WORKING PAPER
ALFRED P. SLOAN SCHOOL OF MANAGEMENT

The Potential of "Spin-off" from A Systems Perspective

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November 1990

WP 3224-90-BPS

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Abstract

The pros and cons for "spin-off" "strategy" are indeed very diverse, and so are the "spin-off" patterns ever studied and identified. This paper adopts a systems perspective and emphasizes the systems design and integration aspects of military (and aerospace) mission-oriented programs. Because many of these programs are technically conservative (e.g., under urgent time pressure) and concentrate on exploiting the existing technology rather than carry out radical scientific and technological advances, it is unlikely that they will originate major innovation, much less technological "spin-off" to civilian industry. However, the systems efforts and experience in these programs may be applied in civilian arena with strong systemic character. As an illustration, the U.S. Navy's role in the early history of radio technology and industry is investigated. This case shows that, in a strictly technical sense, the Navy contributed little. Nevertheless, the Navy consolidated radio technology and industry at the national level for military purposes during World War I, and played a key role in helping establish an "all-American" coordinated radio industry after the war. The Navy's enormous and far-reaching "spin-off" contribution in effect originated from its appreciation of the strategic importance of radio to national security and economy, and its national-level systems integration experience gained during wartime. Along with other programs in which systems efforts were the primary focus, this case provides a "new" pattern of systems "spin-off" which so far has been largely overlooked.

The Potential of "Spin-off" from A Systems Perspective

1. Diverse Views about and Patterns of "Spin-off"

In recent years, the U.S. "spin-off" strategy (if it could be so called) has been a hot and controversial topic. On the one side, it is argued that the large defense-related R&D investment has distorted the allocation of resources in the national economy while the military and civilian technologies have been diverging,[1] and there is a negative correlation between the military (total and R&D) expenditure shares and investment levels and productivity growth among major non-communist industrialized countries after 1960s.[2] The rise of West Germany and, particularly, Japan, both with far lower military budget (or R&D) share in GNP than the U.S., have often been raised to contrast with the erosion of U.S. competitiveness in many manufacturing industries since the 1970s.[3]

On the other side, it is advocated that military enterprise and aerospace programs are an effective way of generating new technology[4] which could help maintain the U.S. technological leadership and benefit civilian industry in the long run. Jet engines, nuclear power, semiconductors, computers, satellite communications are among the examples most frequently mentioned.

Indeed, the views about the contribution of military (and aerospace) programs to the economic performance are very diverse. One reason is that many analyses use different standards as reference. For example, the defense programs could be compared with R&D sponsored by National Science Foundation, by other Federal agencies, or by commercial companies. They could also be assessed against a system which is differently managed. And there could even be investments of different weights along the spectrum of basic research, applied research, development, engineering, technology validation, etc., and inclusion of different schemes in tax collection, reduction and credit.[5] Certainly it can be argued that it is inappropriate to consider cost of "spin-off" because the cost should be charged against the targeted missions. But when the investment is very big, and "spin-off" is used as one reason to partly justify the investment, then the consideration of "spin-off" cost, however difficult in quantitative terms, makes some sense.

For strategic implications, it may also be useful to understand "spin-off" patterns. In this regard, there have been some studies of important cases. For instance, in semiconductors and computers, though DOD supported relevant research, the key technological progress did not take place under DOD's direct sponsorship of R&D contract. Instead, DOD's assured procurement of high performance products at virtually any prices induced some firms to invest their own R&D resources, and their endeavor achieved great success. In the case of jet engine, the commercial aircraft could utilize rather directly the products developed for military purposes. In nuclear power and satellite communications, the defense needs created a technological infrastructure and support systems, like abundant nuclear technical data, space launch vehicles, etc. The civilian industry therefore could grow economically at the margins of the military efforts.[6] Still, some programs did not create significant scientific and technical advances. But they accelerated the progress by overcoming the resistance to technological change through demonstration. As an example, the use of computers in highly visible space programs was said to have greatly increased the acceptance of computers by the business world. Finally, as the early history of semiconductors shows, the practice of mission agencies (mainly DOD and NASA) to establish a competitive market encouraged many small firms to enter the markets. Some of them (e.g., Texas Instrument) ultimately took over conservative established firms' leading position and rejuvenated the industry.[7] Though the cases as discussed above are neither exhaustive nor necessarily representative, they do reveal the great variety and complexity of "spin-off" patterns.

2. A Systems Perspective for Mission-Oriented Programs

From a systems perspective, because military (and aerospace) programs are mostly mission-oriented (except those supporting relatively fundamental and basic research), they usually start with final needs analysis and final systems requirements, followed by the breakdown into a hierarchy of both technical and managerial planning and implementation tasks. In the end all the tasks should be integrated well into the targeted systems and the systems should meet the requirements mandated by the mission. Although the whole process is iterative--some initial quality specifications may be adjusted upward or downward depending on the technical progress or resource availability, military programs are usually under big time pressure or pressure from the final product or systems requirements. The ultimate force behind this pressure is the enemy's threat which may be real or perceived.

In this sense, military programs are very different from fundamental research--mainly to increase the understanding and knowledge about some phenomena. Their targeted mission may not be able to "wait" for, though they may push through more investment, some novel technologies to emerge or become mature enough to be applied. Under some extreme conditions, during wartime for example, the military have to use what are readily available for urgent purposes without any time slack. Then the programs have to be technically conservative, and mainly focus on exploiting the existing state-of-the-art rather than trying to generate significant scientific and technical advances. As a result, the "systems effort" may not bring about something significantly new in any technical sense. Rather, to achieve mission objectives many things are put together in configurations which are different from or far larger in scale than civilian ones. The experience, capability and lessons resulting from this systems effort may facilitate the establishment of some industries with strong systemic features. In this line, the U.S. Navy's role in the early radio industry provides a classic example.

3. U.S. Navy and Radio Technology and Industry

3.1. Industrial Fragmentation before World War I

Until the 20th century, despite the influence of Mahan's thought of naval power, naval ships at sea were very difficult to communicate. Naval exercises and maneuvers involved high degree of autonomy of each ship and usually were not accompanied by well coordinated fleet action. This situation lasted until the invention of radio.

Wireless telegraphy[8] was first demonstrated publicly by Guglielmo Marconi in England in 1886. The apparatus was brought to the U.S. in 1889. Although the U.S. Navy kept abreast of its development by sending naval officers to Europe to study and by sponsoring some American experiments, its action to install the equipment aboard ships and to set up shore radio stations was not active. Many high-ranking naval officers, including admirals and captains, resented the idea of receiving orders by wireless. They thus opposed with might the new agency of communications.[9] Besides, in the first decade of this century, few American suppliers were ready to furnish the apparatus. The Navy used the Slaby-Arco system; the Army the Braun system, both from Europe. The Fessenden and deForest systems, the two American systems, were used respectively by the Weather Bureau and a circle of naval officers. Meanwhile, the Marconi system was largely in the commercial arena. Therefore a virtual chaos existed in the U.S. wireless systems.[10]

Ignoring the wireless systemic character (which requires compatibility between different suppliers' systems) and avoiding being dominated by specific suppliers, the Navy tried its "composite" system by purchasing only components and having naval personnel integrate the different devices on an ad hoc basis. So there was no technical standardization or uniformity. Each Navy yard and station pursued its own method of installation and repair, leading to a proliferation of many different types of wireless sets throughout the service and high cost and low maintainability.[11]

In April 1912, Congress enacted the Radio Act to regulate the radio activities which had created great interference and even misinformation.[12] The Act prohibited independent "amateur" operators from transmitting in the preferred portion of the radio spectrum. It also sought to ensure that ships would always have access to wireless services. Thus Navy radio stations were now required to transmit and receive commercial messages if there was no commercial stations within a 100-mile radius.[13]

3.2. Systems Integration and Consolidation during Wartime

At the outbreak of World War I, however, the Navy's network was found lacking systematic coordination. Because shore stations were set up in series, each could only work with the two stations adjacent to it along the chain. If one link broke down, no transmissions were relayed beyond that point. Furthermore, most stations were under the control of Navy commandants whose influence was confined to individual yards and who, with multiple responsibilities, had little reason or incentive to improve this function.[14]

To strengthen the command and control system, in 1915 the Navy organized the Office of Communications, supervising telegraph, telephone, cable and radio communications, and reporting directly to the Chief of Naval Operations. It also set up Naval Communication Districts with high-powered stations covering the range of thousands of miles. Coastal stations were upgraded, and the whole network was centralized, with clearly defined and articulated lines of authority leading from bottom to top of the hierarchy and from field units to central office. This consolidation and centralization of radio operations ensured radio's progress under Navy's auspices. This also helped bring about a new naval strategy--a more centralized structure at sea and on shore.[15]

Upon the U.S. entering the war in April 1917, President Wilson, according to the 1912 Radio Act, authorized the Navy to take over all radio stations (mostly American Marconi Company's), except those already under Army's control. Since then the Navy was responsible for the design, purchase, installation and upkeep of all radio systems. This led to standardization of apparatus, better control of suppliers, and high rate of production and delivery. Because of the great demand of radio, American firms, such as General Electric, Western

Electric and AT&T, now began to enjoy Navy's patronage. Moreover, the government also instructed all domestic suppliers to make use of the best components, no matter who owned the patents. The government guaranteed to protect all suppliers against infringement claims and encouraged the inventors not to be oversensitive to relatively free use of their apparatus during the national emergency.[16] Under this arrangement, American inventors and firms concentrated on R&D and production, and achieved significant continuous technological advances.[17]

3.3. Establishment of A Coordinated Industry after War

Because of the experience of managing such a nationwide wireless communications system, the Navy realized deeply the strategic importance of radio to the national interest. After the war, the Navy began to promote the creation of a "coordinated industry" and an "all-American" company to control the radio communications in the U.S. In 1919 the Navy first blockaded GE's sale of Alexanderson Alternators to the Marconi Company which was now embarking upon the ambitious attempt to dominate wireless communications throughout the world. This alternator was one of the few American products (another with similar function was the Poulsen Arc), without which the Marconi stations would be at great disadvantage. But right after the war no companies of American origin were in a position to purchase this expensive sending apparatus and thus to sustain GE's expensive manufacturing plant operations. In parallel with the advocacy for government ownership of wireless communications (then one possible way to prevent the Marconi interests, to whom the government would soon return many commercial stations, from building up a monopoly in this field), the Navy brought forward the proposal that GE itself take the lead in forming such a communications company. The Navy argued that GE could greatly strengthen its position as being both a manufacturer and customer of the expensive equipment.[18]

In the meantime, understanding that government effective pool of patents from various companies during wartime would be followed by industrial rivalry and complete stalemate because no firms (e.g., AT&T, GE and Westinghouse) had patents enough to make a system, the Navy worked with GE to form a giant American radio company. They first aimed at acquiring the whole assets and expertise of the entire American Marconi Company. In September 1919 the British parent Marconi Company, knowing the U.S. government firm stance, finally made a reluctant consent to sell its American interests. And the Radio Corporation of America (RCA) was launched in October 1919. One month later the American Marconi Company became officially merged with RCA.[19]

RCA was chartered that not more than 20% of the stock might be held by aliens as voting stock. The concern over its possible anti-trust character was mitigated by the patriotic mood and the argument that wireless and cable communications would be competitors to each other.[20] To pool patent rights, RCA reached cross-licensing covenants first with GE in November 1919. In July next year, RCA, GE, AT&T and Western Electric signed a so-called "extensive agreement," granting each party exclusive or non-exclusive rights with certain limitations to utilize patents held by any of the four. This cross-licensing idea--criticized for its monopolistic features--originated not from GE or RCA, but from the Navy. It was asserted that this arrangement was obviously the only way of consolidating the conflicting interests in inventions and patents whereby a great national communications system could hope to function. So the U.S. government approved.[21]

To secure the congruence of national and private industry's interests, RCA invited government participation in stockholders' and directors' meetings. President Wilson in January 1920 appointed the director of Naval Communications to fill this position and to cooperate directly with RCA to establish an all-American wireless service of international dimension.[22]

4. Implications

In a technical sense, the U.S. Navy did not contribute much to the radio technology. It adopted civilian technology, mainly of foreign origin, for its urgent military mission which required large scale systems approach at the national level. This experience resulted in its appreciation of the strategic importance of an American-owned coordinated industry. From a systems perspective, the Navy's crucial contribution to the radio industry is at the highest systems level where no civilian counterparts could aspire to achieve. In fact, neither GE nor Westinghouse (which was GE's chief rival, strong in wireless transmitters and receivers, and made a quick alliance with International Radio Telegraph Company to get into radio broadcasting business after the formation of RCA)[23] nor other major firms had contemplated entering into the field of wireless communications. Without the Navy's eloquence to turn their thoughts to the possibilities of communications as a separate business, they would have continued to adhere only to their traditional manufacturing business.[24] As a result, the American radio communications industry owed the Navy a great debt for its far-sighted and systemic vision and patronage.

In some sense, it is not surprising that the above case belongs to the field of C3I--command, control, communications and intelligence, where systems design and integration of all software and hardware (many of which may be discrete subsystems without naturally embedded strong interdependence among them) are pivotal to the ultimate success. The birth of PERT (Project Evaluation and Review Techniques) is another good example. It was due to the urgent time pressure on the Navy in 1958 to develop the Polaris missile system (solid-fueled, intermediate range ballistic missiles armed with nuclear warheads and fired from submerged submarines) that the management concentrated on planning and controlling this element of the program and developed PERT to serve this purpose. The Polaris program in many respects was a great success in the history of military systems development, and PERT later became an indispensable part of complex project management.[25]

The preceding discussion points to some unique aspects of military programs. Because many programs are under big time and mission pressure and should aim at systems integration at the national level (or based on mobilized national resources), the required systems effort could very often hardly be matched by civilian counterparts. This, as a result, provides the potential opportunities for "spin-off." Unfortunately, this potential has so far been overlooked. Most studies merely focused on specific products or processes, or noticed that many military requirements are more and more divergent from civilian needs. Hopefully this paper could turn some attention to the crucial role of systems development in mission-oriented programs, from which some tremendous systemic "spin-off" may originate.

Notes

1 The diverging trend of modern military and civilian technologies have often been raised in recent years. One example is the machine tools used by Air Force to manufacture parts of complex shapes for military aircraft. In civilian industry, these machine tools have few applications. Some other examples include radiation-resistant semiconductors for nuclear weapons, "stealth technology" for fighters and bombers, and nuclear-powered laser for the Strategic Defense Initiatives (SDI). But so far there have been no rigorous studies in this line.

2 The data during 1960 through the early 1980s of 17 non-communist, industrialized countries have be analyzed using multiple regression in DeGrasse (1983), pp. 35-76.

3 According to Nelson (1990), the U.S. obvious erosion in technological and economic leadership began in 1970s.

4 Since World War II, military officers, who were traditionally viewed as technologically conservative, have been seen as technological enthusiasts. See Roland (1987), p. 373.

5 Ten standards used to evaluate the effects of defense R&D spending are identified in Carter (1989), pp. 4-6.

6 For a brief discussion of these three "spin-off" patterns, see Carter (1989), pp. 6-8.

7 For defense and space programs' demonstration effect and stimulation of small innovative firms to enter the markets, see Schnee (1978).

8 Telegraphy was the first application of radio technology. By the end of the First World War, wireless telephone was added; and shortly after the war, radio

broadcasting became a big business. For the early history of radio technology and industry, see Archer (1938) and Barnouw (1966), vol. 1.

[9] Archer (1938), p. 73.

[10] Archer (1938), p. 73.

[11] Douglas (1985), pp. 150-151.

[12] The disaster of the Titanic liner on April 15, 1912 accelerated this Congressional action, because this accident exposed the importance of wireless telegraphy on the vessels and the necessity of government regulation, without which the radio interference would greatly impede the rescue. See Archer (1938), pp. 105-106.

[13] Douglas (1985), pp. 153-154.

[14] Douglas (1985), p. 165.

[15] Douglas (1985), pp. 166-167.

[16] Douglas (1985), pp. 167-169; Archer (1938), pp. 137-138.

[17] Douglas (1985), p. 169.

[18] For the Navy's objection to this deal, see Archer (1938), pp. 159-167.

[19] For the negotiation and purchase of the American Marconi Company, see Archer (1938), pp. 169-174.

[20] Archer (1938), pp. 169-170.

[21] Archer (1938), pp. 180-181, 184-186 and 194-195.

[22] Archer (1983), pp. 183-184, 186-188 and 196.

[23] For Westinghouse's entering into radio broadcasting, see Archer (1938), pp. 190-204.

[24] Archer (1983), p. 191.

[25] For the development of the Polaris system, see Sapolsky (1972). For a brief review of the history of PERT, see Moder, et al. (1983), pp. 10-14.

Bibliography

Archer, Gleason L. (1938), *History of Radio to 1926*, New York, NY: The American Historical Society, Inc.

Barnouw, Erik (1966), *A Tower in Babel: A History of Broadcasting in the United States*, New York, NY: Oxford University Press.

Carter, Ashton B. (1989), Analyzing the Dual Use Technologies Question, a paper presented to the Workshop on "Military and Civilian Technologies: A Changing Relationship" in Harvard University Kennedy School of Government on November 1.

DeGrasse, Robert W., Jr. (1983), *Military Expansion, Economic Decline*, Armonk, NY: M.E. Sharpe, Inc.

Douglas, Susan J. (1985), Technological Innovation and Organizational Change: The Navy's Adoption of Radio, 1899-1919, in Smith, Merritt Roe (ed.), *Military Enterprise and Technological Change*, Cambridge, MA: The MIT Press.

Moder, J.J., Phillips, C.R. and Davis, E.W. (1983), *Project Management with CPM, PERT and Precedence Diagramming*, New York, NY: Van Nostrand Reinhold.

Nelson, Richard R. (1990), U.S. Technological Leadership: Where Did It Come from and Where Did It Go? *Research Policy* 19:117-132.

Roland, Alex (1990), Technology and War: A Bibliographic Essay, in Smith, Merritt Roe (ed.), *Military Enterprise and Technological Change*, Cambridge, MA: The MIT Press.

Sapolsky, Harvey M. (1972), *The Polaris System Development*, Cambridge, MA: Harvard University Press.

Schnee, Jerome R. (1978), Governmental Influence on Innovation, *Research Policy*, January:2-24.

1-10-91