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Breakthrough Innovation – A Comparative Analysis between Germany and the US

By Delia Wenzler and Julian Witt

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Abstract and Policy Implications

Disruptive innovations can solve major global challenges. However, the system in Germany does not sufficiently favor the development of such innovations. The disruptive output of leading nations like the United States puts increasing pressure on Germany's innovation leadership. The German innovation agency SPRIND was founded in 2019 and is a suitable instrument to promote disruptive innovations. The SPRIND itself cites the American innovation agency DARPA, which has been promoting disruptive innovations since 1958, a role model. Therefore, the aim of this paper is to conduct a comparative analysis of DARPA and SPRIND. To answer the research question, secondary sources were used. In addition, two expert interviews were conducted with employees of SPRIND. The result of this paper is a systematic comparison that identifies the key differences and similarities between the two agencies. SPRIND is based on DARPA in key success factors, such as the person-centered approach, funding instruments or risk management. However, compared to DARPA, SPRIND has a major disadvantage; namely several administrative hurdles which inhibit agile action.

1. Introduction

Major societal challenges such as climate change, new treatments for diseases, and new mobility concepts require innovation (Bunde et al., 2020, p.4). Innovations and new technologies change the world as well as the life of everyone (BMWi, n.d.). Especially disruptive innovations which can solve current social, ecological, and economic problems. The last breakthrough innovation from Germany was the automobile over 120 years ago (Deutschlandfunk, 2021). Radio, television, or Aspirin are also breakthrough innovations that originated in Germany. But disruptive innovations of today, such as the Internet, have their origin in the United States (SPRIND, n.d.d). More specifically, the innovation agency "Defense Advanced Research Projects Agency" (DARPA), which deals with disruptive innovations, laid the foundation for the development of the Internet. This agency has been successfully operating in the United States since 1958 (DARPA, n.d.a). That is why it is worth looking across the Atlantic when it comes to disruptive innovations. Recently, disruptive innovations have been promoted with the help of "Federal Agency for Disruptive Innovation in Germany" (SPRIND). In this regard, the agency's stated model is DARPA (Heute im Bundestag, 2018). But how exactly is the agency in Germany based on the approach from the United States? This question will be answered in the context of this paper and the main differences and similarities will be shown in a comparative analysis.

The first part of the paper defines the term innovation. For this purpose, five dimensions of innovations are explained. Furthermore, the meaning of disruptive innovation is clarified. Subsequently, the disruptive innovative strength of the United States and Germany is briefly introduced. To answer the research question, the second part of this paper, first describes government support of disruptive innovations in the United States and then in Germany.

Finally, based on the findings, the two agencies are compared to each other. It will be shown how the German agency is oriented toward the agency in the United States.

Initially, secondary sources were used to answer the research question. The secondary data research mainly comprises scientific literature, research reports of the Fraunhofer Institute and the ifo-Institute as well as publications of the BMBF, BMWi, SPRIND and DARPA. From these sources, findings regarding the two innovation agencies, DARPA and SPRIND, were collected and systematically compared for the comparative analysis. Subsequently, two expert interviews were conducted with employees of SPRIND, to gain further high-quality insights into the comparison of DARPA and SPRIND. A semi-structured interview was chosen for this purpose. After the planned questions had been sent out by e-mail, the interview was conducted as video conference with a duration of about 30 to 40 minutes. In conclusion, the information obtained was integrated into the previous comparison of secondary sources.

2. Innovations

2.1 Dimensions of innovations

When talking about innovation, two terms need to be differentiated: Invention and Innovation. An invention is a useful idea and a creation of something new. On the other hand, an Innovation is the successful conversion of the invention into the market (Hotz-Hart, B. et al., 2014, p. 26; Corsten, H. et al., 2016, p. 6). For a more detailed understanding of what an innovation is, five dimensions will be explained in more detail.

Objective Dimension: The first dimension is the objective dimension. It answers the question of what is new (Hauschildt, J. et al., 2016, p.6). The OECD differentiates between four types of innovations (OECD, 2005, p.46-52):

- **Product innovation:** Implementation of a product or service with new or improved characteristics or with a new intended use.
- **Process innovation:** Implementation of a new or improved production or delivery method.
- **Marketing innovation:** Implementation of a new marketing method with a change in product or packaging design, product placement, product promotion or pricing.
- **Organizational innovation:** Implementation of a new organizational method in a company's business practices, workplace organization, or external relations.

Intensity Dimension: In addition to the differentiation of the types of innovation, the level of innovation can also be differentiated. The intensity dimension deals with the question of how new an innovation is (Hauschildt, J. et al., 2016, p.12). In innovation research, a difference is made between incremental or sustaining innovations, which involve small changes or improvements, and radical or disruptive innovations, which initiate large-scale changes in markets, providers, and technologies. This paper is mainly about disruptive innovations respectively “Sprunginnovationen" (Cuhls, K. et al., 2019, p.2, 4). Rafael Laguna, the founding director of SPRIND defines "Sprunginnovationen" as an innovation that changes lives. The world is no longer the same as it was before (Deutschlandfunk, 2019). According to the Fraunhofer Institute, “Sprunginnovationen” are changes, that create a new dynamic market or achieve high market penetration in existing markets within a short period of time after the establishment of the innovation, through significantly better cost-benefit ratios. In addition,

“Sprunginnovationen” displace previous offerings and providers from the market or supplement the existing range of offerings. Moreover, “Sprunginnovationen” can arise from completely new technical approaches and from a recombination of unrelated innovation processes (Cuhls, K. et al., 2019, p.2, 4). In the context of this paper, disruptive innovation is interpreted as the Fraunhofer Institute's definition of "Sprunginnovationen".

Subjective Dimension: This dimension shows which individuals or groups of people notice what is new. It is not only about the new technical features but about the subjective recognition of what is new. A technical innovation could be new for individuals, experts, managers, a sector, a nation, or the whole humanity (Hauschildt, J. et al., 2016, p.17-20).

Procedural Dimension: The next dimension is the process dimension. It clarifies the question of where internal innovation begins and where it ends. This context can be illustrated by an innovation process (Bösch, D., 2007, p.15). The “stage-gate model” offers an approach of how the innovation process works. Starting with the idea, the innovation process is divided into several phases. After each phase, a gate is passed through which decides on the continuation of the process (Corsten, H. et al. 2016, p.22). An example of a simplified innovation process is shown in Figure 1.

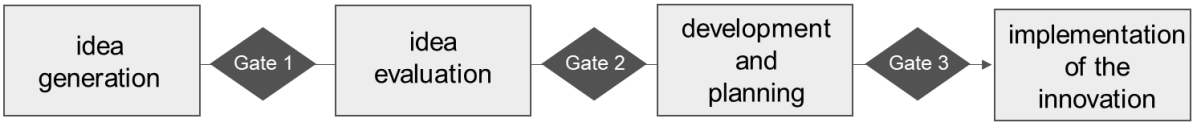

Figure 1: Example of an innovation process
Source: Own representation based on Dworschak, B. et al. (2012, p.24); Corsten, H. et al. (2016, p.22).

Normative Dimension: The normative dimension is about the success of the innovation. Not everything new is an improvement of the status quo. The success is often measured in profit, revenue, and cost savings. These key figures are future-orientated and can only be checked in hindsight (Hauschildt, J. et al., 2016, p. 23).

2.2 Disruptive Innovation activities of the United States and Germany

Research and innovation are important factors influencing the competitiveness of nations, ensuring future prosperity and economic sovereignty. Already for a long time, the support of R&D has been anchored in policy because the benefits of the results of R&D are not only relevant for the researchers, but also benefit many others (Bunde et al., 2020, p.1, 3). The Global Innovation Index can be used to assess the innovative potential of individual countries. This index includes a variety of indicators such as human capital and research, infrastructure as well as knowledge and technology outputs. A successful innovation system is based on balance across all innovation areas. Switzerland, Sweden, and the United States lead this ranking, while Germany is ranked 9th (Dutta, S. et al., 2020, p. 15, 203-208). Figure 2 shows a section of the Global Innovation Index ranking from 2020.

Country/Economy	Score (0-100)	Rank
Swizerland	66.08	1
Sweden	62.47	2
United States of America	60.56	3
United Kingdom	59.78	4
Netherlands	58.76	5
Denmark	57.53	6
Finland	57.02	7
Singapore	56.61	8
Germany	56.55	9
Republic of Korea	56.11	10

Figure 2: Global Innovation Index – TOP 10
Source: Own representation based on Dutta, S. et al. (2020).

In particular, the output of disruptive innovations from leading countries such as the United States challenges the innovative leadership of Germany (BMBF, 2018, p.1). DARPA is an established innovation agency in the United States that specifically promotes disruptive innovation. The organization can look back on several innovations for the military but also for the civilian sector. These include, for example, the “Global Position System” (GPS) and automatic speech recognition (DARPA, n.d.a; DARPA, 2018, p.12). On the other hand, the German innovation system was primarily focused on developing innovations that are based on existing technologies, products, and services (Harhoff, D. et al., 2018, p.9). Before the establishment of SPRIND, Germany did not have a system that favors the development of disruptive innovations. Companies are only motivated to remain marketable through incremental improvements and to amortize investments quickly. If anything, startups, that have trouble getting money, develop disruptive innovations (Deutschlandfunk, 2019). Therefore, the need for support of such disruptive innovations is particularly high. The German government's interest in introducing this funding instrument is that disruptive innovations used in Germany contribute to sustainable economic growth, the creation of new high-quality jobs and a significant improvement in the quality of life (BMBF, 2018, p.1).

3. Government support of disruptive innovations

3.1 Government support of disruptive innovations in the United Sates

In 2018, government innovation support accounted for 23 per cent of the total R&D spending in the United Sates. The Federal Government’s share of this value is around 96 per cent. Consequently, the Nonfederal Government takes only 4 per cent of the government R&D spending (Congressional Research Service, 2020a). Federal agencies are mainly responsible for government innovation support. More than 20 federal agencies promote innovations (Bunde et al., 2020, p.7). The federal agency with the largest budget is the “Department of Defense” (DoD). In 2020, the DoD had a budget of about 64 billion U.S. dollars. This accounts for 41 per cent of total government innovation spending (U.S. Government Publishing Office, 2020, p.238). The R&D budgets of 2020 for each government agency are shown in the following figure.

By Agency	Budget 2020 Estimate	shares in percent	Cumulated shares in percent
Defense	64.544	41,38%	41,38%
Health	40.818	26,17%	67,55%
Engergy	19.219	12,32%	79,87%
NASA	14.057	9,01%	88,89%
National Science Foundation	6.752	4,33%	93,21%
Agriculture	2.941	1,89%	95,10%
Commerce	1.948	1,25%	96,35%
Veteran Affairs	1.313	0,84%	97,19%
Transportation	1.134	0,73%	97,92%
Interior	973	0,62%	98,54%
Homeland Security	532	0,34%	98,88%
Environmental Protection Agency	492	0,32%	99,20%
Smithsonian Institution	330	0,21%	99,41%
Education	259	0,17%	99,58%
Others	661	0,42%	100,00%
Total	155.973	100,00%	-

Figure 3: R&D budgets by agency in 2020
Source: Own representation based on U.S. Government Publishing Office (2020, p. 238).

Furthermore, there are innovation agencies in the United States that specifically promote disruptive innovation. These agencies include, for example, the “Defense Advanced Research Projects Agency” (DARPA), which works on behalf of the DoD. This concept emerged in 1957 as a reaction to the launch of the first satellite by the Soviet Union. The United States feared that the country was losing their technological leadership. Therefore, DARPA was founded one year later (DARPA, 2018, p.12). The main objective pursued by DARPA is to promote advanced technologies to create benefits for the military (Van Atte, R., 2019, p.30). Due to the fact, that other disruptive innovation agencies such as ARPA-E or IARPA were modeled after DARPA, this paper focuses on the structure of DARPA (ARPA-E, n.d.; IARPA, n.d.).

DARPA is an independent organization that reports directly to the top of DoD with minimal bureaucracy. Organizational flexibility enables fast reactions to changing technological conditions (Azoulay, P. et al., 2018, p.9). There are only three hierarchical levels: a director, a series office managers, and program managers (Piore, M. et al., 2019, p.55). DARPA currently consists of six technology offices, which employ about 100 technically accomplished program managers. All managers are employed for a temporary period of three to five years. Program managers are tasked with proposing R&D funding activities in specific technology areas (programs) as well as selecting and supervising performers (Windham, P. et al., 2019, p.9-11). Often, the program managers come up with their own ideas, from which programs emerge. But it can also be that program managers are hired for specific or existing programs (Cheney, D. et al., 2019, p.283). Over three to five years, the individual projects can be financed with a budget in the tens of millions U.S. dollars (Windham, P. et al., 2019, p.9-11). For programs with strong progress, an extension over several program generations is possible (Van Atte, R. et al., 2019, p.465). DARPA follows a portfolio approach, which means that a wide range of R&D programs are funded. The agency is aware that research does not always lead to success. Therefore, several projects can be funded within one program (DARPA, 2018, p.17). For a program to continue, set milestones must be achieved (Jackel, L., 2019, p.317). In addition to the programs, each office organizes an annual open competition. Overall, DARPA is purely a funding agency, that does not have internal laboratories for research (Windham, Patrick et al., 2019, p.9-11). The 2020 budget for DARPA was 3.556 billion U.S. dollars (DARPA, n.d.b).

3.2 Government support of disruptive innovations in Germany

In Europe, the main instrument is the Horizon Europe framework program. This program has a planned funding volume of 100 billion Euros. (BMBF, 2020, p.86, 87). However, EU funding for innovation is not as significant as the innovation funding provided by individual countries (Bunde et al., 2020, p.25). In Germany, the Federal Government and the 'Länder' essentially provide the government R&D spending. In 2018, the government covered 27.8 per cent of total R&D spending (BMBF, 2021). The Federal Government promotes R&D activities primarily with instruments such as project funding, departmental research, and institutional funding (BMBF, 2020, p.60-69). Another government funding instrument is the "Federal Agency for Disruptive Innovation" (SPRIND), which was founded as a federal government owned company at the end of 2019 (Federal Ministry of Education and Research, 2020). SPRIND is represented by the Federal Ministry of Education and Research as well as the Federal Ministry for Economic Affairs and Energy (Bunde et al., 2020, p.32). The agency was founded as SprinD GmbH in Leipzig. (BMBF, 2018, p.3). The planned budget from 2019 to 2022 is at least 151 million Euros. However, funding of around one billion Euros is expected within the planned ten-year term (BMBF, 2018, p.5). With the support of this agency, research ideas with the potential of becoming breakthrough innovations for civilian applications are discovered and further developed (BMBF, n.d.; BMBF, 2018, p.1).

To fulfill this mission, the Innovation Agency uses two instruments: Innovation competitions and projects. (Harhoff, D. et al., 2018, p.10). Through the innovation competitions, innovative, socially relevant challenges, such as power supply by electricity storage or organ replacement from the laboratory, are addressed (BMBF, 2018, p.3; SPRIND, n.d.a). Project proposals can be submitted through the SPRIND website. If the project shows the realizable potential of a disruptive innovation, it is presented to the Supervisory Board. A suitable financing tool, such as the establishment of a project limited liability company is selected for each cooperation that arises. Figure 4 illustrates the concept of SPRIND.

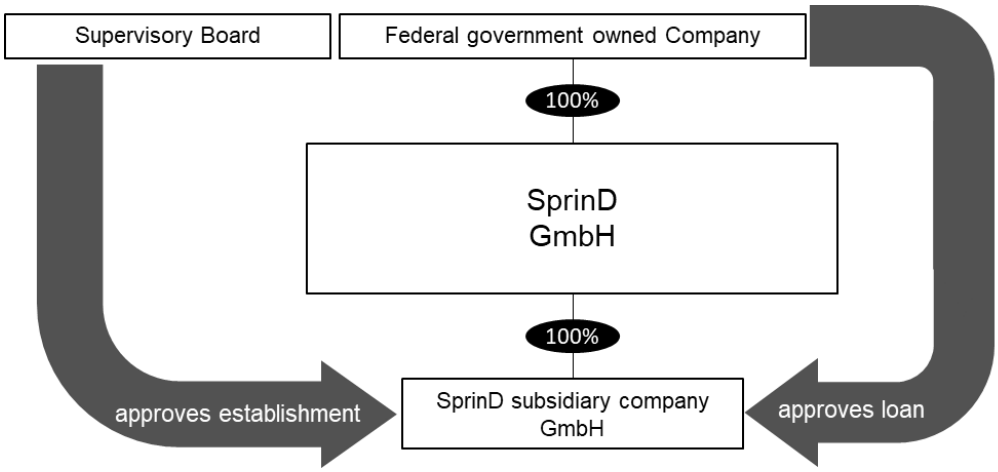

Figure 4: concept of SPRIND.
Source Own representation based on the interviews with SPRIND.

In addition to financial support, SPRIND also helps putting together a team, building a network, and supporting the accounting or controlling (SPRIND, n.d.c). The projects support R&D activities for a duration of three to six years to solve specific problems. The projects are managed by innovation managers who are hired on a temporary basis for a maximum of five

to six years. Innovation managers have a superior technological understanding and are recruited from science or business. Their task is to propose concrete problems, selection of suitable project ideas and project teams, allocation of financial contributions of the project performers as well as the monitoring of the project progress (BMBF, 2018, p.4). In the context of project monitoring, projects that do not reach the defined milestones can be cancelled. However, this should not be considered a failure (Harhoff, D. et al., 2018, p.6). SPRIND has the mindset that failure is part of taking big risks (SPRIND, n.d.b). Moreover, the possibility of supporting different solutions within a project at the same time spreads the risk of failure (BMBF, 2018, p.4).

3.3 Comparative analysis of DARPA (United States) and SPRIND (Germany)

After introducing the innovation agencies of the United States and Germany, these agencies are now compared to each other. For this purpose, the differences are first pointed out before the similarities are explained. Figure 5 shows an overview of the differences between DARPA and SPRIND.

	DARPA	SPRIND
Establishment	1958 as a reaction to the first satellite by the Soviet Union	2019 because technological leadership is challenged by other countries
Administrative hurdles	Minimal bureaucracy with short decision-making processes	Long decision-making processes and legal restrictions
Budget	3.556 billion U.S. dollars in 2020	1 billion euros for 10 years
Funding allocation	Majority of funding allocated at national level	Funding from the individual countries is dominating
Mission	Disruptive innovations for the military	Disruptive innovations for the civil application area
Specialization	Specialization on military innovations	Open-topic (energy, health, etc.)
Market transfer	Largest customer for the developments is the DoD	Transfer to products and market launch a major challenge

Figure 5: Comparison between DARPA and SPRIND (1)
Source: Own representation.

DARPA was established over 60 years before SPRIND and is therefore an established concept. In addition, DARPA has a record of some successful disruptive innovations, which is still in the future for the German innovation agency. A key difference is that DARPA has few bureaucratic hurdles. The minister has no voice in the thematic structure of the agency. At SPRIND, on the other hand, three ministries sit on the supervisory board and intervene. In addition, there are regulations such as state aid law. An expert of SPRIND identifies a great need for action here, because otherwise a success story like DARPA will not be possible in Germany. This lack of freedom was also criticized by Chancellor Merkel at the 2021 Research Summit (Ronzheimer, M., 2021). According to an employee of SPRIND, a kind of real laboratory would be a solution. This would enable the agency to be more experimental and work more freely with the money. Probably the biggest intended difference is the mission of the two agencies. DARPA specifically funds disruptive innovations for the military. While these may also have social benefits, such as GPS, the research projects are primarily intended to serve national security. On the other hand, innovation funding of SPRIND relates to disruptive innovations for civilian applications. Another difference is the size of the budget. The 2020 budget in the United States is more than 3.556 billion U.S.D, while the budget in Germany is

only 1 billion Euros for the planned 10 years. While the United States allocates the volume of funding for innovation at the national level, funding from the individual countries is dominating in Europe. However, supporting disruptive innovations, which are very risky and costly, would make sense at the European level because disruptive innovations seek solutions to major societal challenges. A European level disruptive innovation agency would be beneficial by pooling resources and diversifying risks, which would increase the chances of success. It also considers the potential benefits for all European countries. However, one problem with funding at the European level would be the different distribution of support across member states (Bunde et al., 2020, p.4, 35, 39). According to a SPRIND employee, there will be national developments in Europe for government funding of disruptive innovation. However, the European Commission will coordinate the cooperation of individual countries for large projects with high risk and capital requirements. Another difference is that SPRIND is an open-topic organization. In the United States, there are separate innovation agencies for areas such as defense, energy, and health. The advantage of DARPA is that it focuses on a specific topic, which means that a lot of expertise can be developed. But an expert from SPRIND considers the openness of topics in Germany to be an advantage due to the emergence of synergies between projects. An advantage of DARPA is that the DoD is the most important customer of new developments. Consequently, converting innovations into concrete business models is not a central task of the agency. However, the transfer of research results into new products and their market launch represent a major challenge for SPRIND due to its civilian orientation (Bunde et al., 2020, p.22, 37, 38). During the interviews, it was noted that SPRIND promotes technologies with a technology readiness level of 3 to 7. This means that the market launch is the responsibility of the companies. But during the competitions SPRIND will use the tool of “Pre-Commercial Procurement” (PCP). With the help of PCP, SPRIND as a client will order the development of something new.

On the other hand, there are several similarities between the two innovation agencies. Figure 6 presents an overview of the similarities between the agencies.

	DARPA	SPRIND
Funding instruments	Programs and innovation competitions	Projects and innovation competitions
Program management	Program manager (Expert, temporary hiring, scope for action)	Innovation manager (Expert, temporary hiring, scope for action)
Program duration	3 to 5 years	3 to 6 years
Idea finding	Programs: mainly from program managers Competitions: from agency itself	Projects: from innovation managers Competitions: from agency itself
Risk diversification	- Portfolio approach: serval programs - Several projects within one program - Monitoring of the programs (milestones)	- Portfolio approach: serval projects - Serval approaches within one project - Monitoring of the projects (milestones)
Culture of error	Not all research can be successful	Failure is part of the game

Figure 6: Comparison between DARPA and SPRIND (2)
Source: Own representation.

If the approach of the two agencies is considered, the strong orientation of the German innovation agency to the American model is revealed. The innovation agencies primarily use programs (called projects by SPRIND) and innovation competitions as funding instruments.

Furthermore, an employee at SPRIND reported that, like DARPA, the teams are motivated by the agency during the innovation competitions to exchange ideas with their competitors to achieve better results. Additionally, both countries follow a people-centered approach in promoting disruptive innovation. At DARPA, programs are the responsibility of program managers, and at SPRIND, projects are the responsibility of innovation managers. These managers are experts at both agencies with appropriate technological expertise. In addition, new inputs are guaranteed with a temporary hiring of about 3 to 6 years. Furthermore, project managers and innovation managers have special scope for action. This includes, for example, the selection of the performing persons. However, subsidiaries of SPRIND must demonstrate through procurement law that funds are being used efficiently. The United States does not have anything like procurement law, which makes Germany much more inflexible (Deutschlandfunk, 2021). According to an expert of SPRIND, an additional difference is that program managers at DARPA are the highest-paid public service employees in the United States. But innovation managers at SPRIND are paid according to the Collective agreement for the public sector. This requires a lot of enthusiasm on the part of innovation managers. The programs or projects are expected to have a duration of up to five years. But at DARPA, there is the possibility to extend programs. This is also in line with the Fraunhofer Institute's assessment that some disruptive innovations require longer-term funding of more than 10 years (Cuhls, K. et al., 2019, p.10,11). An expert of SPRIND believes that projects that are doing well and need more time could also be extended at SPRIND. However, the empirical values are missing in this case. In the end, it is a decision of the federal government if the cooperation with a subsidiary is extended. Another similarity is in the idea generation process. Both agencies rely on suggestions from program managers or innovation managers. The ideas for the competitions originate from the agencies themselves. Moreover, DARPA and SPRIND are trying to deal with the high risk involved in supporting disruptive innovation. Because of that, the programs or projects are monitored. As soon as a research project is deemed to be unpromising, it can be cancelled prematurely. In addition, the risk of the individual programs and projects is spread by allowing multiple solution paths to be pursued within a program or project. Moreover, the portfolio approach of both agencies spread the risk of failure. When it comes to risk, both the American and German innovation agencies, make it clear that mistakes are tolerated, and failure is part of developing disruptive innovations.

4. Summary and Conclusion

Innovations are essential for a nation to remain competitive. Disruptive innovations ensure sustainable economic growth, job creation and improved quality of life. In this paper, the question of how the German innovation agency SPRIND is oriented towards the American innovation agency DARPA was investigated.

In some characteristics, DARPA and SPRIND are different. A major challenge of SPRIND is overcoming bureaucracy. While DARPA can act very flexible and with a minimum of bureaucracy, SPRIND has some administrative hurdles that hinder agile action. Furthermore, DARPA has significantly greater government procurement power because of the DoD. Another difference is the dominance of the promotion of disruptive innovations in the individual European countries rather than at the European level. However, individual countries will cooperate on major projects. In addition, unlike DARPA, SPRIND is an open-topic organization, which means less specialization but also creates synergies.

On the other hand, the two agencies share a commitment of taking big risks. Therefore, a culture that allows failure is embedded at DARPA and SPRIND. SPRIND also uses DARPA as a model for risk management. Other similarities are the instruments used: programs or projects and innovation competitions. Moreover, program managers are a special characteristic of DARPA. SPRIND adopts this person-centered approach by having experts lead the project as innovation managers. However, due to procurement law, for example, innovation managers do not have the level of freedom that program managers do.

In summary, SPRIND is an important tool to close the gap between basic research and finished product in Germany. However, only time will reveal if SPRIND is the right way because a disruptive innovation cannot be developed overnight. Orientation towards a successful approach such as DARPA is essential to increase SPRIND's chances of success. But to be as successful as the American model, more freedom for SPRIND must be created. A change is necessary because the low administrative hurdles are a key factor in DARPA's success.

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