been agreed and enacted. Therefore, one of the challenges that FuturICT will have to face is the integration of scientists and researchers from a range of disciplines, each with their research methodologies and cultural norms.

Furthermore, there will be challenges to building up the shared knowledge and mutual understanding of the research methods and models derived from the discipline of other scholars. This will take time and goodwill, as will the process of learning to work in a multilingual team, with different cultural approaches to solving problems, managing the workload, running a project etc. Multi-national teams have to cope with different time zones, different public holidays, different accounting practices, and different dates of term and teaching responsibility, since many of the researchers in the project will be university teachers too. Although these may seem like simple factors, they can generate organizational friction, which will slow down the smooth operation of any new major collaborative project.

FuturICT will be based on many sites, with a number of core partners and a growing and evolving number of contributing and sub-contracting organizations, as calls for proposals are issued and projects and workpackages are completed. This will mean that FuturICT will have many aspects of a Virtual Organization, enabled by electronic means to support collaborative working. This will mean electronically enabled meetings using video-supported telephony, shared documents that can be worked on simultaneously by small teams of collaborators, shared diaries and schedules etc. This will require a balance between sharing and openness, and discretion, security and commercial confidentiality.

Although many researchers may be accustomed to electronic communication, the team dynamics and organizational behaviour of the Virtual Organization will need to be considered and managed with foresight. Supporting the Virtual Organization will be a real organization with its own legal identity and resources, tasked with the management and administration of the FuturICT project. This organization will have the full backing of key FuturICT participating centres, yet as an organization with a singular purpose it will be well positioned to consider and fulfill the needs, goals and expectations of the project as a whole.

Finally, it should not be overlooked that an important integrating factor of the Flagship project is the management norms and regulations required for EU funded projects, such as Seventh Framework Programme 'Integrated Projects', 'ERA Nets' and other instruments with which the team members are already familiar. Thanks to the familiarity of team members with these procedures, there should be fewer problems in operationalizing the contracts and legal obligations into an overarching FuturICT governance structure and project management systems.

6.2 Scale challenges

Few scientists have the opportunity to work within a major programme during their career. A major programme in the commercial or public sector is often defined as a project or portfolio of projects that costs more than \$1B and lasts more than 5 years. FuturICT is of a similar scale (\$1B), and is planned to last for 10 years. Few experienced project managers in the commercial or public sector work on projects of this scale in their professional career, so academic scientists and researchers are very likely to find this an unusual experience, and one for which they may be ill-prepared.

The challenges of projects of this scale are well documented [8]. Often, projects are delivered over budget, late, and not meeting their specifications. Frequently, it often happens that for infrastructure projects, the usage (in terms of passengers or journeys, for example) does not meet the expectations on which the project was

originally justified. There are many possible reasons for this pattern of poor outcomes, despite much work by researchers, public bodies, and the associations and institutes of project management in the UK and US to identify and recommend good practices that should eliminate the behaviours and common problems that lead to undesirable outcomes [1].

6.3 Optimism bias

One frequently occurring behaviour on the part of those who propose and justify the project is optimism bias. Optimism bias causes people to assume that previously seen problems will not occur, or will be easily solved, with minimal impact on cost and time to deliver. Although every project is unique, projects may be categorized and compared. These studies show that high-technology, high-risk projects tend to be particularly vulnerable to delays and problems. All of the proposed FET Flagship projects are examples of these high risk projects, so are all likely to encounter significant delays and challenges during their lifetime.

Large scientific research projects have many of the characteristics of risky projects, but some other unique features that bode well. Risk factors include: advanced, untried and novel technological developments; multi-disciplinary teams; and multi-site working. Other problems that occur frequently in any sort of large project include lack of a clear goal, poorly defined objectives, and poor governance. However, the advantages available to large academic research projects include a well-disciplined and coherent academic community with clear social norms, and the likelihood that the designers and builders of the system will be amongst the first group of users. Hence, they have a built-in interest in seeing that the project will have a successful outcome.

Large technical projects can quickly become very complex, in several senses of the word. First, there can be a very large amount of information that needs to be distributed around the extended project team. This information needs to be generated, approved, logged and archived by the distributors. It needs to be read, understood and processed by the recipients. Secondly, as the number of participants in the project grows, the number of possible interactions between the participants and their teams grows polynomially. Thirdly, the project team and the object that they are creating can both develop emergent effects, both in the ways in which the team members interact, and in unexpected and unanticipated interactions between components of the produced object. These effects can be very difficult to identify and overcome, because they are systemic and are due to the very nature of a large project.

6.4 Structural challenges

One of the early challenges of implementing a large-scale European project is to assemble a world-leading consortium of European and international actors and fuse them into an effective project consortium. This consortium must then be structured in such a way that the following requirements continue to be met throughout the project's lifespan.

6.4.1 Collaboration

The structure should provide for a truly European and integrated effort, and allow the unrestricted flow of ideas, knowledge and researchers within the project. As such, the project will contribute directly to the goals of the European Research Area, particularly those related to healthy competition and the free circulation of researchers

and knowledge. In order to enable frictionless collaboration between the community of scientists, industrialists and users who will be participating in the development of FuturICT, we will make provide funds for frequent face-to-face meetings as well as on-line and virtual meetings; there will be conferences and workshops held at local, national and international level; FuturICT will be present as an exhibition stand, conference session, presentations or keynote speaker at as many as possible European and global conferences within the technical and industrial scope of the FuturICT project; and special cross-cutting special interest groups will be set up, such as Young FuturICT, which will build up the FuturICT collaboration and awareness networks of the future.

6.4.2 Responsibility

Clear lines of responsibility must be established, so that the project work, reporting and liaisons with external stakeholders can be correctly reported and managed without confusion. In FuturICT this will be achieved through the implementation of the governance structure detailed within this document, as well as via contractual instruments at the institutional and consortium level. It will be crucial to ensure that those responsible for monitoring the quality of the work of the project have the ability to reject work of substandard quality, and thus withhold project resources until the issue is corrected.

6.4.3 Flexibility

The consortium structure should be flexible and able to adapt to changes as the project progresses through its funding cycles. The structure should also be flexible enough to allow funding to flow from a number of different sources into the project and be allocated correctly to the relevant participants, according to clearly stated and agreed policies. The European funding instruments that will be available to the Flagships during their later stages are unspecified at this time, so the legal structure must be flexible enough to adapt to the changed situation, without requiring major upheavals to the governance structure and management practices. As the project progresses, new associates and partners will be included where they have particular expertise that is needed for the FuturICT programme or in response to FuturICT Grand Challenges [11], so flexibility will be needed in the management of contracts, governance structure and management processes.

6.4.4 Administrative coherence

The consortium must be structured to fit the requirements of the various funding mechanisms, as well as being consistent with national legislation and the rules of all of the legal instruments that are to be used to deliver the project.

Achieving all of the above requirements is a challenge that should not be underestimated, particularly in projects requiring the involvement of a large and international group of heterogeneous organizations. These challenges are compounded when the project's funding streams must also be drawn from a number of different European, national and private sources, as this introduces a number of overlapping legal and financial regulations, which will be considered in more detail below.

6.5 Legal and financial challenges

The Flagship projects are being created in a period of negotiation and considerable uncertainty. Therefore, there will also be a number of legal and financial challenges that must be anticipated and mitigated. The constraints and possible funding instruments are discussed below.

The first cycle of funding for the FuturICT project will be drawn from the European Commission's Seventh Framework Programme (FP7), which concludes in 2013. The use of this instrument would mean that the FuturICT project will be initially constrained by some of the legal and financial regulations that must be applied to all FP7 projects. Some of the most pertinent issues arising from these constraints are outlined below.

6.5.1 Consortium limitations

FP7 instruments are not designed to allow the participation of parties other than the consortium members in project work. Coupled with the limitations on the size of the consortium, this limitation is problematic in projects of the scale anticipated for FuturICT. It will be up to the management team to find a workable solution to this problem in conjunction with the European Commission's services.

6.5.2 Third party limitations

FP7 instruments are not designed to allow the participation of parties other than the consortium members in project work. Coupled with the limitations on the size of the consortium, this limitation is problematic in projects of the scale anticipated for FuturICT. It will be up to the management team to find a workable solution to this problem in conjunction with the European Commission's services.

6.5.3 Competitive call limitations

Strictly speaking, competitive calls for proposals released by project consortia, and subsequent funding of the proposed work, are not supported by the available FP7 instruments. A workable solution must also be found for this problem, as without the ability to publish competitive calls, the FuturICT goals of supporting the best science and healthy competition will be compromised.

6.5.4 Planning complexities

From a contractual perspective, it is very likely that any FP7 project will be required to remain internally consistent as a single project, i.e. a 'stand-alone' project in terms of its effort and goals. This will mean modifications and adaptations to the overall FuturICT flagship project plan, as the relevant parts of the flagship will need to be apportioned into the FP7 Grant Agreement.

6.5.5 Outside funding

The treatment and control of outside funding (both national and private), as well as funding from programme managers such as research councils, would have to be agreed with the Commission beforehand.

The development of the legal and governance structures will require a robust model of how the organizational dynamics of FuturICT are likely to evolve, given the nature of the project's research challenges, the rapidly evolving technological background, and the personalities and working relationships of the principal scientific and managerial actors who are already in place. However, the structures presented below are the output of many hours of meetings and discussions, as well as consultations with other domain experts and people with experience of managing large science projects.

7 Innovation and expected paradigm shifts

Like ATLAS, the team members of FuturICT will consist of scientists and researchers employed by their home university or research institution, supported by a small, core team that will provide the project or programme management and support. In this way, the day-to-day research work of FuturICT will be carried out by networks of small cells of scientists, who are accustomed to working together in their teams, but with mechanisms in place for regular face-to-face meetings of the entire FuturICT community through, for example, FuturICT Weeks. Frequent use is already being made of video-conferencing, through web-based tools such as FlashMeeting.

7.1 Impact

The FuturICT Project will contribute to the goals of the upcoming 2012 European Research Area Framework, and thus improve the performance of the European research system as a whole in the related fields. These goals are to:

- improve the quality of doctoral training, attractive employment conditions and gender balance in research careers;
- improve mobility of researchers across countries and sectors;
- enhance cross-border operations;
- improve dissemination, transfer and use of research results, including through open access to publications and data;
- improve exploitation of existing research infrastructures;
- improve relevance of research to society, and make it more responsive to societal needs.

7.2 Governance

Establishing a clear and effective governance structure is critical to the project's success. Ensuring that this structure meets the needs of the project is both an initial and an ongoing task, and cannot be dealt with lightly. This structure requires:

- Defined roles
- Clear responsibilities of these roles
- Management structures and reporting arrangements to deliver the project's work
- Clear and free communication between groups and between individuals.

In order to support these goals, and to ensure integrity and good practice, FuturICT will set up a governance structure that follows good practice from other major science projects and recommendations from programme and project management guidance. The governance structure may be amended from time to time as FuturICT develops, in response to changes in funding, technology, leadership and legislation, for example. In particular, although FuturICT is beginning during the FP7 regime, it is not possible at this time to know what the legal and governance requirements of Horizon 2020 will be, so we must be able to amend the governance in response to these requirements as they become clearer.

A guiding principle in the design of the governance of FuturICT is the separation of policy and implementation. The level of strategic policy setting will be distinct from the operational level, although both will be informed by the other, since issues of cost, timeliness and legal and ethical constraints will have to be understood and clearly set out throughout the governance and management structure. This distinction will be enforced by a Flagship Strategy Board that sets policy, and an Executive Board that oversees the implementation and operation of the workpackages.

7.3 Management

The programme management team will set up a Project Office, which will be responsible for the administrative support tasks, such as managing the outward-facing website; managing the archive of documents, publications, social media mentions, press releases, films, photographs and images; managing the calls for proposals; overseeing finance, recruitment and HR; and planning and managing the FuturICT Weeks and other events. These tasks will be undertaken by skilled and experienced administrators who will carry out these essential tasks in order to support the delivery of the science. In addition, there will be a Technology Transfer Office and a FuturICT Foundation that will manage the funding of development projects; support the licensing and exploitation of IPR, and raise additional charitable donations and commissioning of research that cannot be funded within the terms of the FuturICT project.

The day-to-day management of the programme will be supported by a Core Management Team made up of no more than six people, who will be the key post-holders within the FuturICT governance structure. They will be supported by a Project Office, which will provide the professional administrative expertise on contract management, finance, project management, human resource management etc that would not be expected from academics.

Further detail of the vision and implementation of this approach may be found below in the next sections.

7.4 Multidisciplinarity

A guiding principle of the governance of FuturICT is to ensure the fruitful integration of and collaboration between the three scientific disciplines on which FuturICT is built. In other words, we must avoid people becoming silo-ed or retreating back into their home institutions or disciplines. Rather, we build the governance upon the model of the FuturICT community as a network of collaborators who may be involved in more than one of the workpackages at any time, so that the workpackages are assumed to be networks of researchers who are interacting and directed towards a particular goal.

Multidisciplinary research cannot be achieved overnight, and can take a considerable time to build up the mutual understanding, trust and respect that are the

basis of any kind of research. Scholars from different disciplines are accustomed to using different research methodologies, whether qualitative, quantitative, simulation-based, or involving interventions and action research. However, by working together and sharing approaches to complex problems, the scientific outcomes and research methods can be improved.

To enable multi-disciplinary research, several initiatives will be supported by FuturICT including:

- Multi-disciplinary workshops, that will
 - consider and compare each discipline’s approaches to setting research questions and selecting research methods to address a problem,
 - identify differences in approach to modelling a problem,
 - identify homonyms and synonyms within the vocabularies used to discuss and frame a problem, e.g. different understandings of words such as ‘complex’, ‘value’ and ‘norm’. Social scientists and mathematicians, for example, would have quite different interpretations of these words.
- Short courses for students and post-doctoral researchers to introduce them to the methodologies of other disciplines, with comparative approaches to research questions.
- Incentives for encouraging within FuturICT the co-authorship of papers in disciplines beyond the authors’ original discipline.
- Prizes and awards for the best multi-disciplinary papers, books and other publications.
- Special funding for multi-disciplinary short projects.
- Opportunities to work with artists to explore the expression and investigation of multi-disciplinary topics through novel media.

A true community takes time to build up the network of relationships and shared values. The vision and goals of FuturICT will bring many researchers together from a range of disciplines. The formation of the community will be encouraged and expedited through community-building activities that will foster the values of trust and respect which will sustain the project through, and beyond, its planned ten-year lifecycle.

7.5 Promoting wide participation

Taking our lead from the ATLAS project, we can learn from how they manage the engagement of 37 countries and over 100 research institutions. The ATLAS project has a strategy level body which is made up of one representative from each of the funding nations, regardless of the size of the financial contribution that each country makes. (It is the case that ATLAS only pays for the materials that constitute the Experiment – the salaries of the scientists are paid by their host institutions. Therefore, the national representatives are representing the funding bodies that may be paying for the salaries of the researchers, travel and accommodation at ATLAS, and contributing to the materials for the components that are manufactured locally. The universities and research institutes are also contributing through salaries and other costs.) This, although the financial contributions may vary greatly in absolute size, they will also vary significantly with respect to the GDP of each contributing nation.

We propose that the governance of FuturICT should also include a Funders’ Panel, which would meet annually during the FuturICT Week. This would also include one representative from each funding organization that is contributing funding and support to FuturICT, either through the salaries of scientists, research council funding via an ERA-NET, or support of projects aligned with FuturICT.

In addition, to encourage community-building at the national level, FuturICT will encourage and support national one or two-day workshops, which may be part of the FuturICT Week, so that scientists from each nation can find out more about each other's research projects, set up exchanges of students and researchers, and encourage collaboration and co-authorship of papers.

Finally, it is intended that the FuturICT Flagship project will promote a 'Stairway to Excellence', in line with the European Union's plans to enhance the European Research Area. This 'stairway' will see the twinning of organizations participating in FuturICT, with elite internationally-renowned organizations providing support, advice and best practice to more nationally-renowned organizations. Through this process, the nationally-renowned organizations will proceed further and faster on their path to international renown and excellence, and thus further permanent benefits of the FuturICT project will be realized across the consortium and across Europe.

7.6 Science/policy balance

From the outset, the FET Flagships have been identified as science-driven projects that are intended to bring about a step change improvement in Europe's leadership of new technologies, and as a desirable place for European scientists to work. In order to achieve these benefits, there has to be a fair balance struck between the needs of the scientists who will be doing the work, the taxpayers and politicians who will be funding the work and enjoying the benefits of its outcomes, and the businesses and commercial organizations who will seek to exploit the outcomes in order to bring the benefits to society and create the wealth that will cover their risk. The needs of these separate interest groups and stakeholder communities must be acknowledged and given fair voice in the governance and management of FuturICT.

At the strategic level of FuturICT, there will be representative bodies that will be separately presenting to the Flagship Strategy Board the communities' views through the advisory boards and representative panels. The chair of each of these boards and panels will be a voting member of the Flagship Strategy Board. Furthermore, a representative of the EU as the main funding agency will also be a member of the Flagship Strategy Board.

Thus, the advisory and representative boards will enable the principal stakeholder groups (scientists, business people, citizens and taxpayers, and national funding agencies) the opportunity to present their views and to comment on the planned direction of FuturICT research and its achievements to date. Thus, the Flagship Strategy Board will be a balanced group of the representatives of the external stakeholder groups, with a balanced number of scientists and members of the FuturICT research community and management team.

8 Proposed governance structure

The governance structure provides a clear distinction between policy setting and operational enactment, so as to provide a clearly understood path for reporting information, making decisions and escalating issues. See Fig. 2.

At the top of the governance structure will be a Flagship Strategy Board that will agree the strategic direction and objectives of the FuturICT project. The Flagship Strategy Board will contain scientists from the FuturICT team, as well as a near-equal number of external members with experience at the highest levels of international science, and with experience of managing large projects, institutes in universities or research centres, science-based businesses or funding agencies. The Flagship Strategy

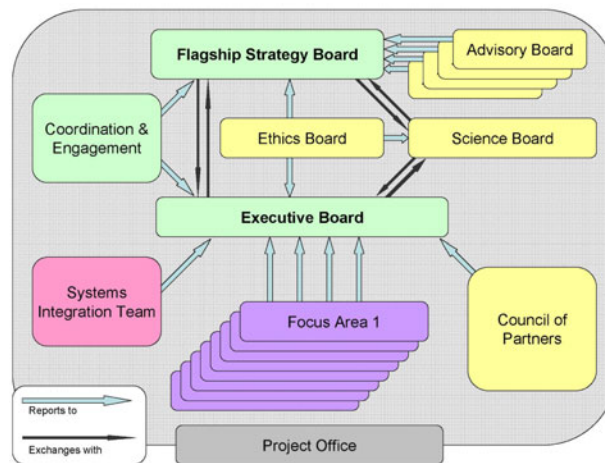


Fig. 2. The proposed FuturICT governance structure.

Board will meet three or four times per year, with one meeting during the FuturICT Week (see below).

The Flagship Strategy Board will be supported by advisory boards that will be responsible for helping to shape FuturICT policy in response to on-going or ad hoc matters. These are as follows:

- Science Board. Made up of senior scientists with experience of managing large projects or scientific institute, who will be able to provide management advice and scientific ideas.
- Users' Representative Panel Made up of representatives of citizens, businesspeople, and policy-makers who can advise on the practical and ethical issues arising from the research and development of FuturICT ideas.
- Innovation Advisory Board Skilled entrepreneurs and technology transfer experts who can advise on routes to exploitation of FuturICT research.
- Funders Panel Representatives of the funding organizations that are supporting FuturICT research, likely through an ERA-NET+.
- Ethics Board will responsible for setting the culture and proposing policy on ethics for the FuturICT programme. This board may receive input from external organizations or any members of the FuturICT collaboration community, and will be responsible for proposing policy and responding to requests from the Flagship Strategy Board.

The Ethics Board will be at the heart of the FuturICT project, since actual or perceived unethical behaviour could be highly damaging to the success of the project. FuturICT will be dealing with the highly sensitive matter of large datasets, so care will need to be taken on the ethical management of this data, its secure and safe storage, and the explanation to the public of the purpose of the research [17]. The Ethics Board may be called upon from time to time to take action when a particular policy presents issues for which there has been no previous policy formulated, or when a policy already formulated and endorsed by the Flagship Strategy Board needs to be applied in exceptional or challenging circumstances.

Distinct from the Flagship Strategy Board's level, there will be a Calls & Awards Board which will consider proposals arising from the Flagship Strategy Board for new calls for proposals (subject to the prevailing contractual obligations at the time) and will write the call for proposals and devise acceptance criteria, timelines and submission protocols. Where awards are to be offered for special achievements, the

criteria will be established and the timelines agreed. The procedures and schedule proposed by the Calls & Awards Board will be passed to the Executive Board for implementation by the Project Office. The Innovation Advisory Board will liaise with the technology transfer organizations of the participating universities and research institutes to help identify opportunities for exploitation of the research outputs of FuturICT. This may be through the creation of spin-out companies or the licensing of innovative tools, software and techniques. Support or putting these innovations in place will be provided as necessary by the legal division of the Project Office.

In this way, the activities of policy-setting and implementation are kept entirely separate. Although calls for proposals are recommended by the Calls & Awards Board, they are endorsed by the Flagship Strategy Board, overseen by the Executive Board and carried out by the Project Office. This ensures a clear line of control and responsibility, and enables transparency through an open audit trail.

No large project can succeed without good leadership. Although there are many different leadership styles, the project leader will set forth a clear vision for the project; empower and enable the team members; interact with the internal and external project stakeholders; create a culture of trust and ethical behaviour, and take ultimate responsibility for the successful outcome of the project.

The principal *operations* committee is the Executive Board (EB), which is responsible for the enactment of the goals, objectives, Focus Areas (FAs) and Work Packages (WPs) as set out by the Flagship Strategy Board. The EB is responsible for setting up the leadership team for each FA of the project, monitoring progress towards objectives, and allocating resources to each WP. Where progress of a FA is not as planned, the EB can take remedial action, such as reallocating resources. The chair of each FA leadership team is a member of the EB. The principal administrative functions of FuturICT are covered by the FuturICT Project Office, such as a Finance, Recruitment, Project Management, Technology Transfer, Legal Management, Risk Identification, and Press & Publicity. The Executive Board will meet at least once per month, and as often as once per week during the ramp-up phase. Details of membership, roles and responsibilities, terms of office, quora and frequency of meetings for all committees may be found in Table 1 below.

The **Council of Partners** is constituted of one authorized representative of each of the organizations that participates in the ‘core’ European project Grant Agreements as formal partners. The Council of Partners is responsible for all contractual matters arising from the European Grant Agreements, including the approval of requests for amendment on behalf of the participating organizations and applying sanctions to participating organizations who fail to fulfill their obligations under the contract.

The **Funders’ Panel** is made up of scientists or administrators who are responsible for liaising and networking within the FuturICT community for each country, for overseeing research activities in their country and for distributing reports and deliverables. The Funders’ Panel will also form the core of an European-funded ‘ERA-NET Plus’ funding structure or new kind of multi-national platform, should these instruments be implemented. The Chair of the Funders’ Panel will be a member of the Executive Board.

Project Office. The principal administrative functions of FuturICT, such as a Finance, Recruitment, Project Management, Technology Transfer, Risk Identification, and Press & Publicity, are carried out by the Project Office, which will distribute its functions between ETH Zurich and University College London. Specialized professional skills, such as contract management and human resources management, will be available to the PO for consultation. The Resources Manager and Coordination

Table 1. Summary of Committee Structures and proposed terms of reference.

| Board or Committee | Frequency of meetings | Voting members | Non-voting members | Term of membership | Quorum |
|---|--|--|---------------------------|---|--------------------------------|
| Strategy Board (SB) | Twice per year during ramp-up phase, including FuturICT Week. | Chair; Chair of Management Committee; Nominated member of EU; Chairs of Advisory Boards; Chairs of Representative panels; Leading scientific figures | PO Leader | <i>Ex officio</i> for chairs. Two years, renewable for two more | Half + 1 of the voting members |
| Executive Board (EB) | Once a month via video-conference + FuturICT Week; more often during ramp-up phase | Chair of EB; Focus Area Leaders or their deputies | PO Leader | <i>Ex officio</i> | Half + 1 of the voting members |
| Science Board | 2-4 times per year inc. FuturICT Week | No more than 20 | n/a | Two years, renewable for two | n/a |
| Ethics Board | 2-4 times per year inc. FuturICT Week | No more than 15 | n/a | Two years, renewable for two | Three voting members |
| Science Advisory Board/ FuturICT Ambassadors | Twice per year inc. FuturICT Week | No more than 25, including co-opted members from WPs | n/a | Two years, renewable for two | Three voting members |
| Innovation Advisory Board | Twice per year inc. FuturICT Week | No more than 15 | PO Leader | Two years, renewable for two | Three voting members |
| Awards Board | Twice per year inc. FuturICT Week | No more than 15, including 1 SB member | n/a | Two years, renewable for two | Three voting members |
| Users' Representative Group | Once per year during FuturICT Week | No more than 15 | n/a | Two years, renewable for one | Three voting members |
| Funders' Panel | Once per year during FuturICT Week | One representative from each of the funding organisations | PO Leader; 1 SB Member | Two years, renewable for one; <i>Ex officio</i> | Half + 1 of voting members |
| Systems integration Team | Once a month via video-conference + FuturICT Week; more often during ramp-up phase | One representative from each of the Observatories and ICT-heavy FAs/WPs | PO leader | <i>Ex officio</i> | Half + 1 of voting members |

Manager will lead the PO, and will be non-voting members of the EB. One of the key tasks of the Project Office will be to establish a shared information platform accessible to the whole project, allowing access and contributions to information about the project, its goals and its progress. This platform will also support the implementation of the project's risk and crisis management strategies, allowing issues to be raised, tracked and ultimately resolved by members of the FuturICT consortium.

Systems Integration Team. ICT will be a hugely significant part of FuturICT, and it is important that it is given due prominence, especially during the early stages when hardware, data structures and software will be specified. The integration of the ICT systems across multiple sites and pre-existing projects is crucially important to the future success of this project. Thus, we include a committee with specific remit to oversee the design and management of ICT systems. This committee will be supported by the principal functions from the Project Office, and will work closely with the chairman of the Executive Board. The chair of the SIT will be one of the key decision-makers in the FuturICT's coordinating team. The members of the SIT will be the leaders (or their deputies) of all of the Focus Areas that have a significant responsibility for ICT design, implementation or expenditure.

Core Management Team. The day-to-day management of the FuturICT will be the responsibility of a small, close-knit group of no more than seven responsible individuals who have intimate knowledge and experience of the many aspects of FuturICT, including the multi-disciplinary scientific aspects; management of the funding and contracts; managing relationships with funding agencies, the EU and business collaborators; managing project progress and reporting and managing the outward- and inward-facing communications. The key people who will manage these responsibilities are the Chair of the Flagship Strategy Board, the Chair of the Executive Board, the Chair of the Systems Integration Team, the Chair of the Funders' Panel and the Manager from the Project Office. They will be in regular daily communication, using a range of electronic means.

The **FuturICT Foundation** will be a charitable foundation, likely established in Belgium or the Netherlands, which will receive, manage and distribute charitable donations from individuals, corporations and other foundations. This money will be used to support research initiatives which are outside the original scope of FuturICT. FuturICT donors will be invited to the FuturICT Week, and to view demonstrations of the project's deliverables and outcomes.

The proposed governance structure may be amended from time to time as FuturICT develops, for example in response to changes in funding, technology, leadership and legislation. In particular, although FuturICT is beginning during the EU Seventh Framework Programme regime, it is not possible at this time to know what the legal and governance requirements of the upcoming Horizon 2020 Programme will be, so we must be able to amend the governance in response to these requirements as they become clearer. Further details may be found in Table 1 and Fig. 2.

8.1 Community-building

Multidisciplinary research cannot be achieved overnight, and can take a considerable time to build up the mutual understanding, trust and respect that are the basis of any kind of research. Scholars from different disciplines are accustomed to using different research methodologies, whether qualitative, quantitative, simulation-based, or

involving interventions and action research. However, by working together and sharing approaches to complex problems, the scientific outcomes and research methods of each separate and joint discipline can be improved.

To enable multi-disciplinary research, several initiatives will be supported by FuturICT including:

- Multi-disciplinary workshops,
- Short courses for students and post-doctoral researchers to introduce them to the methodologies of other disciplines, with comparative approaches to research questions,
- Incentives for encouraging within FuturICT the co-authorship of papers in disciplines beyond the authors' original discipline,
- Prizes and awards for the best multi-disciplinary papers, books and other publications,
- Special funding for multi-disciplinary short projects,
- Opportunities to work with artists and journalists to create novel interfaces and opportunities for exchange and interaction between science and the general public, in order to communicate the exciting and far-reaching paradigm shifts arising from FuturICT.

8.2 Diversity management

The effective encouragement of female and minority scientists will be based on encouraging and supporting effective networks. The effective inclusion of non-traditional scientists, such as females, minorities and disabled, will be encouraged by:

- Interaction with local equal opportunity offices,
- including at least one non-traditional scientist within the leadership team of every Focus Area,
- publicizing the work of non-traditional scientists at all levels of FuturICT,
- providing talks and events on effective networking during FuturICT weeks,
- gathering data on collaboration and co-publication networks as evidence of improvement in non-traditional networking,
- ensuring that there is at least one non-traditional scientist, and preferably two, presenting at every showcase event,
- encouraging more than one non-traditional author on publications,
- inviting non-traditional scientists to propose and develop new support instruments to enhance the achievements and impact of their communities.

The effectiveness of FuturICT's commitment to gender and minority encouragement will be improved and audited by the engagement of an external organization (e.g. Athena Swan).

8.3 FuturICT weeks

Every year, there will be at least one FuturICT Week (similar to an ATLAS week, as above). This will be a plenary session that brings together as many members of the community as possible, at all levels and stages in their careers, to present findings, report progress, debate issues, and establish collaborative networks. To enable community-building, FuturICT will encourage and support national and international workshops, which may be part of the FuturICT Week, so that scientists from each nation can find out more about each other's research projects, set up exchanges between students and researchers, create a job market for multi-disciplinary scientists,

and encourage collaboration and co-authorship of papers. The FuturICT Week will be held annually at one of the national hubs, to which the entire FuturICT family will be invited. This will be the main opportunity to share the outputs of FuturICT with the public, to engage in academic conferences and workshops and to review the strategic direction of the project. The representative panels, i.e. national funding agency representatives, commercial supporters and citizens, will hold their annual meetings during this week, and will be invited to attend all technical and public presentations. Each technical Focus Area will have a half-day session to present their achievements in the past year, indicating their progress against their planned deliverables. Pending issues will be reviewed during meetings of the Executive Board and Flagship Strategy Board. Winners of FuturICT Awards and other prizes will be also announced at plenary sessions during FuturICT Week.

The FuturICT Weeks will provide an opportunity for other international special interest groups to hold meetings and satellite conferences. For example, we intend to support research themes that address the management of big science projects and the ethics of complex projects. These themes will make contact with other Flagships and large science-driven projects to build communities and share research findings and best practice.

8.4 Widening participation

It is intended that the FuturICT Flagship project will promote an ‘Excellence Through Collaboration’ initiative, in line with the European Union’s plans to enhance the European Research Area. This ‘stairway’ will see the pairing of organizations participating in FuturICT; with elite internationally-renowned organizations providing support, expertise and best practice to more nationally-renowned organizations. Through this process, the nationally-renowned organizations will proceed further and faster on their path to international reputation and excellence, and thus further permanent benefits of the FuturICT project will be realized across the consortium and across Europe. To facilitate this process FuturICT will reach out to other Flagship projects as well as other projects, communities, countries and communities, through initiatives proposed by the Representative Panels in particular, as well as other members of the FuturICT Community.

8.5 Planning in practice

To explain how this governance structure would work in practice, we consider planning at three different time scales, and the response to a crisis.

8.5.1 Long-term planning

A new research area is identified of key relevance to FuturICT, perhaps suggested by a member of the Science Board, or to address a new research problem identified within one of the Working Groups. Since this has long-term implications, it is brought to the Flagship Strategy Board, who decide whether to issue a call for proposals in this area or whether to ask the FuturICT Foundation to raise new funds to support this topic. They ask the Calls & Awards Board to recommend the appropriate format and scope of the proposals, suggest a timeline, define the criteria for acceptance, and propose the amount of funding that will be made available. This is approved by the Flagship Strategy Board, and passed to the Executive Board for enactment through the Project Office.

8.5.2 Medium-term planning

A new research topic has been established within FuturICT, within an identified Focus Area, a named leader and specified Work Package objectives. A new WP is set up, which will report to the Executive Board, through the relevant Focus area team. Training and support are provided to the new WP Leader and team members by the Project Office.

8.5.3 Short-term planning

A Work Package decides to hold a workshop to present their findings to the academic community. They approach the Project Office for advice and support, who suggest including sessions for the commercial community and the public. The WP Leader agrees, and keeps the Focus Area leadership team informed of the plans. The Project Office invites interested participants and makes the administrative arrangements, including the arrangement of any Non-Disclosure Agreements. The Press & Publicity officers in the Project Office set up a publicity event, invite journalists and filmmakers, and stream the event over the Internet. A VIP event is organized for donors by the FuturICT Foundation, and a focus feedback forum is arranged for members of the advisory boards. The Project Office help arrange the meeting, inviting academic participants, and produce a summary meeting report afterwards, for publication on the FuturICT website.

8.6 Risk and crisis management

During any project spanning duration of over ten years, and with this level of technical complexity, crises are inevitable and will often be unanticipated. FuturICT plans to address crises in several ways. First, there is a Risk Working Group within the FuturICT Project Office which will review and test the outputs and procedures of FuturICT to seek out, amongst others, security, legal and personnel risks, in order to anticipate, identify and mitigate as many crises as possible before they occur. Second, the Executive Board and the Project Office will establish and support a clear procedure for laying down a secure audit trail that monitors progress towards Focus Area deliverables and objectives. Third, an ethical culture of trust and personal responsibility will help to ensure that crises can be confronted in a mature, rational fashion. Fourth, the clear lines of reporting and accountability in the governance structure mean that the crisis can quickly be located within the responsible committee, who may call on support from the advisory bodies and individual experts available within the strategic committees and the Project Office.

Amongst the possibilities that have already been considered are such risks as:

- Funding shortfall;
- Unavailability of key personnel;
- Ethical or functional inadequacy, including failure to deliver.

For each of these risks, the response of the governance system has been identified and reported, so that should an incident occur or situation arise, the members of the governance system would be aware of how to respond. Training materials will be prepared as part of the setting up of the complete governance structure, and as part of the induction of new members to the committees.

8.7 Ethics

A proper and continued consideration of ethical issues will be at the heart of FuturICT, including the secure and safe management of data. This will support and enable good science since it will help to ensure that we do not stray into unacceptable research practices or topics. The FuturICT consortium will also need to consider carefully the prospects of 'dual use', where the technologies developed within FuturICT may be used to the detriment of society as well as for its benefit. This is a current research topic within ethics and philosophy, and FuturICT will become a part of this ongoing conversation. As a research community that will receive at least part of its funding from the public purse, we need to be respectful always of the needs and concerns of the stakeholder communities that fund and employ these research and development activities.

8.8 Internal reviews

A procedure will be set up to carry out internal reviews, so that the processes and outcomes of the FuturICT project may be subject to scrutiny approximately once every 18-24 months. This will enable people throughout the FuturICT community to learn about the total picture of FuturICT, and to learn how to improve and adapt the operations of FuturICT, as we move forwards into a landscape of advancing technology and social change. There will be about five members of the Strategic Review Team (SRT), combining scientific and managerial expertise from universities, research centres, potential and actual FuturICT users, national funding agencies and commercial organizations from around the world. The SRT will have access to all documents relating to the management of the FuturICT project, including financial, contractual, commercial and scientific reports. They will be able to interview colleagues at all levels of the project, and will be expected to visit research centres and Observatories associated with the FuturICT project.

9 Knowledge/Innovation transfer and dissemination

The principal vehicle for sharing the knowledge and innovation from governance and management will be through specialized workshops and conferences held during the FuturICT Weeks. The governance of large science projects is a topic that has not received a great deal of research attention in the past. For those within the FuturICT community, workshops and induction training courses and materials will be provided so that new members of the FuturICT community will be able to understand the governance structure, the decision-making responsibilities and the agreed procedures for escalating issues. Procedures for revising the governance structure of FuturICT will be established and included in the training materials. These will be prepared under the guidance of the Project Office and an online version will be made available to all members of the FuturICT community.

FuturICT will set up a community of Science Programme Managers, which will meet during FuturICT Weeks to share, agree and disseminate best practice in the management of large science projects. The members of this community will be drawn from the management of other large science projects, both within the EU and internationally, and the programme managers of national and EU funding agencies. We will also investigate links with other large research and development communities, such as NASA, and the project and programme management institutes, such as the Project Management Institute (www.pmi.org) and the Association for Project

Management (www.apm.org.uk). All three organizations hold annual conferences, and we will investigate setting up special sessions, workshops and short courses to share our experiences of managing innovative science programmes of this scale.

These measures to promote the FuturICT outputs are intended to enhance global and European innovation and competitiveness. Big Science installation projects, typically associated with experimental physics, have demonstrated the distinctive potential that Big Science centres offer as a source of knowledge spillovers in national innovation systems [2]. More specifically, Big Science can act as an important first customer for emerging technologies, can be leveraged in all phases of the innovation trajectory and can be leveraged for advancing development projects.

10 Roadmap

The preliminary roadmap for the ramp-up phase of the FuturICT project is outlined in Table 2 below.

10.1 Deliverables

The deliverables of the Governance and Infrastructure Working Group of the ‘ramp-up’ phase of the project will be:

- A clearly defined and published map of governance and guidance on the justification of the structure and decisions supporting the chosen methods of infrastructure and project management,
- A functioning and efficient set of procedures and committees that ensure a high-integrity community with ethical, transparent and robust management and communication practices,
- Transparent and auditable procedures for managing financial, legal and human resources,
- A community of practice that extends beyond FuturICT that meets annually to review and compare best practice on the management of Big Science projects,
- An annual conference proceedings and publications in journals of project and programme management,
- Co-authored and multi-authored books on the management and governance of Big Science projects and programmes,
- A website that includes short films and videos on the management and governance of Big Science projects and programmes,
- A spin-out or consultancy service on the management and governance of Big Science projects and programmes.

10.2 Success/evaluation criteria

- An efficient, trusted governance structure that passes all assessment, auditing and evaluation exercises carried out on behalf of the EU and other auditing bodies,
- Invitations by members of the committee structure in FuturICT to present to other projects and to advise on the design of scientific programme governance.

Table 2. Preliminary outline roadmap for the ‘ramp-up’ phase of FuturICT (2012 to 2015).

| | |
|----------------------------------|---|
| End of the FuturICT Pilot | <ul style="list-style-type: none"> – Present and explain governance structure to FuturICT partners. – Set up and appoint members to key committees, i.e. Flagship Strategy Board, Ethics Board, Science Board and Executive Board. – Implement a disciplined approach to communication, minute taking, agenda-setting etc. so that community is establishing management and governance practices ready for the commencement of the FuturICT flagship – Agree funding instruments with partners and EU so that proposal may be written for the initial ‘ramp-up’ FP7 phase – Enter into discussions with the European Commission and identify the likely funding instruments for the later Horizon 2020 phase |
| Start of Funding (mid 2013) | <ul style="list-style-type: none"> – Appoint Project Office team – Appoint members of committees not already in place – Prepare training materials on governance, decision-making responsibilities, procedures for escalation etc. and make them available online. |
| First FuturICT Week (early 2015) | <ul style="list-style-type: none"> – Hold a workshop on FuturICT governance to obtain feedback and provide training – Host first plenary sessions of committees that meet annually – Update training materials based on feedback |
| Future FuturICT weeks | <ul style="list-style-type: none"> – Hold annual meeting of Big Science Management and Governance Interest Group – Prepare training materials – Publish conference proceedings, websites and books |

10.3 Dissemination Strategy

- Workshops, conferences and training sessions at FuturICT Weeks,
- Guidebooks and website on FuturICT governance,
- Books, conference publications and journal articles on the management of Big Science projects and programmes,
- Links with other project and programme management professional bodies, with invitations to speak at each other’s professional meetings.

11 Summary and concluding remarks

The paper has set out in some detail the motivating factors behind the design of the governance and operations structure of the FuturICT project. There are many

challenges in establishing a project that will likely involve over 1,000 scientists from a range of disciplines and national cultures that will endure beyond the 10 years of the initial funding from the European Commission. We have drawn together experiences from the management of large projects and programmes, as well as the management of ATLAS – a large physics-based project - to design a bespoke model for the governance of FuturICT. The values of integrity, transparency and ethical behaviour are at the heart of this model, values that are key to integrating the global community of scientists who will be engaged with this project. Although a great deal of thought has gone into developing this model, we also accept that it will certainly continue to develop and change up to the beginning of the main FuturICT programme, and even through the years beyond.

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