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FROM MANAGING INFORMATIONAL ASYMMETRIES TOWARDS A SYSTEMIC ASYMMETRIES APPROACH IN TECHNOLOGY TRANSFER: A critique based on the SME strategy at ONERA – the French Aerospace Lab™

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(ABSTRACT)

The technology transfer process between a public laboratory and a company has been the subject of many publications and has been widely discussed in economic theory. This paper highlights several newly identified asymmetries occurring between the different agents taking part in the process.

The theoretical corpus of the article draws upon empirical sources, being based on the recent experience of one of the most dynamic Technology Transfer Offices (TTOs) in France: the case of ONERA (the National Office for Aerospace Studies and Research) and the SMEs.

In such a cooperative innovation process, we will show that certain collaborative tools or practices emerge, aimed at reducing information asymmetries or acting as compensation mechanisms for other types of asymmetries between the partners at a microeconomic level; especially in France where there is a gap between the public R&D laboratories and the SMEs in terms of Technology Readiness Levels (TRLs). Some of these compensation mechanisms, particularly those related to the knowledge management, could be adapted and reshaped for agents engaged in R&D and innovation in various other sectors, perhaps inducing positive amplification effects on innovation behavior, and thereby on economic growth at the macroeconomic level within the "national innovation system".

Keywords: *French SMEs, technology transfer, information asymmetries, innovation systems, TRL, DRL*

INTRODUCTION

The technology transfer process between a public laboratory and a company has been the subject of many publications and has been widely discussed in economic theory as well as in applied economics (e.g. the *Journal of Technology Transfer*). Here we will deal with the specificities related to this process in France and, in particular, in the field of technology transfer arising from the field of aerospace and defense.

These specificities relate to the characteristics, capabilities and competencies of SMEs and public research laboratories. This paper will be based mainly on feedback regarding the strategy implemented for the development of an economically 'healthy' relationship between ONERA (*Office National d'Etudes et Recherches Aérospatiales*, the National Office for Aerospace Studies and Research) and the SMEs. The choice and definition of collaborative tools will be explained together with the analysis of the initial results and the prospects envisaged.

We will contend that, in a cooperative process of innovation, these tools become mechanisms for reducing informational asymmetries **(**Stiglitz & Weiss, 1992**)** or "compensation mechanisms" (Paun, 2009) for other asymmetries between the various players at a microeconomic level. These newly identified asymmetries, **Institutional (Culture) asymmetry** (regarding the institutionalist theory of Veblen, 1914), **Technological (Information in the case of Technology Transfer) asymmetry, Risk and Time Scaling asymmetry**, often act as barriers to the technology transfer process, while simultaneously being critical for the eventual high intensity of the innovations pursued. The greater the asymmetries, the stronger the impacts on the intensity of innovations, always supposing that the differently involved actors in the innovation process do succeed in working together. This involves the effective implementation of asymmetries reduction (or compensation mechanisms) bridging the various agents.

Some of these mechanisms, more related to the knowledge economy, could be adapted and reshaped for other agents in the R&D and innovation domain, and for evaluation or regulation authorities of this domain. Their implementation for these other players could induce a amplification effect on innovation and its direct effects on economic growth at the macroeconomic level within the framework of the "national innovation system" **(**Freeman, 1987; Lundvall, 1992; Nelson, 1993**)**.

I – CONTEXT, POSITIONING AND ROLE OF THE ACTORS IN INNOVATION

A brief description of ONERA's economic environment is necessary for a better understanding of the reasons for these tools and their operation, as well as a reminder of the fundamental principles of innovation and the role of technology transfer in this process.

ONERA is a scientific and technical public corporation with commercial and industrial characteristics (EPIC). Its mission is defined as follows: "... to develop and direct research in the aerospace field; to design, develop and implement the necessary technical tools and benches for carrying out this research; to ensure, in association with other R&D organizations, the circulation, at a national and international level, of the results of this research; to support their utilization by the aerospace industry; and possibly to facilitate their application outside the aerospace field".

This quotation is important for understanding ONERA's position in the TRL[1] chain (Mankins, 1995), its role in technology transfer, and more generally its role in innovations generated on the basis of the technology that it has created.

This nuance is very important, particularly in the 'ideological opposition' between those who prioritize a 'publication' strategy and those who prefer one that stresses a 'patent', because premature disclosure, in the form of articles or conferences, ensures the circulation of knowledge but also facilitates uncontrolled utilization of the results of research by industry, including competitors of the national or European industry.

It must also be observed that ONERA has to transfer the results of its research (in order to "... support utilization...") to the aerospace industry and also "... outside the aerospace field..."

Its supervisory authority is the Head of the French national armaments organization (DGA). The other organizations with which ONERA has close relationships are the DGAC[2], CNES[3], the ESA[4] and of course the European Commission (EC) through contracts that are part of the PCRD[5]. Its strategic customer-partners are the large French or European aerospace groups, such as Airbus, Eurocopter, Astrium, Snecma, Thales and Dassault. During its entire existence ONERA has devoted most of its activities to studies directed by or for this first circle of institutional or industrial partners.

The last consolidated figures show an annual operational budget of 230 M€, of which 62% comes from R&D service contracts, and a labor force of 2040 employees.

I.1 - Specificities of the Aerospace and Defense field

This brief description of ONERA's economic environment needs a complementary analysis of the players from the point of view of the utilization of its research results by industry.

[1] Technology Readiness Levels

[2] General Directorate of Civil Aviation
[3] National Centre for Space Studies
[4] European Space Agency
[5] Research and Development Framework Programme

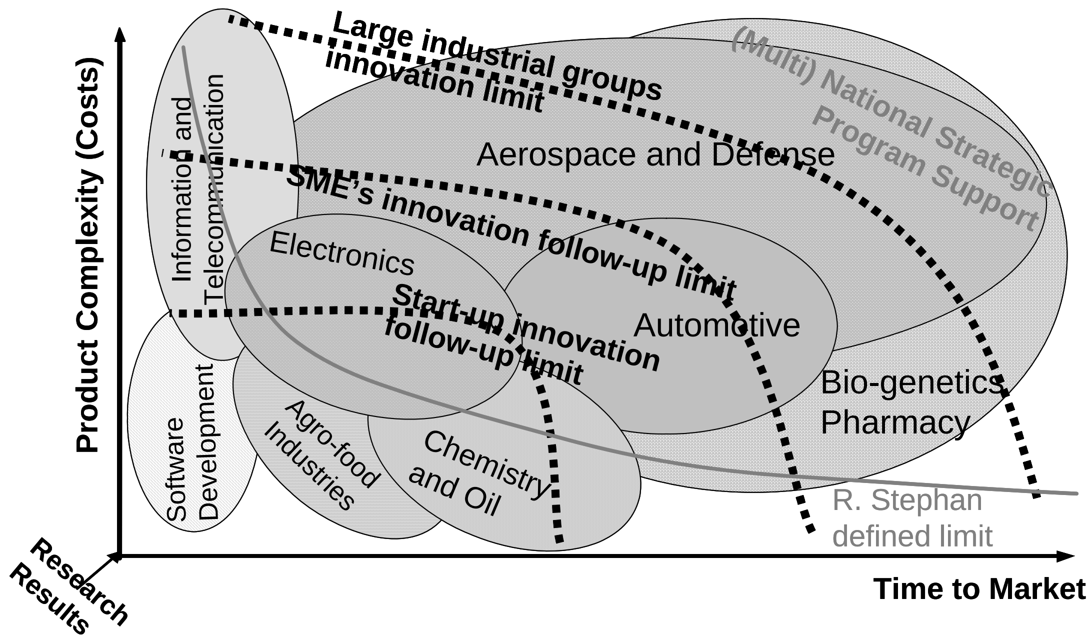

Figure 1: Limits to innovation process control by the creator (or assimilator) of technology, by technological sector : - R Stephan limit - - Authors proposed limits

So Figure 1 presents a classification of the market sectors according to two parameters: the time involved in launching products resulting from a new technology on the market, and the complexity of the products intended for this market, roughly approximated by the cost of a unit of the product **(**Stephan, 2006**)**.

R. Stephan, while presenting this figure, proposed a generic limit to innovation process control (up to the successful delivery of the new product and/or service to the market) by the carrier-creator of the technology itself.

It must be admitted that an SME has less material means to establish a successful new product/ service in the market than a large group. This is even more evident for a start-up partner. Thus we proposed to decline the limitation curve into 3 limits corresponding to these 3 type of actors and modify the original shape of the curve to one better adapted. These new proposed limits are generically represented in the Figure 1.

The specificity of the aerospace and defense markets asserts itself very quickly because these sectors, which are generally 'complex systems' (Hobday, 2000), require a lot of time for the development and introduction of a new product on the market. We note that even large groups, beyond a certain limit, need institutional support at the national level, if not at the international level, to develop new technologies.

So in what circumstances would ONERA be able to respond well to its prospective mission of "developing and directing research" and its transfer mission "to support the utilization of its results by the national industry"?

By being located within the upper limit of the diagram, the large aerospace sector and French and European defense groups stand out as designated partners for successfully 'bearing' (i.e. acting as generator, carrier and user of) the new technologies suggested and/or developed by ONERA. This is particularly the case for the incremental or specialized innovation of the large groups. Such 'bearing' is however less obvious in the case of technological breakthroughs (see McCooe, quoted in Golob, 2006), and this is even more the case in the civil aerospace sector where technologies used onboard planes must be safe and tested technologies. For these aspects, since its creation ONERA has developed and maintained effective strategic partnerships with the large national groups which have mostly become multinationals in recent years. This partnership policy will not be the subject of our analysis here.

The fundamental question raised during the development of ONERA's implementation strategy is that of access to markets, for breakthrough technologies resulting from a specialized research sector such as aerospace. From this point of view, the preceding diagram, presenting the limits to innovation processes, illustrates the point that, to put a 'breakthrough technology' on the market, thus challenging the existing products and/or business models, such as may be designed by a national skill centre, the best vectors are the SMEs.

Technological demonstrations that result in innovation will not necessarily take place in the aerospace market but can arise in any of the market sectors in which the SME receiving the technology can itself control the innovation process completely (until the successful introduction of the new product to the market). Some niche markets will be accessible, even in the aerospace sector (green aviation, small-scale drones, leisure, etc.). Once the technology is demonstrated, there are strong chances that the large aerospace groups will integrate this technology as a tested module into the systems they are designing **(**Mouchnino & Sautel, 2007**)**.

The strategic choice was taken at ONERA for the development of a partnership relationship with a national and European SME. If no SME is identified, the launching of a start-up partner could be studied, subject to the economic outlook and adequate financial support.

I.2 - ONERA-SME Relationships

Like any healthy partnership relationship, that between ONERA and an SME must be a winning one for both parties. Both partners must have strong positions **(**Cowan, Jonard & Zimmermann, 2003) with each adopting its own role so that their collaboration generates significant added value. So ONERA develops its best technological solutions, possibly breakthrough technologies, and the SME implements its product development, industrialization and marketing capabilities in order to reinforce its competitive advantage in its markets or to create new ones.

These complementary roles, based for one side on a 'craftsman instinct' and for the other on a 'predatory instinct', opposable in the sense given by the theory of Veblen **(**1899**),** generate significant asymmetries between the two partners.

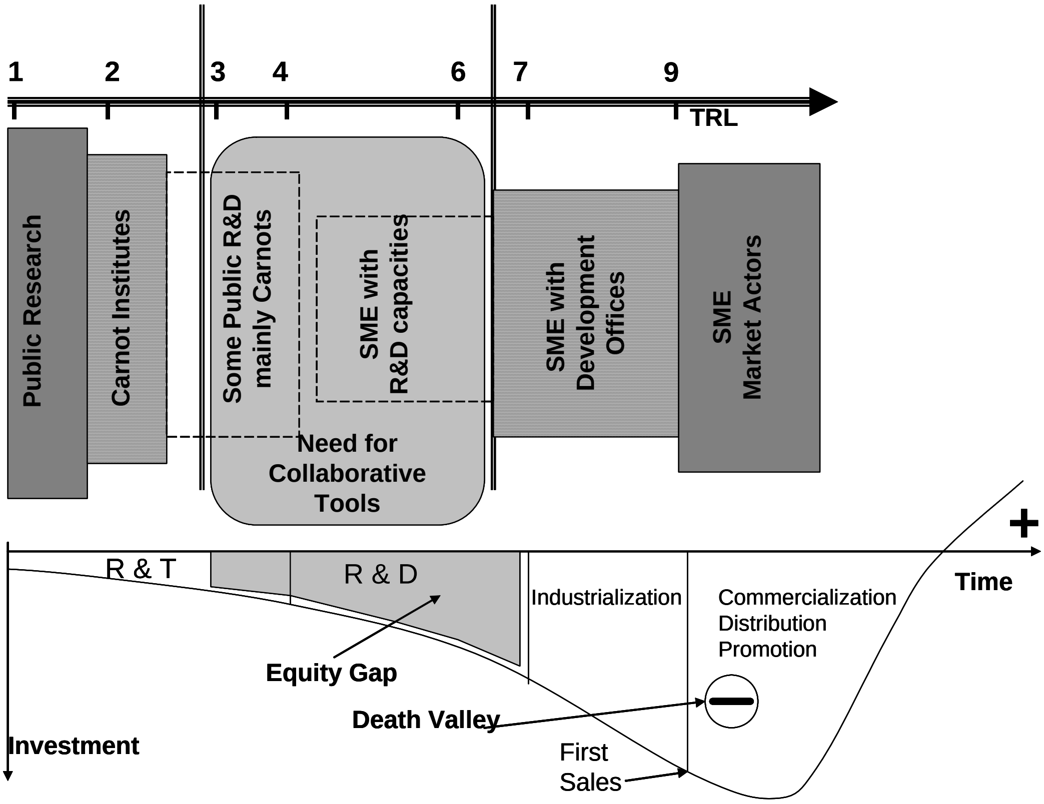

Figure 2: Asymmetries between public R&D laboratories and SMEs, by TRL scale

Figure 2 presents the existing asymmetries between the public R&D laboratories and the SMEs in France by showcasing their respecting positions with regard to the TRLs (Mankins, 1995).[6] It should be stressed that the majority of the public R&D laboratories in France carry out their activities at the levels TRL 1 (basic research) and TRL 2 (applied research). The 33 Carnot Institutes, being responsible for 470 million of research carried on in partnership with industry, representing about a half of the yearly budget for French research undertaken in partnership with industry, are generally well involved in applied research (TRL 2). Very few of the Carnot Institutes could carry their research up to laboratory demonstration levels (TRL 3-4). Exceptionally and limited to particular programs, some of the Carnot Institutes could bring their technology to the operational levels (TRL 6-7).

Beside these figures, the SMEs are currently running their business at TRL 9 (these are selling products, services or components). Fewer than 10% of French SMEs have Development Offices able to integrate (or absorb) operational prototypes (TRL 6-7), in order to structure production chains and introduce new products to the market. And even fewer have R&D capacities able to understand technologies available at Lab Demonstration Levels (TRL 3-4). Thus, the Technological Asymmetry existing between public R&D labs and the SMEs becomes obvious.

[6] This figure was first presented and generally accepted at the 'Rendez Vous Carnot', Lyon, France, 2010 within the last Round Table dedicated to collaboration between Carnot Institutes and the SMEs.

In addition, is well known that between the same levels an equity gap is evident in some European countries, hence the European Investment Fund (EIF) and several publicly-owned banks (like CDC in France) have dedicated important financing programs to compensate for this Europe-specific 'amorcage' equity gap. This of itself will induce an important Risk Asymmetry between the public R&D and the SMEs.

These asymmetries must be reduced (for the informational asymmetries) or compensated for (technological capacities, financial and institutional risks) in order to support this new co-development relationship between the parties, as put forward in this analysis. The collaborative tools will thus be reduction and/or compensation mechanisms of the existing asymmetries between ONERA and its SME partners, with the aim of creating a "Trust environment" between the two agents.

Owing to their small size (INSEE, 2008) but also to the structural weaknesses of the innovation support system set up by SMEs and/or start-up partners in France **(**Serfati, 2008**;** Levy & Jouyet, 2007**),** French SMEs must have suitable support mechanisms (private or public) for the success of a possible common development program with ONERA, in order to absorb new technology and to make a success of their international commercial deployment.

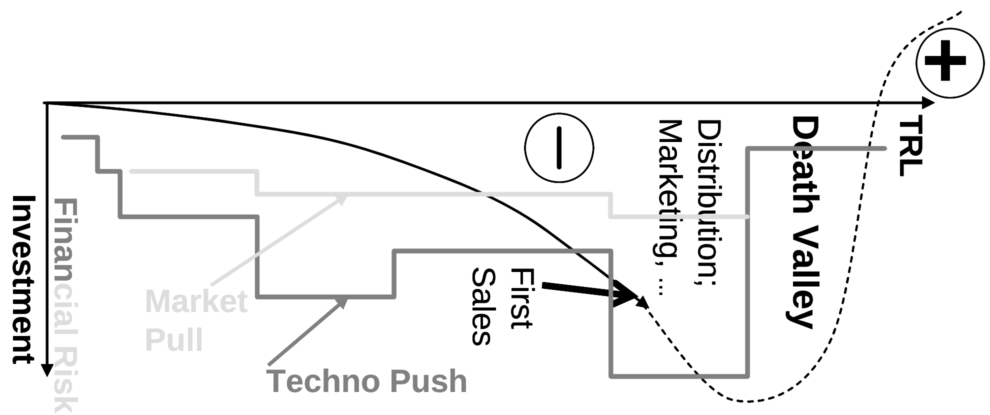

Figure 3: Risk curves related to the Technology Development Investment Curve

Two different approaches were targeted by ONERA's Technology Transfer Office (TTO). More than ¾ of the signed agreements were obtained through a Market-Pull approach and under ¼ were obtained from a Technology-Push approach. Figure 3 supports this part of our analysis.

Indeed, following an intensive advertising campaign based on slogans like: "Come to see us if you have a Technology issue! We are the MacGivers of the Science and you will never be alone", the majority of its SME partners did come to see ONERA addressing their technology issues. They had generally already identified a business-growing opportunity while calling on ONERA's TTO and they were looking for missing competencies in their company. We call this a Market-Pull approach. Technology-Push occurs when ONERA's TTO promotes a technology newly developed within ONERA and negotiates a license with an interested SME (or start-up).

Market-Pull projects have until now been successful to a higher degree. Accordingly, we propose our analysis of these results. In Figure 3, the risk curve for the technology-push approach is given by the blue line, while the red line shows the case of the market-pull approach. We can observe that both exhibit a high level of risk while investing in operational technology demonstrations and above all in launching New Products (goods and services) into the market. Nevertheless, we remain confident about our implicit assertion in Figure 3 that, throughout the cycle, the risk levels are lower in the Market-Pull approach than with Technology-Push.

This lower risk exposure is induced at each stage by the fact that the SME partner has already identified a market and already possesses a structured production chain (including a supply chain). These considerations act as drivers throughout the technology collaborative development process, raising the company's rating on the TRL scale, thus reducing its risks and costs. The Market-Pull approach also seems to accelerate the technology development process; thereby accentuating the dynamic capabilities that the firm is able to parade,.

We further adopted a hybrid strategy for ONERA while working with SMEs. Indeed even if the market-pull approach seems to be less risky and sooner beneficial, and even if it is producing incremental and often radical innovations by changing the domain for the adopted aerospace technology, we do believe that some technology-push activity will continue to be important for eventually nurturing disruptive innovations in ONERA's core business domain. Another important reason in continuing to promote technology-push activities through its TTO is the higher degree of motivation provided to its scientists while promoting their newly developed technologies.

This hybrid strategy places the agents of the innovation system in a cooperative network generating newly created value through a process of technology transfer.

II – <u>THE ONERA-SME PARTNERSHIP STRATEGY</u>

The ONERA-SME technology transfer process cannot be analyzed without taking account of the relationships of the two players with their own reference frames, in terms of evaluation and sectoral/territorial regulations, in the sense of Granovetter **(**1985**)**. These are mechanisms that are external to the simple ONERA-SME relationship which must intervene and accompany this dual relationship throughout the entire collaborative project, and some of the collaborative tools proposed take them into account.

Initially, an analysis of the role of each player during the innovation process is proposed and even, albeit in a more restrictive way, in the technology transfer phase.[7] As mentioned above, the activity of the public R&D laboratories in France involves, structurally, TRL levels lower than level 3-4, corresponding to the laboratory prototype stage. Only a few basic ideas conceived by the researchers attain this level of technological maturity and even fewer cross levels 3-4 to go on to levels 6-7, corresponding to the demonstrator in operational conditions or a product. This is because the development of technological demonstrators is no longer part of the mission given to public research in France, a situation that is actually even worse for products.

II.1 - Asymmetries in technology transfer relations and collaborative tools to reduce them

It can be seen that the research activities in TRL 1 and 2 are really mostly by the research laboratories because few SMEs are able to conduct their own research at these low TRL levels. Most innovating SMEs (apart from those that ate really small labs in their own right) invest more in R&D activities after demonstrating technological feasibility, because their ultimate mission is to sell

[7]We are being reductive here, and consider that ONERA will have little influence on the launching of the new product developed by the SME; in fact, this neglects the power of publicity represented by the 700 annual participations by ONERA scientists in International Conferences, as well as the capacity to bring into play synergies with large industrial companies and institutions.

products successfully, with an economic logic of seeking profits.

So, what can be done with a technology that reaches a research laboratory at level TRL 2? At this stage, a laboratory prototype can be shown to be feasible by simulation and/or the existence of certain elementary components with strong chances of success. Who must now invest in the development of this prototype and on which criteria should the decision be based?

It seems obvious that at this stage the laboratory should consult the possible bearing vectors in the market: large groups and SMEs. If the technology developed corresponds to a strategic axis of development in a large group, quite naturally the latter will be interested in the appropriation of this technology or, at least, in a competitiveness comparison with other solutions. The partnership process that would take place between the laboratory and this large group is not the subject of this analysis.

The case that interests us is that in which an existing SME is interested in this technology, whatever its branch of industry. When no SME or large group expresses interest in the use of the new technology then there only remains the option of launching a start-up partner, in the case of a ‘disruptive’ technology with high development risks and market potential, to be confirmed by market research; otherwise the development has to be abandoned.

II.1.1 - *Technological asymmetry and Risk asymmetry*

On the two assumptions, both for a SME and for a start-up partner, the problem of maturing technology up to the TRL 3-4 level is still the same. It will be very difficult to get the SME or the start-up partner to finance this maturation. All this is related to the structural problem of financing developments in France but also to the lack of leading-edge scientific skills within the SME, allowing dialog with researchers and the appropriation of technology under the TRL 3-4. An asymmetry of technological capacity is revealed here and an asymmetry of the risk (financial) between the two participants: the public research laboratory and the small company.

Indeed, 95% of French SMEs are small companies with less than 50 employees **(**INSEE, 2008). The development and demonstration of a new technology based on emerging technology from aerospace costs at least around one million euros (according to our own experience in the relationships with our SME partners), without counting the launching and development costs of the product line. However, most of the innovation assistance available in France is limited to 50% of the global amount (see Oseo, 2008, on refundable advance). This means that an SME that undertakes the development of a new product for a breakthrough innovation must assume half of the costs itself. For an SME with twenty people, €500K may well represent 25% of its annual wage bill.

Here, a significant risk asymmetry is to be noted between the SME and ONERA because possible failure could mean a cessation of activities for the former. The same amount represents the cost of four ONERA researchers. Moreover, the financial risk exists and is not negligible, especially in the EPIC culture, where we will see later that the scientists involved in the technology transfer relationship are very little aware of the risk for ONERA compared to the degree of the risk assumed by the SME. Other authors **(e.g.** Serfati, 2008) have also stressed the importance of social relationships (including cultural relationships) in the innovation process. This difference in mentality was identified without any ambiguity in the collaborations undertaken by ONERA with various SMEs.

II.1.2 - *The shared risk development contract*

A mechanism to try to solve this technological maturation and asymmetry problem has been developed at ONERA: the *shared risk development contract*. This type of contract was developed and signed, for the first time in France, between an EPIC and a business firm.

For this phase of technology maturation ranging between TRL 2 and TRLs 3-4**,** the risk is still too great to be borne entirely by an SME as long as the technological proof, at least in the laboratory, as well as a complete comprehension of the technology, have not been achieved. It seemed right to us that ONERA, as a creator of technology, should be able to join future industrial and commercial owners in order to reduce the risks, and share the possible future benefits. The partnership is based on a technical and economic analysis of various phases of the development and on a *Business Plan* detailing the market prospects and investment returns on the new product. Based on this, ONERA can decide to assume part or all of the costs, within the framework of the co-development, the refunding of which, with profit-sharing based on business success, will take place or not, depending on the prospects for the use of the product.

The negotiation of the percentage allocated to sales, so as to cover ONERA's costs and its exposure to risk, is conducted according to criteria allowing the development of the company but also bearing in mind the fact that ONERA must make a positive return on all the operations of this kind. Thus, this contract is not a sort of license, nor a subsidy. The principles on which this contract is based are those of a service provided by ONERA on the basis of a determinable (though undetermined) price with payments deferred in time, negotiated between the parties on the basis of later sales and for a length of time agreed upon as part of the same negotiation.

This type of contract proves to be a very good tool, both financially but also technically, for collaboration with co-design in mind, for the development of a new product, a logic equivalent to that described by Cowan **(**2003**)**. This tool means two parties can together cross, within the meaning of Aoki's theory **(**Aoki, 2000**),** based on a Nash equilibrium (Nash, 1950), a possible financial and technological comprehension barrier that may otherwise induce blocking.

In addition to compensating for risk and technological asymmetries between the two parties, this contract has also subsequently proved to be a good tool for reducing transactional information asymmetries **(**Akerlof, 1970; Stiglitz & Weiss, 1992**)** between the start-up partner and its investors. Indeed, at the time of the phase of 'due diligence' between the creators of the start-up partners and the Business Angels, the *shared risk development contract*, signed with ONERA, yields paramount information on both the product and the target market, and on the technological developments and their costs.

This last years, at ONERA, several contracts of this type were signed with various commercial companies. Four of these companies have succeeded in raising significant funds from investors.

II.1.3 - *Institutional asymmetry (mentality and behavior)*

The *shared risk development contract* is a collaborative tool that compensates for technological and risk asymmetries. Such a tool also compensates indirectly for a very important asymmetry in the relation between the transmitter and the receiver in the process of technology transfer, institutional asymmetry, a term introduced here analogously with the terminology of institutional economy, within the meaning of "thought and action practices" by Veblen (1899) of "shared mental models" and "belief structures that intervene as formal and abstract constraints to structure human interactions" by North (1994).

This asymmetry has been thoroughly analyzed because it can sometimes induce a more significant form of blocking in a dual relationship: cultural blocking. The institutional word must be understood as a sum of the rules, but also in its abstract aspect, as a sum of beliefs, prejudices, instincts and behaviors: "Institutions are dominant thought and action practices" (Veblen, 1899). All these elements are generated historically, according to the way in which the actions are carried out and are assessed, but more especially through received education.

Historically, applied research in France is really quite concentrated in national research centers specialized in a particular field (IFP, CEA, ONERA, Inrets, Inra, Inria, etc.). The universities have generally not been perceived as possible players in applied R&D. The proof is that before the Allegre Law in 1999, very few universities in France had a research result utilization service, and even these, before the Pecresse Law in 2007, did not have a complete autonomy which would allow them, among other things, to have a close relationship with the economic world.

The *Summary report of assessment of the universities of the wave* B (AERES) made an observation which alludes to this: "... Socio-economic milieus.... their influence on the policies and strategies of the establishments are generally weak, because of their lower level of involvement in the councils of the establishments".

The utilization activity developed since the Allegre law seems itself to be directed toward research contractualization and expertise-based services, but hardly at all in the field of technology transfer. The following can be read in the same report: "Utilization - this is a declared objective in all establishment strategies. Management structures (service, SAIC[8], subsidiary companies, direction, etc.) exist in the majority of these, for industrial contracts and service performance. On the other hand, the management of patents and licenses and, generally, of intellectual property, financially costly and requiring specialized skills, is accessible to these establishments with great difficulty. A really effective utilization policy would require the creation of consortia within a regional or even national framework to reach the critical size necessary for effectiveness."

Leaving, in passing, to the reader the appreciation of the desirable ways of improvement, as they are recommended in this quotation, we should mention that, nowhere in this report is a mechanism suggested for listening to the needs for development being expressed by the markets.

In the *Guide of the expert - Wave C* of May 2008 of the same Agency (AERES) we can find positive developments going in the direction, in terms of the evaluation criteria, of taking into account activities around the utilization of research within the organizations being assessed.

It is explicitly requested that the number of patents, the number of declarations of inventions, the cost of the patents, as well as the revenue generated by these all be taken into account but, above all, the number of licenses. However, other fundamental indicators are lacking for a complete measurement of utilization activity, such as the revenue from possible capital shares held in the companies profiting from technology transfer, the evolution of the value of these companies, or the number of jobs created on the basis of these technologies.

This, coupled with consideration of a criterion on the patentable technology detection activity within the establishment, but not of one on the capacity of listening to the market needs, or the capacity to carry out market research, will generate a culture of *technology push* instead of a *market driven* culture, generally recognized as a better generator of innovation.

Thus, the economic culture of the researchers is built throughout their career by indicators on the basis of which they are assessed, the most important indicator being recognition by peers, gained mainly through publications by the researcher according to panel reviews. However, while publication circulates research results efficiently, without an adequate preliminary control it is contrary to the utilization mission of national industry and likely to reveal unprotected know-how.

In this same guide, the number of A and A+ type publishers is an important criterion in

[8] Industrial and Commercial Business Services

assessing establishments. The identification criteria of these authors include international patent deposits but do not stress those that were granted a license. Also, protection of the results is confused with their utilization and as a result it is likely that a great number of patents of no importance may be obtained because they do not contain any criterion bearing on their economic impact. It would undoubtedly be necessary to optimize the respective weights of a license, the incomes obtained with the latter, the patent and the publication.

There is a legitimate question to be asked here: when does a license generating significant income have the same weight (or even a greater weight) than an article published in *Nature*? There is indeed no antagonism between a patent and the publication of results from their source, only a priority on the submitting of the patent is to be respected. Our colleagues in the Anglo-Saxon world have shown that publications in *Nature* are not in contradiction with very profitable licenses. If a license counted for three traditional patents or nine publications … could this induce a change of mentality within the public research community?

Moreover, this mentality is the subject of an unambiguous analysis in this same report concerning the governorship of research establishments: “in multiple-field establishments, faculty-centered organization remains very vigorous. In certain recent universities, it is an acknowledged will. The evolution of mentalities and practices is thus very slow…”.

The recent “Carnot Label” awarded to research establishments with partner research activities with industry (Carnot Law), has made it possible to evaluate the co-operation between industry and public research in France. Thus, the 33 Carnot Institutes, accounting for only 12% of the French public R&D manpower, generate nearly 50% of the research contracts with industry, for a total budget of €450 M, representing merely 1/3 of their annual consolidated budget. The share of this budget with the SME is however insignificant.

So how could a researcher be convinced that the utilization of research results is a noble aspect of his or her activity? This mentality, based rather on the “craftsman instinct” within the meaning of Veblen (1914), induces a strong asymmetry in the relationship between a researcher and an SME director, who will rather act according to a “predator instinct” from the “cultural” point of view, during their interaction for a technology transfer. This asymmetry may be strong at the beginning of the relationship, and can be compensated for gradually if a favorable environment is created to help the relationship to evolve from a transactional framework towards that of co-operation.

Now that this institutional asymmetry concept has been introduced, we can see that the technological capacity asymmetry triggers collaboration between both participants and that the compensation of information and institutional asymmetries is the facilitator because, at the beginning of their relationship, both parties face problems arising at the same time from the lack of technical information but also from the capacity to implement these once they are available (for example, it is not enough to read a patent to be able to manufacture a new product).

II.1.4 - *Spin-off Charters*

The *shared risk development contract* is one of the mechanisms allowing the compensation of institutional, technological and financial risk asymmetries, during the first phases of technology transfer. To allow later developments, up to the marketing of products, ONERA has adapted its *Spin-off Charter*, as another collaboration tool, in order to support the integration of researchers into the SME, when a technology transfer towards the SME takes place.

This evolution results from acknowledging the failure of the existing spin-off policies of the public research establishments, whether in France or elsewhere in Europe. The great scarcity of researcher spin-offs is a logical consequence of the natural differences in skills necessary as between the enterprise world and that of research. Success in the creation of a company depends not only on the quality of technology, but particularly on that of the management team, and on financial and operational resources, in order to control marketing, commercial, financial, industrial and productive components, making it possible to move, in a limited period of time, from a good technology to a business success. The goal of the *Charter* revision, toward integration of the researcher wishing to "spin-off" into an existing structure, is thus to support the meeting, within a pre-existent framework, that of the SMEs, of these components of success so as to reduce the risks, both for the researcher, and the SME, and ONERA as well.

The departure of the researcher to the SME wishing to accommodate him or her, with the transfer of a technology in which he or she is an expert, takes place under conditions that are at the same time safe and incentivating; in particular, the traditional conditions: the possibility of returning to ONERA during the first three years, financial aid, and the financing of training to reinforce the necessary skills for his or her new mission.

The main point is however the condition of opening the SME capital to the researcher in order to position him or her as an "entrepreneur" on the same level as his or her new partners (at least 5% for a small company; flexible for an average-sized company). This makes development of "cultural" positioning possible for the spin-off researcher, and a clear confirmation of the interest of the receiving SME for the new business that the researcher will contribute to develop and manage within it.

II.1.5 - *ONERA-SME Technology Charter*

In order to give a more general framework to these relations, to gather the collaborative tools, to define the principles of the expected collaboration with the SME, and to ensure this collaboration policy can be maintained for the foreseeable future, ONERA made the strategic choice of setting up an *ONERA-SME partner technology Charter*.

This Charter itself had to go beyond the simple problems of technology transfer and explore all the collaboration possibilities between ONERA and the small business world. It represents a moral engagement of the two parties, based on the principles and methods of collaboration and the values governing them. It also means the two parties wishing to collaborate can be on active watch, reciprocally validating their collaboration potential, and be able to start a collaborative project at the earliest opportunity.

This Charter is fully positioned as an institutional collaborative tool, within the meaning of Aoki's theory (Aoki, 2000**)**. The two participants do more than give themselves the means by which to develop together because they are both on active technological watch in their respective markets, identifying opportunities for joint projects.

It relies on simple and tested principles of « win - win » and « give - give », providing benefits for each participant, as summarized below:

i) Mutual benefits

a) Technological [9] *benefits and opportunities for an SME*

This partnership makes it possible for the SME to have access to R&D contracts in partnership with ONERA, to scientific expertise in the entire civil and defense aerospace field and to technology by means of licenses, simulations, calculations, testing tools, simulation tools or software runs[10] and technological watches.

This can reinforce its competitive advantages within the framework of R&D contracts by

[9] for SMEs involving themselves also in the development of technologies in addition to their use

[10] launching of the computations on the ONERA super-computers

proposing solutions comprising a stronger scientific added value thanks to the contribution of ONERA, both by becoming integrated into experimental projects and technological demonstrations, and by allowing more competitive services with a better adjusted division of the types of services provided by ONERA and the SME.

It gives access to markets and customers that would be difficult for an SME to reach alone, since the latter will now have the benefit of the "ONERA Partner" label to present to large institutional and industrial accounts.

The SME can also profit from the outcome of developments in contracts with ONERA for progressing towards commercial use of new products in its markets.

b) Benefits and opportunities for ONERA

This partnership reinforces the competitive advantages of ONERA within the framework of R&D contracts, achieving this in various ways:

- by offering more cost-competitive services with a superior division of the types of service provided by ONERA and the SME;
- by proposing more flexible and more directly operational solutions;
- by allowing greater reactivity, in particular in "original" and "changing" requests, within the framework of prototypes and experimental projects;
- by better controlling the costs and times of the production tasks necessary for the projects.

The partnership offers access to customers/end-users not directly accessible by ONERA, supports mutual enrichment and emulation between the teams of ONERA and the SME, allows ONERA to be proactive and play a driving role in the industrial world and offers more dynamic potential outlets for utilizing the research results and, in particular, ONERA's technology transfers.

ii) Types of partnership

Several partnership modes can be implemented to carry out this project, such as partnerships in R&D contracts, the expertise and use of ONERA means, shared risk development contracts, technology transfer/utilization of ONERA know-how, this going as far as the detachment of researchers and/or their spin-off to the SME.

ii() Profile of targeted SMEs

The desirable profile for **targeted SMEs** must allow a fast self-identification by the SME of its own capacity to enter into a partnership framework with ONERA by:

- having a production activity or technology service;
- working in a field that can benefit from the outcome of ONERA's research;
- devoting - or having an objective to devote – at least 8% of its AC to R&D (this minimum can be modulated according to the size of the company)
- having a financial viability;
- satisfying the SME criteria of the European Union;
- adhering to the values of the *ONERA-SME Charter*.

iv) The "values"

This *Charter* is primarily a moral engagement between the parties, resting in particular on a common vision of the business rules of the partnership like, innovation based on scientific and technical excellence, a quest for performance, constructive competition and fair-play, independence and commercial ethics.

II.1.6 - *Results*

To date, 87 SME have signed the *ONERA-SME Charter* and more than 40 licensing agreements, know-how communication agreements or shared risk development contracts are currently running, with various industrial partners in a variety of fields. Of these, 28 were signed over the past four years, corresponding to the new development policy, while the remainder (12) represent the historical “heritage” of the old ONERA development policy.

Following the successful implementation of the new collaborative tools during this period, the number of collaboration agreements signed went from one to more than ten agreements per year. The number of spin-offs went from one spin-off every five years to one spin-off on average per year. Fifteen new proposals for common R&D contracts also came to light during this last period.

Table 1 provides a selection of the partnerships with SMEs, this selection having been made on the basis of their diversity.

Table 1: ONERA–linked SME partners (selection only)

Partner	**Application**	**Type of collaboration**
Leosphere	Wind lidar	License, common R&D and spin-off contract
Oktal-SE	Electromagnetic environment simulation	Software licenses and common R&D contracts.
Phasics	Laser interferometer	License and ONERA post-graduate student recruiting
Protip	Biomedical prosthesis containing porous Titanium	License and shared risk developmen t contract
Ixsea	Inertial navigation	License
Sirehna	UAV	Common R&D contract and software license in fluids
Satimo	Medical imagery	Common developmen t contract and license
Isitek	Medical supervision in residence	License on sensors
Microcertec	US machining of ceramics	License
Fogale-nanotech	Capacitive sensors	License
Andheo	Fluid mechanics and energetic	Software license and common R&D contracts
Sofratest	Flow measuring	License
C3EM	Fissure monitor and experimental data acquisition station in wind tunnels	License, common R&D contracts
Secapem	Real-time shot acquisition and validation system	R & D contract and software license considered
Mapaero	Pressure-sensitive paint	Know-how communicat ion agreement
Michalex	Micro-indentation at very high temperatures	License and shared risk developmen t contract
ACV Aeroservice	Quiet green aircraft	R & D contract and shared risk developmen t contract envisaged

Nheolis	New type of wind power station	Shared risk development contract
Keopsys	Laser	License

II.2 - The point of view of the SME – changes and perspectives

A first experience feedback is now available with the results of an investigation conducted with the SME partners. A questionnaire concerning the ONERA-SME collaboration was addressed to them, and 42 of the 68 SME partners, at that time, answered it. Of these 42 SMEs, more than 80% have become partners of ONERA over the last four years.

This questionnaire thus made it possible to confirm the first concrete results, in particular the creation of 170 jobs, at these 42 SMEs that answered the questionnaire, since the beginning of their relationship with ONERA. Among these, 104 jobs can be ascribed directly to the new activities developed by SMEs based on ONERA technology. The amount of funds raised by the partner SMEs amounts, to date, to more than €20 million.

One of the particularly important questions with regard to the confirmation of the role of collaborative tools in the reduction of information asymmetry between the SME and other economic participants was: “To what extent has your relationship with ONERA influenced your development?” It revealed that half of those who answered confirmed having an image or credibility benefit thanks to the partnership.

With regard to the development of the relationship with ONERA, half of those who answered would like to reinforce their direct relationship with ONERA researchers (either in the form of direct expertise, or within the framework of a spin-off of the researcher into their team). Half of those who answered also wish to be better informed about developments in hand and the strategy of ONERA. The two indicators show a will and need for compensation of the technological asymmetries and reduction of the information asymmetries that still exist between the SMEs and ONERA.

The answers to this questionnaire and the knowledge of the operating rules of ONERA have led to proposals for new mechanisms, mostly within ONERA, which could compensate for a number of the asymmetries between the SMEs and the Office even more. Thus, a need for the following aspects was identified:

- development of a specific strategy whereby several SME partners develop together, with ONERA, technological demonstrators of the ‘systemic’ type; the consortium thus constituted no longer adopting a management characteristic of a sequential innovation process but horizontal management (Rothwell, 1992) more suited to multiple-field and multifunctional teams;
- the development of an *SME partner skill catalogue*, to be distributed within ONERA to the research teams;
- the periodic organization of a joint event between ONERA and the SME, to which other participants such as customers will be invited, and the various innovation assistance structures;
- the creation of a network of experts, with adequate training, to provide a single interface with the SME;
- the possibility of conducting market research;
- the development of joint ONERA-SME laboratories for maturing technologies.

II.2.1 - The common technological maturing laboratory as a collaboration tool

In addition to other collaborative tools, it seems appropriate, in the case of complex projects requiring a technological maturation between TRL 2 and TRLs 3-4, for it to be possible for this to take place in the public laboratory’s own maturation lab, a joint arrangement for which future technological developments are managed cooperatively with the SME partners. This laboratory would accommodate mixed teams composed of SME (or start-up) employees and researchers. The personnel costs would have to be borne by each party for its own staff. Mechanisms external to the SME-ONERA relationship, making it possible to ensure up to 80% of the wages of a professor (or researcher) recruited by an SME, have been put in place recently at Oséo.

The question of the financing of this Common Technological Maturation laboratory could also be resolved by making use of the additional Carnot contributions (under the Carnot Law) that the Institutes that are members of the Carnot Institute Association receive to boost their scientific and technological resources within the framework of their partnership policy. This is because one of the goals of the Carnot label, amongst others, is to support technology transfers. It remains a fact that no technological maturation should be done without preliminary market research, with product/market cross-referencing as obligatory methodology.

The Common Technological Maturation laboratory will also function as a new collaborative tool facilitating the compensation and reduction of technological asymmetries (in its institutional aspect and in terms of its lack of information) between the two participants in the technology transfer but also compensation for the risk asymmetry.

II.2.2- DRL, new concept for understanding and measuring the Market Pull approach

We observed that the innovation process was subordinated to the reference adopted system. Indeed, all the actors involved in Technology Transfer process have their attention “glued” to the TRL scale. In practice, even speaking about the Customer Voice we still ask (or are asked) about “what is the TRL level” for the appropriate technology sensed to tackle the Expressed Need by an industrial who’s addressing our R&D Commercialization Office.

Why continuing to refuse the evidence? : Even the Customer Voice is sunk inside the TRL scale and our minds are thus Technology Push driven. Why not referring from now on, when facing an industrial expressing to the R&D Commercialization Office to a new scale related this time to what we call the **Demand Readiness Level (DLR)** (Paun, F., under press for the Innovation Encyclopedia by Springer) identified by a customer on a given market?

It actually means that it is the right timing to define an additional scale and plot it in a reverse manner related to the classic TRL scale in order to have the appropriate comprehension of the Market pull process. The author is proposing this schematic further for a better comprehension.

DRL Level	**Demand Readiness Level**		
1	Occurrence of a Feeling "something is missing"		
2	Identification of a specific need	Market certification and sales authorisation	9
3	Identification of the expected functionalities for the new Product/Service	Product Industrialisation	8
4	Quantification of the expected functionalities	Industrial Prototype	7
5	Identification of the systemic capabilities (including the project leadership)	Field demonstration for the whole system	6
6	Translation of the expected functionalities into needed capabilities to build the response	Technology development	5
7	Definition of the necessary and sufficient competencies and resources	Laboratory demonstration	4
8	Identification of the Experts possessing the competencies	Research to prove feasibility	3
9	Building the adapted answer to the expressed need on the market	Applied research	2
		Fundamental research	1
		Description Technology Readiness Level	**TRL Level**

Paun. F., 2010 : Demand Readiness Level as equilibrium tool for the hybridisation between Technology Push et Market Pull approaches

For example, if an industrial partner have a DRL on 8, he will be able to identify and speak with the appropriate scientist to launch a collaborative R&D program for developing a new product or service. Same type of matching between different levels could be observed at each level of the previous table.

This is now better understood why “each case is a specific one”. Looking in two references systems, one for the Technology Push approach and the other one for the Market Pull approach, we could predict the given particularly timing when an technology transfer agreement is ready for signature. Further research are on the process to Postulate that the Technology Transfer Agreements between R&D laboratories and Industrials are only possible if the sum DLR+TRL is at least equal to 10.

Since many years the TRL scale allowed various analysis of the technology transfer and technological innovation processes by positioning the various stakeholders along this scale. TRL scale allowed the identification of various asymmetries between the actors and thus suggested the introduction of various reduction or compensation tools at Onera (and not only). Trough this contribution, we proposed a new reference system for better addressing the Market Pull approach while doing technology transfer and technological innovation. The DLR scale could also be the object of the same dynamic exchanges and analysis that the TRL scale induced among the academics or practitioners communities. The aim is that this new tools for a hybridized approach will significantly improve the innovation and TT practices trough a better understanding of the different factors and staging allowing the agreements signatures to creating value. For a TT Officer or a Strategy Industrial Director will be important to survey the matching of the levels on the 2 scales while placing the participating actors, identifying the existing asymmetries between them and activate compensation or reduction tools for dealing with these asymmetries. When the sum of the 2 indicators will equalize 10 the deal between the Industrial and the R&D laboratory becomes feasible and will interest all the stakeholders of the innovation project, including the investors (private or public).With a better understanding and control of the hybridization strategy between Technology Push and Market Pull approaches the innovation system tends to evolve towards a better compatibility with the social and environmental requirements inevitably market pull driven as in the case of eco-innovation.

III – CONCLUSIONS

The first results show a series of development successes for innovative products/services based on technologies created by ONERA, and this in very varied sectors, going from biomedical prostheses to the wind power market.

As for any form of transaction, in a technology transfer process, the parties involved are informationally asymmetric. The new SME policy at ONERA has highlighted other forms of asymmetries characterizing the technology transfer and partnership research between a public research organization and an SME in France: technological capacity asymmetries, institutional 1 time scaling asymmetries and those related to the financial risk.

The collaborative tools deployed at ONERA within the framework of its new development policy, the *shared risk development contract*, the *ONERA-SME Charter* and the *Spin-off Charter* are mechanisms designed and implemented to ensure the reduction of the information asymmetries and compensation for other asymmetries between ONERA and its partners. The Common Technological Maturation Laboratory and the use of the

DRL are another proposals for collaborative tools similar to those already in place.

The relationship established between ONERA and an SME is perceived more as a cooperative relationship for a co-development rather than as a simple study service (i.e. transactional). This relationship imposes compensation for financial risk and technological capacity asymmetries in addition to institutional (mentality) asymmetries and the reduction of information asymmetries between the two parties. Attention is thus drawn to the importance of the "issues of confidence and interest" (Cowan et al, 2003) in a technology transfer relationship with regard to the questions of opportunity and uncertainties in a product/service sales relationship.

Moreover, the *ONERA-SME Charter* and the *shared risk development contracts*[11] have also proven to be very effective tools in the reduction of information asymmetries between the SME (or the start-up partners) and other socio-economic players (investors, competitiveness centers).

This research work contributes to Stiglitz's "information asymmetry theory" by acknowledging the need to reduce and/or compensate for different asymmetries while carrying on a cooperative process like technology transfer which has impacts on all levels: direct impact on the agents (micro), on the regulators (regions and sectors – meso), and on economic growth (macro).

III.1 - Impacts at the micro-economic level

At ONERA, the cultural change taking place amongst the researchers involved in a relationship with an SME can be noted. Their contractual liability is reinforced by a better awareness of what is at stake that the successful transfer of their know-how to the SME represents. They adopt the "predatory instinct" (Veblen, 1914) of an entrepreneur, interested in transfer opportunities for their technology outside the aerospace field. The implemented tools operate as relational facilitators in the relationship between ONERA and the SME but also in the internal relationship with ONERA between the scientists and the support structures for utilization.

The success of the operation of collaborative tools changes the internal operation rules specific to ONERA and allows proposing new internal mechanisms, such as the creation of a network of experts as a single ONERA interface with the SMEs, and the future possibility of carrying out Market Research. The purpose of these mechanisms will be to increase still further the effectiveness of the partner relationship with the SME.

III.2 - Impacts at the meso-economic level

The first successes with the signing of the *ONERA-SME Charter* by more than 80 SMEs recognize and prove the significant role that ONERA can play as a source of innovations and also as a catalyst for a cluster of skills and multi-sector innovations. This is valid for all the regions where ONERA is represented, thus confirming the views of other authors (Etzkowitz, 1999; Florida & Cohen, 1999).

ONERA's change of strategy in the choice of its customers, because of its opening to the world of the SME, has had an effect on the diffusion of its technologies beyond the aerospace field and especially on its

[11] The shared risk development contract has been developed by ONERA DCV team during the last 5 year. The authors of this article who took part in developing of this tool, wish especially to thank Corinne Le Hong for her contribution in updating the Risk Sharing co-Development contract and to Frédéric Lamy for his contribution in updating the same contract but also to the entire team who is now continuing capitalizing and developing the concept with SME partners.

positioning in other market sectors as well as in its relationship with its customesr. Having a study service relationship with a large industrial group, ONERA has now also given itself the opportunity of having a co-development relationship with the SME partners.

The intervention of ONERA in multi-sector innovations, on the basis of its research results in the aerospace field, puts the Office in competition with other traditional suppliers of research, in each of their specific fields. This has an impact on the "forms of competition" (costs, quality, speed of development) and ONERA could thus find itself in an advantageous position due to its multidisciplinary skills.

The new form of "multi-sector innovation" competition, induced by the new ONERA-SME policy, could prove to be important from the point of view of access to public funds. Thus ONERA, in partnership with a suitable cluster of SME partners, is able to bid for public programs to build technological demonstrators. In some of these programs, this could generate fair-play competition with its own strategic partners among the large aerospace industry groups.

ONERA's new policy of development with SMEs offers a solution to the problem encountered in a general way by clusters of companies, of the competitiveness center type, that are based on the effects of agglomeration and of specialization (Weber, 1909/1929). This cluster model has proved risky for long-term development due to exaggerated territorial specialization and the lack of job diversification, skills and sectors in the region, which could thus become a "small world" (Watts & Strogarz, 1998).

The positive effects of this new policy at the territorial level have been confirmed for the effects of complementarity and the interactions thus generated between various SMEs (Zimmermann, 2002), encouraging them to work in complementary sectors, not necessarily belonging to the region competitiveness centers.

One of the results of the practical application of the new ONERA-SME policy is that ONERA became a "distant source" (Maskell et al., 2005) of new ideas and expertise for other competitiveness centers outside the aerospace field. Thus, ONERA's SME partners and members of these so-called competitiveness centers no longer depend only on internal interactions specific to the center that they are members of in order to have access to R&D resources, but also benefit in their innovation work from skills that are external, in the geographical and sector sense. This reasoning has proved to be valid also for the case of geographically isolated SMEs that encounter difficulties in becoming members of the centers of another area, the partnership with ONERA allowing them an important access to R&D skills.

As a transition to the macro economic level, an important perspective could directly impact the development policies of regionally specialized clusters, as with the national strategies for innovation. The R&D laboratories will adapt their behavior by intensively using asymmetries compensation/reduction mechanisms in their relationship with the regionally specialized SMEs but also with other SMEs, not regional or acting in other domains. Thus, the regionally specialized clusters (supposing there is more than one present in the same region) will be interconnected through direct collaborations occurring between some of their "provider (R&D labs)" and technology "consumer (technology adopter SMEs)" members. They will also be interconnected with other non-regional clusters. These types of interactions, driven through either Market-Pull, Technology-Push or Hybrid approaches, will exchange technology inside and outside their related clusters, with no more monitoring by Clusters Authorities. To upgrade this type of possible multiple embedded innovative system, mainly based on technology transfer between providers and consumers of technology, we consider that smart grids models could be an appropriate approach (Paun, 2010).

III.3 - Impact at the macro-economic level

The relationships that the SME partners have developed with ONERA allow changes towards sector-based operating rules specific to the innovation assistance structures or to regional development, in relation to professional networks, in the sense of "cumulative causality" (Veblen, 1914) or of "recursive causality" (Morin, 1990). Thus, it has been observed that some of ONERA's SME partners, especially the decisional committees of this type of structure (competitiveness centers, trade associations), proselytize for this new type of tool for collaboration with public research with other members of the said committees.

Other national structures grouping various innovation players actively examine some of the collaborative tools developed within the framework of the new SME policy of ONERA. These tools are often the subject of analyses by think tanks made up of these national structures, in order to exchange ideas regarding good practices between their respective members.

The adoption and/or generalization, after the inherent adaptations due to the sector-based specificities of the various parts, of these collaborative tools by these other structures or networks could induce the same positive results as those obtained by ONERA and its SME partners, on innovation at a national scale.

Many authors have identified, in the various studies of the conditions and mechanisms of financial support for innovation and their impact on economic growth, that information asymmetry (Akerlof, 1970; Stiglitz & Weiss, 1992) is one of the major factors influencing the financial risk taken to generate innovations.

The ONERA-SME collaborative tools have shown what their role can lie in the reduction of this asymmetry between these SME (and start-up) partners and their respective investors. Indeed, the fund-raising required for the development of projects by the SMEs became much easier. The generalization of this type of tool will no doubt mean the constitution of a better *Business Angels* culture and *Venture Capital* in France and, especially, the appearance of new investors due to the reduction in financial risk as a result of the reduction of information asymmetry between the SMEs (or start-up partners) and investors. As an example, the *shared risk development contract*, signed by start-up partners with ONERA, proved thereafter to be a facilitator document in the phase of *due diligence* between the start-up partner and its *Business Angels*.

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