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Lewis M. Branscomb : Dual Use Technologies
——Innovation and Diffusion of Technology in and between Civil & Military Sectors

日本工学アカデミー

THE ENGINEERING ACADEMY OF JAPAN

"Dual-Use Technologies"

Innovation and Diffusion of Technology in and between Civil & Military Sectors

Lewis M. Branscomb

1945年	米Duke大学卒
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1951年	米商務省国立標準局入り
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1969年	米商務省国立標準局局長
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1979年	米国立科学財団理事会(National Science Board)委員
1980-84年	同　　会長
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このほか、大統領科学顧問委員会委員、国務省科学・外交諮問委員会委員、米国物理学会会長等を歴任。

Thank you very very much, Dr. Inose. It is a great pleasure for me to have this very distinguished audiences, leaders of the Japanese technical community.

It is also a pleasure for me while I'm here to discuss research goals that we share with our colleagues in Japan. We look forward to a good cooperation in sharing information and sharing ideas as we look at a number of issues in science and technology policy in which both countries have a substantial interest.

My discussion is on the subject "Innovation and Diffusion of Technology in and between Civil and Military Sectors." This is what I mean by "Dual Use Technology."

- Many nations converging on dual-use industrial strategies
  - (USSR, China: conversion)
  - (USA: shared base)
  - (Japan: spin-on home defense, spin-off for aviation ind.)
- Globalization of markets important:
  - foreign source military components
  - COCOM difficulties
  - multinationals must separate their defense subsidiaries
  - "trickle-up" commercial technology

Fig. 1 Global Trends—Dual-Use Technology Policy

First, I would like to observe that this is an issue not peculiar to the United States. Many nations are moving their policies in ways that readjust the relationship of military to civil technology. The Soviet Union and China are both attempting to use the skills they have developed in the military sector to improve the performance of their commercial sectors. In the United States there is a realization that the expense of maintaining two poorly coupled sectors, one for military technology the other for commercial technology, must be adjusted to find a more efficient way to make a technical progress with greater economy. I think even in Japan the issue is significant because the great strength in Japanese technology is in commercial industry. It is from this base that Japan's defense forces can rest on a solid technology foundation which is also a very economical technology base.

These trends are driven in part by the globalization of technology, capital, markets, and indeed of human talent. In this global economy all nations will find that their military forces depend upon technologies from outside of their own borders. Notwithstanding United States government reports that view with some concern dependency on foreign sources for technology, that dependency is inevitable. Dependency should even be welcome so long as the dependency is within our mutual security alliance.

Another consequence of this trend is that traditional arrangements for limiting the diffusion of military technology to potential opponents become very much more complicated, indeed to the point of being unworkable.

More and more businesses are becoming multinational. If they also wish to engage in defense business, they will have to that defense business for the home country in a separate business unit. This in turn impedes the transfer of technology from that military business unit to the multinational, commercial elements of the company.

Finally there is the emergence of a relatively new form of innovation, different from traditional innovation processes used in defense industry. This is best illustrated by the Japanese consumer electronics industry, in which new technology is introduced first in a very inexpensive consumer product and then made more sophisticated to meet more sophisticated markets. This approaching, starting with low cost, high volume production, is quite different from the "*trickle-down*" approach that is traditional when military technologies are used to drive commercial technology. The "trickle-down" process assumes that the initial product has very high, unique function, at a high cost and low volumes, followed by evolution toward lower cost and function. That the U.S. military have recently made a small investment in technology for high definition television is perhaps a recognition of this fact.

When we focus on the diffusion of technology from one sector to another, it is instructive to ask ourselves the question "How shall we determine how the research and development budget of a firm should grow as the revenue of the firm grows from many different sources ?"

If we ask the same question at the national level, it takes the form "How shall we compare the adequacy of investments in R&D between one nation and another ?"

For a firm: how does R&D grow with revenue for equal competitiveness ?
For national economies: how to compare national R&D statistics ?
Perfect market for knowledge:
U.S. national R&D = 3 × Japan
Imperfect market:
$$\frac{\text{U.S. non-defense R\&D}}{\text{GNP}} = \frac{2}{3} \times \text{Japan}$$
R different from D

Fig. 2 Scale Economies for R&D

If there is complete sharing of research and development knowledge, which, of course, is not the case, within an economy like the United States then the total level of R&D is appropriate measure of technical support for growth. We observe the U.S. has a big advantage, three times the total research and development expenditure of Japan.

But if the market for knowledge is completely imperfect and does not diffuse that at all, (also not the case), then we observe that U.S. non-defense R&D as percentage of GNP is only two-thirds that of Japan.

It's clear that it makes a big difference whether you believe diffusion of technology from one sector to another is rapid and efficient or is difficult and rare, when you attempt to measure the synergy, or lack thereof, between R&D investments in the two sectors.

It's also quite clear that research is quite different from development in its propensity for rapid diffusion.

Total U.S. R&D outlays	$125B
Total Defense R&D*	44B (incl. IRAD @)
Federal only	32B
Defense procurement	142B
Fraction of national R&D defense related	40% @
*includes R&D plant	@ incl. private (est)

Fig. 3 U.S. Defense Expenditures 1987

Let me familialize you with the numbers. Fig.3 gives the magnitude of 1987 of U.S. total R&D outlays, government and private; the defense component of national R&D, with private investment and without; defense procurement, (purchases of defense systems); and the estimated fraction of national R&D that is defense related.

It's worth perhaps reviewing how the United States technology policy arose, following a distinction due to Prof. Henry Ergas at OECD. After World War II the United States had very little competiton in high-tech activity. The United States had major global responsibilities and a very strong research base. It was not surprising that the policy was to focus on big technology leaps, for example, the Apollo mission to the moon, as a mechanism for driving technology generation. This is strategy compatible with the major military emphasis in technology and with the assertion of a U.S. global leadership role.

By contrast, the policy in Germany has been to emphasize the diffusion of technology throughout the economy. By Prof. Ergas's analysis Japan lies somewhere between the American and the German approach. My conclusion is that in current circumstances the United States clearly needs to pay attention to the advantages of the diffusion-based strategy for technology. It is for this reason that the dual-use technology issue is now beginning to attract attention in the United States.

The basic question with respect to dual-use technology in the U.S.A. is "Does the big military R&D investment help or hurt American industrial competitiveness ?"

There are strong advocates of both interpretations: that military procurement and R&D do promote civilian technology and also that they exact an opportunity cost by driving up expense and diverting scarce technical resources from commercial work. Both explanations are probably correct in different parts of the technological economy.

I believe there is general agreement even among those who disagree about the importance of these factors that in the debate about U.S. industrial competitiveness other issues are more important. Among these issues are: the low savings rate in the United States, lack of attention to export markets by companies that never had any experience in exports, and finally, a lack of attention to process technology, manufacturing, and quality, which are more important to competitiveness than R&D, at least in the short term.

The interesting question in the United States today is "To what extent will the Federal Government take industrial technology policy seriously, and if it does, through what mechanism will technology policy be formulated and expressed ?" There is some evidence that the Defense Department in fact is the *de facto* agent of industrial policy in the United States. I might note that is also a source of some Japanese concerns.

Since the Defense Department has a very large budget it is easy for the President to initiate a technology project by asking the Defense Department to do so. Defense has done just that in the cases of SEMATECH, high temperature superconductivity, and the high-definition television project. The budgeted funds in defense for the very high performance integrated circuit program (VHSIC) involved an expense of nearly a billion dollars. Although its purpose was not to push the semiconductor technology but was instead to persuade the three military services to use higher levels of integration than they were accustomed to using.

The Defense Science Board in 1988 issued a report recommending that the Secretary of Defense play a much more explicit and formal role in national economic policy. There is profound political discomfort in the United States with industrial policy. One way to minimize this discomfort is by restricting industrial technology plolicy to the Defense Department, which has a Constitutional charter for engaging in technology investment in the private sector, through the federal executive responsibilities for defense and foreign affairs. Thereby, the political process seems to avoid setting the precedent that a new relationship between the government and the private industry is being established.

It may be that the Department of Commerce will in fact play a decisive role in the evolving technology policy. The evidence for that is the organization of a new Technology Administration in the Department of Commerce, a new mission and a new name for the National Bureau Standards, and the fact that Secretary Mossbacher has agreed with his predecessor, Secretary Verity, that this is an appropriate thing to do.

Now let me consider a matter of definition. When we speak of dual-use technology flow, we may have in our minds an artifact or a piece of finished goods which has been designed for one purpose, let us say a military purpose, which might be used for a commercial purpose. At the next level down in the technology chain, we can identify the machinery, the tools and processes which could be used to manufacture a different artifact useful in the other sector. That is also a form of technology migration or diffusion. At another level down, the same team of engineers might be developing tools and processes for the manufacture of goods in both military and civil sectors. That is what I mean by "co-development." And finally there is a base of public science and engineering knowledge that everyone shares. The diffusion of knowledge within this realm is familiar to us and is relatively free. I suggested here some identification of common terminology with these different levels.

Technology level	Technology flow phen.
artifact	spin-off or spin-on
tools and process	technology transfer
co-development	technology sharing
public knowledge	technology diffusion

Fig. 4 Terminology—Types of Technology Flows

When we speak of "spin-off," we think of a military object being used for a civil purpose. "Spin-on" is the reverse, a civil technology being used in a military way. "Technology transfer," "technology sharing," and "technology diffusion" are not strictly distinguished definitions, but we will need to develop some language to describe the different forms of technology flow at these different levels (Fig. 4).

Early stages: (example: microelect.)
"spin-off" driven by military R&D
Novel function
small volumes, high costs
initial government market
Technology driven
Mature stages:
"spin-on" driven by civil markets
Large volumes, competitive costs
incremental technol. improvement
Market driven

Fig. 5 "Spin-off" and "Spin-on" —Life Cycle for Dual-Use Technology

The direction of the flow of technology may also change with the age or maturity of the technology. Microelectronics originally had important stimulation from the military. When it was a young technology, it had characteristics not inappropriate for military use. But when the technology matured the U.S. Government was less than 10% of the market for microelectronics. Today as commercial industry pushes for rapid incremental improvement and low cost production, microelectronics development shifts from technology-driven situation to a market-driven one. We are now in the condition where the military technology is mostly taken from the civilian technology base not the other way round.

Aerospace Industry:
- Jet engines
  - (GE and Pratt-Whitney)
- Aircraft
  - (Boeing 707, 747, V-22, FS-X)
- Communications Satellites
  - (Hughes Space Communications)

Specialized Defense Prime Contractors
- Grumman
- General Dynamics
- Martin Marietta

Large High-Tech. Manufacturers with
- Primary Civil Sales (92.7%)

Fig. 6 Industry Structure

The amount of inter-sectoral technology flow also depends upon the organizational structure of the industry that one examines. I distinguish three groups of large prime contractors in the United States. The first is the aerospace industry, where dual-use technology flow is relatively efficient, especially in the manufacture of jet engines and communication satellites, and to a lesser degree in aircraft. The Hughes Corporation has the same team of engineers building commercial communication satellites and military communication satellites. Hughes executives claim that their competitiveness on both in commercial and military markets are importantly assisted by this common technology base.

The airframe industry is a more complicated story. You all familiar with the success of Boeing in developing the Boeing 707 passenger aircraft from an adaptation of the KC-135 military tanker. The Boeing 747 was a design derived from an unsuccessful bid for tne the military C-5, which contract went to Martin Marietta. Since then Boeing has not been successful in deriving an civilian aircraft from a military predecessor, although they have tried on a number of occasions.

The V-22 Osprey aircraft is a Boeing-Bell joint venture military development of a tilt-wing vertical take off aircraft, for which advocates believe there is an important commercial future. Although the new secretary of defense has given the V-22 a low priority and recommended cancellation, the Congress has voted the funding.

Finally, I include FSX in Fig.6 only because in the U.S.newspapers this is associated with Japanese interest in developing a commercial aircraft industry.

My conclusion is that the important dual-use technologies in the aerospace industry are not airframes themselves but are the computer designs, the aeronautical testing and modeling, the CAD/CAM systems, and other tools that are very expensive and can be used to derive all kinds of aircraft, both military and commercial. This technology sharing and diffusion are more important than "spin-off" or "spin-on."

There are several large defense contractors that have very little civil business, and do not diffuse their technology outside their company. Such companies, three of which are listed in Fig.6, will not be an important factor in the flow of technology from military to civil use.

If I exclude these companies plus McDonell Douglas, from the list of large prime contractors in the United States, the remaining next 15 large companies have on the average 92.7% of their revenue is derived from their commercial products, not their military products. IBM is typical; only 2.7% of IBM revenue comes from the Federal systems division, in which all IBM contract R,D, and production of special products for the government is performed. I would suggest that it is unreasonable to imagine that chief executive officers of these firms spend a lot of time worrying about whether the military technology in their companies will have a big effect on their commercial interests.

- Full technology sharing (COMSATs)
- Weak technology diffusion (Software)
- Flow from military to civil (Titanium metallurgy)
- Flow from civil to military (Microelectronics)

Fig. 7 Synergy in Dual-Use Industries
Four possible situations

The technology may flow in either direction (military to civil or civil to military) and the flow may be either strong or weak (Fig.7), I've already given the example of communication satellites, where it is very strongly shared.

In computer software the flow is weak largely because the military prefer to use their own unique languages and programming environments, which are not commonly used for commercial applications.

There certainly are other examples where the flow may be strong and in either direction, with the direction of flow due to the maturity of the technology.

As we thought about this problem, we realized that two situations had to be considered at once. Imagine that the U.S. technology system is made of the institutional elements in Fig.8. On the left side of the figure, we have organizations concerned with the production or marketing of goods. On the righthandside of the figure we have research and development

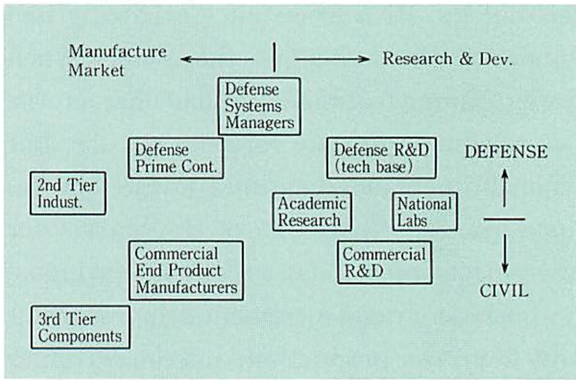


Fig. 8 Modes of Intersectoral Technology Flows

organizations. The bottom half of the diagram is the commercial or civilian world, and the top half of the diagram is the defense world.

We conventionally think of dual use issues involving the flow of technology vertically on this diagram, whereas innovation processes flow from right to left. It's my conclusion that in the United States, from the policy point of view, the bigger issues concern innovation effectiveness, not with technology flow between military and civil sectors.

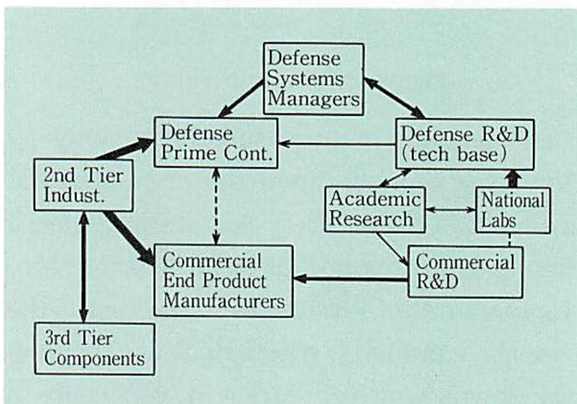


Fig. 9 Modes of Intersectoral Technology Flows

In Fig.9 I've attempted to suggest in a pictorial way the relative strengths of the technical linkages by representing them proportional to the thickness of the lines. Many of these institutions are very weakly linked one to another. The National Laboratories, for example, which tend to be strongly connected to defense research and development, have very little connection to commercial research. Defense R&D itself is poorly connected to military systems in the field, for many developed systems are never manufactured and those manufactured may take 10 or 15 years to make the trip from the research on the concept to final installation.

Please understand that these boxes in Figs. 8 and 9 do not represent separate institutions in most cases. This is a functional diagram. Commercial R&D, commercial end product manufacturing, and defense R&D may all be inside one company, though usually in different divisions of the company. One of the weakest linkages in this diagram is "spin-off" and "splin-on," which are between these two manufactured products, one for commercial and one for defense purposes.

Next I would ask you to think about the different kinds of technology flows through different mechanisms which may reflect themselves in different paths on the functional diagram. For example, we believe it is very likely that procurement is a more important source of defense stimulation of commercial technology than is defense R&D. One example is the fact that in the 1950's and 1960's laboratories like Los Alamos Scientific Laboratory, which had a military mission, would buy the first copy of every Control-Data and IBM "super-computer" as they came out.

The Pentagon is now emphasizing a policy called "civil off-the-shelf" or "COTS" technology. Defense services are urged to buy commercial products where they can adapt them to the military use. Last year Digital Equipment Corporation announced a new model of the VAX computer. There was a simultaneous commercial announcement by Raytheon Corporation of the computer called MILVAX, which was architecturally identical to the new Digital Equipment machine. It was completely developed in MILSPEC hardware by Raytheon Corporation and was priced at only about 30 percent more than the commercial non-hardened computer from DEC. Ordinarily a specially developed computer for the military might cost 10 times as much as the equivalent commercial machine. IBM at earlier time had done something similar with a product called MIL-370. Neither MILVAX nor MIL-370 have been very successful, for the military services are very slow to accept the "COTS" procurement strategy.

We have already talked about co-development of jet engines and communication satellites. There are also genuine examples of "spin-off." One of the best examples is the invention of the microwave oven by Raytheon Corporation. At the end of World War II, Raytheon Corporation had 15,000 employees all working in military work which was coming to an end. Raytheon was very eager to find civilian business. The microwave oven was conceived by an engineer whose responsibility was the burning-in of magnetrons. He understood the dissipation of heat in the loads to which the magnetrons were coupled, and began to think how this energy could be put to use.

It took about 15 years to make a commercial profit from this investment. Raytheon first sold expensive microwave ovens to restaurants in small numbers and gained experience. They then had the idea that it would be possible to make a comsumer product. They were smart enough to realize they knew nothing about marketing consumer products, so they made a merger with Amana Corporation, which made and marketed refrigerators quite successfully. Amana did the design and selling of the product. The corporation initially subsidized the magnetron, which at that time cost $135 against an allowable cost of $30 to be successful. Raytheon was then able to enter the consumer market. They made about six or seven billion dollars over the next eight years and then gradually found business less interesting as Japanese and Korean companies gained market share and profit margins declined.

- Typically small to middle-sized
- Receive .25 of prime contract value (estimate)
- Manufacture industrial components, tools or specialty materials
- Do not sell direct to defense, but to prime contractors and civil mfgrs.
- Specialized technology skills
- Often have technology ties with customers

Fig. 10 Second Tier Industrial Firms

A very important mechanism for leveraging defense technology investments is the stimulation of second-tier, specialized industrial component suppliers. These second tier companies sell both to commercial end-product manufacturers and to prime contractors for defense projects. An example would be Lord Corporation, which is expert in electromechanical vibration isolation. Lord does not sell products directly to the Defense Department or such defense R&D contracts. It has none of the administrative problems that defense contracting entails but it does enjoy the technology challenge of defense subcontracts. Lord builds the vibration isolation for the V-22 aircraft. It also enjoys in some other military programs a steady load of business over a period of years that allows them to take a bit more risk in the operation of the company. These middle-sized industrial suppliers are important dual use enterprises. We know little about them statistically, because information about them is treated as proprietary information of the prime contractor, who may go to whatever supplier he wishes.

There are estimates that something like 25% of the military prime contracts flow through to such second tier companies, in which case something like 35 billion dollars is flowing to them.

Finally I come to the ultimate dual-use resource—people. Technologies flow primarily through people, not through documents. The character of engineering education in the United States is very importantly influenced by the nature of the Federal research support for the universities. Although most of the scientific research in the universities comes from NSF and NIH, engineering research support comes primarily from the Department of Defense, NASA, and Department of Energy. Very often it is the development programs in those agencies, not their research, which calls upon the research help of academic engineeers. The result is that the engineering culture of our universities and colleges is of the defense type, even if the research work does not have any direct involvement in actual defense applications. These defense sponsored research projects tend to emphasize sophisticated function, to pay very little attention to manufacturing or to cost, and therefore how to design for low cost and ease of manufacture. Thus US engineering schools may not be making the best possible contribution to civilian industry.

I suspect that the Japanese situation is not so different and in both countries the private sector must retrain the engineers after they are employed in order to be successful in commercial work. But the differences in engineering culture and business culture between civil and military markets also provide a disincentive to firms to move people from one side of the firm to the other. That is another reason why technology flow between military and civil sides of business is very slow even within a single firm.

In the United States, because of the security clearance requirements of the defense industry, many of them hire only American citizens. This is in fact not a legal requirement but is a practical thing for the companies to do. Sandia Corporation has 2,500 doctorates on the technical staff, many of them engineers. This must be a significant fraction of doctoral level of engineers in the United States. Because of the passing of the baby boom and the diminishing numbers of students of university age in the United States and the reluctance of as many students to choose engineering as a course of study, the commercial sector may face a more serious problem than otherwise be the case in staffing technical positions in the future.

Now let me summarize. The requirements for inter-sectoral flows of technology are three: first, you must have the legal right to access to the information; second, you need some experience in the technology to be able to absorb it; and third, you have to have the opportunity to apply that experience to the other sector. There are many circumstances in which two of these three conditions are fulfilled but not the third, and as a result there is very little consequence from the relationship between the two sectors.

Unfortunately it is not possible to make a net assessment of the influence of military technology on civil competitiveness in the United States. The amount of synergy differs in different industries; clearly is weak when the civil technology is ahead.

The effect of the military investment is also weak when the technology needs of the sectors diverge. I seriously doubt that anyone will make a commercial product out of a nuclear-powered X-ray laser in space. The difference in the business and engineering cultures of the two sectors provides a big inhibition to technology diffusion. So does the industrial structure of ''dual-use'' firms, which often for purely administrative reasons causes the military work to be segregated in an arm's length subsidiary.

Technology sharing by the two sectors may be strong, of course. One example is jet fuel for aircraft. All around the world both air forces and airlines buy jet fuels using common specifications. The fact that jet engines for civil and military aircraft are similar may also be an essential requirement for this to be true.

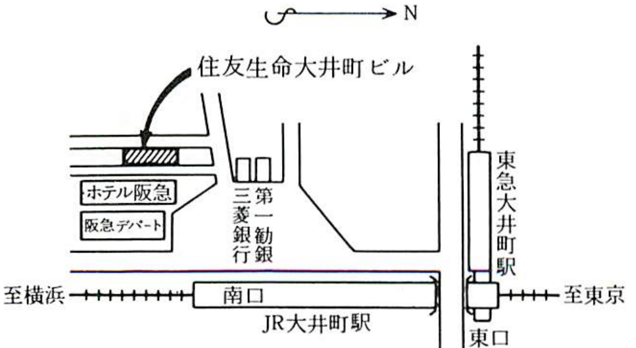
I have discussed the example of aerospace where capital costs very high, the production volumes are low and design tools are important and may be common.

I made the point that I believe that addressing weaknesses in the innovation process or in the speed or effectiveness of the connection between R&D and production is probably a more important policy issue than addressing weakness in the inter-sectoral flows of technology.

Procurement may be more important than R&D as a source of government provided synergy. The U.S. needs to pay more attention to the second-tier industry and to the defense acquisition process, so not to discourage companies from a dual use approach.

I have suggested that there is the beginning of a consensus on Federal technology component of industrial policy, but I don't believe either the defense or commerce department efforts to develop technology policy will be particularly effective in the near future. However, they may serve to signify change in the debate about how the commercial industry in the U.S. might be assisted in serving both military and commercial needs more effectively.

案内図



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