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Open Innovation at Huawei

We want to develop HIRP into an open innovation brand of Huawei that is well known amongst industry, research institutes and universities.

- Zhijun Xu, CEO (by rotation) of Huawei[1]

Founded by Ren Zhengfei in 1987, Huawei Technologies Co., Ltd. (Huawei) took about 20 years' time to grow from a sales agent for telephone switches into the world's leading provider of information and communications technology (ICT) solutions. Huawei had more than 76,000 research and development staff that served one-third of the world's population across 170 countries. The company owned the largest number of patents in China and ranked among the top worldwide.

To enhance its research capabilities and strengthen its industry leadership in providing ICT solutions, Huawei emphasized open innovation and created win-win research collaborations as an efficient, cost-effective way to achieve technology and industry breakthroughs.[2] Starting as early as 1999, the Huawei Science and Technology Fund was established to sponsor industry-related projects in universities. It was Huawei's firm belief that academic research had historically been, and still was, an important resource driving ICT development [See **EXHIBIT 1** for past successes].

To further strengthen the collaborative research efforts and achieve systemic innovation, the Huawei Science and Technology Fund was reshaped into the Huawei Innovation Research Program (HIRP) in 2010. The HIRP was a more systematic approach to allow Huawei engineers to successfully collaborate

[1] Information provided by Huawei.

[2] Teri Melese, Salima.M. Lin, Julia L. Chang and Neal H. Cohen, "Open Innovation Networks Between Academia and Industry: An Imperative for Breakthrough Therapies," *Nature Medicine* 15 (2009): 502-507.

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with academic teams at top universities to achieve technology breakthroughs and solve complex technical problems.

As head of Huawei's Technology Cooperation Department, Edward Lin was in charge of HIRP. He and his team had worked hard to develop HIRP into a well-known research brand for open innovation. By 2016, HIRP had entered into open innovation collaborations with over 300 universities across 20 countries. Lin and his team had also worked hard to address problems typical to open innovation. The 'not invented here' syndrome[3], for instance, was addressed by ensuring that KPIs (Key Performance Indicators) used to evaluate Huawei engineers were strongly linked to the outcomes of open innovation collaborations.

As Huawei's industry position evolved from an industry follower to an industry leader [See **EXHIBIT 2** for the changes reflected in research collaboration], Huawei needed to explore new research opportunities to lead the industry's technological development. Like diving into the unknown, Huawei had to take on more risks and get involved in projects for which it possessed little existing knowledge or in-house research capabilities. How could HIRP assist Huawei in making this transition?

The Company

Huawei, headquartered in Shenzhen, was founded by Ren Zhengfei in 1987 with an initial investment of CNY21,000.[4] It started as a sales agent for telephone switches, a core equipment of the telecommunications network. In order to compete with foreign telecommunications equipment manufacturer. Huawei decided to develop its own research and development (R&D) capabilities to make switches. This was very different from other Chinese companies that formed joint ventures with foreign companies to obtain technological know-how and manufacturing competences.[5] In 1992, Huawei launched their C&C08 digital telephone switches, the first major product developed in-house. In 1997, the company made its first move into a global market by providing fixed line network products to a Hong Kong company.

In 2012, Huawei overtook Ericsson to become the largest telecommunications equipment manufacturer in the world.[6] By 2014, its total revenue was USD46.5 billion [See **EXHIBIT 3** for financial performance], and it ranked 228th among the Fortune Global 500 companies with a valuation

[3] The Not-Invented-Here (NIH) syndrome refers to "the tendency of a project group of stable composition to believe it possesses a monopoly of knowledge of its field, which leads it to reject new ideas from outsiders to the likely detriment of its performance." Quoted from Ralph Katz and Thomas J. Allen, "Investigating the Not Invented Here (NIH) Syndrome: A Look at the Performance, Tenure, and Communication Patterns of 50 R&D Project Groups," *R&D Management*, 12(1), 1982:7.

[4] USD 1 = CNY 8.2898. (World Bank's annual average middle exchange rate in 1987)

[5] Chris Mellor, "Huawei Who? We Probe the Sleeping Storage Dragon's Brains: China's Massive Giant Flexes its Enterprise IT Muscles," *The Register* (06 November 2015): http://www.theregister.co.uk/2015/11/06/huawei_who/, accessed 19 November 2015.

[6] "Who's afraid of Huawei?" *The Economist* (4 August 2012):9.

of USD4.3 billion. In the same year Huawei became the first Chinese company named among the Top 100 Best Global Brands by Interbrand@.[7]

> *For more than a decade, the thing I have thought about every day is failure. I don't look at success and have no sense of glory or misplaced pride, what I have is a sense of crisis. Maybe this is the reason why we still survive today. We all have to think together about how we are going to survive, for then we may at least survive a little longer. A time of failure will definitely come, and everybody should get prepared for this. This is my unshakeable belief, which also follows the historical law.*
>
> - Ren Zhengfei, CEO of Huawei[8]

Huawei's culture was embedded with a sense of urgency at all levels, partly because of the cut-throat competition in the ICT industry. As a result, Huawei's staff were keen on business opportunities and shared a strong sense of responsibility and an eagerness to learn new skills.[9]

By 2015, Huawei had more than 170,000 employees that worked in more than 170 countries, with products serving one-third of the world's population. Seventy-five percent of Huawei's overseas employees were non-Chinese. LinkedIn identified Huawei as one of the world's 100 Most InDemand Employers.[10]

Huawei had also taken major positions in more than 170 standardization and open source[11] organizations and had submitted more than 38,000 proposals on standards.[12] By the end of 2015, Huawei held over 41,000 patents in the major jurisdictions around the world. Huawei had over 24,000 granted patents in China and was China's No. 1 patent owner and applicant consistently for a number of years.

Huawei used a pipeline strategy, so named because this strategy was similar to a utility company developing a plumbing system to supply water, to develop a digital network system to facilitate information flow. Guided by the pipeline strategy, Huawei set the annual targets and made technology plans.

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[7] Huawei, "Huawei Innovation Research Program (HIRP): Innovation Funding and Partnership Opportunities from the ICT Leader," slide presentation, 2015, Huawei.

[8] Weiwei Huang et al., *Dedication: The Foundation of Huawei's Human Resources Management* (Beijing: China CITIC Press, 2014).

[9] The wolf-styled corporate culture has three characteristics: a superior sense of smell, an indomitable spirit of selfless offensive, and a teamwork spirit.

[10] Huawei, "Huawei Innovation Research Program (HIRP): Innovation Funding and Partnership Opportunities from the ICT Leader." slide presentation, 2015, Huawei.

[11] Open source refers to the software for which the source code is made available for the general public to use and/or modify without any charge.

[12] Huawei participated in developing a number of industry alliances including ETSI ISG mWT, SDN, and eLTE, and held major positions in international ICT organizations such as IEEE-SA, ETSI, WFA, TMF, oneM2M, OMA, and OASIS.

> *Huawei's development has two driving forces: one is market pull - to provide solutions to meet customer needs, and the other is technology push – to use new technologies to provide better services at lower costs.*
>
> - Zhijun Xu, CEO (by rotation) of Huawei[13]

To meet customers' demand, Huawei wanted to lead the ICT industry's development and set the development's pace by focusing on critical emerging technologies and new mindsets, such as next generation WiFi and the Internet of Things, customer-centric innovation, and open partnerships.

In terms of management structure, Ren Zhengfei, the founder and CEO, jointly led the company with a rotating CEO [**EXHIBIT 4**]. Huawei was structured around three business groups, each serving a different customer segment [See **EXHIBIT 5** for Huawei's products and services][14]:

- Carrier Network Business Group
- Enterprise Business Group
- Consumer Business Group

To support these three business groups, the Productions and Solutions Department was established in 2014 as a centralized, product-oriented R&D platform. On the strategic level, Huawei also had created the 2012 Lab that focused on developing future technologies of strategic significance. Huawei regarded the lab as the innovation engine that would lead the company's future development.

Huawei Innovation Research Program (HIRP)

Research and Development

Of Huawei's employees, a total of 45%, or 76,000, engaged in R&D research. [See **EXHIBIT 6** for Huawei's R&D investment over the ten-year period]. [15]

> *Huawei has developed 28 innovation centers with customers globally, which helps Huawei to integrate global resources, generate innovative ideas and provide experimental sites. Innovation is not only Huawei's competitiveness now, but should also be its sustainable competitiveness in the future.*
>
> - Ken Hu, CEO (by rotation), Huawei[16]

[13] Zhijun Xu, "Huawei's pipeline strategy," *Winwin* November (2012).
[14] Huawei, Annual Report 2014 (Hong Kong: Huawei, 2015); and Huawei, "Huawei Innovation Research Program (HIRP): Innovation Funding and Partnership Opportunities from the ICT Leader," slide presentation, 2015, Huawei.
[15] Huawei, "Huawei Innovation Research Program (HIRP): Innovation Funding and Partnership Opportunities from the ICT Leader," slide presentation, 2015, Huawei, Hong Kong.
[16] K. Hu, "Global innovation demands level competitive playing fields and IPR protection", in *Global Innovation Index 2013*, Shenzhen, China. July17, 2013

As an innovative company[17], Huawei was the first to introduce certain innovations that were later adopted industry wide. The innovations ranged from telecom infrastructure networks to innovations in terminals. For example, in 2003, Huawei was the first to come up with the idea of distributed base stations[18] to distribute mobile communications that became a milestone in the development of global mobile communication technology. Compared to the traditional approach, distributed base stations saved a lot of installation time and costs. This innovation was later adopted by leading telecom companies including Vodafone and Telefonica.

> *Huawei will innovate on three levels: fundamental innovation, allied innovation, and ecosystem research. Fundamental innovation is the foundation of all other innovation activities. However, it is also very challenging, as it requires longer payback periods. As a key player in the ICT industry, Huawei has made long-term investments in basic research to drive the industry forward. This is our unshakable commitment to the industry. Over the past 26 years, we have invested at least 10% of our annual revenues in R&D every year. Just last year, Huawei spent 14% of its annual revenue on R&D. We also allocate 10% of our total R&D investment on future technologies research.*
>
> - Ryan Ding, President of Products and Solutions, Huawei[19]

To encourage open innovation [see **APPENDIX 1** for a detailed explanation], Huawei had established research collaboration with more than 300 universities and research institutions in over 20 countries. Huawei was working on innovative ICT solutions with different industry partners that included strategic partners (such as SAP and Accenture), solution partners (such as Hexagon, IBM, Sobey and Honeywell), telecommunications operator partners (such as Vondafone and Deutsche Telekom), and channel partners (such as Blue-consult, COMNET, WOHLER and ARROW).[20] In terms of the research collaboration between universities and enterprises, Huawei wanted to focus more on both solving the problem of bottlenecks and developing ground-breaking technology.

Program Development History

> *We continue looking for new technologies and technical innovations. The ICT industry has a close relationship with university research. We will consider cost technical advantages and comparative advantages to select partners. During the innovation process, we emphasize on doing the part we are good at, leaving the remaining part to open research collaboration. This is an important way we can build up our strategic capabilities.*

[17] K. Wagner et al., "The Most Innovative Companies 2014: Breaking through is hard to do," *The Boston Consulting Group* (2014), accessed January 2016.

[18] A distributed base station consists of a Baseband Unit and several Remote Radio Units to create a single powerful cell over several sites, which enables flexible coverage along railway lines across tunnels and bridges. Its size and weight are one tenth and one fifteenth of a traditional base station respectively. All the parts can be hand carried, saving time and efforts during deployment.

[19] Ryan Ding, "Open innovation for a better connected world", *Communicate* 76 (2015): 9-12.

[20] Huawei, "Huawei Promotes Open Innovation and Win-win Collaborations at CeBIT 2015," 23 October 2015, http://huawei.com/ilink/en/about-huawei/newsroom/press-release/HW_417711, accessed October 2015.

- Edward Lin, Head of Technology Cooperation Department and HIRP[21]

In 1999, Huawei set up the Huawei Science and Technology Fund and started working with the top universities in mainland China. In 2004, Huawei started looking for university partners outside mainland China. The first project outside the mainland was launched in 2005—a project with Professor Vincent Lau at the Hong Kong University of Science and Technology (HKUST).

> *At that time, Huawei wanted to enhance their visibility in the international community, mostly in the standardization efforts. My first project was IEEE 802.22, the world's first cognitive radio standard. To have at least 75% supporting votes to push something into the standard is difficult because different members come from different companies with their own agendas. At the end of the day, we completed the project and managed to push four mandatory contributions into the standard. Huawei was quite happy with the outcome and has continued to work with us ever since.*
>
> -Vincent Lau, Chair Professor, Department of Electronic and Computer Engineering, HKUST[22]

While running the Huawei Science and Technology Fund, Huawei encountered many challenges common to open innovation:

Information Asymmetry Problem

Huawei was unfamiliar with academic teams and their research activities at the university. Huawei had to spend a lot of time and effort to look for suitable research partners. Sometimes Huawei had to discard projects because it could not find any suitable partners. Meanwhile, a lack of proper communication channels existed for those academic teams that wanted to establish research relationships with Huawei.

Bi-lateral Knowledge Transfer Problem

Huawei wanted to know more about the latest research results and the hottest research topics in academia, which enabled the company to quickly identify emerging trends and to collaborate with a suitable academic team to seize market opportunities in a timely manner. Academic teams were also interested in knowing the research demands of Huawei to fine tune their research directions.

Communication Problem

A need existed to develop an effective and efficient communication channel to save both Huawei's engineers and the academic team's time and effort to ensure that a project could proceed as scheduled and produce quality research results on time.

[21] Edward Lin, "Five Challenges of Open Innovation", presentation, December 11, 2015, HKUST, Hong Kong.
[22] Interview with Vincent Lau on 30 September 2015,on the campus of HKUST.

To address these issues and encourage innovative research that could add value to Huawei's products and services, HIRP was established in 2010. In 2014, Huawei launched HIRP's open innovation platform at http://www.huawei.com/en/hirp.[23]

By the end of 2015, Huawei had developed long-term research relationships with a number of top universities and academic teams [See **EXHIBIT 7** for a sample of research partners]. At HKUST, the collaboration had led to the setting up of the Huawei-HKUST Innovation Laboratory. The HKUST and Huawei founded the lab to facilitate research collaboration and to give operational advice to academic teams. By 2015, 24 professors from different departments had participated in 53 research projects and produced more than 90 technical solutions through the Huawei-HKUST Lab. Top journals and conferences published these research findings. By publishing papers in collaboration with professors, Huawei also improved its international visibility and reputation and expanded its network in academia.

> *These collaborative research projects [with academia] give me a lot of opportunities, allowing me to have eye-opening experiences, to build professional networks and to get external support. The research outcomes constitute an important part of our work, supporting our team's KPI.*
>
> - Cheng He, IT Director Engineer, Huawei Noah's Ark Lab[24]

Moreover, research collaboration with universities enabled Huawei to develop important technologies that they were not capable of developing internally. For example, Huawei and Professor Yang from Xi'an Electronic Science and Technology University set up a media research lab in 2005. In 2012, the algorithm model proposed by Huawei's IPTV (Internet Protocol Television)[25] Team and developed by Professor Yang's team successfully became the core part of two international ITU (International Telecommunications Union) standard specifications.

Management of HIRP Projects

Huawei developed a systematic way to manage collaborative research projects from initiation to evaluation [See **EXHIBIT 8**]. Each project had its own project management team to ensure that the project was kept on track.

Project Selection

Every year Huawei presented a strategic plan based on its experts' forecasts of future technological development trends, the aggregated real demand of customers, and the technical bottlenecks encountered in R&D activities. Based on this strategic plan, every department set its research targets and assigned these targets to individual engineers [**EXHIBIT 9** for HIRP's research domains].

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[23] Last accessed 26 February 2016.
[24] Group interview on 20 October 2015 at Huawei headquarters, Shenzhen.
[25] IPTV delivers television services such as live and time-shifted television, Video on Demand over a packet-switched network.

Individual engineers then had to decide whether to achieve their research targets on their own or through external collaboration. Huawei had a model to help make this decision [See **EXHIBIT 10**]. Taking into account the requirements of academic teams, the decision was based on whether Huawei possessed the internal expertise to reach the research target and whether the collaborative efforts were new technology exploration that might benefit the ICT industry in the future. Huawei tended to seek collaboration for those research targets with insufficient in-house capabilities and targets that covered previously unexplored business opportunities.

> *When we consider whether to look for external research collaboration, we consider these questions: whether we have enough internal resources and facilities? Whether the outputs can be better with external help? Who are the experts? Whether the money invested is worthwhile? Also, since the timeline is not easily controlled, we normally will do urgent projects in-house.*
>
> - Freddy Fu, senior engineer, The 2012 Lab, Huawei[26]

Next, if the department preferred external collaboration, any engineer could propose a research project to his or her departmental evaluation committee. While approving the project, the committee would also take into account its departmental research targets and budget.

If the departmental evaluation committee approved a research project, then the project would be classified as HIRP Flagship or HIRP Open. The HIRP Flagship was an invitation-only call for proposals that targeted world-class, full-time faculty members engaged in leading ICT-related research at top universities and research institutions around the world. It provided large-scale, multi-year, and contract-based awards to support research projects that were of significant strategic importance and of mutual interest to both Huawei and the academic team. The HIRP Flagship focused on the important technologies in key research areas. For example, in 2015, Huawei had a two-year Flagship project with the University of Manchester to explore the applications of graphene in the ICT industry.

The HIRP Open projects were more forward-looking projects to exploit new research areas; areas that Huawei was unfamiliar with and in which it had yet to develop capabilities. At least once a year, HIRP issued a call for HIRP Open proposals that included a list of research topics Huawei was interested in. This call for proposals was published on the HIRPs website. Besides the topics suggested by Huawei, professors were also able to submit research proposals on other topics to HIRP Open as long as they believed Huawei or the industry as a whole could benefit from this research. This arrangement helped to cover research topics that Huawei had not thought of. Upon receiving proposals, the members of the Huawei Technical Experts Group, which consisted of senior researchers, would carry out a formal review process to decide on which of the submitted proposals to support. If an academic team had participated in HIRP Open projects in the past and had achieved very good research results, Huawei would typically invite them to HIRP Flagship to pursue a long-term relationship.

In an effort to exploit innovative ideas, HIRP had increased its funding allocation to HIRP Open projects. In 2015, HIRP Open listed 100 research topics and received nearly 400 research proposals, about 15% of which were on topics not listed by HIRP Open.

[26] Group interview on 20 October 2015 at Huawei headquarters, Shenzhen.

Research Partner Selection

The selection of a research partner was a process of matching industrial needs with academic research interests. Huawei developed a systematic approach to select academic research in which its engineers played an active role.

First, in order to identify potential academic partners, the engineers normally browsed Huawei's expert database or tapped into their professional networks, which included previous and existing research partners, for recommendations. After identifying potential academic teams specializing in relevant research areas, Huawei's engineers would contact them to discuss the possibility of collaboration.

To enrich Huawei's expert database, Huawei's engineers took every opportunity to make contact with the top researchers in related research areas. They regularly attended leading industry exhibitions and top-level academic conferences to survey the latest research trends and the key researchers on the frontline. The engineers considered all research areas even if some areas were not relevant to Huawei at the moment because they might become relevant later.

Once the engineers identified academic teams, they would systematically evaluate the suitability of each academic team while taking into account the teams' research capabilities and their need for funding [See **EXHIBIT 11**]. The research capabilities comprised the scientific capabilities, which were assessed by looking at their publications, and the innovativeness of the applied technologies, which were assessed by looking at the number of patents.

Next, the engineers initiated contact with potentially interested academic teams to discuss the potential research project. At this point, the academic teams needed to consider very carefully whether or not to work with Huawei on the project. Besides financial support, academic teams often mentioned knowledge sharing, student training, and job satisfaction as the reasons why their professors wanted to work with Huawei.

> *We can learn a lot from Huawei's product R&D team who are experts in their products. After I left the industry, I am detached from the day-in day-out real-world challenges. Working with Huawei gives me a solid angle to understand what the real problem is. Sometimes you work in theories, you lock yourself in an ivory tower and imagine what the problems are in the real world. If you don't have some inputs from the real world, you can easily get it wrong. So the kind of inputs provided by Huawei are very important to me. It enhances my knowledge of the real world.*
>
> -Vincent Lau, Chair Professor, Department of Electronic and Computer Engineering, HKUST[27]

University professors normally relied on their PhD students to carry out day-to-day research activities, and most students did not have any industry background. The collaboration provided financial support to PhD students and helped students develop their research skills, fine tune their attitudes toward work jobs, and improve their employability.

[27] Interview with Vincent Lau on 30 September 2015 on the campus of HKUST.

Moreover, research collaboration with Huawei gave professors access to cutting-edge equipment that was not always available in university labs. Huawei's research funding enabled professors to pursue new research topics that led to publications and even more research funding. This success also helped to attract more top students.

> *The [Huawei] people we work with are very smart. They say: Professor Zhang, you spend two-thirds of your efforts on the problem that we believe will soon be pushed to standards. One-third of your efforts can be spent on anything. If it doesn't really relate to Huawei it is ok…*
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> *If your technology just exists on paper, then after a few years, there will be hundreds of papers obscuring yours. There is no long-term impact. For those of us working on networking and communications solutions, the most effective way to move your technology beyond paper is to find a major industry player, like Huawei. Huawei may even push your technology into the standard because they have such strengths. So, why not? I'm happy. Their feedback to us is very useful too, for example, telling us that our assumptions may not be realistic at least for the next ten years because the equipment providers will never change their devices.*
>
> - Qian Zhang, Tencent Professor of Engineering, Department of Computer Science and Engineering HKUST[28]

Nevertheless, not all professors were willing to work with Huawei. Some professors were worried about the communication overhead, especially if they had not worked with Huawei before. Some professors did not have enough resources to take on Huawei's projects because of the small size of their academic team or time constraints. Some professors, especially those who had never worked with industry, had great difficulty in understanding what Huawei wanted and in correctly estimating the required research efforts.

Finally, based on the search results and initial communication with academic teams, the engineers would recommend a select number of academic teams to Huawei Technical Experts Group. The group then chose the most suitable candidates for specific projects. The project acceptance rate for HIRP Open was about 20%, similar to that of NSFC[29] projects. Due to prior communication, the HIRP Flagship had an acceptance rate of over 60%.

> *We may choose one or more external researchers to work on the same research topic, when they have different merits. Sometimes they can give us different solutions, allowing us to consider the possibility to integrate their strengths into our products. Sometimes we even ask them to work together by complementing each other.*
>
> - Xiaolong Luo, senior engineer, Products and Solutions[30]

[28] Interview with Professor Qian Zhang on 05 October 2015 on the campus of HKUST.

[29] NSFC stands for National Natural Science Foundation of China, which is a state organization to provide research grants to support basic and applied research in China.

[30] Group interview on 20 October 2015 at Huawei headquarters, Shenzhen.

Historically, Huawei had a lot of research relationships with Chinese academic teams. The longer history of these relationships and the effective communication channels had established mutual trust between Huawei and Chinese universities. With Huawei's emergence as a global ICT leader, the collaborative research projects with academic teams outside China were expected to grow fast. In 2016, they already outnumbered those projects with Chinese academic teams.

Research Agreement Finalization

Once research projects and the partners were selected and Huawei and the academic teams reached agreement on the details of the projects, Huawei formed a research project management team for each project.

Key elements of the research agreement were patents, the professors' research preference, and the nature of the research project. Targets were partially based on Huawei's review of the existing academic research, which served as the minimum project requirement.

Patents

Huawei was well aware of the importance of patents and the contribution that the technology cooperation and HIRP projects had made and would make to Huawei. Unlike software companies, such as Google and Microsoft, Huawei had grown up as a hardware company in an industry where patents were fundamentally important and a key barrier to entry. Patents allowed companies to have the exclusive right to the technologies in order to protect their commercial benefits, especially if the patent was accepted as the technology standard.[31] In respect of the intellectual property policies varying across countries and universities, Huawei would discuss with the professors to decide the patent ownership based on business demands before the research collaboration started. When negotiating with some American universities, patent ownership sometimes caused issues in personnel arrangements and cooperation methods.

Meanwhile, Huawei attached great importance to proprietary technology protection. They would clearly explain Huawei's policies about information disclosure to professors in the first instance. For example, patent applications should always be filed prior to academic publications. Professors should get the prior approval from Huawei before publishing their research papers. Both Huawei and professors would discuss and agree upon which technologies were qualified as proprietary technologies. They would go through a formal procedure to sign up a Non-Disclosure Agreement before signing the formal research collaboration agreement. As a result, both parties would normally abide by the agreement and technology leakage hardly happened.[32]

[31] Major companies with a large portfolio of patents often have legal departments looking for patent infringement by their competitors. If your company owned a key patent needed to produce a product, and your competitor did so too, then the two of you could probably make a deal and both manufacture the product. If they owned a vital patent but you did not they could make it very expensive if not outright impossible for you to manufacture the product.

[32] In case of technology leakage, the local collaboration manager would immediately get in touch with the professor to stop the action causing technology leakage and to get more details of the event, such as the time and place, the disclosed technical particulars and the audience. These details would be compared with the information Huawei had already learnt.

Professors' Research Preferences

Some professors preferred that Huawei approach them with specific problems and well-defined research topics so that they could plan and manage the research projects effectively without much communication overhead. Other professors preferred to engage in research projects that could lead to high-quality academic papers. Therefore, they believed that putting in the time and effort to explain their research ideas and discuss them with Huawei to come up with a research direction was worthwhile.

> *They are very smart in finding research partners by checking past research experiences and expertise. When Huawei approaches you, it's the best opportunity to discuss with them to find a problem that is of interest to both of you. You need to know clearly whether you can deliver nice patents and write very high quality papers, making Huawei and your students happy. Otherwise, you may feel quite annoyed that you are just solving their problems, like doing homework for them. You need to drive the discussion. It may be time-consuming, involving 2 or 3 rounds of communication. But this is worthwhile and important.*
>
> - Qian Zhang, Tencent Professor of Engineering, Department of Computer Science and Engineering HKUST[33]

Nature of Research Project

The nature of the projects determined the details of the contract. Products and Solutions was a product R&D team that worked on the project day in and day out, so they knew what they wanted from research collaboration and were easily able to tell what was working and what was not working. Their projects often had a problem-solving focus. These projects were normally short-term, sometimes only lasting for half a year with the funding to support one student. On the other hand, strategic research projects with Huawei's 2012 Lab had more scope for innovative ideas. But its downside was that at the start of the project, engineers might not know and would not be able to explain exactly what they wanted to achieve.

Once the agreement was signed, Huawei would form the project management team that comprised a cooperation manager, a project manager, and a local collaboration manager [See **EXHIBIT 12** for details].

- A cooperation project manager might be in charge of a big project or a number of small projects, but each project had to have a cooperation project manager to oversee the project progress.
- An engineer could take the role of project manager, who acted as the beginning-to-end contact person for the academic team. In many cases, the project manager was also the ultimate end user of the research output. The end user should understand the research topic and was responsible for delivering and presenting the research outcomes to the company's evaluation panel. For those projects initiated by professors, an end user in the company was not always easy to find. In those

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Next, the cooperation manager would discuss with business departments to determine the severity of the technology leakage. Then, they would report to managers at different levels, taking appropriate actions to stop the further spread of the proprietary technology.

[33] Interview with Professor Qian Zhang on 05 October 2015 on the campus of HKUST.

cases, the project manager played the role of middleman and had to look for an end used in Huawei. In such cases, explaining the research to the project manager who might not fully understand the research outcomes or the end users' requirements but had to deliver the research outcomes to the end user could be a painstaking process for the professors.

- HIRP also had local collaboration managers who were familiar with local universities and could provide assistance to engineers who were working or wanted to work with local academic teams.

Project Management

Huawei had two approaches to managing the HIRP projects that depended on the nature of the project and the level of collaboration. One approach was that Huawei sent engineers, sometimes even equipment, to the universities to work side-by-side. This approach was more suitable for those projects requiring both engineers and the academic team to use their expertise and to work closely together to solve a bottleneck. However, this practice depended on the working culture. American universities commonly have to work side-by-side with industrial partners, which was not the case in Hong Kong universities. Some academics felt such side-by-side collaboration was too intimidating, which dissuaded them from working with Huawei.

The other approach was more relaxed, which was suitable for research projects in which the professors had most of the expertise and Huawei was unable to contribute much. In such cases, academic teams and Huawei normally had regular face-to-face meetings, or teleconferences if the travel was too great, to exchange ideas and keep track of the research progress, with the meeting frequency determined by the project's specific requirements.

Huawei's project management team spent a lot of time and effort to ensure effective communication between engineers and the academic team as the project progressed. As a commercial organization, Huawei put great emphasis on the time to market, while academics thought more about the significance of research outcomes and publications. Effective communication was the key to making sure the project's objectives were in alignment between the two parties and the project was delivered on time and up to the required standards.

> *We have had a lot of freedom in terms of setting the research program. They said, "tell us what you think is the novelty". Since the project started, they have become more prescriptive on what they want and when they want it delivered. We're under a lot of pressure, and more than from research council grants to deliver results, but we're coping. They are deeply involved in tracking and monitoring what we do because they want to be sure the involvement is bringing results. We do feel the pressure but it's positive pressure and stimulating.*
>
> - Dr. Filippo Fazi, Engineering and the Environment, Southampton University[34]

Although industry-based research institutes understood Huawei's research needs, their solutions were usually not as innovative as those of academic institutes. Professors who did not have any industrial background often provided suggestions that were interesting and insightful but not so

[34] Information provided by Huawei.

practical and feasible. Professors who were high achievers in their academic research and were actively engaged in industry-based applied research were the ideal partners to work with.

> *Professors are very good at theories and may not consider the challenges of mass production. They tend to use the most advanced technologies to build the prototype without considering the commercial value. They may not fully understand the importance of meeting tight deadlines during the product development process. All in all, I think we benefit most from their theoretical guidance and broad thinking.*
>
> - Xiaolong Luo, senior engineer, Products and Solutions[35]

Moreover, both engineers and academic teams benefited from the bilateral knowledge transfer through effective communication. Huawei's engineers were capable researchers and fast learners, usually with Master's or above academic qualifications. By working with top academic teams, Huawei's engineers learned the research process and acquired new knowledge. Because Huawei's team was working on the same research area and often had research collaborators with other universities, each with a slightly different research focus, the engineers also shared relevant comments and suggestions from other academic teams. Therefore, this kind of information exchange not only helped Huawei to understand the technology, but the academic team also found that the feedback was very helpful.

Project Evaluation

> *We find it difficult to evaluate the intangible assets. How to choose proper key performance indicators? How to use objective criteria to evaluate research outcomes?*
>
> *These are difficult questions. While problem-solving research projects can be assessed using project specifications, we need to be more flexible for those explorative projects in terms of setting targets and exchanging ideas. Like futures, sometimes we are not sure whether the project is necessary and whether real demand exists.*
>
> - Edward Lin, head of Huawei's Technology Cooperation Department [36]

Huawei had a systematic way to evaluate research projects outcomes [See **EXHIBIT 13**]. Depending on the significance and value of the project, Huawei had internal evaluation committees at different levels to assess project outcomes as provided in each contract. For example, Huawei categorized patents into different levels: normal patents and important patents. Huawei believed that the so-called high quality or important patents had a long-term impact and helped the company to be in a good position in relation to the standard. To assess this type of patent, their internal evaluation team was made up of senior researchers who sat in different standardization committees, including those who helped to push the technologies into the standards. They used the likelihood of a technology being accepted by the standard making committee as one of the key criteria to evaluate important patents.

[35] Group interview on 20 October 2015 at Huawei headquarters, Shenzhen.
[36] Edward Lin, "Five Challenges of Open Innovation", presentation, December 11, 2015, HKUST, Hong Kong.

> *If you are using standardization experts and their parameters to evaluate a project's value and significance, a lot of fundamental technologies will not be treated as important patents because they cannot be standardized.*[37]
>
> - Qian Zhang, Tencent professor of engineering, Department of Computer Science and Engineering HKUST[38]

The first internal project review normally took place halfway through the project, as specified in the contract. If the evaluation was not satisfactory, then Huawei's engineers and the academic team would jointly find the reasons why and make improvements. Huawei was willing to adjust its expectations if the objectives of the project turned out to be too ambitious or technically not feasible.

Immediately after the project was completed, the value of the research outcome was carefully evaluated by the evaluation committee. Huawei's project manager was responsible for presenting all of the research results to the internal evaluation committees at all levels to determine whether the project was successful or not.

> *To prevent the Not-Invented-Here problem, we organize periodical conferences to award the projects and encourage the team members to share their success experiences. We also allowed the engineers to take full credit for the research outcomes of collaborative projects, treating the same as internal research projects.*
>
> - Edward Lin, head of Huawei's Technology Cooperation Department [39]

It was important not just for the academic team but also for Huawei's project manager that the project was positively evaluated. This was because the performance assessment of all project participants including both the academic team and the project manager were primarily based on the committee's evaluation of the project. Hence, the academic team should strongly support the project manager to enable him or her to have the competence to present the project. For the patent evaluation too, the project manager was the only person to fight for the patent. The academic team had no direct involvement in the evaluation process.

> *The [Huawei] team working with me are like partners, because we share the same rewards. Since our deliverables are counted as their deliverables, they can get the credit if I'm successful. In most cases, this is an aligned goal. So, we are not competitors. We have mutual trust.*
>
> - Vincent Lau, Chair Professor, Department of Electronic and Computer Engineering, HKUST[40]

[37] Not all good technologies can be standardized because standardization needs to balance user requirements, technological possibilities, production costs, and government regulations etc. [See Gregory Tassey "Standardization in Technology-Based Markets," *Research Policy* 29(4-5) (2000): 587-602.]

[38] Interview with Professor Qian Zhang on 05 October 2015 on the campus of HKUST.

[39] Edward Lin, "Five Challenges of Open Innovation", presentation, December 11, 2015, HKUST, Hong Kong.

[40] Interview with Vincent Lau on 30 September 2015 on the campus of HKUST.

Only a very small percentage of the projects failed to meet their preset targets. For those projects that failed to reach the preset targets, Huawei would assess the reasons behind these failures. Was the research target set too high and unreachable? Or, did other project management problems exist? After all, failure was not always a bad thing because ground-breaking research projects were naturally associated with higher levels of risk and uncertainty.

> *While I was working for Bell Labs, they encouraged you to take risks. At the end of the year, if you have achieved all of the goals you set at the start of the year, it is no good. That means you haven't taken enough risks. Of course, if none of your goals have been achieved this is not good either. Bell Lab tries to strike a balance. This is the mentality of the culture. A lot of great inventions don't come from your Day One Plan.*
>
> - Vincent Lau, Chair Professor, Department of Electronic and Computer Engineering, HKUST[41]

The final evaluation was normally conducted three years after completion of the project. The objective of this evaluation was to see whether the research outputs were commercialized and used in their products. In slightly over two-thirds of projects this was the case. Since HIRP projects were normally forward looking, especially for central R&D, they often took a long time to go from an idea to a product. Therefore, this commercialization evaluation for central R&D was not weighed as importantly as that for product R&D.

The Way Forward

As Huawei had transformed from being an industry follower to an industry leader, the company faced the challenge of leading the industry's technological innovation. Developing breakthrough technology normally takes a long time and demands great risks. Huawei believed that open innovation, particularly driven by industry-university collaboration, was the golden key to facing the challenge. Lin and his team had achieved preliminary success in developing HIRP into a well-known open innovation platform that created mutual benefits for Huawei and its research partners. The key to the success of HIRP was the carefully designed and executed processes of open innovation that started from project initiation to completion and evaluation. While what Lin and his team had done was significant, they felt that the HIRP model still had its problems and wondered how to enable HIRP to adapt to the wider innovative environment. Moreover, Lin knew that the number of projects that met their preset targets and were commercialized and used in projects was very high. Did this mean that HIRP in its current format was not incentivizing Huawei engineers to take on enough risky projects that could reshape the industry?

Lin and his team were keen on improving HIRP but were not so sure what to do. What were the strengths and weaknesses of HIRP and how could HIPR help Huawei to build up new competences? What further changes should they make at Huawei to truly reap the benefits of open innovation?

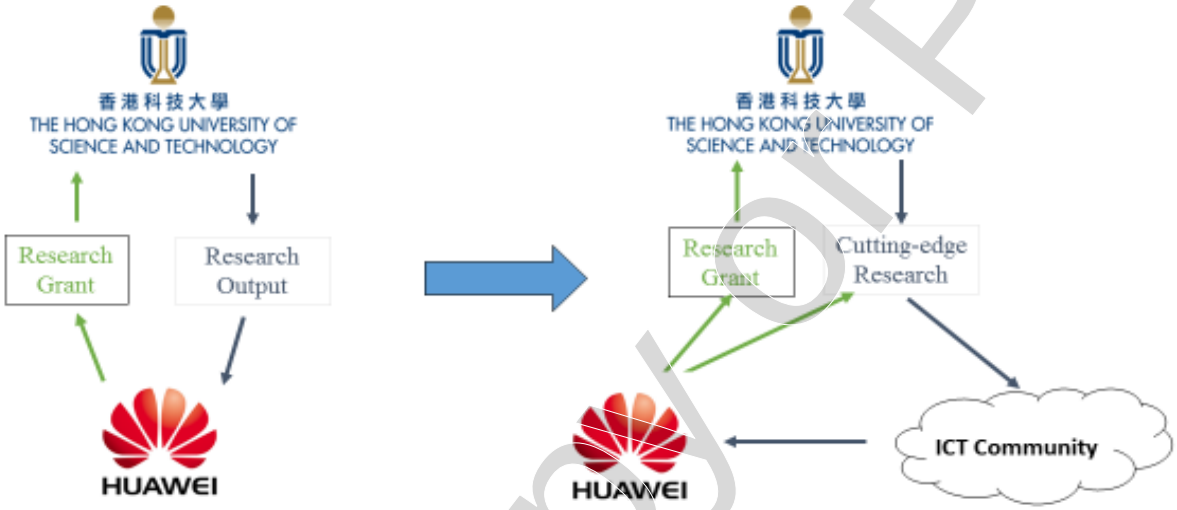
[41] Interview with Vincent Lau on 30 September 2015 on the campus of HKUST.

EXHIBIT 1: SUCCESS OF ENTERPRISE-UNIVERSITY COLLABORATIONS

Year	Name of Company	Academic Leader, Name of University	Achievement
1965	IBM	John Tukey, Princeton University	Fast Fourier Transform as a breakthrough in signal processing
1987	Apple	Avie Tevanian, Carnegie Mellon University	Mach Microkernel as the operation system (OS) that later developed into Apple's Mac OS.
1999	CISCO	Nick McKeown, Stanford University	12000 Core Router iSLIP traffic management algorism to strengthen Cisco's leading position in high-end routers.
2008	Huawei	L. V. Chao, Hong Kong Polytechnic University	100G Optical Network Prototype as the world's first vendor displaying such prototype.

Source: Y. Xu, "Open Innovation: The Shortcut from a Follower to a Leader," in *Business Review Forum*, Shenzhen, China, November 27-28, 2015.

EXHIBIT 2: CHANGES IN RESEARCH COLLABORATION: THE CASE OF HUAWEI-HKUST



Source: Y. Xu, "Open Innovation: The Shortcut from a Follower to a Leader," in Business Review Forum, Shenzhen, China, November 27-28, 2015.

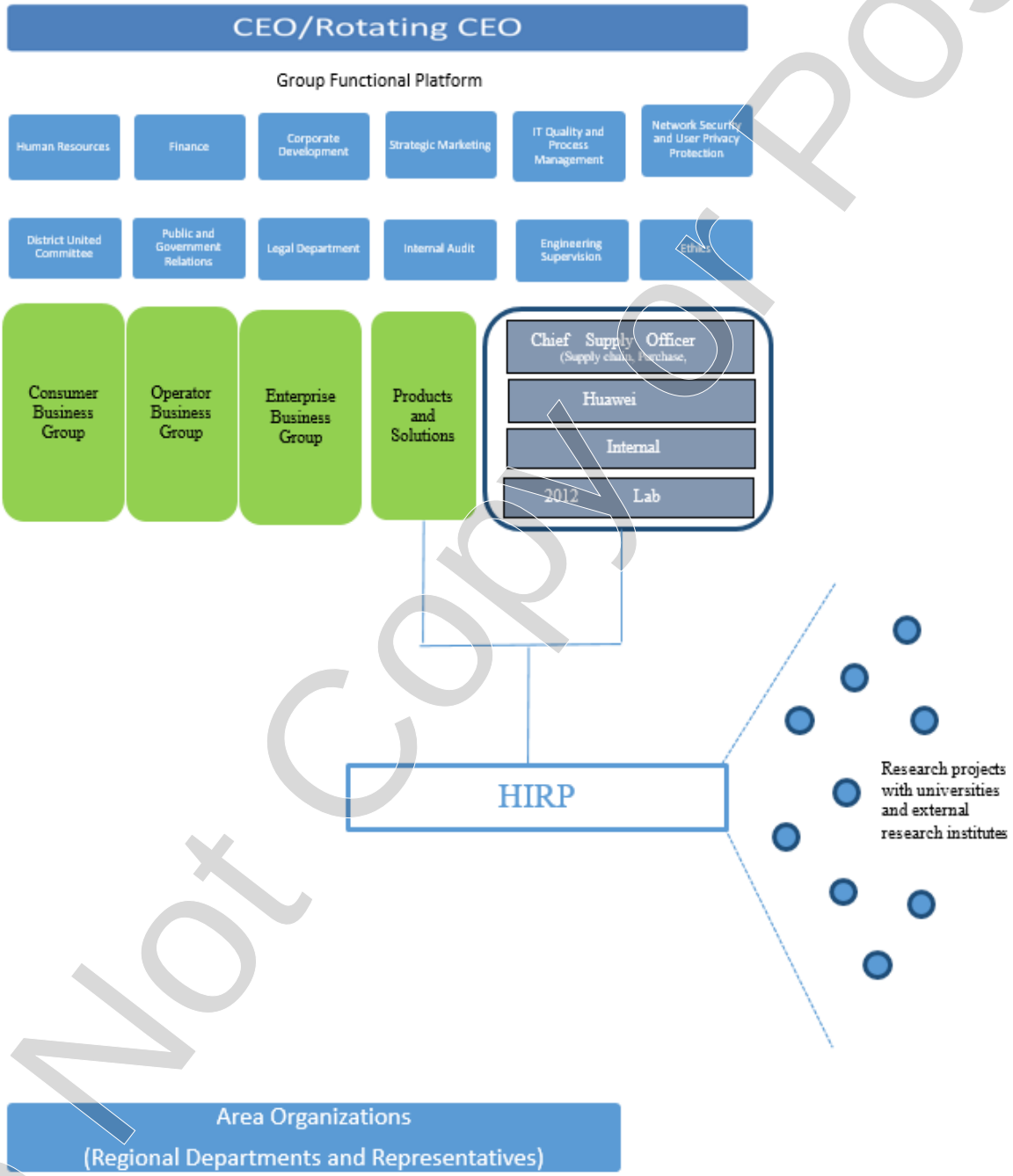
EXHIBIT 3: HUAWEI FINANCIAL PERFORMANCE

	2015 (CNY millions)	2014 (CNY millions)	2013 (CNY millions)	2012 (CNY millions)	2011 (CNY millions)	2010 (CNY millions)
Sales Revenue	395,009	288,197	239,025	220,198	203,929	182,548
Operating Profits[42]	45,786	34,205	29,128	20,658	18,796	31,806
Net Profits	36,910	27,866	21,003	15,624	11,655	25,630
Operating Capital	89,019	78,566	75,180	63,837	56,996	60,899
Total Assets	372,155	309,773	244,091	223,348	193,849	178,984

Source: Huawei Annual Report 2014 and 2015.

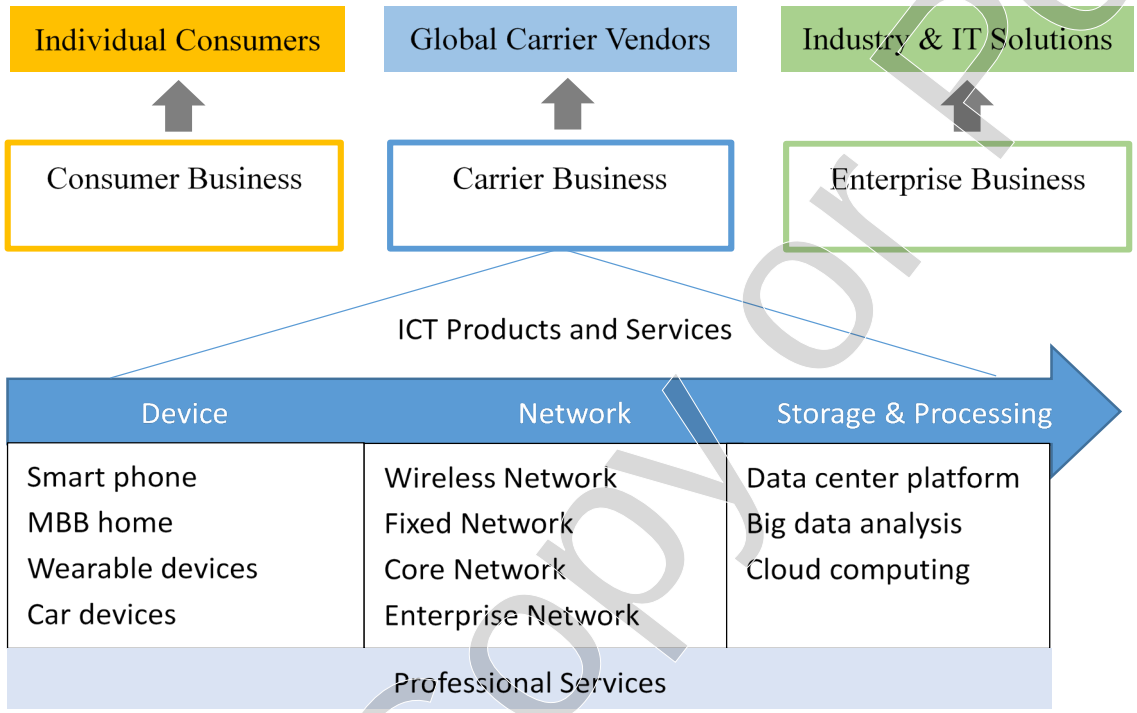
[42] Operating Profits here are calculated as Earnings Before Interest, Taxes, Depreciation and Amortization (EBITDA).

EXHIBIT 4: HIRP AS AN OPEN INNOVATION PLATFORM



Sources: Information provided by Huawei Technologies Co., Ltd.

EXHIBIT 5: HUAWEI'S PRODUCTS AND SERVICES



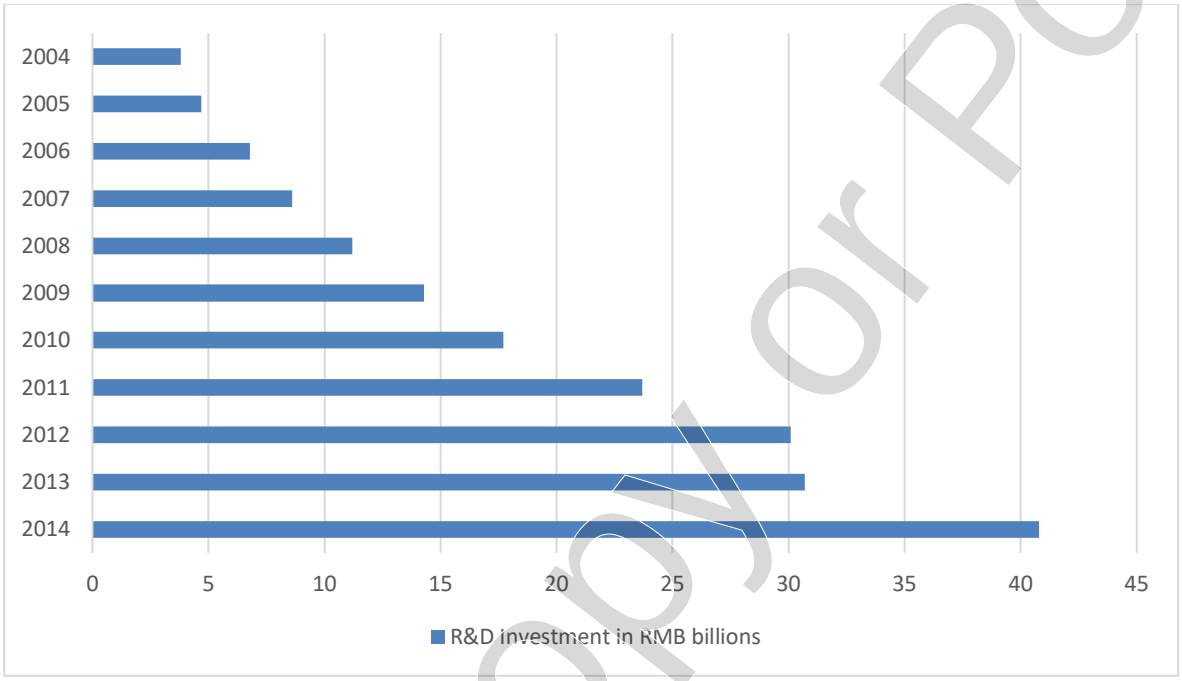
- **Carrier Network Business Group**: In 2015, Huawei served 45 of the world's top 50 carriers, which accounted for 77% of Huawei's revenue generated from the carrier network business.

- **Enterprise Business Group**: In 2015, Huawei served more than 100 global top 500 companies with 480 data centers worldwide that included more than 160 cloud database centers. Huawei worked with SAP, Accenture, and other strategic partners in a variety of innovative projects in the areas such as cloud computing and big data.

- **Consumer Business Group**: Huawei first entered the consumer market in 2003. In 2015 Huawei was among the top three according to GfK Group, a Germany-based consumer market research group, and ranked 88th in Interbrand's Top 100 Best Brands. In Europe, it was among the top three in Spain, Italy, Belgium, Switzerland, and Portugal in terms of sales volume. Between 2010 and 2015, the number of smartphones Huawei sold increased by 30 times from 3 million to 108 million.

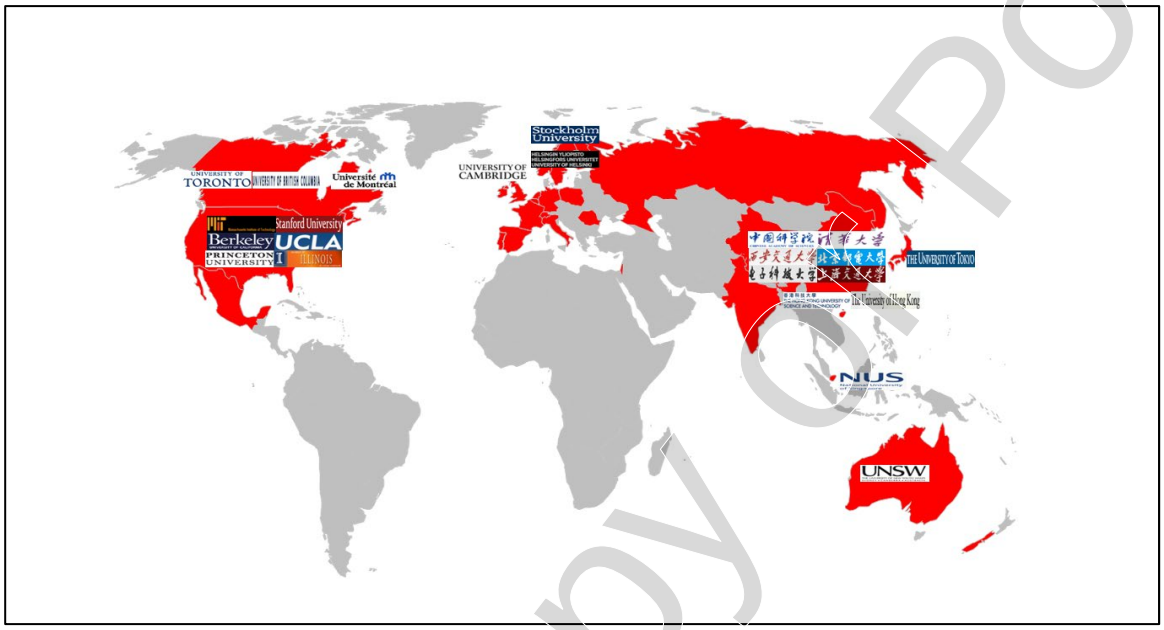
Sources: Information provided by Huawei.

EXHIBIT 6: HUAWEI R&D INVESTMENT BETWEEN 2004 AND 2014



Sources: Information provided by Huawei Technologies Co., Ltd.

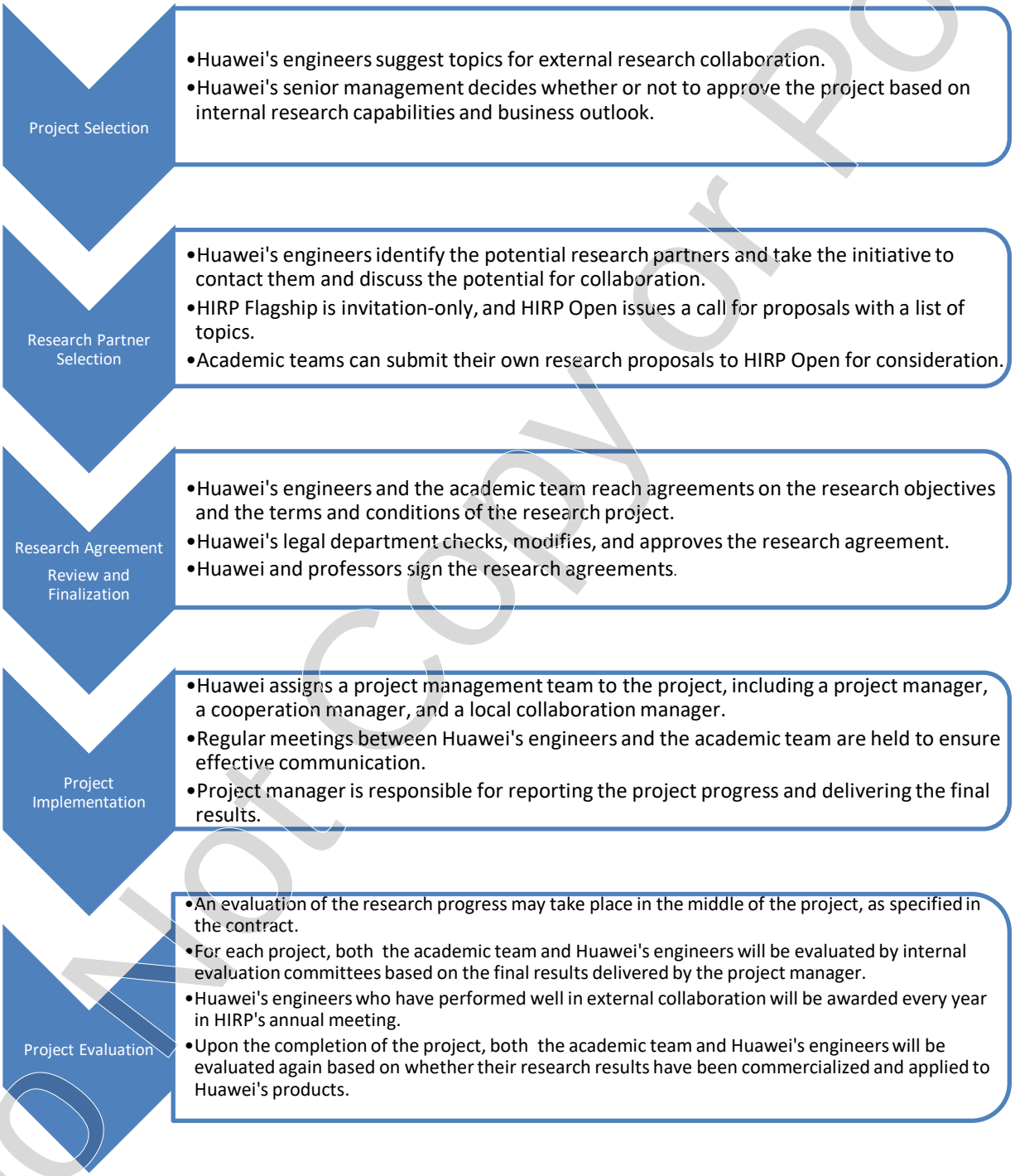
EXHIBIT 7: SOME OF HUAWEI'S RESEARCH PARTNERS



Continents	Universities
Asia	Tsing Hua University, China Academy of Sciences, Shanghai Communications University, Xi'an Communications University, University of Electronic Science and Technology of China, HKUST, University of Hong Kong, University of Tokyo, National University of Singapore etc.
America	Massachusetts Institute of Technology, Princeton University, University of California, University of Toronto, University of British Columbia etc.
Europe	Cambridge University, Manchester University, Stockholm University etc.
Australia	University of New South Wales etc.

Sources: Information provided by Huawei Technologies Co., Ltd.

EXHIBIT 8: HIRP PROJECT FLOWCHART



Source: Information provided by Huawei Technologies Co., Ltd.

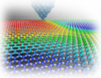
EXHIBIT 9: HIRP'S RESEARCH DOMAINS

5G/Wireless Communication Technology : New Air Interface (SCMA、Polar Code、 F-OFDM) , IRF, Antenna, Radio transmission, Architecture and Resource Management, Tool Software, etc.

DC3.0 : Computing Technology (Neuron computing, Heterogeneous acceleration, distributed computing, Cloud Computing, in-cache computing) 、 **Storage Technology (** Magnetic storage、storage software、Data Management、File System) , **Optical Interconnection**

Future Network : Network Modeling (Business Model, Network Manageability 、OTT traffic modeling , IoT traffic modeling) , **Future Internet Architecture (** future network addressing, cooperating routing, network control)

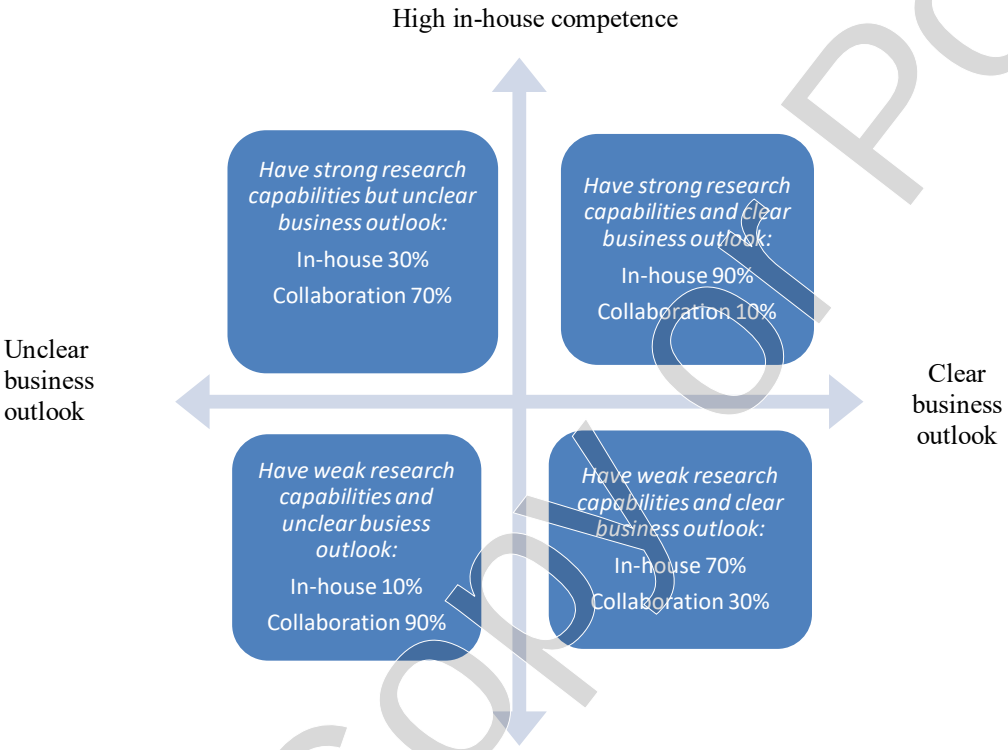
Big Data : Big Data Analysis and Mining、NLP、OLAP data warehouse、distributed database, deep learning



Fundamental Technologies : Security Technology, Media Technology, Material Technology, Engineer Technology

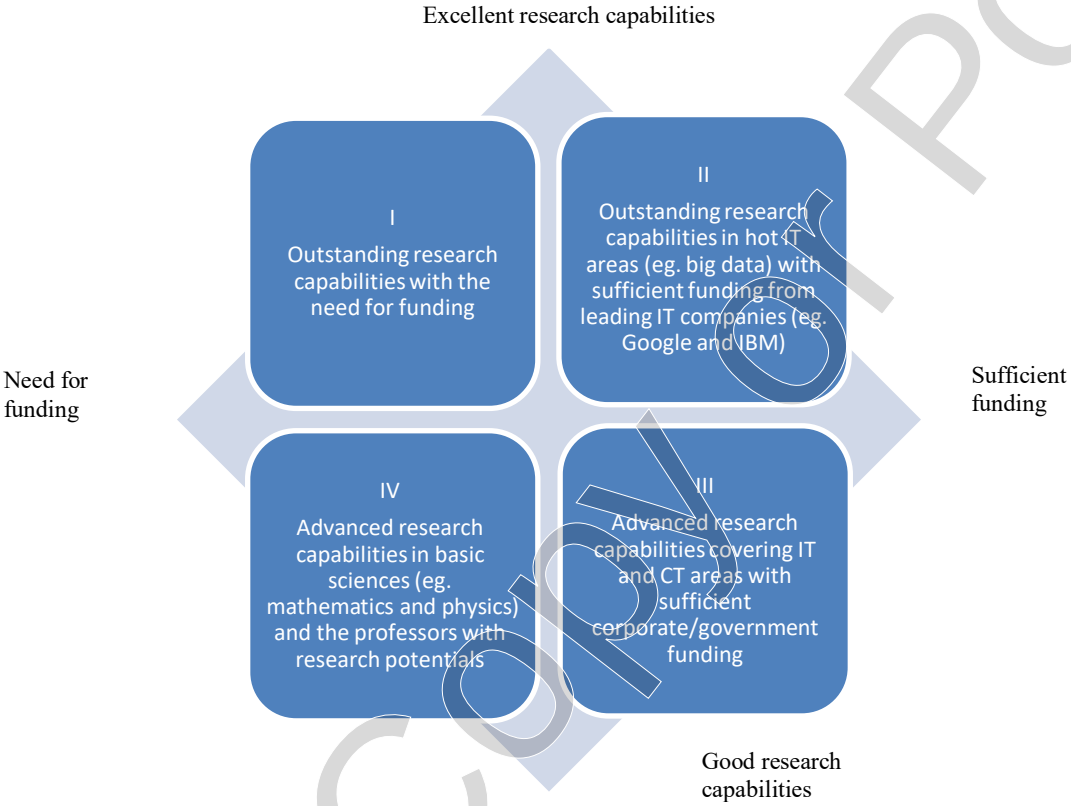
Source: Information provided by Huawei Technologies Co., Ltd.

EXHIBIT 10: HIRP'S OUTSOURCING DECISION-MAKING



Sources: Information provided by Huawei Technologies Co., Ltd.

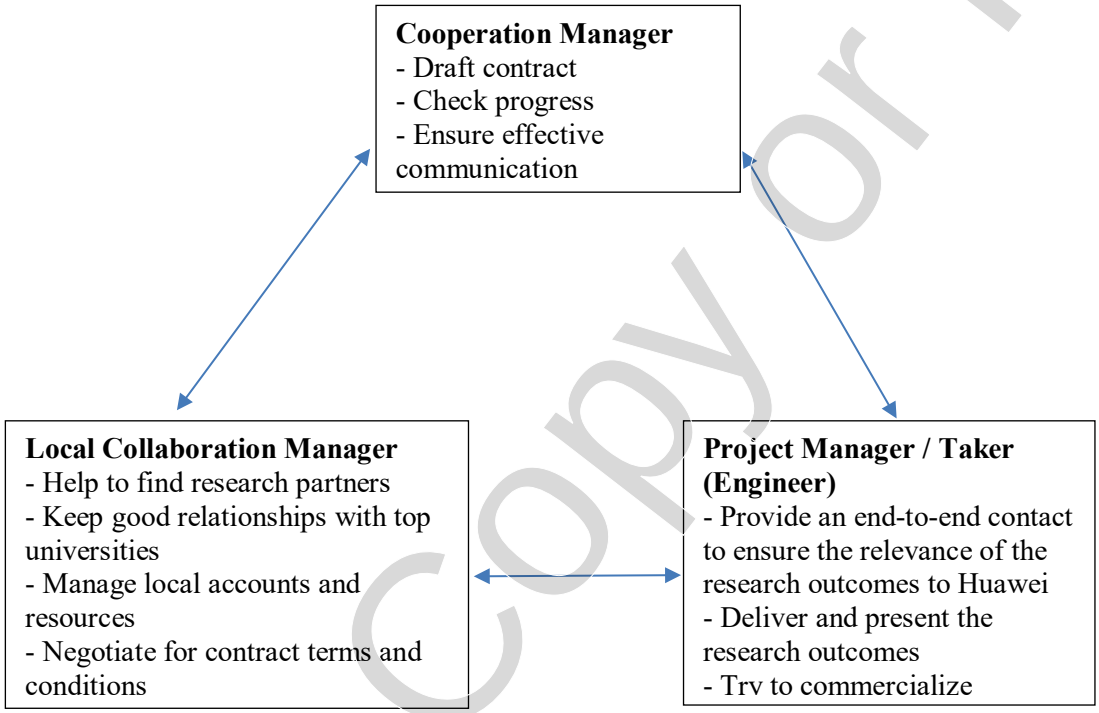
EXHIBIT 11: HIRP'S PARTNERSHIP SEARCHING STRATEGY



Category	How difficult to negotiate for the IPR?	How difficult to decide on the research direction?	How difficult to overcome technology export control?	How difficult to manage the funding?
I	Very difficult	Very difficult	Very difficult	Very difficult
II	Most difficult	Most difficult	Most difficult	Most difficult
III	Very difficult	Difficult	Difficult	Not difficult
IV	Not difficult	Not difficult	Not difficult	Not difficult

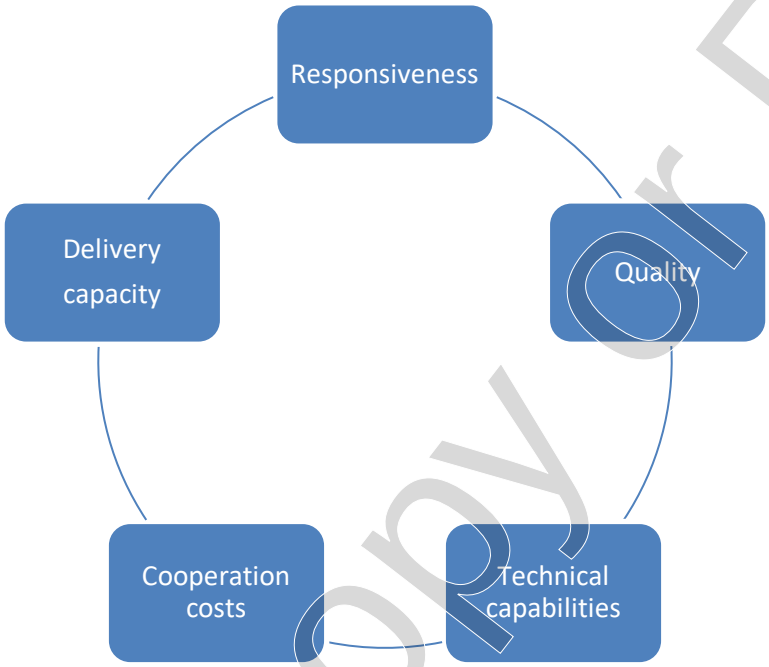
Source: Adapted from Edward Lin, "Five Challenges of Open Innovation", presentation, December 11, 2015, HKUST, Hong Kong.

EXHIBIT 12: HUAWEI'S IRON TRIANGLE IN PROJECT MANAGEMENT



Source: Interview with Huawei Technologies Co., Ltd.

EXHIBIT 13: HUAWEI'S PROJECT EVALUATION



Research Output Evaluation - Academic Team	Evaluation Requirements	Research Output Evaluation - Project Team
- Focus on quality academic teams through survival of the fittest - Encourage research outputs through continuing collaboration - Promote research outputs to improve academic influence	- Strictly follow the standard to carry out group evaluation - Invite third-party experts to participate - Ensure the evaluation is serious, fair and objective	- Ensure the input-output ratio is not lower than in-house research - Deliver research outputs in time to support technological innovation - Improve individual and group performance

Source: Edward Lin, "Five Challenges of Open Innovation", presentation, December 11, 2015, HKUST, Hong Kong.

APPENDIX 1: OPEN INNOVATION

Open innovation is the opposite of closed innovation. In traditional closed innovation, companies had to invest a large amount of resources to develop their own labs and internal R&D capabilities to develop competitive products. They were able to reap most of the profits from new products, which also allowed them to hire the best talent and reinvest in internal R&D. This became a virtuous circle of idea generation, development, and commercialization within a company.[43]

However, this circle had changed. Intensified competition shortened the product development life cycle, and it was impossible for companies to solely rely on their research capabilities because time-to-market was critical. The technological intensity[44] increased to a level that even large companies could not afford to develop technology on their own. Meanwhile, global technological cooperation became possible because of the availability of venture capital, low logistics costs, efficient ICT, high mobility and accessibility of knowledge workers, and increased homogeneity across different countries. Industry morphing created new business opportunities that allowed new alliances from different industries to form and achieve synergies that led to complementary partnerships.[45] As a result, the open innovation model emerged [See the table below]:

CLOSED INNOVATION	OPEN INNOVATION
The smart people in our field work for us.	Not all the smart people work for us, so we must find and tap into the knowledge and expertise of bright individuals outside our company.
To profit from R&D, we must discover, develop, and ship it ourselves.	External R&D can create significant value: internal R&D is needed to claim some portion of that value.
If we discover it ourselves, we will get it to market first.	We do not have to originate the research in order to profit from it.
If we are the first to commercialize an innovation, we will win.	Building a better business model is better than getting to market first.
If we create the most and best ideas in the industry, we will win.	If we make the best use of internal and external ideas, we will win.
We should control our IP so that our competitors do not profit from our ideas.	We should profit from others' use of our IP, and we should buy others' IP whenever it advances our own business model.

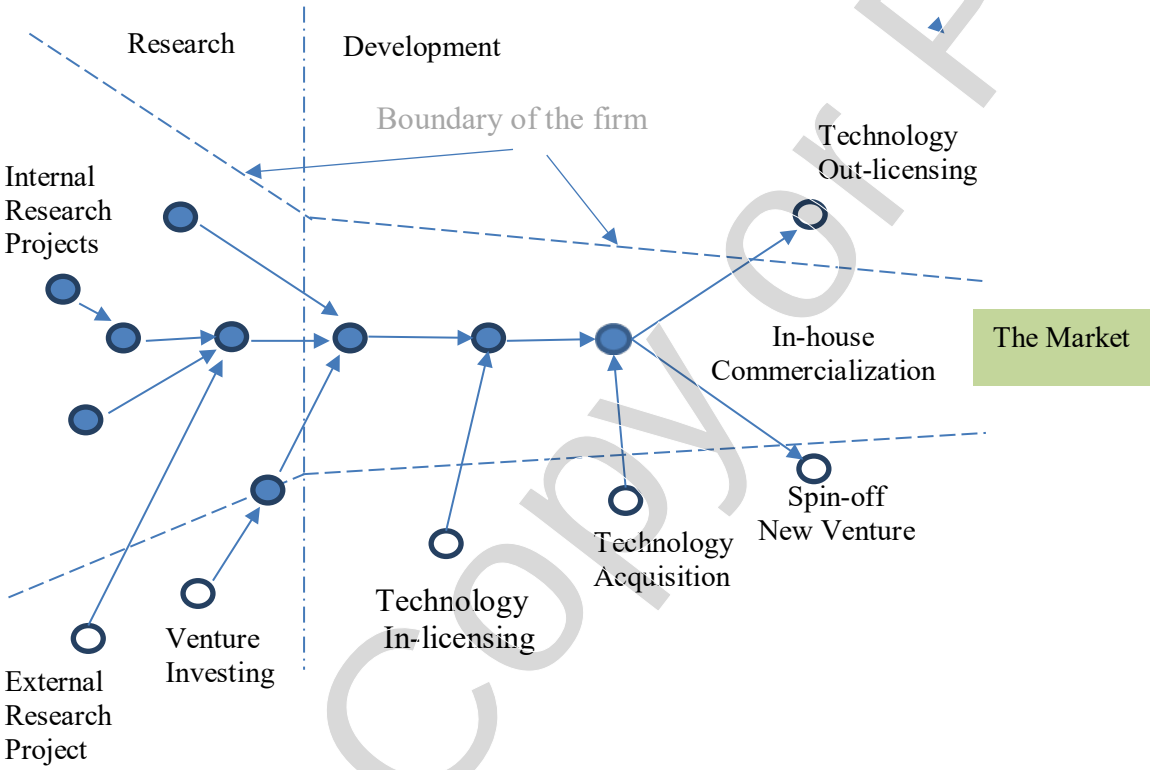
Source: Adopted from Henry Chesbrough and Jason M. Eichenholz, "Open Innovation in Photonics: The Case for Sharing and Harvesting Innovations in Photonics," *SPIE Professional* January (2013): 24-25.

[43] Henry W. Chesbrough, "The Era of Open Innovation," *MIT Sloan Management Review* Spring (2003): 35-41.

[44] Technological intensity refers to "the degree to which scientific research effort contributes to an industry's productivity increase and/or revenue enhancement, is commonly measured by the industry's ratio of own-performed research to its output." [Source: Kristian S. Palda, "Technological intensity: Concept and Measurement," *Research Policy*, 15(4) (1986):187-198.] According to OECD's classification, high-technology industries included "Radio, TV and communications equipment" and "Office, accounting and computing machinery" [Source: http://www.oecd.org/sti/ind/48350231.pdf, OECD iLibrary, accessed November 2015]

[45] Xu, Yan "Open Innovation," HKUST EMBA for Chinese Executives Program, 2014.

By breaking the organizational boundary, companies were able to open up their internal innovation processes to the inputs and contributions from external parties as well as to export their unused ideas to other companies to use [See the diagram below].



Source: Chesbrough, Henry, *Open Innovation: The New Imperative for Creating and Profiting from Technology.* Boston, MA: Harvard Business School Publishing Corporation, 2003.

The table on the next page gives some examples of different types of open innovation in the real world.

TYPES OF OPEN INNOVATION	EXAMPLES
External Research Project	InnoCentive was developed by Eli Lilly to allow about 75,000 contract scientists around the world to provide solutions to solve specific scientific problems.
Venture Investing	Samsung's Open Innovation Centre had a ventures group which was responsible for R&D investments in startups. In Israel, Samsung Venture Investment Corporation supported several local startups, including StoreDot that developed a charger to recharge a smartphone in 30 seconds and Rounds that developed a group video call app.
Technology In-licensing	After forming a strategic partnership with Carl Zeiss in 1995, all Sony's cameras used Carl Zeiss's high-quality lens.
Technology Acquisition	Cisco acquired the ideas, technologies, and IPs it needed by developing partnerships or investing in external companies, and some of the companies were founded by the veterans of its competitor, Lucent. This approach allowed Cisco to use the research outputs from the world's leading R&D organizations.
Spin-off New Venture	ASML, the largest supplier of photolithography systems for the semiconductor industry, was a Philips spin-off.
Technology Out-licensing	Apple gave other companies the right to use its technologies to earn some money as well as to develop relative applications through other companies. Apple invented Accelerometer (tilt sensor) to detect the rotation with a shaking to shuffle function and a dual display function that iPod Nano 4 used. This technology was also used by Nintendo in its console game Wii as the motion sensor in the remote controller to detect the movement of game players; its dual display function was used by Samsung in Haptic mobile models; and the technology was also used by Lenovo as hard disk protection etc.

Source: Chesbrough, Henry, *Open Innovation: The New Imperative for Creating and Profiting from Technology.,* Boston: Harvard Business School Publishing Corporation, 2003.; Huston, Larry and Nabil Sakkab, "Connect and Develop: Inside Procter & Gamble's New Model for Innovation," *Harvard Business Review*, March (2006):58-66; Xu, Yan, "Open Innovation", lecture notes of HKUST EMBA for Chinese Executives Program, 2014; and other related company websites.