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学科会聚与创新平台

高新技术高峰论坛

GAOXIN JISHU GAOFENG LUNTAN

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编者感言

由浙江大学和香港科技大学共同筹办的以学科会聚和创新平台为主题的高峰论坛，受到了许多专家、学者的高度重视。他们不少人亲临会议，发表具有远见卓识、启迪思维的讲演，充分阐明了在纳米技术、生物技术、信息技术和认知科学迅速发展、加速会聚的新时期，这些科学将会对科技、经济和社会发展各方面产生难以估量的共振效应。NBIC 将是创新成果喷薄而出的重要源泉。它将无情地冲击 19 世纪沿袭下来的分科而治、因循守旧的传统观念。与会代表如感同身受的领略到科学动态、交融、会聚的新境界。

科学史表明，科学家不只是知识的发现者，更是知识的综合者。古今中外的大学问家，都是在综合知识中创造，在发现知识中综合，在综合的过程中，按照内在的逻辑关系，把已知知识条理化、系统化，发现矛盾和空白，再作观察、试验论证，得出新的原理，补充和完善知识体系。这就是科学发展的过程。在本次论坛上，演讲者们从科学技术最新发展的事实出发，把这一原理进行了淋漓尽致的阐述，这对广大科技人员来说无疑是有现实参考价值的。

科学技术发展到今天，新学科不断涌现，学科间的传统界限不断消失，学科间的交叉、渗透成了主要的发展趋势，已导致学科的综合化、整体化发展，学科创新平台的建设也就应运而生，形成了一个高层结构纵横联系、动态发展的新格局。为贯彻落实国家的“十一五”科技发展规划，实现学科会聚、构筑创新平台已是不可逾越的阶段。否则，单学科只能在原有的知识框架内苦斗，难以跟上世界科技发展的滚滚洪流。出版本论文汇编，是期望对学科会聚和创新平台建设起到催化和推进的作用。

本次论坛的顺利举办和论文集的出版，得到了香港聚大行唐学元先生的资助，得到了香港科技大学张慧敏校长助理、浙江大学科技战略发展研究中心、浙江大学科技处的大力支持和帮助，在此表示衷心感谢。

编委会

2006 年 9 月

目　录

讲　者　报　告

论　坛　来　稿

建设科技平台　会聚学科力量
提高研究型大学的自主创新能力

赵沁平

党和国家高度重视提高自主创新能力。胡锦涛总书记多次强调，要把提高自主创新能力摆在全部科技工作的突出位置。提高自主创新能力是推进产业结构调整和转变经济增长方式的中心环节，是增强国际竞争力的必然要求，也是我们建设世界一流大学和高水平研究型大学的必由之路。

一、自主创新能力的要素

自主创新能力有三大要素：创新人才、创新体系和创新文化。创新人才是自主创新能力的主体，创新体系是自主创新能力的条件，而有利于创新和创新人才成长的文化可以说是自主创新能力的灵魂。

一个国家要提高自主创新能力，成为创新型国家，一个地区或行业要提高自主创新能力，成为创新型区域，都必须考虑这3个要素。一所大学，特别是作为国家创新体系重要组成部分的研究型大学，要提高自主创新能力，也必须从这三方面入手加强建设。

学科是大学的基础和基本构成单元，大学的科技创新成果从学科产生，创新人才从学科走出，学科自然就成为大学自主创新能力的载体和自主创新能力的体现。大学要提高自主创新能力，就要从3个要素入手建设一批高水平的学科。

二、学科划分与新学科的形成

1. 学科划分

学科起源于科学研究即人类对自然和社会规律的探索，是根据不同研究对象或对象属性，对自然、工程、社会、人文等进行的一种划分。随着科技进步、社会发展以及社会分工越来越细，学科也不断分解，派生出新的学科。

科学研究产生知识，有了知识也就有了知识传授。由于学科的划分和社会的分工，也就有了按学科的知识传授。知识创新和知识传授是学科的两大内涵，也是学科存在的两大基础。

学科的划分可以有不同的着眼点：一是面向科学研究，其发展形成取决于人类认识世界、改造世界进程中所面临对象的不断扩大、变化和所用手段的不断发展、进步。面向科学研究的学科需要保持先进性、前瞻性和灵活性，学科划分和分级可以很细，变化也可以较快。二是面向人才培养。这类学科划分（目录）应当具有科学性、系统性、规范性和宽口径的特点，其学科人才要有明确的适用领域，同时社会对该学科人才还要有一定的需求量。

此外，还有各种着眼于其他行业应用的学科划分。

学科划分应当是发展的、动态的，同时又应当是相对稳定的。由于自然、社会的复杂性，人类认识的局限性，任何一种划分也都是相对的、软性的。人类主观划分的学科永远存在交叉问题，交叉学科的人才培养问题归根到底要靠培养机制改革来解决。

2. 新学科的形成

新学科的形成有两种方式。

一种是分解派生，即在已有学科的基础上分解派生出新的学科。就如核裂变，一个重原子核分裂为多个较轻的原子核，同时释放出巨大能量一样，一个学科分解派生出新的学科，将会对相关的科学技术产生巨大的推动作用。早期新学科的形成主要是这一途径，现在仍然不断有新学科在分解派生。

第二种是会聚融合，包括学科会聚和学科融合两种模式。学科会聚是不同学科的专家学者会集在一起，共同解决一些复杂、重大的科学和工程问题。学科会聚并不一定形成新的学科。学科融合指的是不同学科在某些层面、某些方向上融会结合成为新的交叉学科，就如同核聚变，几个较轻的原子核聚合成一个原子核，同时释放出巨大能量，学科的会聚融合对科学技术发展也有巨大的推动能量。学科的分解、派生是学科在新的层面会聚融合的基础，现代许多新学科是通过会聚融合产生的，例如生物医学工程、环境科学等。

3. 几点建议

研究型大学要有意识地针对科学研究和人才培养两种不同目标，根据分解派生和会聚融合两种不同的新学科形成途径，采取不同的模式、机制和组织管理形式来设置、建设、发展自己的学科。

要结合自己的特色优势，科学、合理地运用在已有博士、硕士学位授权一级学科中自行设置二级学科的自主权，发展交叉、新兴学科，改革研究生特别是博士生的录取、培养办法，以利于交叉学科的科学研究和人才培养。

同时也要根据科学技术的发展和社会的需求研究论证新的人才培养一级学科，并积极向有关部门建言献策。

三、高水平学科的建设与科技平台

1. 高水平学科的建设

高水平学科的建设内容主要有4个方面：汇聚、培育学术队伍；凝练、引领学科方向；构筑科技平台与建立相应的管理体制；营造有利于科技创新和创新人才培养的文化环境。最后一点尤其重要。在许多科学技术领域我们与发达国家的差距并不大，技术追赶也相当快，但在新科学新技术的首创性方面存在很大差距，自主创新能力的提高还需相当长的时间。其中一个重要原因就是我们的大学缺少深厚的有利于科技创新的文化。这是一个很大的话题，将另文论述。本文主要谈科技平台的建设。

2. 会聚型科技平台

科技平台的概念来源于计算机软件开发的工具环境，狭义理解指的是科学研究的设备设施，广义上理解就是科技创新的综合环境。科技平台从所支持的学科角度出发，分为单学科型科技平台和学科会聚型科技平台；从平台功能出发，则可分为研究与开发平台、工程化与成果转化平台和科技公共服务与支撑平台。不同类型的科技平台需要不同的建设模式和

组织管理体制。对学科会聚有直接凝聚作用同时又极具有挑战性和体制创新空间的，就是学科会聚型科技平台。

3. 学科会聚的4种类型和4种聚合力

学科会聚一般来说有4种类型。(1)学科交叉成长型：不同学科的研究者为了共同的科学目标主动会聚在一起，研究解决共同的科学问题；(2)工程任务拉动型：围绕国家指令性任务会聚在一起进行攻关，如清华大学的核能、北京航空航天大学的无人机等；(3)新型技术推动型：新兴综合性技术的发展，例如虚拟现实技术等可以推动不同学科的会聚；(4)科技平台吸引型：不同学科的研究者长期依托同一大型科学设备，例如加速器等开展研究，导致一些学科的会聚。

学科会聚需要有强大的持久的凝聚力，否则无论从何开始建设，到头来都会退化到原先分散或貌合神离的状态。这方面我们已有不少经验教训。学科会聚的聚合力大体说来有4种，即重大科技设施或者成龙配套的设备；重大基础研究、战略高技术任务或重大科技工程；高水平高素质学科带头人以及有利于学科会聚和自主创新的管理体制、运行机制和文化环境。目前特别需要学校下决心花大力气的是会聚型科技平台的管理体制和运行机制。

四、对学科会聚型科技平台建设的几点建议

1. 学校要根据不同会聚学科的情况，制定不同的学科会聚型科技平台建设的模式、方案、路线和策略。要因校制宜、因学科制宜。大体说来有以下几种建设模式：一种是集中规划、集中管理、集中建设，现在已经批准筹建的几个国家实验室都是这种模式；一种是集中规划、集中管理、分别建设；还有一些是集中规划、分别管理、分别建设。最后一种过于分散，很难保证高水平实现其集中规划的目标。

2. 创新科技管理体制，特别是校级科研管理体制。我们的科技管理体制和运行机制要有利于激励创新包括激励个人自由研究和激励创新团队的不同机制，有利于汇聚人才，有利于会聚学科、整合资源，有利于对新方向、新机遇的快速决策反应。我感觉目前我国大学科技管理能力有一些重要缺失，比如对国家和大学自身科技发展战略的研究，对科技发展机遇的快速反应与自主投入预先研究、自由研究以及资源整合等。校级科技管理体制，外可以借鉴中国科学院，内可以借鉴大学研究生院的模式。

3. 学科会聚型科技平台的管理体制要有利于最大限度地发挥4种会聚力量，可以考虑建立与不同会聚和建设模式相适应的，独立的、半独立的，专门的、半专门的，集中的、集中分布结合的研究院或研究中心。总之，要组织得力、管理有效，能够确保科技平台的建设和学科会聚目标的实现。

4. 建立科学合理的评价指标，选择适当的检查时间点。国家在科技平台建设上投入了大量资金，我们一定要珍惜，要用好。科技平台作为一个建设项目，要有建设目标、建设内容，同时在学校也应制定相应的建设评价指标和合理的检查时间点。

Building a Foundation for Research and Technology Competitiveness

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Thank you very much, Professor Chu. It is a pleasure to be here. After listening to the Minister, however, I am not sure that there is a whole lot I will say that he didn't say extraordinarily well.

I think one of the things that is important to acknowledge upfront is the contribution Professor Paul Chu has made to organizing this conference. Thanks again, Paul.

I appreciate greatly the invitation to be here and the work that Ireland and Irish Universities are beginning to do with the Hong Kong University of Science and Technology (HKUST). We view HKUST as a key, unique institution in this region of the world, and expect to work closely with it in the future.

I also want to mention that this past January 1 accompanied the Prime Minister of Ireland on a visit to Beijing, where I had the good fortune to sign an agreement with Professor Chen for a new R&D partnership between the Chinese National Natural Science Foundation and the SFI of Ireland. We committed ourselves not just to signing an agreement, but to actually doing something and to getting the researchers of both countries together. And we have begun. A group of Irish scientists and biologists visited Beijing and Shanghai this past spring, and next month we will have two large groups of Chinese researchers visit Ireland. So we view this relationship with China to be a very important partnership.

Many of you in the audience will know that in the early 1980s, specific leaders from China visited the Shannon Development Area of Ireland and were inspired by the success of the Shannon economic model. It is my understanding that this visit to Ireland became one of the inspirations for the Chinese development over the past 15 years or so. Thus, the relationship with China is a special one for Ireland. And despite the countries' vastly different sizes, the history of the past century has important similarities in terms of being primarily agricultural economies, having primarily closed societies, and transformed by leaders with imagination and people who want to make a difference for their societies. And one of the driving factors for Ireland was the reality that the Irish population was decreasing. People were leaving the country rapidly to find an economic opportunity elsewhere. The country recognized that the only way it could turn itself around was through a huge investment in education and to build upon a well-educated population in the future.

I have a couple of slides to show today, but before discussing them with you, I want to give a little bit of background about the country and its size and the changes taking place during the same rapid period of Chinese advancement. Now, one of the things that I think is interesting to recognize is that most of the world today recognizes Ireland primarily for its literature, as four Irish writers have been awarded Nobel Prizes in literature. The world also recognizes Ireland for its music. Many in China have seen something called "River Dance" and are familiar with Irish music. But many people would not realize that Ireland, a small island, has a unique history in science. It is part of that history that we are hoping through the Science Foundation Ireland (SFI) to rekindle, and we already see the roots of excellence and innovation growing over the country in these early years. Those of you in this room who are chemists will know the name Boyle for his gas law work. Boyle was an Irishman. Many of you here who are physicists, chemists or engineers will know the name Hamilton. Hamilton was a great mind, and we are privileged that he was a professor at Trinity College, a university in Dublin. Those of you who are in computer science and many related fields will be familiar with Boolean algebra, and it turns out that George Boole was a professor in Cork, Ireland. These individuals formed a huge foundation for Ireland in science and engineering and especially in the creation of ICT.

Another name I think many of you will recognize is that of a distinguished and important scholar of the past century — Erwin Schrö dinger. In 1939, the President of Ireland recruited Schrö dinger to Ireland, and he spent about 25 years doing research in Ireland. Many of you who are in the field of biology will be certainly well familiar with the work of Watson and Crick, and the double-helix. You may not be so familiar with Schrö dinger's book "What is Life"? It was based on his lecture at Trinity College, Dublin and was published in 1944, and led Watson and Crick, and other chemists, physicists and biologists of that generation to study the structure of DNA, which led to the modern revolution in biology. So there is a huge tradition of excellence and innovation in Ireland; and we hope to use those traits to stimulate more in the future.

It is also important that most of us who are scientists and engineers are used to working with models, and we try to scale the models up and apply them to real-world systems. I'd like to give you something to think about from the Irish model. The sizes of Ireland and China are vastly different, but Ireland may provide a good model for different regions of China to emulate in terms of scalability, and then you can perhaps see that scalability apply across the country. It may also be a model for different states in the United States to think about, as they look at scalability as well. SFI is a model that is relatively new — began within the past five years.

Prior to 1990, there was really very little research in Ireland. The period from roughly 1916—1960 covered a period of war (revolution and civil wars) and reconstruction of the society and there was very little money. If one goes back to 1988, the unemployment in Ireland was almost 20%. And 1% of the population was leaving the country each year. That was a hugely difficult time. Back in the 1960s, the Irish government made some radical decisions to

invest in education, recognizing that science and engineering were going to be keys to the country's future. And they knew that in the following few decades, though they might lose a lot of their young people to live abroad, the leaders hoped they might be able to attract them back in the future — but in any case they wanted to make sure their children had a solid education and could succeed anywhere. I think in that story is a parallel to the same kinds of things that took place or have taken place in China. Again, it is about scalability and the impact can be the same. Key people are who will make the difference.

In Ireland, after the decisions on education were made — the decisions to open up education and make it free and mandatory for everyone — they then opened the universities and made them free. Now approximately half of the young people get university education. And a vast majority of them study science, engineering and mathematics. That is critically important for the 21st century, absolutely critically important.

My concern now is that Ireland's success over the last 10 years has created what I see as a problem for most of the western countries. Once you become successful, the young people begin to think of other things to study rather than science, mathematics and engineering. So there are warning signs in Ireland now about a declining interest in some of the subjects, just as in other western countries. Even in China, at some point you probably will have to consider how to continue to encourage people to study science, mathematics and engineering. I believe that you have some advantages now because of the scale and the importance of specific national projects. For example, I had the privilege to visit the Three Gorges Dam this past week. This is a huge and truly significant national project which will motivate and encourage young people to look at big problems and study technical disciplines — and appreciate the interdisciplinary requirements as well. And then you have the marvelous success of your space program, which excites young people as well.

Going back in the 1990s, Ireland recognized that it had to do more than just depend upon past methods. It realized that it had to invest in science and engineering for the future, and had to create a way to bring back innovation and have ideas come from its own people, not just borrowed from foreign investment, although it was very successful in that area. So in 1999, the government of Ireland, led by the Prime Minister and Deputy Prime Minister, organized the Technology Foresight Review. They decided to look at the country's current competitive position with a goal to maintain its success. The Irish per capita income has gone from being roughly 60% of the EU average to, by the current year, almost 135% of the EU average. That is a huge transformation in the economy. And now the new countries in the EU are looking to Ireland as a model for economic transformation. But Ireland recognized that it had to do things differently to build on that success, and it did — just as we heard last night from some of the opening speeches. Ireland focused on a knowledge-driven economy — that is, on ways to take ideas and create new opportunities for the future. And one of the difficult challenges that I think we all faced is how you support and create an environment to encourage people in science, mathematics and engineering to pursue their own interests in research.

One of the challenges that I had when I was at the National Science Foundation was to try to encourage the US universities to think about their responsibilities to society. It is not just that they get money to do research. We have a special obligation in universities what is to think about the entire education system in the country. To think about how to generate the prosperity that enables research and great universities to exist. I don't know of any poor countries which are able to have great universities and great scholars who consistently do world class research and win Nobel prizes, etc. So, in my opinion, there is no conflict between an investment in research that the government might make and the desire to have social and economic prosperity. And I think part of the discussion of convergence of disciplines that we are talking about has to begin to address the reward system, so that you have a way to encourage cooperation between researchers in industries and researchers in university systems which advances knowledge and provides benefits to the society.

SFI has to invest in research in the context of the strategic value to Ireland. We can't just simply spend money to spend money. We don't have that kind of luxury. In Ireland we had the specific advantage of the huge software engineering and manufacturing base. We also had nine of the world's top ten biopharmaceutical companies in Ireland. So when the Technology Foresight Review took place in 1999, the decision was to start something which is called Science Foundation Ireland (SFI). It was started initially to underpin or support these two large inter-disciplinary sectors of the society, the ICT and biotechnology sectors. If we didn't take advantage of that competitive advantage Ireland had, we would be fooling ourselves. A country of four million people has to make careful decisions. Initially, the SFI remit was to encourage and build strong research programs in ICT and biotechnology (BIOT) but this was later expanded to include the broader frontiers of science and engineering. And my suggestion to you is that Ireland can be as competitive in the ICT and BIOT fields as anywhere because these are relatively new fields. We are not trying to invest in costly, mature areas such as nuclear and high energy physics, for example. We are investing in the most modern knowledge areas, and our young people and your young people can advance there as rapidly as anyone else in the world.

I was asked to make Science Foundation of Ireland a competitive institution — based on international standards of "excellence". Our goal is and was to do so, but on a very selective basis as we are not a country large enough to cover all fields. Thus, we understood we had to make choices or set priorities and we knew we had to base our decisions/investments on excellence. We had to establish a system which was credible and trusted by the research community in Ireland and the world at large. In small or large countries, research scientists and engineers (S&Es) operate with common core values which include creativity and a focus on excellence. That is why we focus on world-class standards of excellence.

The language of S&E and mathematics is shared globally; thus, the technical research community has been involved in "global" competition before the term "global" became a commonly used word. And, in the world of research, we cooperate and compete and we respect

the achievements and creativity of other colleagues in all countries. That is how science has advanced so powerfully during the last century. We exchange undergraduate, graduate and post doctoral students. We share the development of knowledge through our publications, books and lectures and almost uniquely. So, at SFI we chose to use international peer reviewers for these reasons. We borrowed general concepts directly from the US National Science Foundation and adapted them to Ireland. Why NSF? Because it is a acknowledged world leader in the support of creative researchers. The NSF model has evolved over a period of 50 years; hence, a significant majority of the world's researchers are familiar with NSF because of their research experience as students, post docs or senior researchers in the US. Most scientists in this room, in fact, probably have had experience with the NSF in the US.

SFI provided a model that the research community in Ireland understood and could work from. While we borrowed the NSF model, we adapted it for Ireland. We used it in a way that guaranteed external (international) review, because the country was too small to use internal scientists. For our larger "centers" (CSETs), we used not only international postal or mail review, but we also invited technical experts to come to Ireland to carry out detailed site reviews to determine if the proposed center was truly world-class. As with the NSF decision process, the SFI external reviewers and panelists recommend an action to SFI. And the external reviewers also provide SFI with questions and issues which need to be resolved before SFI finalizes its decision.

Since SFI is accountable for the decisions and the use of taxpayer money, it is essential that all SFI staff take full responsibility for the decisions and be in the position to explain to the researcher why a project was or was not funded. Thus, like NSF, SFI staff make the final decisions on the basis of the external review and SFI shares the results directly with the scientists and engineers in a completely transparent manner.

To summarize, the SFI put in place a demanding and internationally respected peer review system by using the highest standards — and we were calibrated in the early days by NSF colleagues and we benefited as well by calibration from individuals experienced with the UK research councils. It was a challenge and a lot of work, but the benefits are a robust and excellent research community in Ireland. And, when a scientist or engineer receives an SFI grant, there is a broad recognition that the researcher is truly an outstanding scholar. And that has increased the pride and confidence of the Irish research community. The SFI grantees are world-competitive researchers/scholars.

For the individual scientists that we recruited to Ireland and helped to fund, we also made sure the decisions were typically made in eight to twelve weeks. We felt that speed was very important to make Ireland friendly to scientists and science as well. We do not want to spend 1 or more years trying to decide on a proposal or person because things are changing too quickly in the world and the research competition is too intense. And, we want to give review feedback in a timely manner to help distinguish SFI and Ireland. We have aggressively recruited researchers from the international community to further enhance the talent already in Ireland and to

complement the world-class researchers there. We recruited scientists from Oxford, Imperial, Max Planck Institutes and from the United States. We have recruited aggressively and brought back Irish scientists who are working in other countries. And in less than five years, we have invested in over 450 research programs, we have almost 500 million invested in research, and we have begun to establish new research partnerships in the areas of ICT and biotechnology. And there is interdisciplinary convergence.

SFI has a broad responsibility now to strengthen the connection between the research-based universities that are being built and the research base being built in the companies. In the past, companies in Ireland were primarily manufacturing companies, but that focus has shifted to knowledge-based endeavors. The statistic which probably staggers the mind is that this small population leads the world in software exports. Ireland also has some of the world's best game programmers which connects us to other parts of the computer society. So Ireland is ambitious, but Ireland knows it has to compete on the basis of excellence. It will not be successful by saying it is good enough for Ireland. It has to be good enough in the world. So SFI places a very high emphasis on the quality of proposals and current track records of the researchers as we reach funding decisions. The Foundation is governed by an international board of 12 people — eight Irish people and four international experts. And they have the final say, with their perspective on the world of competition.

A member of our first board, Prof Robert (Bob) Laughlin, is also to speak at this High Tech Forum. Bob is a Nobel Laureate from Stanford and a very significant and helpful member of the SFI board. And people like Prof Laughlin always push our focus on creativity and excellence, so SFI staff cannot relax or become complacent with such a strong Board. Thus, our staff have to consistently ensure that we are the best we can be and that we are helping to build a truly first rate research climate and supporting world competitive researchers whose work will add value to Ireland in the long term. The Board demands that we take intelligent risks — that SFI is opportunistic.

The slides just show how rapidly economic prosperity grew in Ireland over the last two decades. You will see the growth of Ireland, and if I put China up there you will see similar kind of percentages, huge similarities. Ireland has become a model for the support of future research by the EU — that is, the EU wants to build a pan European research council and it has eyed the success of the SFI and may borrow aspects of our work, particularly, the SFI laser-like focus on excellence.

Again, the reason we decided to make Ireland "friendly to scientists and science" was that we could not compete with the UK, Germany, France, or the USA, for example, as those countries had very large, established research systems. We had to create a model for Ireland who was less bureaucratic, and friendly to scientists.

I had worked in the National Science Foundation in the US, I had worked in US universities, and I understood well the frustrations of scientists and engineers with respect to unnecessary bureaucracy and paperwork. So we did a couple of things intentionally. We created

a small spectrum of programs, and we imposed very few rules, but there were a couple of principles:

• SFI was initiated by making relatively large grants of 5 years duration to individual researchers. SFI viewed the grants as investments in Ireland's future.

• For the SFI centers (or larger, interdisciplinary grants), these awards had to be even larger and had to encourage partnerships with industries; thus, they have a duration of up to 10 years.

• It should not matter how old the researcher was — what was important was how good the research was and is — as SFI was committed to supporting quality and performance.

• SFI should be opportunistic.

The goal was to minimize paperwork and to encourage innovation in the research community and not to regulate or control the community. We wanted to encourage and inspire new ways of thinking. Again, the progress we have made is reflected in the fact that we were asked by the EU this past year to lead a review of European research in framework programs, which are extraordinarily important programs for Europe. But they are excessively bureaucratic. And the EU asked me to chair a group to look at the future of European research in a way that would minimize the bureaucracy and particularly focus on outstanding researchers and the support of excellence.

My last point would be to go back to what the Minister said in his earlier lecture. I think it is essential to build an incentive-based system. You want a reward system which encourages innovation and new fields of work. And, importantly, you want to keep things simple. It is easy to put on a lot of oversight, and auditors in place, but if you do too much of that you will end up spending more money and getting less innovation out of the process. And I think if you take the risk you need to take, you will find that you will transform the society in terms of its potential for economic success and prosperity. You will create an entrepreneurial culture which will grow and evolve over time and have enormous quality and value to society, if you focus on the incentive based system.

We at SFI, and more broadly in the Irish research community, look forward to working with our colleagues in China mainland and Hong Kong in the years ahead. We look forward to building new research partnerships which are based upon the most creative ideas which will benefit the people of the world.

Thank you very much.

工程的综合性

中国工程院院士　朱高峰教授

各位嘉宾，先生们、女士们，早上好！非常感谢会议的组织者给我这么一个机会来介绍我个人的一点看法。关于主题的重要性，我先举个例子。几年以前，因为我们教育改革里面学科目录的改变，在本科教育里面把物流专业给去掉了。我遇到几个物流方面的专家与教授，跟我说，他们期望我能不能帮他们呼吁一下，这个物流专业很重要，社会上非常热，需要大量人才，应该恢复这个专业。我就跟教育部有关司局去探讨这个问题。他们问我，你说物流属于哪个大类？首先这个目录，刚刚赵部长已经讲了这个问题了，关于学科分类一下子把我卡住了，我确实回答不上来。我想了半天，当然也不熟悉这个大类怎么分法。属于管理吧，物流不仅是管理问题，还有物理实物、技术方面的问题，你说属于哪一类技术吧？我也说不出归哪类。最后我回答了一句，正因为说不出来归于哪个大类，所以更需要建立这么一个学科。我不知道他们能不能接受我这个思想。我觉得对于我们在整个科学技术的发展中，类似的问题经常会遇到，因此，我们今天探讨的课题是非常有意义的。

另外一点我需要申明一下，学科会聚，顾名思义是关于科学方面的问题，我今天讲的是另外一个领域，是关于工程方面的问题。实际上前面两位演讲者都已经谈到学科会聚里面的一个推动力是关于工程方面的需求，举到的很多例子都是关于工程方面的问题，所以在学科会聚里面，工程的发展与需要，恐怕起了一个非常重要的作用。而对工程本身来讲，我不好讲会聚，它是个综合的问题。所以下面我分别来说说5个方面的问题，首先是科学技术体系，然后是现代工程内涵、工程综合内容以及一些特点，最后再举几个实例。

一、科学技术体系

要讲工程，首先要在科学殿堂里面讲清楚这个事情。因为从科学来讲，科学是人类探索自然和社会现象并取得认识的过程和结果，它包括自然科学和社会科学。自然科学是我们探索认识自然的过程和结果，社会科学则是探索认识人类社会的过程和结果。这里的“过程”是指研究和探索的活动，即认识过程，也就是科学研究活动。“结果”是研究和探索得出的科学的理论体系，即理论化的知识。科学本质上属于认识世界范畴。

而技术是人类在改造世界的过程中采用的手段，它本质上属于改造世界。例如：天文学上要弄清楚天上有多少颗星，哪颗星在什么地方，做什么样的运动，这是认识世界，是科学。但怎么去探索是在什么地方，弄清楚就需要有方法、手段。古时候没有，就用人类肉眼去看，现在我们有天文望远镜等各式各样的手段，这是技术问题。又如：什么时候发生地震，作出预测或进行系统记载，都属于认识世界的范畴。但如何预测，如何预防地震，同样需要方法、手段。这些方法、手段就是技术。技术属于改造世界的范畴。

工程是人们综合应用科学的理论和技术的手段去改造客观世界的具体实践活动以及它所取得的实际成果。工程中不仅含有许多技术方法，也涉及大量的科学理论问题。在长期的生产和生活实践中，人们根据数学、物理、化学、生物等自然科学和经济、地理等社会科学的理论，并应用各种技术的手段，去研究、开发、设计、制造产品或解决工艺和使用等方面的问题，逐渐形成了门类繁多的专业工程，如水利工程、机械工程、航天工程等。

讲工程的时候，首先得把这个问题要交代清楚。

二、现代工程内涵

工程的历史很长，在人类历史上已经有成千上万年了。而现代工程的内涵主要有几个方面。

首先要有理论基础。现代工程与古代工程的不同，比如金字塔到底如何建成，到现在仍然是个谜，我们对这件事的理论基础还讲不清楚。但是当时有没有这种理论基础，我想也很难说。再比如兵马俑里面的那个铜车马，冶金技术已经达到非常高的一个水平，但是当时有没有现代冶金学的理论基础？恐怕还没有，还说不清楚。但是，现代的工程必须需要有理论基础，这个我想大家都应该很明白了。

第二个就是要有现代技术手段，这个也应该相当明白。

除了这个以外，现代工程还有两个方面：一是要有一个组织体系。现代工程有了理论、有了技术，以一种什么样的组织形式去做，是一个非常大的学问。没有一个好的组织体系，工程是做不成的。有的工程可以在一定常规的组织去做，有的大的工程则需要在一定的非常规组织下去做。比如一些大的工程，三峡工程、青藏铁路要采取临时性的组织、专门的组织去做，这样的话才能够做好。对于航天工程，尽管我们有了很完善的航天组织体系，但对于某一项具体工程而言，仍需要在一个非常规组织体系下完成，当然不排斥常规组织体系。

另一个是运行机制，有了组织体系，以什么样的机制来运行，这又是一个很重要的问题。所以，作为现代工程而言，这几个方面都是必须要有的，当然还可以讲出其他的问题，我就不多说了。

三、工程综合内容

三就是工程的综合性，就是工程综合的内容是什么。我想有下面几个方面：

第一个是关于学科的综合，在工程里面，不仅仅是单一学科的问题，人的实践活动不可能是某一个专门学科的事情，举个非常简单的事情，比如敲打榔头，比如做一个榔头，不仅仅是物理、机械的问题，还有材料、化学、数学等。因此，工程里面本身就包涵了学科的综合，它要运用多种学科。比如飞机的基础学科是空气动力学，但就这么一门学科能支撑航空工程吗？它里面有大量的机械、材料、化学、动力、电子信息等问题。所以学科的综合是本身就存在的。

第二，从工程本身来讲，那就讲专业，就是专业的综合。几千年来，我们已经形成了一些基础的工程。专业里面有两类，一类是基础工程，比如机械工程、电器工程、化学工程、生物工程。在这个基础上还有一些专业工程，比如航天工程、采矿工程、炼油工程。这本身就有各种不同的综合，有些专业工程就综合了基础工程在里面。

第三个方面是科学与技术的综合。科学理论与技术手段的综合，这应该是很清楚的。