Simultaneous and Balanced Development Strategy of Science, Technology and Innovation in Developing Countries

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In this letter, it is shown how by having the self-consistent innovation system consisting of program offices, design offices, technology development centers and knowledge-based companies, manufacturing engineering centers, industry, national laboratories and universities, it is possible to create emergent science and developed advanced and emergent technologies. By introducing the national laboratory and the factory-laboratory strategy and combining these two concepts together, we show how it is possible to initiate the creation of the emergent science and the development of the emergent and high technology and provide the resources needed to do this. Also, based on the strategy of aggregating needs and deep technological cutting and using the factory-laboratory strategy, we will show how to develop basic technologies by networking national laboratories with domestic and foreign universities and laboratories. By defining the characteristics and specifications of basic technologies, the understanding of this concept and the strategy of deep technological cutting and pooling of resources has been provided.

Basically, research activities can be divided into eight categories as shown in Fig.1. It is expected that the start of any research activity will be the holding company's program office. This office provides the feasibility and possibility studies documents by using the research results of the studied offices, and based on these documents provide the acquisition plan (acquisition program). This program is communicated to executive units by the program office, of course, after the approval of the relevant authorities. The program office is responsible for the accuracy of the program information and its monitoring, inspection, and control. It should be noted that the entry of this program is a map or atlas of science and technology. These documents are prepared and compiled by the holding company or higher institutions of an organization. According to the concept of capabilities, the holding organization specifies what kind of technologies should be developed in order to finally achieve the capabilities. Prioritization in the map and atlas can be done using the existing method such as the analytical hierarchy process. At the end, the program office specifies how to acquire these technologies by presenting the acquisition program and informs the relevant organizations. It should be noted that executive organizations are composed of two main parts. The first part is the design office and the second part is executive centers. The design office makes the criterion for the preparation of sub-plans of its actions, and in order to realize and achieve the outputs of the acquisition program, it acts on the implementation of sub-plans in the executive centers of own organization or other organizations. Also, these offices have full facilities for designing, simulating and testing such as hardware in the loop, software in the loop and human in the loop, and they are responsible for obtaining the results listed in the subprograms. In executive centers that can be universities, research centers, national laboratories, technology development centers, manufacturing engineering centers, industry and service research centers, which are equipped by manufacturing and testing laboratories in order to fulfill the notified sub-programs. In this way, the communication between the program offices and the upstream headquarters and the innovation system is determined.

Research Type	Strategic Research	Basic Research	Prototype Research	Development Research	Production Research	Overhaul and Service Research	Market Research	Release Research
Subject of Research	Feasibility and Possibility Studies	Emergent Science and Technology	Laboratory and Prototype Manufacturing	Q.C and Q.A	Repeatability and Stability of Production	Services and Overhaul	Brand and Future of Market	To sell old technologies
TPL	NA	1<TRL<3	4<TRL<6	7	8	9	NA	NA
Responsibility	Program Office of Holding Company	University and National Lab	Science-based company and technology development center	Engineering Manufacturing Center	Inductry	Service Center	Studies Office of Holding Company	Release Office of Holding Company

Fig.1 (Color online) Different types of research, research topics assigned to them, Technology Readiness Level and Responsibility

The important point in the creation of science and the development of such technologies is that, basically, they are complex issues. The complexity here means that in their creation or development, people with very high academic expertise from different countries have participated together, the costs are high and it usually requires advanced hardware, software and knowledge. On the other hand, implicit and non-implicit knowledge is localized in the specific place of world and creation and development are done in the form of collaborative efforts, just unlike the previous sciences and technologies that used competition, coordination and cooperation models. In order to solve this problem, the global strategy is to use the two methods, which are the factory-laboratory method and the national laboratory method, and integrate them with each other. The position of the national laboratory in the development of technology is after universities and along with knowledge-based companies and technology development centers (Fig.2) [1].In this integration, a national laboratory with other national laboratories and research laboratories inside or outside a country are placed in a collaboration network and provide services to each other. Fig. 3 shows some national laboratories [2] in United State which who work in the development of energy-related technologies [3].

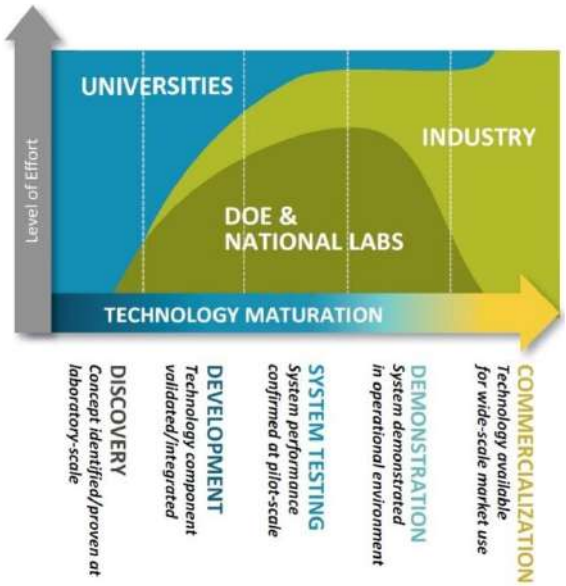

Fig.2 (color online) National Laboratory's Place in Technology Development - US Department of Energy [1].

Today, many national laboratories around the world are involved in the development of advanced technologies, among which the United States has the largest and most influential national laboratories.

A factory-laboratory is created when a national laboratory is placed in a collaboration network with other national laboratories and research and academic laboratories inside or outside the country. The members of the National Laboratory are elites and first-rate national and international students with national and international honors, who are the faculty of the Ministry of Science. In the national laboratory, courses are not offered and researchers only conduct research. Part of the budget required for this laboratory is provided from the research budgets of the organizations and ministries that participated in the establishment of the laboratory.

Fig. 3 (Color online) Examples about the National Laboratories of the US Department of Energy [1].

In fact, the program offices of investor organizations allocate and hand over the necessary credits according to their needs (Fig.4). Of course, it is worth mentioning that part of the required liquidity will be provided through the sale of technology and in the form of international collaborations. As a result, a large part of the research in the national laboratory is carried out based on the needs of organizations inside or outside the country, and a part of that need is generally focused on fields that are of less interest to investment organizations, but in the opinion of the government, are important in the future. Therefore, they will be supported by the government in the form of the concept of economy of science.

Therefore, in order for the creation of science and the development of technology to eventually lead to the production of wealth, the needs of the program offices are provided to the management of science and technology development of the presidential technology headquarters. Since this management is in close contact with the vice-chairs of various organizations and on the other hand,

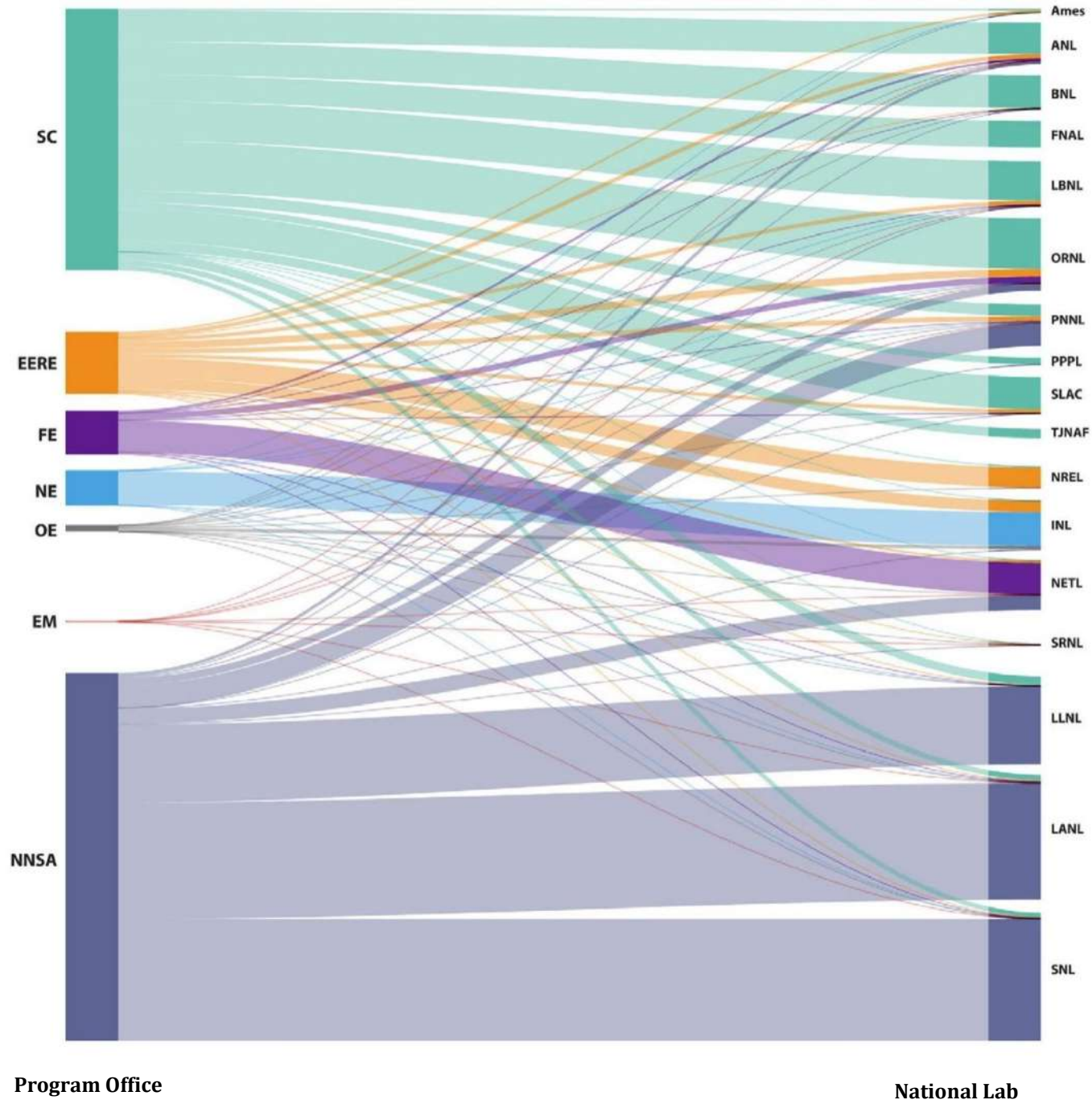

Fig. 4 (Color online) Allocation and allocation of funds to the National Energy Laboratories in the United States by program offices [1].

it is the custodian and manager of national laboratories, in a working group consisting of representatives of all organizations and national laboratories, it reviews and categorizes the requirements and prepare the request for proposal (RFP) document for every need in the council. Then, by announcing the call through various media, he requests national laboratories, research centers and universities to send their proposals to the council's secretariat by a certain date. The secretariat of the council, by creating specialized working groups consisting of the most selected experts in that specialized field and the secretary of one of the members of the council, who does not have the right to vote, justifies and prioritizes the proposals and informs the proposer and the council the result. After summarizing all prioritized projects in the council, the council meeting is held with the presence of the head of each specialized working group and the final prioritization is done. The collection of proposals is done once a year and the final response is provided no later than six months after the publication of the RFP document. Considering that the application

documents for proposals are prepared and arranged in the council and the selected projects are finally selected by the council, priority is usually given to technologies that are the common needs of most organizations. On the other hand, the pooling of resources in the above-mentioned way and the support of the government in special cases minimizes the problem of providing the required credits for research. Also, cooperation in the form of a factory-laboratory minimizes the problem of needing experts, hardware, brainware, and substitute knowledge. This technology development strategy that is needed by most organizations and in order to develop it, the resources of the applicant organizations are pooled, is called the strategy of technological deep cutting and pooling of resources.

In order to better understand the technological deep cutting strategy, we present an example of advanced semiconductor technology, here. It is well known that one of the most important features of advanced technologies is the diversity in output products and the similarity in the need for the necessary infrastructure for development. Fig. 5 shows the telecommunication applications of two advanced technologies of semiconductor components, namely Gallium Arsenide (GaAs) and Gallium Nitride (GaN) [4].

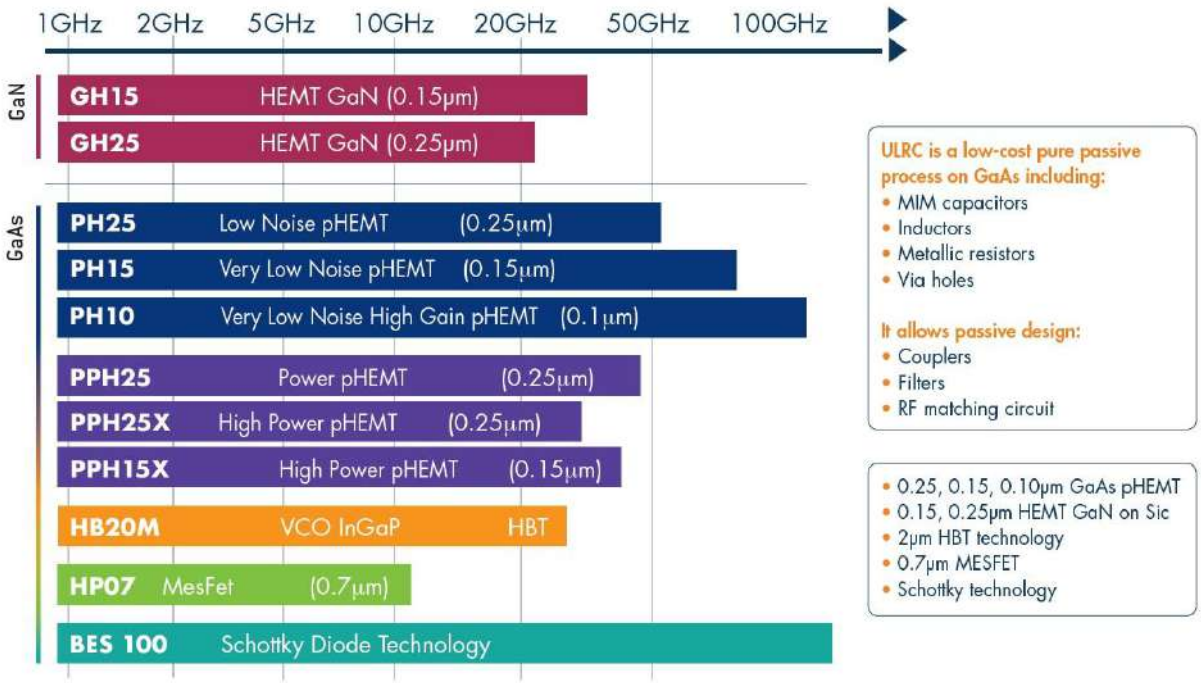

Fig. 5 (Color online) The applications of GaAs and GaN technologies from the perspective of high frequency [4].

According to Fig. 5, it can be seen that both GaAs and GaN technologies are dual-purpose. In other words, they have both military and civilian uses. Also, as Fig. 5 shows, the basic element of this technology is a transistor whose electrons have high mobility. If the electron passage area is made of pi-type semiconductor, the suffix pi is added to the name of this transistor such as p-High Electron Mobility Transistor (p-HEMT). Figs. 6 and 7 show the different applications of GaN technology [4,5,6]. Based on the proposed strategy if different industrial actors are interested in the establishment of a factory-laboratory network for acquisition HEMT technology, they can acquire a common part between different technologies (e,g Transistor) in this way and develop the rest of the technology in their own organization and thus minimize the aforementioned problems in the field of GaN superior technology development.

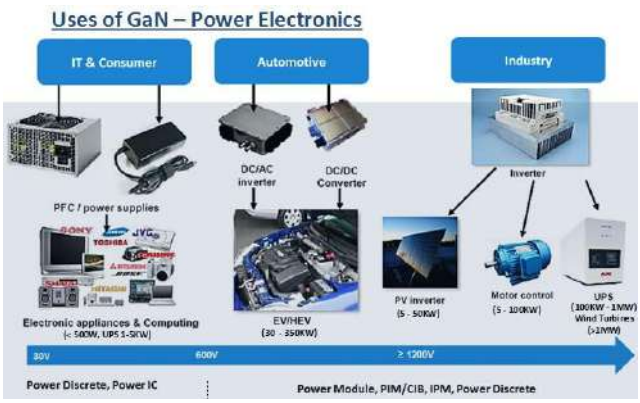

Fig. 6 (Color online) Application of power electronics of GaN technology in various industries [5].

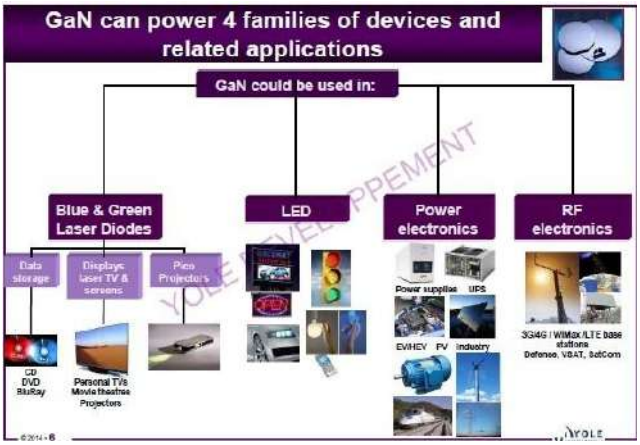

Fig. 7 (Color online) Various applications of GaN technology from laser to radio frequency [6].

Therefore, similar to the emergent science and technology development process, the technology management can be done by forming an advanced technology development council consisting of the researchers of all investor organizations and forming specialized working groups in the field of each of the specialized needs. The results of the investigations carried out by the working groups are reviewed in the council meeting with the presence of the head of each working group, and based on specific indicators and metrics, the plans are prioritized using the hierarchical analysis method, and their needs are addressed using the factory-laboratory method. Most of the funds needed to carry out such projects are provided and transferred from the budget of the applicant organizations, and the rest of it is provided and transferred by the government based on the concept of economy of science in order to support the production of emergent and fundamental science and the development of emergent and advanced technologies (Fig. 8).

For developing of basic technologies, the below items should be noted:

• The definition of the basic technology is presented in order to facilitate the development of advanced technologies and solve the problems in this development.

• The basic technology that is defined in this way can cover the main needs of intermediate and applied technologies (Fig.9) and lead to meeting the needs of different organizations. Also, this kind of technology was updated through a little investment.

• One of the main advantages of developing basic technologies is the creation and development of advanced industries based on advanced local technologies that can be developed and updated with little capital.

• It should be noted that the basic technology is obtained from the aggregation of needs and a deep technological cut from them, which may be on a Nano, Micro, Meso, and so on. The only important extension of which is being advanced.

• Basic technologies cover up to the end of intermediate technologies and do not include other types of technologies.

• In order to know the basic technology, there must be a good knowledge of the advanced and intermediate technologies in order to be able to gather the needs and failure of the technology properly.

• The deep cutting of technology is done in specialized working groups, therefore the working group members must have sufficient knowledge of the specialized field and the concept of basic technology, and the working group members must first reach a common understanding.

• The position of the basic technology compared to other technologies is shown in Fig. 9, therefore it has a fixed concept, but it may be advanced to the level of intermediate technologies based on the needs of organizations.

• A deep understanding of the underlying technology can be gained by comparing the formation of the universe based on quantum field theory. In the theory of quantum fields, everything is made up of fields and these are the fundamental particles that make up the universe. Similarly, it can be said that these are the basic technologies that make up the application, subsystem and system technologies.

• Basic technologies are necessary for the development of advanced local technologies and if they are developed based on the strategy of deep technological cutting and pooling of resources, they will not only bring about the improvement of the level of science and technology of the country at the world level, but also advanced and justifiable industries from They create an economic opinion that they can use the forces with higher education, although the workers in the development of basic technologies are also from the society of elite and high-ranking educated people.

It should be noted that between the creation of science and the production of wealth (innovation), there are three stages which are technique, technology and skill. Technique is placed after the creation of science. Technique is a knowledge and awareness which is science-based and does not lead to the direct creation of wealth (in the general sense). Technology is placed after technique. Technology is a knowledge and awareness which is the science-based and directly leads to the creation of wealth (in the general sense). Skill is placed after technology and before innovation. Skill is art and the ability to do work, which is not science-based and is obtained due to practice and based on experience, and innovation is the ability to

create wealth (in a general sense) from technology. Therefore, what is considered in this article is science, technology and innovation in this category.

In summary, in this article, we have shown how by having an innovation system consisting of program offices, design offices, technology development centers and knowledge-based companies, construction engineering centers, industry, national laboratories and universities, it is possible to produce science and development. Technology took action. By introducing the national laboratory and the factory-laboratory strategy and combining these two concepts together, we showed how to start the production of the first science and the development of the first technology and provide the resources needed to do this important thing. Also, based on the strategy of aggregating needs and deep technological cutting and using the factory-laboratory strategy, we showed how to develop basic technologies by networking national laboratories with domestic and foreign universities and laboratories. By defining the characteristics and specifications of basic technologies and providing practical examples done at the world level, the understanding of this concept and the strategy of deep technological cutting and pooling of resources has been provided.

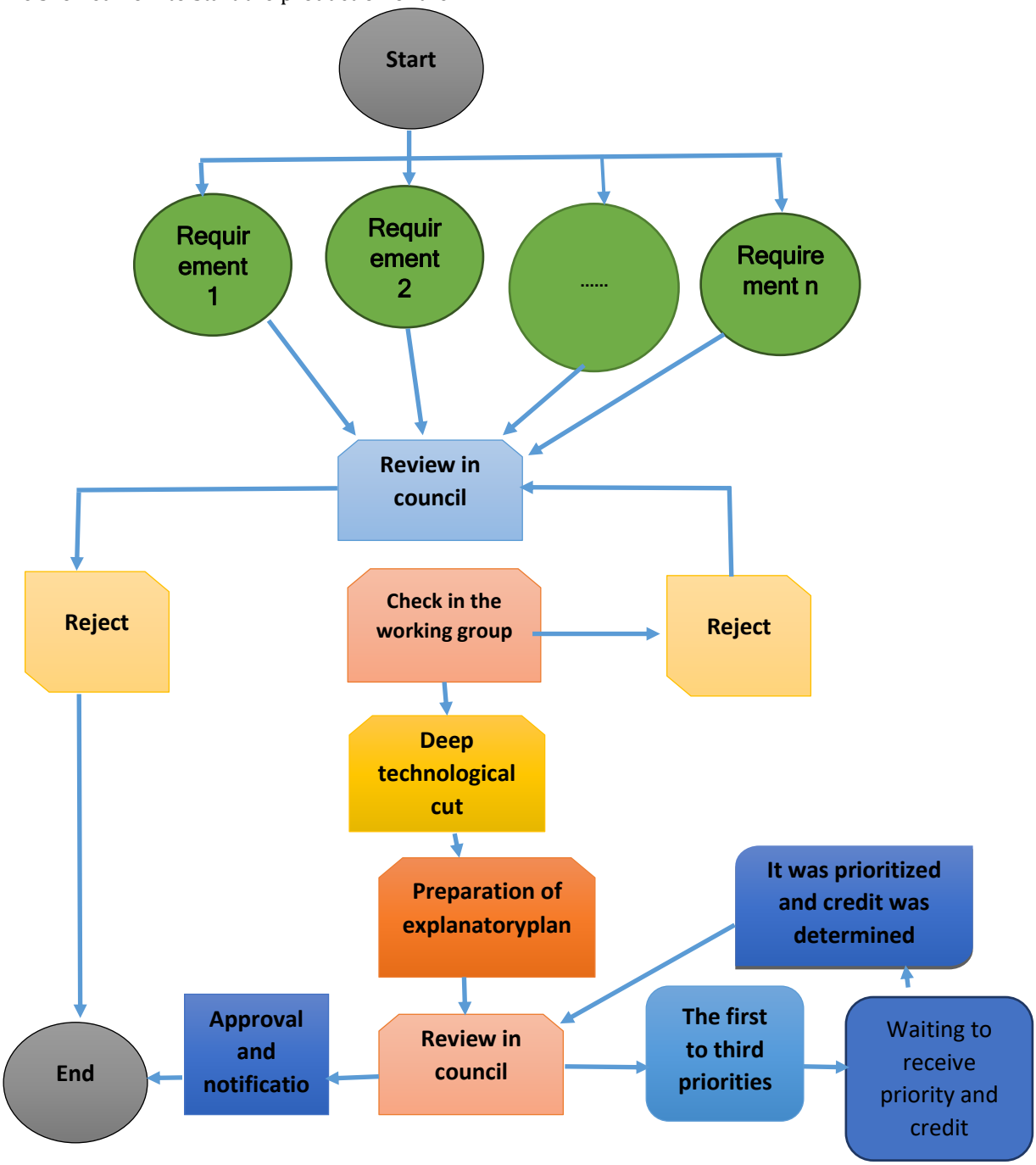

Fig. 8 (Color online) The process of calculating the basic technology resulting from the aggregation of needs and deep technological cutting.

Cost reduction and wealth creation efficiency increase

Innovation	Applied	Sale
	Intermediate	branding
	Basic	Marketing
	Studies	Market analysis,Liquidity supply
Technology	Systematic	System and Supersystem
	Applied	Sub systems such as Receiver and Transmitter
	Intermediate	Semiconductor Components, Casting parts,...
	Basic	Purification and extraction of materials, Crystal growth,...
Science	Applied	Applied Physic, Material, Chemistry, ...
	Intermediate	Fundamental Physics, Biology
	Basic	Mathematic, Philosophy

Type and example

Fig.9 (Color online) Different types of science, technology and innovation

References

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