Acronym of the project	LMH	
Title of project in French	LabEx Mathématique Hadamard	
Project title in English	Hadamard Mathematic LabEx	
Coordinator of the project	Yves Laszlo Institution: FMJH and Paris-Sud University	
Funding (8 years)	**EUR 10,000,000**	
Disciplinary field	■ Other subject field	
Scientific areas	Mathematics	
Ce projet, ou un projet proche, a-t-il été soumis pour LABEX2010 ?	■ no[1]	□ yes Acronym: Coordinator:
Ce projet est-il la suite, pour tout ou partie, d'un ou plusieurs projets soumis à LABEX2010 ?	■ no	□ yes Acronym: Coordinator:
Participation in an « Initiatives d'excellence » project	□ no	■ yes Acronyme: IPS

Institution leading the project

Institution	Research Organisation reference
FMJH	FCS campus Paris-Saclay

All acronyms used in the text are summarized and explained in the glossary in the Annexes' document.

Jacques Hadamard

[1] The FMJH has submitted for the first LabEx call a very different project without success (Acronym: FMJH, Coordinator: Yves Laszlo).

Partner's affiliation

Laboratory/Institution(s)	Unit number	Research Organisation reference	AERES grade
LMO	UMR 8628	Université Paris Sud-CNRS	A+
CMLS	UMR 7640	École Polytechnique-CNRS	A+
CMAP	UMR 7641	École Polytechnique-CNRS	A+
CMLA	UMR 8536	ENS Cachan-CNRS	A+
IHÉS		IHÉS	None
LMV[2]	UMR 8100	UVSQ-CNRS	A
IpHT	URA 2306	CNRS-CEA	None
UMA (POEMS and OC)	UMR 7231	ENSTA ParisTech-CNRS-INRIA	A+
LTCI (STA and Mic2)	UMR 5141	Telecom ParisTech-CNRS	A+

The MIA (INRA) is already an important partner of the LabEx. However it is not a full partner at this time[3].

Institutional Partners:

First Industrial Collaborators:

[2] The LMV is an important partner of the highest international level. We believe that, in particular thanks to the recent success of its recruitment policy, the LMV will achieve the highest grade in the next AERES evaluation.
[3] We believe that it will reach the LabEx after the next evaluation which will benefit from assessment by both mathematicians and biologists.

TABLE OF CONTENTS

SUMMARY

After the revolution in physics in the first half of the 20th century, which impacts on our everyday life, the past fifty years have seen two radical evolutions in science and technology: the explosion in computing science and computing power on the one hand, and the explosion of data and concepts in the life sciences, with genetics, neuroscience, ecology, etc., on the other. Although considerable scientific successes and economic developments have followed on from these revolutions, they present no less considerable challenges: for example, in biology and medicine, multi-scale modeling of biological mechanisms, or, in computer science, security and systemic complexity issues (P=NP, massive data mining, etc.).

Mathematicians, whose discipline has experienced historically unprecedented development over the past fifty years, must be major partners in modeling and understanding the problems presented. This is a role that they have been playing in physics and continue to play. Mathematicians must not only suggest qualitative models, but, thanks to scientific engineering's huge capabilities in terms of digital modeling and massive data processing, they have to produce qualitative and exploitable data. It is clear that this dramatic development will also lead to an internal revolution of our subject by means of the appearance of new concepts and theories.

The mathematicians in the Paris-Saclay area form a top international-level scientific community which has already existing interactions in the fields of fundamental physics, the life sciences and information science and technology. We want to seize the tremendous opportunity provided by the presence and the future relocation of some major scientific institutions onto the campus, including numerous of the best French Engineer training institutions (Grandes Écoles). We present a project aiming to take our knowledge to another scale, strengthening our attractiveness for success in the top-level development of interactions between mathematics and these three extremely exciting fields on the one hand, and between mathematics in engineering, which integrates them, on the other. This is the aim of the LabEx project that we are going to describe.

In order to overcome some of the traditional weaknesses of the French model of higher education and research: namely, the compartmentalization between disciplines, as well as between fundamental research and innovations, we want to develop four scientific projects at the interface of mathematics and other sciences, as well as a common graduate school of mathematics. Our goal is to create new scientific communities at the interfaces of mathematics and other disciplines, using the leverage effect of training programs, structuring and federating their forces in a future major scientific hub.

Two of these scientific projects have reached maturity and are ready to be launched immediately.

- **Mathematics and the Life Sciences**, an innovative research and innovative program involving research institutes, universities and companies in a burgeoning and crucial field where France is not yet a credible player at the international level.
- **Mathematicians and Engineers**, a federative and ambitious research and training program in applied mathematics, which aims to break down barriers between the traditional players in the field: universities, Grandes Écoles, company R&D departments.

The next two projects will begin at the research level and then develop training aspects in the medium term. These are major issues in the renewal of mathematical interactions with traditional fiel

- **Mathematics and Fundamental Physics**
- **Mathematics, Information and Communication Science and Technology.**

Our final project will be an important tool for the success of the above projects. We plan first to federate the dispersed doctoral schools in mathematics into a common doctoral school, and then progress towards further integration and structuring by creating a common School of Graduate Studies:

- **The École Doctorale Mathématique Hadamard**

This in turn will have a strong influence on the teaching of mathematics on the whole campus, from universities to Grandes Écoles, at a time when the PhD is becoming the norm in the French higher education system.
The Fondation Mathématique Jacques Hadamard (http://www.fondation-hadamard.fr) is already successful in bringing together the mathematics departments[4] on the Paris-Saclay campus in international projects. This makes it a natural choice to lead this major development.

1. TECHNICAL AND SCIENTIFIC DESCRIPTION OF THE PROJECT

[4] At the present time, CMAP, CMLS, CMAP, LMO and IHÉS. The LMV, UMA and IPhT, LTCI will soon join the FMJH as associated members.

1.1 PROGRAM DESCRIPTION, VISION, AMBITION AND SCIENTIFIC STRATEGY.

The mathematics departments of the Université Paris-Sud, École Polytechnique, ENS Cachan and IHÉS, the founders of the Fondation Mathématique Jacques Hadamard (FMJH), form a research cluster which covers the full spectrum of research in mathematics, from pure and fundamental studies to applied mathematics. This cluster may be compared to the leading mathematical clusters found in the Boston area, San Francisco Bay area, Princeton or Chicago.

Despite strong international recognition –as proved by the many international prizes won by the 386 members, including 4 Fields Medals- the visibility and future of these departments is blurred by the specificities of the French higher education and research system, and their attractiveness to international and national students certainly suffers from the confusion induced.

Broadly speaking, the French higher education and research system is divided into three types of institutions:

- Research Institutes, where top-quality research is performed, but which have very little or even no connection with training programs, especially at the undergraduate and master's level.
- Grandes Écoles, which, in some sense, may be compared to engineering schools in Anglo-Saxon countries, bearing in mind that in France the teaching in these Grandes Écoles is more focused on the main scientific disciplines (mathematics, physics and chemistry) than on technology issues. Through a selective admission process, they attract some of the very best undergraduate students, but most of these Grandes Écoles do not offer proper training based on research and PhD programs. Moreover, they seldom have top-quality fundamental research departments and some of them clearly lack international visibility.
- Universities, which despite some improvement over the last 5 years and their strong commitment to research, suffer from a negative image, both among private companies and the general public. Nevertheless, some of them are recognized at international level.

Despite some undeniable historical successes, this complicated structure is now understood to be counterproductive:

- The development of new sciences, e.g. the life sciences and even computer science, etc., and inter-disciplinary sciences is slowed down. This is because it is set apart in a system exclusively devoted to producing students for the Grandes Écoles, whose training is still based on the main scientific disciplines;
- The high compartmentalization between structures has hindered the cross-fertilization of fundamental and innovative research;
- This complicated structure is impossible to understand outside of France, and this has consequences on its attractiveness to foreign students and scientists.

The vigorous development of the Paris-Saclay campus, where 23 institutions are scheduled to move to a common location, is a unique opportunity to overcome these difficulties. All members of the Paris-Saclay campus are aware of the above problems, and, more importantly, they have deliberatlely chosen to structure themselves on the international model of a university (training by research, PhD as the standard degree) and thus to create the Paris-Saclay University.

Mathematicians have a major role to play in this dramatic development. They are not spared the negative effects caused by this intricate structure, but they are probably best placed to overcome these difficulties. The mathematicians on the Paris-Saclay campus form a close-knit community, in which interaction between training and research is understood to be essential. Moreover, all institutions on the Paris-Saclay campus have highly-recognized mathematics research departments, which are already used to working together during scientific collaborations, as well as in organizing joint master's programs. The important work and recent success of the FMJH in developing shared programs among the mathematics departments of the Paris-Saclay campus encourages us to go further. We want to try to help the whole scientific community on the Paris-Saclay campus to overcome some of the traditional weaknesses of the French model of higher education and research.

At the level of mathematics, an important weakness is the inadequate development of the interface between mathematics and other domains or innovation. Overcoming this will require a comprehensive and focused effort from all the mathematics research departments involved. Broadly speaking, we would like to enhance new scientific communities at the interface of mathematics. In order to achieve this ambitious goal, we believe in the importance of new training schemes, which will have not only a structuring effect on the corresponding community but also, more importantly, will create a new generation of scientists with a strong training in mathematics, fully aware of the potential of mathematical research. The FMJH is the natural choice for leading this change.

1.1.1 The "Fondation Mathématique Jacques Hadamard", a major player on the Paris-Saclay campus.

The FMJH is one of the leading figures in constructing Paris-Saclay University, and will become a department of this university. Clearly identified indicators testify to the excellence of the research departments associated with the FMJH: these include the high number of prestigious international prize recipients in mathematics, the quality and number of publications, and the ARWU classification, referred to as "Shanghai ranking" or the A+ rating of the AERES, of the research departments. Created at the beginning of 2011, the FMJH has rapidly developed a shared scientific policy with the various mathematical research departments, with a strong emphasis on international aspects (with successful calls for applications at the graduate and post-doctoral level, creating international networks with China, joint introductory courses on the master's program, financial support for several conferences, high level graduate courses, joint research program with EDF, etc. The FMJH's governance (http://www.fondation-hadamard.fr/?q=en/foundation/organisation) has a clear separation of the powers between consultation /decision /execution. It has demonstrated its ability to make a breakthrough in strengthening the local mathematics research network on the Paris-Saclay campus.

Along with the LabEx Mathématiques Hadamard (LMH) project, we wish to further develop five new specific scientific projects under the auspices of the FMJH.

1.1.2 Five projects: creating research communities, using the leverage effect of training programs

The first four projects are scientific projects, intended to enhance or initiate the interfaces between mathematics and other sciences or applied domains, and heavily reliant on significant efforts on training aspects. These developments will be carried out in two major steps.

For the first 4 years, we wish to further develop two key inter-disciplinary programs, which are ready to be launched immediately:

- **Mathematics and the Life Sciences**: an innovative research and training scheme that aims to develop a brand new community of mathematicians and scientists able to address the main problems in this new field.
- **Mathematicians and Engineers**: a federative and ambitious research and training program in applied mathematics, taking advantage of the high quality of engineering research on the Paris-Saclay campus, addressing the need to the train mathematical engineers, both for applications and innovations.

Then, again taking advantage of the incredible potential and high-quality research departments on the Paris-Saclay campus, and also aware of the significant need for renewed interactions with mathematics, we wish to launch two new inter-disciplinary programs. These programs will start very shortly at a research level, and will later address training aspects:

- **Mathematics and Fundamental Physics**
- **Mathematics, Information and Communication Science and Technology.**

Developing and launching these inter-disciplinary programs will require a careful and precise hiring policy (see below) by the mathematics departments of the different institutions. Furthermore, support from our private partners (in particular companies as in the EDF-FMJH optimization program) will be crucial. The first two projects will benefit from significant financial support from the LMH over 4 years, whereas the last two projects will be gradually launched and will benefit from significant financial support from the LMH after the initial phase has been completed.

The last and fifth major project is the creation of a common

- **School of Graduate Studies in mathematics "École Doctorale Mathématique Hadamard" (EDMH)**

This will be a common tool for the four scientific projects and will bring together PhD students currently spread over the various schools of graduate studies in the different institutions. As will be explained later, this EDMH is currently understood only at the PhD level and is a first step toward a School of Graduate Studies in Mathematics, which will involve both master's and PhD levels. We hope that this new development will have a major positive effect on the attractiveness of our research departments to potential PhD students. We also hope that it will improve the visibility of our PhD program, both at the international and national level, especially to Grandes Écoles and private companies.

In the remainder of this introduction, we shall focus on a brief description of the LMH's five major programs.

1.1.3 Mathematics and the Life Sciences: an innovative research and training program

The life sciences are undergoing a major paradigm shift that is profoundly changing the interface of the discipline with all other scientific disciplines, including mathematics. Throughout the world, this scientific revolution is reflected by the emergence of research and training teams in a new branch of mathematics emerging from contact with biology, and with the life sciences in general. Nevertheless, in view of the importance of the needs and the level of international competition, the use of Mathematics in the Life Sciences is still largely inadequate. Dialogue between mathematicians and biologists/physicians has now become absolutely essential:

- From the mathematician's perspective, to develop models for identifying the key characteristics of biological phenomena;
- From the physician's or biologist's perspective, to enrich and modify their interpretation, benefiting from the multi-scale character of mathematical modeling.

Despite the potential importance and demand, existing projects in France in this area have not yet reached the scale needed to appear as a credible player at the international level. The Paris-Saclay campus operation is a huge opportunity to create a leading structure in this field. The demand from companies and research departments, and the potential for development, are immense. Most of the players and skills are present, but we face the important challenge of structuring, almost from scratch, a new community of scientists at the interface of mathematics and the life sciences. We believe that creating a research and training scheme starting at master's level is the best leverage to achieve this ambitious goal.

Our aim is to draw up a coherent research and doctoral and master's training scheme at the interface between mathematics and the life sciences. We aim to attract mathematics students, nationally and internationally, to challenging issues in the life sciences and promote research at the interface between these two domains.

We believe that the construction of such a program will have a major impact on developing real interaction between mathematics and the life sciences on the Paris-Saclay campus. It will also increase the visibility and attractiveness of this emerging discipline on the campus. The construction of this program can count on a unique pool of strong students, as well as the existence of a structured and highly recognized mathematical community.

Here is a little more detail about the projects we expect to develop, in accordance with the scientific objectives we want to achieve:

- Development of an inter-disciplinary training program to produce mathematicians with strong skills in the life sciences;
- Development of international cooperation (invitations, chairs and reciprocal sabbatical semesters), and with biologists or physicians to acquire new skills and develop projects at the interfaces;
- Hiring top experts in the field.

Some of the actions could be undertaken in collaboration with the Biosys project, which is essentially devoted to the subcellular and multicellular scales. This will generate a clear benefit for both the mathematical analysis of models and data extraction/analysis.

1.1.4 Mathematicians and Engineers: a unique opportunity in France and a federative program.

There is an increasing need for mathematical expertise in small and large technology companies that are developing and/or using algorithms and mathematical modeling[5]. Applications are various, and include climate, the

[5] Traditional fields of interest include teraflop computing on GPGPU, data mining, image processing, simulations using scientific computing, real-time applications, cost-effective design, smart visualization, optimization, etc.

environment, health, energy, risks handling, etc. However, the transfer from academic mathematicians to real-world applications is usually hindered by several difficulties, such as the mathematical formalization of the problems, identification of mathematics within a problem, finding the right experts, or putting people in contact. This situation has been identified in many countries throughout the world, and some of them have already invested to improve and increase the transfer of mathematics to industry (e. g. the "Educate to Innovate" program in the US, or the "Mathematics and Industry" of the European Science Foundation in Europe).

In France, two entities have been very recently set up to remedy this situation, both of which are nationwide. These are the LabEx AMIES and the research group "Maths et Entreprises"[6] supported by the CNRS. Their role is to develop interactions between mathematics and industry. Compared to other countries, however, these interactions are under-developed in France, due to the famous separation between academic research and the Grandes Écoles. Students in academia very often choose research or teaching, whereas students from the Grandes Écoles hired by companies see very few researchers during their studies.

The proposed project is mainly focused on developing, at the level of training institutions, closer collaboration in the domain of mathematics and its applications to engineering science. As we shall see, we aim to use the world-renowned mathematical expertise of our teams to promote closer links between universities, Grandes Écoles and industry in the geographical neighborhood of Saclay. In particular, our project concerns both research and training aspects.

Moreover, as far as industry is concerned, our project possesses a very natural articulation with the aforementioned recently launched national entitities, and could serve as an efficient local relay of their actions.
Mathematicians on the Paris-Saclay campus are particularly well prepared to seize the opportunity for organizing closer collaboration between mathematics and engineering. The recently created FMJH assembles most of the mathematical resources on the Paris-Saclay campus and groups together almost 10% of the entire community of French mathematics researchers. The mathematical laboratories involved in the FMJH comprise almost all mathematical disciplines and include world-renowned researchers. This federative structure could be seen and used as a unique research and training portal for exchange between academia and industry in the field of mathematics. This makes it a partner of choice for institutions or companies looking for collaboration. As a concrete example, we may mention the ambitious program on optimization and operations research (PGMO) developed by the FMJH in partnership with EDF R&D, which aims to create innovative research activities with direct industrial outlets for both training and research (see page 36 of the Annex). Thanks to the INRIA, it will be accommodated in new buildings (300 m^2) on the campus in DIGITEO2. Other similar projects are currently under negotiation, especially with the EADS.

We are absolutely convinced that the LMH has incredible potential to develop the interfaces between mathematics and engineering science at a level not yet achieved in France, building links between top universities, research institutes, Grandes Écoles and industrial companies based around the Paris-Saclay campus. We aim to focus our project in two directions:

- Federate, develop and create research activities and networks;
- Increase input from mathematicians in already existing higher education training programs. The goal is both to attract students from Grandes Écoles onto academic training programs, and for outstanding mathematics researchers to teach on engineering master's programs.

1.1.5 Mathematics and Fundamental Physics: renewing the interactions

The interface between mathematics and physics is classic, and ranges from the study of engineering problems to particle physics. Some of these aspects at the interface with engineering science are already covered in other parts of the LMH project. *We concentrate here on the interaction between mathematics and theoretical/fundamental physics* (particle physics, general relativity, etc). In this general area, the Paris-Saclay campus has remarkable potential, as shown for instance by the work of some of the Fields Medalists on the Paris-Saclay campus, closely linked to problems arising from fundamental physics (statistical mechanics, string theory, etc.). Some collaboration, mainly at a personal level, does exist, but we would expect much more on such on such a scientific campus. After a period for strengthening the exchange of ideas (a common colloquium, top-level invitations etc.), our goal is to

[6] See http://www.maths-entreprises.fr/ .

organize a mathematical physics master's program, both to diffuse certain fundamental concepts in current physics amongst mathematicians, but also to organize a flow of mathematics students into physics laboratories.

1.1.6 Mathematics, Information and Communications Science and Technology

There is undoubtedly a significant need to develop the relationship between mathematics and ICST on the Paris-Saclay campus. This will require some important preliminary thinking, needed to elaborate a general strategy in accordance with the major players in this field (INRIA, Télécom, DIGITEO and its LabEx DigiWorlds). Our initial step will be to organize research-level conferences and invitations. This step will help to define and delimitate further action, especially with regard to training.

1.1.7 Towards a School of Graduate Studies in Mathematics: the École Doctorale Mathématique Hadamard

The PhD degree is undoubtedly the international standard for advanced education in the academic world and, in most countries; it is also the standard for higher education in the economic world[7]. Doctoral training is a major issue for the development of mathematics at top international standards.

Building on their experience of joint master's programs, the departments associated with the FMJH would like to go further by creating a joint "Hadamard School of Graduate Mathematics Studies". As a first step, we will start at PhD level and, in the near future, create the Hadamard Doctoral School in Mathematics (EDMH, *École Doctorale Mathématique Hadamard*). The future Hadamard School of Graduate Mathematics Studies will include graduate studies at master's level. Mathematics departments on the Paris-Saclay campus, which are not yet associated with the FMJH, will also have the opportunity to join this School of Graduate Studies.

The Hadamard School of Graduate Mathematics Studies is mentioned in the Paris-Saclay IdEx project and, independently of the existence of the IdEx, the FMJH's founders and the LMH project partners are resolved go ahead with setting up the Hadamard School of Graduate Mathematics Studies as one of the FMJH's general actions.

We plan to raise the number of PhD students from the current figure of 259 to 310 in six years' time. The new students will come from the previous programs:

- Mathematics students who want to work at the interface with the life sciences
- Mathematics students in applied mathematics, in particular from the Grandes Écoles who are moving to the Plateau.
- Students from abroad, attracted by our now strong international visibility.

We will benefit from the strong demand from companies and research labs for mathematically-skilled doctors, with some expertise in the life sciences, as well as from the general movement in the Grandes Écoles, who regard the PhD as the standard degree. As far as positions are concerned, we are already faced with a strong demand from companies.

1.1.8 Governance and assessment.

The Government Assessment Agency AERES will perform the external assessment process, which involves international experts. Furthermore, the FMJH Scientific Committee (which is half composed of external members belonging to the Paris-Saclay campus) will evaluate the action of the LMH's action every two years. An annual report from the LMH will be included in the annual report of the FMJH, which will be made public.

1.2 SCIENTIFIC DESCRIPTION OF THE RESEARCH PROJECT

We shall now describe the two major scientific programs in detail (Mathematics and the Life Sciences, Mathematicians and Engineers) that we will launch immediately in their mature form. Then, in the final section, we shall summarize our two mid-term projects (Mathematics and Fundamental Physics, Mathematics, Information, Communication and Science Technology).

1.2.1 State of the art and challenges.

[7] In the economic world, see for instance www.medef.com/nc/medef-universites-dete/videos/detail-videos/medeftv/espace-business-innovation-vendredi-2-septembre-9h-10h.html

The common background to both programs is the unique situation of the Paris-Saclay campus, which currently, or at least in the near future, assembles major scientific players: universities, research institutes and Grandes Écoles. This is a unique opportunity and an important challenge, the culture of each of the institutions involved being very different.

A) Mathematics and the Life Sciences (Core group: P. Massart (LMO, coordinator), C. Giraud (CMAP), S. Méléard (CMAP), L. Desvillettes (CMLA), B. Maury (LMO), A. Trubuil (INRA)).

The scientific context and challenges. Over the past few decades, biologists have devoted considerable effort to understanding the genome and the molecular behavior of the cell. They have developed powerful analytical techniques and gathered a huge collection of sequencing and genomics data. At the same time, ecology has become a worldwide challenge. Understanding the behavior of eco-systems and the evolutionary processes that drive them is now a key scientific, economic and political challenge. In both areas, scientists must achieve a more thorough understanding of the interactions within the networks of multi-scale populations, as well as the biological concepts behind them. Modeling is a necessity at every level, from genomes to meta-populations. Consequently, mathematicians face the tough challenge of coming up with new perspectives, either to exploit data or to develop multi-scale models that help to explain and predict the evolution of living systems.

Different branches of mathematics are involved in this stimulating adventure, but very often with a disciplinary, fragmented approach. Our aim is to develop common research interests and train graduate students with a wide range of mathematical tools. These two aspects will allow our community to acquire real expertise in biological problems, in their greatest complexity.

Among current challenges, the analysis and exploitation of massive data sets produced by new technology requires the development of appropriate mathematics. This is true at the molecular level, as well as at the scale of individuals and populations. For example:

- The new sequencing technologies produce massive data sets, the processing of which presents a major challenge and requires new tools in computer science, mathematics and statistics;
- New microscopy or non-invasive imaging techniques require mathematical tools (image processing, inverse problems, etc.) at the highest level;
- New modeling approaches are needed to exploit the emerging types of databases that ecologists and evolutionary biologists are now able to assemble (e.g. GBIF, TRY, etc).

The information already available for studying living organisms, in combination with future innovations, will enable fuller understanding of the mechanisms underlying the multiple functions of organisms. The challenge here is to develop mathematical modeling of living organisms. This is still in its infancy, especially for prediction. Otherwise, the mass of accumulated data will remain largely untapped. Note that the issue is not only about increasing the power of computing resources. There is currently a need to develop new tools for data analysis and modeling. The need to synthesize the information hidden within the data in order to understand, predict and design experiments has never been greater in the biological community. Mathematics is quite naturally and gradually penetrating the life sciences, environmental and risk prediction communities.

The institutional context. Several major research laboratories in the life sciences associated with organizations (CNRS, CEA, INRA, etc.) or higher education institutions (University of Paris-Sud, École Polytechnique, ENS Cachan, AgroParisTech, UVSQ, etc.) are located south of the "Ile de France". Some of them are planning to move to the perimeter of the Paris-Saclay campus and will be even closer in the future. This geographical proximity, and the existing scientific links, will play a key role in the development of applied mathematics for biology and medicine, as well as the food industry, the environment and agriculture. As documented in the partners' descriptions, the members of the core group have already organized activities (conferences, courses) in this burgeoning area.

Institutional challenges. The players working at the interface between mathematics and the life sciences are not presently structured into a visible and well-coordinated community. Despite high demand for students with a strong mathematical background who are able to tackle challenging modeling problems in the life sciences, there is no specific training program on Mathematics and the Life Sciences on the Paris-Saclay campus. As a result, the campus is not attaining the critical mass and visibility that it deserves in this emerging discipline, both in terms of scientific potential and the importance of the issues. We believe that the proposed project, due to its inherently interdisciplinary aspect, is the perfect solution for achieving this structuring, and will make a significant contribution to the specific identity and influence of applied mathematics on the campus. Moreover, one of the main barriers to developing the interface between mathematics and biology/medicine is undoubtedly the significant difference in training and scientific culture between experts from both disciplines. This cultural difference is much more acute than at the interface between mathematics and physics, whose vocabulary is largely common.

B) Mathematicians and Engineers (Core group: F. Alouges (CMAP, coordinator), B. Desjardins (FMJH, coordinator), F. deVuyst (CMLA), L. Dumas (LMV), F. Lagoutière (LMO), E. Lunéville (ENSTA)).

The scientific context and challenges. As far as applied mathematics is concerned, the LMH possesses strong expertise that can be roughly separated into four domains:

- Control theory, inverse problems, optimization;
- Image processing and computer vision;
- Probability theory, statistics and their applications (e.g. machine learning or data mining);
- Mathematical and numerical analysis, scientific computing, and visualization.

Note that these domains are not compartmentalized, and some researchers are currently working at the interface between them. These domains are being developed with some outstanding applications, in particular for image processing, finance, solid mechanics or tomography, to name but a few.

Nevertheless, in order to develop an ambitious mathematics and engineering program, real industrial challenges must be faced. This implies breaking down the barriers between the aforementioned domains and developing transverse mathematics driven by applications.

The institutional context. The development of the Saclay campus is providing an outstanding opportunity to build-up a network between institutions already present (on the Saclay plateau) or who will be there soon. This will achieve the astounding feat of assembling in the same geographical area a significant number of top institutions in their respective fields:

- Many of the top French Grandes Écoles: the École Polytechnique, SUPELEC, ENSTA in 2012, and in the near future, the École Centrale Paris and ENSAE. Other leading Grandes Écoles (École des Mines de Paris, Télécom) are scheduled to move to the Saclay plateau in the mid-term future;
- A leading university (Paris Sud XI), and one École Normale Supérieure (ENS Cachan is scheduled to move to the Saclay campus in 2018);
- Public (INRIA, CNRS) or semi-public (CEA, EDF or Onera) research institutions;
- Research departments of private companies (e.g. Danone).

This is the opportunity to build links between all these partners, creating a collaborative structure that would be absolutely unique in France and comparable to top world-renowned research centers.

Institutional Challenges. Mathematicians face the challenge of giving dynamism to the multiple possible links between those institutions, both at the level of research and training.
To begin with research, the need for mathematics in industrial processes has already led to an increasing number of collaborations between companies (and Grandes Écoles) and more academic mathematics researchers. Unfortunately, these collaborations are still very often based on individual contacts and there is an obvious need for them to be managed more collaboratively, so as to increase their potential and efficiency.
Secondly, at the training level, the main challenge is breaking down the traditional compartmentalization between universities and the Grandes Écoles and enhancing interactions between training programs: it is now clear to everyone involved in the field that engineers need solid training in mathematics (and not only in mechanics or physics, for example). Furthermore, we plan to attract certain engineering students to more academic training programs in applied mathematics, hence developing research in applied science and engineering. Creating more links between universities, and the training of engineers, is the first step towards building-up a solid scientific community, fully aware of the technological challenges and the range of mathematical tools. Such links are at the heart of technological innovation. The credibility and attractiveness of the LMH will be strong asset in this major development.

A specific challenge is the federation of the mathematical research departments of partners who are not yet part of the FMJH, but who will be coming to Saclay soon. These include long-standing collaborators in teams at the

FMJH, such as the Applied Maths Laboratory at the ECP, the École des Mines de Paris, SUPELEC, ENSTA, and the UVSQ Maths Laboratory (LMV).

1.2.2 Goals, objectives and examples

A) Mathematics and the Life Sciences

Encouraging the interaction between the mathematical and life-science communities through systematic joint advisements of PhD theses, internship programs, post-doctorate fellowships, and attracting more students to mathematical issues related to the life sciences (biology, agronomy, etc.) are the primary objectives of this project. The existing potential of the Paris-Saclay campus in mathematics and the life sciences is a great opportunity for a global hub enabling innovative interfaces to develop and emerge. This will promote the visibility and credibility of the LMH in this area at an international level.

Our goal is to draw up a collaborative graduate training and research scheme that develops, assembles and organizes our skills and competences, ranging from data validation to mathematical modeling. Our scientific objective is to develop the mathematical study of problems arising from the life sciences, from conceptual modeling to numerical simulation.

We strongly believe in:

- A *comprehensive approach:* tandem presentation of mathematical tools from different branches of mathematics to take advantage of the complementary input they generate for addressing biological questions. Examples include data analysis and statistical, probabilistic or deterministic modeling.
- A *universal standpoint*: we need to break the traditional scheme of “scale” studies (by population, individuals, cells, molecules, etc.) inherited from the historical classification of the life sciences, in order to create more communication between modelers and mathematicians and adapt concepts that are actually operating at several scales.

Over the next four years, we propose to draw up a world-class research/training program structure focused on the following four scientific themes:

Biological fluids: Biological fluids (blood, air in the lung, etc.) appear in many issues relating to biology and medicine. They require specific and up-to-date mathematical techniques for their modeling, analysis and numerical simulations (Non-Newtonian modeling, ALE meshes to take account of moving boundaries, etc.).
Statistical data processing and model validation: The sustained development of biotechnologies has generated massive amounts of biological data. In order to fully exploit this data, we face the challenge of developing statistical procedures that can handle the following features: very high dimensionality with complex structures, heterogeneity and multiple scales. Solving these issues requires significant algorithmic and modeling efforts (in collaboration with biologists or physicians).
Image processing in the life sciences: imaging devices are essential to acquire quantitative information in biology and medicine. Apart from traditional de-noising problems, there are major needs in segmentation, shape modeling, and volumetry. The variability in positions and shape also poses important challenges for statistical image comparison, and requires complex coregistration procedures, which have been an important research topic in recent years.
Mathematics for ecology and evolution: Understanding the behavior of eco-systems, and the evolutionary processes that drive them, necessitates mathematical modeling at each level, from genomes to meta-populations. Studying the dynamics of these multi-scale populations requires various mathematical tools, such as dynamical systems, stochastic processes, game theory for modeling and statistics and numerical simulation, in order to match data sets.

Two examples of very challenging issues that will be addressed by this project.

Example 1: The influence of the environment on cell development mechanisms, such as embryogenesis. As a result of advances in optoelectronics techniques (cf. IOGS laboratories with whom we will work in the near future), some extremely accurate 3+1 D data are now available. This enables in vivo and real time monitoring of an embryo cell by cell, following the expression of well-identified genes and providing a typical multi-scale problem. In particular, it is possible to provide empirical force fields exerted by the environment (typically, amniotic fluid). The question is to understand their influence on the cell and thus on gene expression that, in turn, through the influence of mitosis, macroscopically affects the embryo. Similarly, the question of how the environment (chemical, physical or "statistical") affects the differentiation of stem cells is still open, as is the influence of geometry on cell proliferation. These types of largely open issues are extremely challenging, both from a fundamental (understanding of life) and biomedical perspective. Modeling of these complex systems is a crucial but essentially open problem. Firstly, this raises issues about model selection type in statistics and about the mathematical behavior of fluids, with the appearance of contrary problems. Secondly, homogenization and dynamical systems (evolution over time) will play an important role in a context in which imaging is the key investigative tool. In order to implement this momentum, we want to develop collaboration with the INRA and IOGS: workshops focused on specific themes, creating project-teams and hosting graduate students from the training program in IOGS teams.

Example 2: Understanding biological regulatory networks: a major scientific challenge that spans biology, ecology and medicine. These networks act at different scales (from a single cell to a whole ecosystem, and from instantaneous stress response to the evolutionary scale), but they share some common features: (i) certain stability properties (resilience, homeostasis, persistence, etc), (ii) structuration by evolutionary mechanisms. Mathematics provides key tools for coupling/decoupling the different spatiotemporal scales and investigating the fundamental properties of these networks. For example, to improve the accuracy of predictive modeling in ecology or medicine, one challenge is achieving better understanding of (i) the impact of the network's topological properties (modularity, nestedness, connectivity, etc) on the stability and efficiency of the system (ii) how these properties have emerged from evolutionary mechanisms. In order to deal with these questions, we propose developing a team focused on the analysis and modeling of biological networks, and attracting specialists in stochastic modeling, dynamical systems, optimization and control on these issues.

B) Mathematicians and Engineers

The heart of this project consists in developing, at the level of training institutions, closer and more numerous collaborations in the domain of mathematics applied to engineering science. We aim to use the world-renowned mathematical expertise of our teams to reinforce interaction between universities, Grandes Écoles and industry in the geographical neighborhood of Saclay. It is essential to consider both the research and training aspects in order to better disseminate mathematical knowledge into industry via the students' education in all institutions involved with the LMH.

The development of the area requires active collaboration between researchers in different mathematical domains (statistics, analysis, numerical analysis, scientific computing), in close collaboration with engineers, specialists in solid mechanics, physicists, and sometimes chemists. All these skills are present on the Paris-Saclay campus but need to be coordinated. Indeed, the gap between the mathematical tools used in real-life engineering and advanced tools designed and analyzed in academic problems strongly suggest the need for better links with and more exchanges between educational and learning processes and high-level science, between the academic and engineering worlds.

By means of a SWOT analysis, and pooling ideas from engineering scientists, we have identified four themes for scientific development over the next few years, for which we already have the scientific potential. They all require the merging of knowledge and skills from different research teams at the FMJH or its partners, and the strengthening of industrial participation and collaboration.

Optimization of industrial engineering processes. In many industrial domains (e.g. energy, finance, transport, telecommunication, logistics, etc.), optimization problems are becoming increasingly complex and crucial for economic development. Traditional methodologies have reached their limit, and today's challenges in engineering science require different approaches[8] to tackle problems, obtain acceptable answers and validate the specific methodologies[9] invented by engineers.

New challenges in statistics. In current applications, the joint effect of the huge size of available data, as well as, paradoxically, the small set of actual observations in our present world, has fundamentally changed the way we use statistics. Specific examples of applications range from object recognition, graph analysis (e.g. social networks), automatic system management from data provided by sensors, to parameter identification, etc. Methods require

[8] Large-scale problems, inter-disciplinary or multi-objective optimization, robust optimization with uncertainty modeling, safety engineering modeling and reliability, hybrid continuous-discrete problems, hybrid deterministic-stochastic optimization, mimetic algorithms, operations research, risk management, etc

[9] e. g. response surface methodology, RSM maps, design of experiments, metamodeling, etc.

methodologies from different mathematical skills. There is a growing demand from companies and other sciences for training and scientific expertise in statistics. In particular, the connection with probabilistic algorithms is also very fruitful due to the use of sparse representation for computing high-dimensional regression problems arising in dynamic programming equations.

New paradigms in numerical modeling. Driven by real world applications and engineering problems, numerical simulation has become increasingly present in our everyday life[10]. Increasingly complex physics[11] is required and, in some cases, real-time simulations are needed for embedded devices. Despite the increased power of computers, such problems require specific algorithmic and mathematical strategies, bridging traditional numerical analysis and scientific computing methods, statistics and computer optimization and visualization techniques to tackle these kinds of challenges seriously[12]. As an example, probabilistic numerical methods (Monte Carlo) have demonstrated their excellent ability to efficiently compute high-dimensional problems but their design in non-linear models still needs further developments (for semi/quasi-linear PDE, fully non-linear PDE related to stochastic control problems).

Real-life robust control problems. Control theory is used to control or stabilize a device (e.g. a car, satellite or petroleum flow inside a pipe), usually in an unstable equilibrium. Most of the time, the state of the system is not known perfectly, and in order to control it robustly, certain key parameters must be identified that can be used to find suitable feedback laws. Once again, such techniques require the development of new methodologies at the interface between control theory, inverse problems, optimization, statistics, and numerical modeling.

Three examples of high potential interactions between mathematics and engineering sciences[13].

Example 1: Optimal robust design of engineering systems. Today's optimization of engineering systems is subject to the curse of dimensionality. Objectives and cost are functions of constraint functions and design, environmental or contextual variables. Moreover, robust optimization problems dealing with the sensitivities of the outputs with respect to the entries are set up in very high dimensional spaces with objectives, constraints and responses formulated as outputs of random variables. Over the past ten years, important progress has been made and documented in the scientific literature. Nevertheless, we are far from what real-life design engineering requires. This is partly because of the high numerical complexity, but also because mathematical methodologies addressing the entire optimization problem need to be invented.

Example 2: Multi-scale modeling. The rapid increase of computing facilities is opening up new perspectives in material simulation and its application to engineering science. Indeed, Teraflop computing is becoming commonplace and enables finer modeling. Reduced models can be replaced by a more fundamental and complete set of equations for a more accurate description of the underlying physics. Nevertheless, the complete physics of the phenomena considered is still far beyond the reach of numerical modeling and poses many mathematical questions. As an example, in solid mechanics, elastic or plastic deformations involve dislocation dynamics that are highly sensitive to defects or grain boundaries inside the material, and these need a quantum approach for a full and correct description. This multi-scale (material, grains, dislocations, atoms) cascade model of materials is still in its infancy. Of huge complexity, it requires coupling between very different theories whose mathematical features are very different (PDEs, ODEs, statistical representation of defects or grains, etc.), and for whose simulation numerical methods are often incompatible or nonexistent.

Example 3: New fields for engineers with an advanced mathematical background. Massive data accumulation in industries obtained by the widespread use of sensors and networking enables the introduction of new services that depend on the development of virtual engineering. This leads companies whose business has led them to perform multifaceted information to add new activities to their portfolio, based on the information collected. These services typically lead to a new kind of decision aid for local authorities or various operators, such as urban planning and the emergence of an intelligent city. This virtual activity requires significant mathematical

[10] e. g. plane and car design, meteorology, packaging, architecture, etc.

[11] fluid-solid coupling in granular flows such as cement, acoustics in fractal domains for anti-noise walls, multi-scale multi-physics modeling, high energy, huge time scales, randomness, etc.

[12] see the joint industry-academic (CEA-CMLA) laboratory LRC MESO, http://www.cmla.ens-cachan.fr/la-recherche/lrc-meso.html.

[13] As far as implementation is concerned, the use of low-cost high performance computing resources, like General Purpose Graphics Processing Units (GPGPUs) that can provide peaks of 1 or 2 Teraflop computing power per board requires specific algorithmic developments to achieve close to peak performance and a complete rethinking of traditional numerical methods.

developments (statistics and stochastic approaches for massive data computations, discrete and continuous optimization of virtual objects as graphs or real objects as physical networks, geometry of these objects, etc.).

1.2.3 Concrete action at the research level

Our programs aim to create new scientific communities via training and research. We are absolutely convinced that training is inseparable from professional research. We aim to act on both fronts at once. However, in order to keep to the structure of the present application, we present here actions dedicated more specifically to research.

A) Mathematics and the Life Sciences

In order to extract information from data that can advance understanding of biological phenomena, it is essential to establish close cooperation between mathematicians in different sub-disciplines, specialists in biology, bioinformatics and medicine working on a given problem but also, in many cases, with physicists and engineers.
One of the main barriers to developing the interface between mathematics and biology/medicine is undoubtedly the significant difference in training and scientific culture between experts from both disciplines. In order to overcome this blocking point, we suggest the following:

Hiring recognized experts at the mathematics/life sciences interface, future leaders of the training program. The timeline for our hiring process will run as follows:

- *In the first year*: hiring, by a participating institution, a mathematician at professorial level, a specialist in collaboration with the life sciences, to manage the start of our master's program. We have advanced contacts on this matter.
- Meanwhile, the FMFH's scientific committee will recruit an advisor from biology or medicine.
- *Second and third year*: The FMJH's scientific committee will investigate possible candidates with both a mathematical and a life-science background, as well as potential areas for development.
- At the same time, the LMH will launch a series of one or two-year invitations of top level scientists - with the appropriate support to achieve excellence (research grant, support for post-doc and graduate students) in order to gain visibility in the area as well as new expertise - who may or may not be potential candidates.
- *Fourth year:* at the end of the process, undertake the actual hiring of a scientist with a strong background in mathematics and the life sciences, financed by Paris-Saclay University or by joint action involving the LMH's partners.

Immersion semesters allowing mathematicians to be assigned for several months, either directly to biological /medical research departments, or to applied mathematics research departments with experience of collaborating with biologists.

Financial support to reduce teaching load and for sabbatical semesters to promote links between mathematicians from different sub-disciplines, giving them more time and resources to devote themselves to new fields involving the life sciences, in which they are not experts (see also the IdEx action: Paris-Saclay Academy).

Organization of inter-disciplinary meetings (conferences, summer schools) enabling projects to emerge that unite specialists from all disciplines on a common problem.

Financial support for developing teams focused on key issues in biomodeling (e.g. on regulatory networks), as well as the development of international cooperation, including biologists or physicians,

B) Mathematicians and engineers

The project we intend to develop takes different and complementary directions. It is mainly focused on facilitating the transfer of research between academic labs, Grandes Écoles and industry.

Promote mid-term industry associate academic positions. Associate professors/researchers from industry in the LMH will be a key success factor: they will enhance the interface between the LMH and their affiliated company in many forms: conferences, internships for master's or PhD students, financial support for equipment, postdoc positions, industrial PhD funding, industrial chairs involving long-term projects with students, etc. From the very beginning of this program, we immediately need one such part-time position.

Financial support to reduce teaching load and for sabbatical semesters. Conversely, it is very important to achieve close coordination with professionals working in academia. We therefore need to encourage researchers aiming to strengthen our project, especially by offering reduced teaching and sabbatical semesters (for both junior and senior researchers) to compensate their duties.

Grants to organize workshops. Sharing knowledge via workshops is very valuable for all participants. Here, the aim is to organize workshops in areas of great importance for engineers and our industrial partners. We plan to provide financial support to help organize workshops, or for members of the LMH to organize workshops in areas of interest to the project.

Set up top Technology Centers of Excellence with financial support from companies. The LMH will build on initiatives and funding from the industry and companies by means of joint labs, academic partnerships, fellowships, joint research centers, joint teaching centers, etc[14].

High innovation by means of high technology devices. Due to its size and partnership policy, the campus will host high-technological resources and large-scale collaborative scientific equipment (computational and visualization facilities) such as the DIGISCOPE[15]. We wish to launch, support and develop exciting maths-based collaborative projects and tools between engineers, students and mathematicians: collaborative optimization, large-scale visualization of scientific data, remote visualization, collaborative engineering, design, new paradigms of teaching and learning by means of non-standard equipment, e-tablets, etc.

1.2.4 Two medium-term projects

A) **Mathematics & Fundamental Physics** (Core group: M. Kontsevich (IHÉS), F. Labourie (LMO, Coordinator)), S. Nonnenmacher (IPhT),T. Paul (CMLS), W. Werner (LMO, Scientific Coordinator)).

Physics has always been instrumental in stimulating and driving mathematical ideas and intuitions. Numerous major recent advances in mathematics are very closely linked to physics, and cross-fertilization with theoretical physics is very much alive. Throughout the world, institutes[16] are playing an important role in this respect.

However, the increasing segmentation of science into subfields, together with the large amount of reading required to reach the forefront of scientific research on any given topic, make it almost impossible to have the global overview of both disciplines that Poincaré or Gauss possessed. Nevertheless, it is an alarmingly small proportion of professional French mathematicians that are aware what the "Standard Model" actually means. A growing proportion of young mathematicians are even ignorant of such fundamental notions or examples as the Classical Mechanic or Ising model.

The LMH's main objective is to bridge this cultural gap, through training at master's level, as well as through common research activities.

The interface between mathematics and physics is extremely large, ranging from engineering problems to particle physics. Some of these aspects, at the interface with engineering science, are already covered in other parts of this LMH project. *We concentrate here on the interaction between mathematics and theoretical/fundamental physics* (particle physics, general relativity etc).

State of the art and challenges. The high concentration of top mathematicians inspired by physics, as well as leading theoretical physics centers, within a 10 km radius of Saclay is almost unique in the world. IHÉS (with both theoretical physics and mathematics), the IPHT (CEA-CNRS, Saclay), the mathematics and theoretical physics departments of both Paris-Sud University and Polytechnique are world-renowned.

[14] For example, nVIDIA's CUDA Centers of Excellence (CCOE) programs (http://research.nvidia.com/content/cuda-centers-excellence) recognize universities expanding the frontier of massively parallel computing using nVIDIA's CUDA language

[15] the DIGISCOPE visualization facility equipment (see www.digiscope.fr, Equipex funding award 2010, 6,7M€) is a collaborative cluster of complex data visualization equipments, interaction and virtual reality facilities spread into different schools, institutes, laboratories and universities (CEA, CNRS, DIGITEO, École Centrale Paris, ENS Cachan, INRIA, LRI, Maison de la Simulation, Paris Sud Orsay, Télécom Paristech, Université Versailles Saint-Quentin) with already operating existing equipments: EVE at LIMSI (See http://eurovr-eve-2010.limsi.fr/), or the WILD wall equipment at LRI See http://insitu.lri.fr/Projects/WILD

[16] The Isaac Newton Institute in Cambridge, the Erwin Schrödinger Institute in Vienna, ICTP in Trieste etc., in France both IHP and IHÉS are devoted to both theoretical physics and mathematics etc.

Active pockets of collaboration do exist in the Saclay area. In this respect, we should mention the CEA/LMO, that has active collaboration between probabilists from LMO and physicists from CEA, and between analysts from LMO (and Polytechnique) with physicists from CEA. IHÉS is an institution where theoretical physicists and mathematicians are mixed, and where seminars and conferences sometimes attract a mixed and wide audience.
The scientific themes covered by these activities include:

- Statistical mechanics, geometry of random objects, quantum gravity
- Quantum chaos, pseudo-differential analysis
- String theory or general relativity and their interactions with mathematics.

These are subjects in which Saclay is exceptionally strong. However, these collaborations -- as spectacular as they may be -- are far below what might be expected on this type of scientific campus. As noted above, we believe that one of the reasons is that physics is almost entirely absent from the curriculum of young mathematicians: for instance even classical mechanics is rarely taught, and very few graduate students have any idea of what prediction in quantum mechanics actually means.

Goals and objectives. At a general level, we aim to break down the barriers between the mathematics and physics communities, so that ideas can circulate between us more freely. Our goal is to create a community of scientists with a shared common culture, in the spirit of the Russian school -- or even the Atiyah school -- where mathematicians and physicists had a much higher level of common awareness than we do at present.

For mathematicians, sharing the basic knowledge of physicists will help to understand some of the unifying intuitions – the Feynman integral is a famous example -- of physicists on the mathematical world. This is particularly important since ideas from physics, often mediated by Witten, now seem to permeate mathematics very far from the traditional ground of analysis and probability: geometric Langlands program, the pervasive use of the motivic language in current physics, etc.

At stake for physicists is supplying research departments with PhD students who have a strong mathematical background and who can communicate effectively with mathematicians. Such a goal is of vital importance for the future of the field in France.

Research actions in Mathematics & Fundamental Physics. Our main goal is to set up a master's program (see below). Before that, the concrete action we propose is:

- To enhance geographic fluidity by supporting longer stays of mathematicians from the Paris-Saclay region in physics research departments, and vice-versa
- To improve the community's self-awareness via a regular high-profile mathematical physics colloquium.
- Two-year invitations – or "Itzykson Chairs" – comprising a salary, research grant and financial support for one post-doc/graduate student for world-class scientists with a shared maths/physics background

B) **Mathematics & Information and Communication Science and Technology.** (Core group: F. Baccelli (INRIA –ENS and CS FMJH), P. Pansu (LMO), L. Decreusefond (Telecom))

The interface between mathematics and ICST has developed strongly in top US universities (e.g. Berkeley, Stanford or MIT) where several research groups at top international level are working at this interface in R&D departments (e.g., in the mathematical center of Bell Labs in Murray Hill or the theory group at Microsoft Research in Redmond). France has not achieved such a level of integration. The present part of the LMH project aims to create the conditions for a comparable development in the Paris-Saclay area over the next few decades, where the density of the activities in these fields in the Paris-Saclay campus has already given rise to numerous new collaborations between Mathematics and ICSTs.

State of the art and challenges. The Paris-Saclay area is home to both academic and industrial research centers in the field of ICST (INRIA and Microsoft for example), in addition to top universities and Grandes Écoles. The imminent changes, including the arrival of Télécom ParisTech, which aims to be the first engineering school in this area in France, urges mathematicians to consider how they are going to interact with information and communication scientists. In other words, this LabEx proposal comes at a time when we will see important and unexpected changes. This is an opportunity that should not be missed.

Goals and objectives. Our goal is to enhance collaboration between mathematicians and information and communication scientists. The goal is for more mathematicians, at various stages of their career, to get involved in such collaboration. In the same way, we aim to provide more opportunities for future ICST scientists to master evolving areas of mathematics.
Let us list a few areas where interaction has been going on for some time, but which could be greatly enhanced.

- The *Harmonic analysis-ICST* interface, which has produced wavelets and their numerous applications, is far from exhausted. Among new aspects, compressed sensing or the use of harmonic analysis on the discrete cube in complexity theory could be mentioned. There is strong expertise on the mathematical side in the LMO and École Polytechnique, and on the ICST side in Supélec and Télécom ParisTech.

- The *Probability-ICST* interface, well-illustrated by the seminal work of Bell Labs (information theory, stochastic network theory) or that of the research group of Microsoft Redmond mentioned above (random graphs and point processes, algorithms for large networks). Again, the LMO and École Polytechnique have strong probability theory groups, whereas the French information theory community is mainly located in Télécom ParisTech and Supélec.
- The *Optimization-ICST axis*, which has strong connections with the LMH Math and Engineer program and the FMJH-EDF PGMO program. New and promising interactions are taking place: optimization methods can be used to assess the correctness of software. Conversely, work has started in order to include techniques from optimization into formal tools. This includes teams from CMAP-INRIA, LIX-INRIA and CEA-LIST.
- Other areas of interaction that need to be explored in the near future are the *Algebra-ICST* interface **(**error-correcting codes and cryptography...), the *Statistics-ICST* interface (in particular, statistical learning) and, at an ultimate stage, the *Mathematical Logic-ICST* interface (Automated proof verification[17]).
- All the mathematical fields alluded to above play a role in ongoing research in *software engineering*, and more specifically in security issues. This central theme in the economic modern world will be an important issue for the LMH's development, in collaboration with the DigiWorlds LabEx project on computer sciences and information theory.

Research actions in Mathematics and ICST. We need to make the mathematical community aware of current issues in ICST (creation of a periodic seminar on ICST oriented mathematics). Experience shows that the guidance of a high-profile expert greatly helps to guarantee the success of such a colloquium. For this, we will implement two-year invitations "von Neumann chairs" comprising a salary, research grant and funding for one post-doc/graduate student – allowing a world-class scientist to stay in the area for a year.

1.3 IMPACT ON TRAINING.

1.3.1 The "École Doctorale Hadamard": Towards the "Hadamard School of Mathematic Graduate Studies" in the Paris-Saclay campus (Core group: D. Harari (LMO, coordinator), F. Pacard (CMLS), Y. Martel (LMV))

As quoted above, doctoral training is the international standard for advanced education and is a major issue for mathematics in order to maintain the highest international standards. Let us recall that, building on their experience of joint master's programs, the departments associated with the FMJH would like to go further by creating a joint "Hadamard School of Graduate Mathematics Studies". As a first step, we will start at PhD level and, in the near future, create the Hadamard Doctoral School in Mathematics (EDMH, École Doctorale Mathématique Hadamard). The future Hadamard School of Graduate Mathematics Studies will include graduate studies at master's level. Mathematics departments on the Paris-Saclay campus, which are not yet associated with the FMJH, will also have the opportunity to join this School of Graduate Studies.

State of the art and challenges. As a result of globalization, French companies need to comply with international standards. In higher education, the PhD degree is slowly but steadily becoming the standard, thus replacing the typically French Diplôme d'Ingénieur. In this general context, the Paris-Saclay campus has decided to increase the number of students from its engineering school with a PhD degree by 30%. A further difficulty in France is that graduate studies at master's and doctoral level are not yet understood as a whole. Although French students are well aware of this dichotomy, such a distinction is rarely understood outside Europe.
The high quality of doctoral training in the FMJH's mathematics departments is acknowledged worldwide: this is proved by the high employment rate of their PhD students, in both the academic and economic worlds, as well as the large number of top mathematicians trained in these departments. For example, the following is a short list of alumni/graduates of these departments appointed by top universities abroad (D. Auroux, E. Candès, Ngo Bao Chau, F. Morel, S. Morel, T. Rivière).

[17] The remarkable achievements performed at LIX and the INRIA - Microsoft laboratory in Saclay should attract mathematicians' attention. At a more fundamental level, the recently discovered connections between type theories and homotopy theory should lead to exchanges between mathematicians and the Coq community.

Developing a strong school of graduate studies at both master's and PhD level has always been a key concern for the FMJH's research department partners, both at national and international level. In particular, this is a key issue for maintaining the quality of French mathematics schools in the future, as well as attracting more students from abroad or from engineering schools. The FMJH, together with the FSMP and the LabEx Bézout, has just won (cf. page 34 of the Annex) a scientific call "DIM de la Région Ile de France" to create a new mathematics PhD network in the Ile de France region, and to promote and finance PhD-level training.
The mathematics research departments of the FMJH's various partner institutions have successfully developed joint master's programs in both pure and applied mathematics, and they have clearly demonstrated their interest in working together and deepening these collaborations. In addition, common projects under the aegis of the FMJH have already proven very fruitful for the mathematics departments on the Paris-Saclay campus: an international graduate program at master's level, international cooperation agreements, shared courses at higher graduate and post-graduate level. The even greater international visibility of the whole structure is especially welcomed by the FMJH's partners.

Goals and objectives. One aim in creating this school of graduate studies is to enhance the visibility of all departments, for both French and foreign students, and to secure the long-term renewal of mathematicians in the whole spectrum of mathematics and its applications. The EDMH will therefore have a strong role in developing the acknowledged strengths of PhD-level training, especially in fundamental mathematics. One of the main challenges the EDMH will have to face is promoting interdisciplinary studies involving:

- Applied mathematics, in close collaboration with company R&D departments;
- Applied or fundamental mathematics for inter-disciplinary subjects, in close collaboration with research departments from other fields.

The FMJH (operational aspects) and its scientific committee (scientific and training aspects) will ensure the diversity of the EDMH's full mathematical spectrum and enhance dialogue between the various subfields, maintaining a proper balance between fundamental mathematics, applied mathematics and interface projects.

In accordance with the overall policy of the forthcoming Paris-Saclay University and the FMJH's goals, the Hadamard School of Graduate Mathematics Studies will develop a shared scientific policy at PhD level between internationally-renowned departments on the campus, with coherent action for the labs' research activity. In particular, one of its tasks will be to find a balance between students with a Paris-Saclay master's degree who then prepare their PhD either on or outside the campus, especially abroad. The visibility will be a great asset for negotiating cooperation agreements with other graded institutions. The EDMH's visibility will contribute to promoting the new grade of "Paris-Saclay campus PhD in Mathematics", which is in line with international scientific standards.

Adding together the PhD students from the FMJH's various partners gives a grand total of 259 PhD students, with a flow of 90 PhD theses defended per year. *In order to keep up with our new LMH programs, and meet overall mathematics needs in other sciences, as well as the campus's general objectives, we need to increase this number to at least 310 within 6 years, a development that requires new funding.*

Specific challenges and actions As stated above, the FMJH's mathematics department partners provide high-quality training for PhD students. Nevertheless, we have identified a series of potential structural problems, which we hope that the Hadamard School of Graduate Mathematics Studies will be able to address:

- Doctoral studies in mathematics are scattered across schools of graduate studies in the different institutions on the Paris-Saclay campus, which certainly affects the visibility of both the offer and the training. A common school of graduate studies will enhance this visibility, both at national and international level, and this will certainly play a major role in the departments' appeal.
- The development of inter-disciplinary research at doctoral or master's level usually presents difficulties (in terms of advertisement, evaluation, or simply at the administrative level) in most French schools of graduate studies. Well aware that inter-disciplinary PhD projects should be nurtured, the School of Graduate Studies intends to pay special attention to inter-disciplinary projects at the interface of two research disciplines. As a specific example, inter-disciplinary research requires specific and thorough preparation of students. In order to develop truly inter-disciplinary scientific projects, we intend to support students at the end of their master's degree so that they can spend a year in a non-mathematical research department associated with their PhD research project.

- The different schools of graduate studies do not presently have the critical mass they need to offer enough advanced lectures for PhD students in mathematics. The common School of Graduate Studies will be able to offer suitable lectures for PhD students. For example, the FMJH has recently created shared courses for PhD students called the "Hadamard lectures[18]", in the spirit of the Nachdiplom lectures offered at the ETH-Zurich.
- PhD students in mathematics on the Paris-Saclay campus do not have a community identity. We intend to develop common activities for all students in the School of Graduate Studies. For example, the FMJH has organized "Introductory master's lectures"[19], which have been greatly appreciated by students. We intend to generalize such initiatives to PhD students.
- In the same spirit, the EDMH will support (web hosting, funding for conferences with a wide audience) former students from the EDMH to organize themselves into an alumni community, so that they can share professional experience and keep in touch with mathematics.
- In collaboration with all the other mathematics departments on the Ile de France, we will organize "Doctoriales de Mathématiques" (three-day events in which graduate students and companies partners get together and listen to one another's presentations) and training internships to help graduate students find jobs. Moreover, we plan to organize graded summer schools[20] with other mathematics groups in France in order to take part in the cooperation network of French mathematicians, and help students to find supervisory or academic jobs, depending on their level of study.
- Most foreign students do not receive training in the French language. We intend to develop[21] proper training in the French language for foreign master's and PhD students at an early stage. We aim to bring students up to the level of TCF (DAP) by the end of the studies. Similarly, French students do not receive enough training in English, and the School of Graduate Studies will offer them proper training. The target is for students to reach the level of 105 TOEFL IBt.
- In order to disseminate the results of PhD students, the EDMH will encourage and support travel grants for graduate students.

Governance, resources The legal structure of EDMH must be drawn up in accordance with the rules governing all schools of graduate studies in France ("*Arrêté du 7 août 2006 relatif à la formation doctorale*"). As with all schools of graduate studies, it will be assessed by the AERES. In addition, since the Hadamard School of Graduate Mathematics Studies will receive funding from both the FMJH and the Paris-Saclay IdEx, annual reports will be presented to the scientific committees of both institutions.

The various partners involved in the EDMH agree to delegate competence and pool resources to the EDMH for joint action. The process is to be progressive but determined, with identified milestones.

The role of the IdEx will be to support the pooling of partners' resources by providing supplementary resources proportional to the pooling level, and to integrate the EDMH's action on its applied and inter-disciplinary programs. The role of the FMJH will be to coordinate the EDMH's scientific programs, and to find resources from the partners to develop new mathematical directions. The role of the LMH in the EDMH program will be to support its creation, with emphasis on the inter-disciplinary aspects, as notably developed in the programs below.

The FMJH will provide the EDMH with 2 new PhD grants each year, meaning that the EDMH will always have 6 PhD students funded by the FMJH.

In order to encourage the process and develop scientific activity, the pooled human and financial resources made available by establishments will be added to the EDMH's resources by the IdEx, in proportions that are to be specified. Apart from pooled resources, the partners commit to support doctoral research in mathematics for at least 10 years. The aim is for a 3-phased achievement (2, 4, and 6 years) of the objective for all mathematics doctoral students registered in partner departments (whether or not funded[22] by the EDMH) to be affiliated to the EDMH.

[18] The first series of Hadamard lectures will be given next March by Felix Otto, in the spirit of the ETH's Nachdiplom lectures.
[19] See http://www.fondation-hadamard.fr/?q=fr/node/210.
[20] The first one should be organized in summer 2012 in Nantes, France.
[21] As experimented by the FMJH this year in its Sophie Germain program
[22] Most of the theses in applied mathematics are not directly funded by the graduate schools.

Timeline: We plan to develop the structure and scientific project of the Hadamard School of Graduate Mathematics Studies at PhD level in the first half of 2012, since it needs to be accredited by the French Ministry of Higher Education and Research for scheduled opening in the fall of 2012. At the same time, the FMJH's various master's programs will be developed and progressively aggregated to the Hadamard School of Graduate Mathematics Studies.

The aim of the LMH project is to initiate new developments for the FMJH's activity by structuring a network of highly recognized labs (according to the requirements of the LabEx call). The EDMH will therefore pay special attention to the LMH's interface programs, namely:

- In the short-term (4 first years), the Mathematics and the Life Sciences and the Mathematicians & Engineers programs.
- In the mid-term (starting in 3 or 4 years), the Maths & Fundamental Physics and Maths & ICST axes.

1.3.2 Mathematics and the Life Sciences: training aspects

Our goal is to create a new and innovative training network, enabling mathematics students to spend some time in life sciences labs in order to obtain a truly inter-disciplinary PhD, thus shaping and structuring a new generation of scientists. The combined skills on the perimeter of the Paris-Saclay campus cover data analysis, as well as the construction, analysis and validation of mathematical models. *This provides the opportunity to build a broad-based training/research program on Mathematics and the Life Sciences, including deterministic, stochastic and statistical modeling. To our knowledge, such a transverse approach to mathematical modeling in the life sciences, involving research institutes, universities and companies would be unique in France, and highly innovative.*

The rationale for a new training scheme. Major research organizations and the private sector in this area are offering positions at doctoral or postdoctoral level. Moreover, at a lower level, there is a demand (in the pharmaceutical or food industry, for example) for suitably trained students (especially in statistics). We already have graduate students choosing to work for companies, but this is a minority and many positions remain unfilled. On the other hand, there is a pool of excellent students who have the opportunity for inter-disciplinary training (in Polytechnique or ENS Cachan, for example) at the undergraduate or pre-graduate level. Unfortunately, the lack of a dedicated training scheme at master's level deters these promising students from pursuing this. The existence of our new program will considerably increase the flow of students into industry.

An innovative training program. There is a combination of skills on the perimeter of the Paris-Saclay campus, both in applied and fundamental science. This provides the opportunity to design a brand new broad training/research program on Mathematics and the Life Sciences. Such a transverse approach for mathematical modeling in life sciences is quite innovative in France.
We intend first to focus on specialized M2 courses (5th year of university) and PhD level, highlighting how mathematical tools are used to address certain issues in the life sciences. Drawing up a full master's training program including a specific M1 (4th year of university) program will then follow as a second step. We will involve new players, such as INRA researchers and foreign visiting scientists. In particular, the MIA has a long experience of collaborations with scientists from the life sciences, and will be closely linked to this training program.
The main objective of the master's program is to train young mathematicians who can develop accurate mathematical answers to complex problems raised by the life sciences. The program aims to give students (i) the mathematical background needed for developing new concepts and models for the life sciences (ii) the ability to interact with biologists or physicians. To this end, the training will include both some fundamental courses in probabilistic modeling, dynamical system, PDE and statistics, and some specialized courses covering issues in ecology, post-genomics neuroimaging and medicine.

Structuring a community. From another perspective, designing this type of training program will be a tool to structure a community that exists, but in too fuzzy a shape to be fully effective within the triangular relationship formed by the academic mathematics community, major research organizations and companies. Drawing up this program requires a recruitment drive in each of the institutions concerned.

Some joint measures will also be necessary to facilitate the promotion of this scientific field and the organisation of its various stakeholders.

- As a first step, we need to increase our teaching strength at master's level, for example by hiring post-docs,

- As a second step, we will hire young leaders in order to create or strengthen research teams (with joint appointments with the help of "future partners" (companies or institutions), for example).
- We have explained above our process for hiring a senior leader in the field.

Funding a gap year. To enable students to gain a real “double culture” in mathematics and the life sciences, we want to fund a “gap year” between the M2 and the PhD for the best master’s students: this year should be spent in a life sciences lab immersion program (internship of at least 6 months). Moreover, at least one semester should be spent abroad for students who have not already spent a scientific semester outside of France. This “inter-disciplinary pre-doc immersion program” for a one-year research project in a life sciences research department (after Master 2), combined with a guaranteed PhD scholarship, will promote inter-disciplinary studies. As a result, students will benefit from an additional training year in the life sciences. More generally, we will offer the option of a fourth contract year for a PhD thesis at the interfaces with the life sciences, with the obligation to spend at least one year in a biology lab.

1.3.3 Mathematicians and Engineers: training aspects

The goal is to attract more students from the Grandes Écoles onto academic training programs, and for more outstanding researchers in mathematics to teach on engineering master’s programs. Attracting engineer students into research jobs is a crucial issue in France: it is the foundation for innovation and competitiveness. Presently, in France, engineers usually have a blurred idea of what is done in research laboratories, especially in mathematics. The Paris-Saclay campus provides an exceptional opportunity to set up educational programs in close collaboration with applied mathematics laboratories, for example by short or mid-term internships, student supervision, case studies and mathematical bibliographical study supervised by mathematicians.

The pool of engineering students in engineering and computer science in the area is unique, with Programs of Excellence in physics, electromagnetism, energy conversion, thermal transfers, structural mechanics, material science, biology, chemistry, operations research, electrical engineering, etc. In order to make courses in mathematics attractive to these students, MSc programs in applied mathematics must be thought of as mathematical tools for engineering[23]. Additional efforts must be made in this direction, by getting more mathematicians involved in engineering training programs, while also opening up MSc programs in applied mathematics to more engineering students. We here develop some specific actions:

Update and align applied mathematics programs with today's innovation challenges. Engineering paradigms evolve very quickly. Uncertainty assessment, for example, is becoming as important as the accurate solving of PDEs. Computational methods must also follow the evolution of large-scale computational resources[24]. Educational programs need to be adapted to follow this fast-moving demand.

Cross-fertilization between training programs in engineering science and applied mathematics.
Mathematicians on engineering programs. We want to develop the active participation of LMH’s applied mathematicians in teaching on engineering programs. Despite some interesting initiatives[25], such participation is still embryonic, even though current innovations in engineering require rigorous mathematical settings, analysis and solution and advanced tools. We also envisage establishing communication with existing LabEx in other disciplines, especially in mechanics (discussions already started with LaSIPS).
Physicists and engineers in applied mathematics programs. Conversely, we want to get engineers involved in traditional MSc programs in applied mathematics, so that applied mathematics students will have a clear idea of the issues and challenges in engineering and computer science. They will also be able to consider the problem they are studying in its entirety, identifying all the problems (modeling, physics involved, entries, criteria, outputs, computational aspects, etc.).

[23] Some existing MSc programs already succeed in enrolling high rates of engineer students. Examples are Modeling & Simulation master’s program (http://www.maisondelasimulation.fr/m2s/), Mathematics, Vision and Learning (MVA, http://www.math.ens-cachan.fr/version-francaise/formations/master-mva/) dedicated to image and signal analysis.
[24] General Purpose Graphics Processing Units (GPGPU) for example has become a cheap high-performance computing alternative that could significantly modify the scientific computing landscape. As an example, Lattice Boltzmann Methods (LBM) are easily portable on GPGPUs devices for computational Fluid Dynamics. Recent developments in ENS Cachan, Farman Institute (http://www.farman.ens-cachan.fr/) lead to real-time simulation of 2D unsteady high Reynolds, Navier-Stokes flows (see http://www.youtube.com/watch?v=vOFcHqImXJ8).
[25] For instance « Regards Croisés Maths-Physique » M1 course at the ENS Cachan provide mathematical viewpoints on physics problems: physical stochastic processes, biological image processing, quantum cryptography and physical dynamical systems

Financial support for summer schools, with participants from different origins. In the area of applied mathematics, the CEMRACS annual summer school involves participants from industry and companies, professors, foreign researchers, as well as master's and PhD students, post-docs, and covers both theoretical aspects and concrete projects. The Paris-Saclay campus will set up and apply for maths/engineering summer schools, such as CEMRACS, so that master's students, engineers and researchers from the FMJH can collaborate on exciting real-life case studies and ambitious projects.

Developing CIFRE PhD scholarships. There is an underused option for obtaining PhD scholarships in academic laboratories with connections to industry: the so-called CIFRE conventions. These stipends are paid half by a company and half by the French state. This little-used option should be developed.

Apprenticeship Master's Grants: Business schools in France usually offer "Apprentissages", in other words, training schemes funded (support for living costs and tuition) by companies for students who are part-time in a working environment and part-time in the business school, very much in the spirit of the CIFRE program but at master's level. In cooperation with companies, we plan to initiate such a training scheme at master's level, for both Grande École and university students.

1.3.4 Short to mid-term training aspects (starting before September 2014)

A) Mathematics and Fundamental Physics Program

Our main goal is to create a two-year master's program in mathematics/fundamental physics, open to international students (with courses taught in English). It will provide the numerous students who are, a priori interested in both mathematics and theoretical physics, with a more mathematical background, as well as a complete and well-thought out program. The objectives of this master's program should include, the *mathematical tools behind the Standard Model* and how it is tested, the *mathematics of phase transition* with a quick look at conformal invariance; the *basics of string theory and supersymmetry*,

More specifically, we would aim to start this maths-physics master's program within four years of the necessary preliminary reflection required for our new and ambitious program. This calls for new types of courses, both on the mathematics side and from physics. Given the breath of mathematical physics, a lot of brainstorming is required to create a stimulating but student-friendly curriculum. We also need time to advertise it properly on a worldwide scale in order to attract really top students. In addition, we also to attract good students from the Grandes Écoles. Finally, we need to coordinate and adapt to the administrative and scientific development of the Paris-Saclay University Project, which will inevitably lead to a complete reworking of the physics curriculum in general.

B) Mathematics and ICST Program

We will fund mathematically-oriented student internships (Grandes Écoles, master's and doctoral level) in ICST labs, increase the number of ICST-oriented maths PhDs and encourage students in ICST Grandes Écoles to simultaneously follow mathematically-oriented master's programs and later enroll on doctoral programs (needs for doctoral fellowships and stipends for master's level internships in maths and ICST labs).

1.4 SOCIO-ECONOMIC IMPACT

The impact of our two major programs, together with the increased power of the Graduate School, will have a tremendous short-term effect on the flux of motivated and well-trained students into industry. As a long-term effect, the appearance of a new generation of engineers/developers, fully-aware of the research issues, will significantly change the currently compartmentalized relationships between mathematicians and companies. Aside from this overall effect, our two major programs will have specific consequences.

1.4.1 Mathematics and the Life Sciences

Apart from the scientific importance, many major socio-economic opportunities are linked to bioengineering, in terms of job offers for our students, as well as developing start-ups and research contracts. We here mention just two identified targets.

The first field is medicine/the pharmaceutical industry/epidemiology. Rationalizing prescriptions is a crucial social and economical issue, notwithstanding the even more important issue of the patient's health. Thus far, the study of the effects, in particular individual effects, of prescriptions is sometimes questionable from the statistical point of view. The challenge of adapting a prescription to an individual – using personal data -- is a well-identified challenge: we have already been successful in this direction, as evidenced by recent developments at the École Polytechnique or achievements with start-ups, such as developing the LIFTOX MONOLIX software (Paris-Sud), recently rewarded by the MESR and OSEO. Nevertheless, the field of potential applications remains immense. The economic demand in this domain should soon provide job opportunities for well-trained students.

A more classic field, for which we have strong and steady demand in terms of trained students (for example, the CIFRE PhD) or research contracts, is agronomy and the food industry. Presently, we do not have a strong enough structure to fully respond to this demand, and the LMH will be an effective tool for responding to this issue.

Finally, the issue of training engineers and policy makers with a strong background in the mathematics driving the evolution of ecosystems is a key challenge for our society.

1.4.2 Mathematicians and Engineers

The socio-economic impact of the relationship between mathematics and engineering science is well-documented. The challenge we face is to rationalize and channel jobs offers, as well as research contracts, more effectively than at present, which is essentially based on individual contacts.

As a tool for this expansion, we will create an *interface portal* between companies and research departments in the LMH. The future Paris-Saclay campus will be a very large structure, with very different institutions. In order to rationalize the relationship between companies (seeking internships, PhD students, proposing jobs or consulting) and the LMH's various departments, we want to create a common and well-identified portal structure with a dedicated administrative staff, which aims to help companies clarify their demands, express their needs and, more importantly, be aware of the possibilities offered by the LMH.

The academic program "*Gaspard Monge Pour l'Optimisation*" (PGMO) between EDF R&D and the FMJH is already a milestone on this ambitious program (page 36 of the Annex).

2. GOVERNANCE.

The LMH LabEx builds on the FMJH and its governance structures (see page **Erreur ! Signet non défini.** and pages 27 to 30 of the Annex). The experience and success of the FMJH has already demonstrated the relevance of its governance scheme. Moreover, this coherent scheme of governance ensures the coherence of the actions of the FMJH's partners.

The director of the FMJH is, *ex officio*, the main coordinator of the LabEx.

Each LMH program will have a coordinator from the LabEx, appointed by the main coordinator and renewed every time the FMJH's steering committee is renewed. If not already a member of the steering committee, such a coordinator will attend the meetings of the FMJH steering committee. In coordination with the main coordinator and the FMJH's direction, the coordinator will prepare an annual action plan that will be incorporated into the FMJH's annual action plan. The main lines of the action plan for each program must be validated by the FMJH's direction.
Each program has a dedicated budget, for which the main coordinator is responsible. After periodically consulting the FMJH's scientific committee for its scientific opinion, the main decisions will be taken by the FMJH's steering committee.
The execution of the program for each LMH program will be ensured by the relevant coordinator, under the operational responsibility of the main coordinator, who is responsible for reporting. Each coordinator will be responsible for organizing an *ad hoc* small and reactive executive team.
The Government Assessment Agency AERES will perform the external assessment process, which involves international experts. Furthermore, the FMJH's scientific committee (which is composed half of external members belonging to the Paris-Saclay campus) will evaluate the LMH's action every two years. The rapid start and development of the LMH's 5 programs will be important milestones. An annual report from the LMH will be included in the FMJH's annual report, which will be made public.