RESEARCH CONSORTIUM AS COLLECTIVE STRATEGY

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Abstract

Recent management literature on R&D partnerships focuses on relationships between industrial firms or private and public research organizations. This is of particular importance in the context of public policy incentives and socio-economic considerations of innovation. The main research objects are technological partnerships, cooperative strategies, joint-ventures or strategic alliances. These studies leave unanswered the case of public scientific collaborations, hardly comparable to industrial R&D consortia tackled in abundant specific literature. To better understand this new research object, we consider it as an agglomerate collective strategy through a study case of the ATLAS collaboration, a particle physics experiment at CERN in Geneva, Switzerland. First, we will show that the high stakes of a unique particle physics experiment, well beyond current scientific limits, leads actors to collaborate together and share resources. Secondly, we will show that a loosely coupled institutional framework constitutes the corner stone for the effective functioning of agglomerate collective strategy.

Key words
Agglomerate collective strategy – Public research – R&D Collaboration

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INTRODUCTION

Management research on Research and Development (R&D) partnerships is abundant in the field of industrial and private organizations. It focuses on government incentive policies on innovation (Dodgson & Bessant, 1996) and on socio-economic considerations of innovation (cf. for example Sakakibara, 1997 concerning Japan ; Dodgson, 2000 in Asian emergent countries). The primary objects of analysis are technological partnerships (Doz, 1987 ; Hagedoorn, 1993), cooperative strategies (*Strategic Research Partnerships* [SRP] : Sakakibara, 1997, 2001 ; Sakakibara et Dodgson, 2003), joint-ventures (Killing, 1983 ; Harrigan, 1985, 1986) and strategic alliances (see for example Olleros & MacDonald, 1988 ; Borys & Jemison, 1989).

However, this large body of research literature leaves unanswered the particular case of public or semi-public scientific collaborations. Such collaborations have certainly industrial benefits or fall-out, but these collaborations are hardly comparable to R&D consortia generally tackled in the literature. To better understand this new object of analysis, we propose here to treat it as an agglomerate collective strategy (in the sense of Astley & Fombrun, 1983) through a study case of the ATLAS collaboration, a particle physics experiment currently (2005) being installed at CERN, Geneva, Switzerland.

The present paper has two key objectives. First, we wish to show that the high stakes associated with a unique, next-generation particle physics experiment well beyond current scientific limits leads actors to collaborate together and share resources. Secondly, we wish to show that a loosely coupled institutional framework constitutes the corner stone for the effective functioning of agglomerate collective strategy.

1. The conceptual framework: "agglomerate" collective strategy in the research sector

As a particular form of inter-organizational partnership, a R&D consortium is defined as a specific organizational form based on a contract between private firms, laboratories and/or public universities, oriented toward a common interest (see e.g. Mothe & Quelin, 1999). In the heart of this generally agreed definition lies the idea of cooperative behavior between organizations, creating mutual dependence links, "pre-competitive" knowledge and non marketable processes (Mothe & Quelin, 2001). Recent and abundant literature in management and organization sciences dedicated to technology innovation illustrates the interest to understand this mode of structuring at an inter-organizational level (see for example : Aldrich &t Sasaki, 1995 ; Doz & al., 2000 ; Evan & Olk, 1990 ; Mothe & Quelin, 1998, 1999 ; Olk, 1998 ; Olk & Young, 1997 ; Sakakibara, 1997, 2002).

However, this research is focused on industrial and market aspects – particularly the "Development" part of R&D – and doesn't tackle partnerships in the public or semi-public sector – the dominantly "Research" part of R&D. Indeed, we note that the cooperative logic is strongly present in the latter form, as well. Such cooperative behavior is also strongly encouraged since many years at the European and international level[1] (see e.g. Autio et al. 1996), the goals not only being in the market field rather oriented towards exclusively scientific purposes. Except for the "research consortium" form, these scientific research

[1]See the European Frameworks for Technological Research and Development

partnerships can be formalized or institutionalized to a varying degree, with different names corresponding to their specific nature[2].

These partnership forms appear to favor exclusively cooperative relations, but seem to ignore the competitive dimension between the interacting organizational actors. The latter is nevertheless certainly present in the field of scientific research, as much in terms of resources to look for or to acquire (*inputs*) as results to produce and to improve in a logic of visibility (*outputs*). The presence of these inseparable elements of inter-organizational dynamics leads us to propose a strategic perspective integrating simultaneously both relations.

Thus, scientific research partnerships need to be viewed as objects of "coopetition" (Brandenburger & Nalebuff, 1995; Nalebuff & Brandenburger, 1997) in which participating research laboratories across related fields interact not only between themselves, but also with various stakeholders in an international framework. This multi-actor, multi-national and multi-disciplinary context well illustrates the presence of agglomerate collective strategy (Astley & Fombrun, 1983). In the absence of articulated strategic actions in cooperative alliances (dyadic or multiple), competitive organizations in the same sector can be viewed as having collective strategies and, thus, managing their interdependencies by uniting their fate (Astley & Fombrun, 1983 ; Bresser & Harl, 1986).

The "agglomerate" (Astley & Fombrun, 1983) or "federative" (Yami, 2003) collective strategies, little studied by researchers in business and management sciences, sheds light on our particular area of interest. It links horizontally competitive organizations, allowing either

[2]There are many different types of public scientific partnerships; e.g. in France: the Research Combined Unities (UMR), the Research Federative Institutes (IFR), The Research Groupings (GDR), the Scientific Interest Groupings (GIS), the public Interest Groupings (GIP); and in Europe: the Excellence networks (REX), and the Integrated Projects of the European Union…

formal or informal relationships depending on the nature of intended benefits or fall-out (scientific, economic, financial…) for the partners. In an industrial context, this type of strategy develops in markets composed of a large number of small-sized firms. It favors the implementation of a centralized coordination structure, such as a cartel, professional associations and federations.

The case of the ATLAS collaboration at CERN, we shall study in details later in section 3, is a scientific collaboration that can typically be quantified as "public and international research consortium". The consortium form of ATLAS is the agglomerate structure. Within this structure, individual, organizational and inter-organizational levels are articulated with a co-construction logic. In fact, researchers with idiosyncratic resources and competences, act as real "entrepreneurs" in their research field and in their sub-structures and projects (group of researchers, laboratory, department, institute,..). These small-sized organizations, that can be assimilated to Small and Medium-size Enterprises or SMEs in the business context, are in cooperative and competitive relations. But, these researchers can also be considered as individuals able to mobilize their personal networks as well as other persons and networks, freely and independently from their affiliate structures. We note here that one of the specificities in the research context is the fact that researchers exist within and outside their home structures, and have mobility opportunities. All these aspects must be taken into account to understand logic of action and processes in the agglomerate collective strategy.

An evolving partnership process is necessary to be able to realize a top-of-the-art scientific experiment such as ATLAS. Our specific focus in the present paper is a sub-project called "Feet and Rails" which provides the central support for the entire experiment. In a highly international collaboration context, this sub-project highlights a particular and original structuring mode. Indeed, the natural evolution and the difficulties encountered and successfully solved in this kind of a project, in terms of organizing the work and facilitating individual needs and interests, illustrates the motivation of actors and their commitment to a multi-disciplinary and multi-form scheme, where the institutional boundaries are not necessarily visible nor legally binding.

2. Presenting the authors and the research methodology

Yami S. , a researcher and associate professor in strategic management (University of Montpellier 1). He currently works on partnership processes and collective strategies, in particular in the field of public and semi-public research organizations[3].

Nordberg M., a physicist and a PhD in Business Administration[4], is the resources coordinator of the ATLAS experiment since 2001. He is a member of the ATLAS Management and the ATLAS Executive Board (see Figure 2 in the Appendix). His position allows him to have a perspective of the entire experiment at the highest strategic level.

Nicquevert B., a mechanical engineer and a Master's degree in philosophy[5] and researcher in human sciences[6] , leads for several years a technical office, being in charge of the design of detector elements in the field of "precision mechanics". He was responsible for the mechanical integration of the whole ATLAS experiment from 1994 to 2001. Since 1996 and

[3]See in particular Yami (2003) ; Fort & Yami (2004).
[4]See Nordberg (1997).
[5]See Nicquevert (1999).
[6]See Vinck (1999).

up to the completion in 2004, he was the project leader for the central support ”Feet and Rails”).

Given the general context of CERN and ATLAS (the study object), we have favored a longitudinal approach for this study case (Yin, 1994 ; Eisenhardt, 1989) in order to fully grasp the relevant aspects related to the ongoing ATLAS experiment. Thus, we proceeded to triangulate various information sources. These included the primary data collected from interviews carried out by one of the present authors (X) in February 2004 with key actors of the ATLAS collaboration and CERN. Secondary data were also collected on ATLAS and CERN, obtained from both public and internal sources. The collected and analyzed data were then checked and completed by the co-authors in their respective domains of expertise.

In order to study strategy process, our methodological approach is based on a step by step perspective (Mintzberg & Quinn, 1996), that permanently confronts observation and concepts, the determinants, forms and performance of agglomerate collective strategies in the field of public and semi-public research. In this way, the study case method used is not only illustrative, it also provides description of a complex organizational reality and opens a line of questioning which can lead to a descriptive, comprehensive model. Such a qualitative research approach can be used in the theorization process (cf. Grounded Theory – Glaser & Strauss, 1967).

The structure of the present paper is as follows. We first present the ATLAS collaboration at CERN as an ongoing agglomerate collective strategy (section 3), demonstrating the presence of many actors and multiple resources at an international level. Then, we focus on the so-called “Russian contribution”, as an illustration of the achieved goals of the sub-project called

"Feet and Rails" of ATLAS. This will highlight the complexity of relationships at different decision-making and organizational levels. Finally, based on our findings, we will reflect on the implications of the study case and conclude on the determinants and the forms of the agglomerate collective strategies (section 4).

3. The ATLAS collaboration at CERN: an ongoing agglomerate collective strategy

3.1. CERN

The Centre Européen de la Recherche Nucléaire (hereinafter CERN) is a large physics laboratory in Geneva, Switzerland. It is devoted to fundamental research, aiming at discovering the ultimate components of matter. This is an international organization: it is composed of 20 European member states, contributing to CERN budget in proportion to their net national income. The annual budget of CERN is about 1 billion Swiss Francs (700 millions Euros). It maintains close relationships with numerous non-member states (e.g. United States, Canada, Russia, China, Japan, Israel, India). The laboratory has about 2 500 staff members on its payroll, one third of whom are physicists and engineers. In addition, some 2 000 people from industrial companies work daily on the site and ca.5 000 visiting scholars, physicists and engineers come from their home institutes to CERN on a regular basis to install and run experiments, and to analyze the collected data. CERN constructs and operates very large particle accelerators and provides the necessary infrastructure and support for the detectors, within the framework of approved research programs.

One of the first major scientific discoveries of CERN was made with the bubble chamber called Gargamelle at the Proton Synchrotron (PS) accelerator, which led to the discovery of the "neutral currents" in 1973. This provided strong evidence for a so-called Standard Model of particles. The particle detectors at the SPS (Super Proton Synchrotron) discovered the particles carrying the electroweak force (which regulates, among other things, the burning of the Sun). For these latter discoveries, C. Rubbia and S. van der Meer were awarded the Nobel-prize in 1984[7].

During the years 1989–2000, the largest research facility at CERN was the LEP (Large Electron Positron) collider. This was a electron / positron machine, built in an underground tunnel with a circumference of 27km[8], at some 100 meters below ground level. It was able to reach center-of-mass energies of more than 200 GeV (giga electron volts[9]) due to the use of powerful superconducting radiofrequency cavities.

The experimental complex of LEP included four detectors whose aim was to track and identify new elementary particles generated by the electron/positron collisions. Among many particle identification technologies used, they also included multiwire chambers. For this development work, G. Charpak was awarded the Nobel-prize in 1992. Assumptions behind the Standard Model were further confirmed with high accuracy, and it was discovered that only three families of particles exist.

LEP was dismantled in 2001 to pave way for the new accelerator, the LHC (Large Hadron Collider) which is built in the same tunnel.

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[7] Idem, pp.74-75.
[8] Ibidem, pp.80-83.
[9] One GeV equals roughly to the energy of a proton in accordance with Einstein's $e = mc^2$.

A wide range of other experiments have also taken place at CERN. These range from studying isotopes, plasma gluons and gravitational waves to even creating antihydrogen atoms. Such achievements demonstrate the high technical complexity of the experimental devices as well as the fundamental nature of research carried out at CERN.

The technical fall-out of this research is very important, and industry takes benefit of it in several forms of technology transfer (Schmied & al., 1984; Y & Verbeke, 1999; Autio & al., 2003). The main domains of technical core competence are superconductivity (developed mainly to generate high magnetic fields, up to several hundred times more than the earth magnetic field), ultra-high vacuum (it is demanding task to construct a 27 km long vacuum tube or achieve vacuum levels comparable to those in space), or electronics for data acquisition (the data rates used exceed several times those used in today's world telecommunication). But the best known spin-off is surely the development of the World Wide Web in 1990 to meet the requirements of the particle physics community. This software combines the use of hypertext and the Internet, and its dramatic expansion and world impact is well known today (Berners-Lee, 1999; Hameri & Y, 1998).

The next generation of experiments is currently under construction for new the proton/proton collider, the LHC. The center-of-mass energy will reach 14 TeV (tera electron volt), 60 times more than at LEP. It will be made of about 2000 superconducting magnets, requiring megawatts of cryogenic cooling capacity and beams circulating in ultravacuum with micrometer accuracy. LHC will allow the exploitation of completely new energy regions in physics.

3.2. ATLAS experiment

A Toroidal LHC ApparatuS (ATLAS) is one of the two general-purpose experiments at the LHC. Built around the vacuum tube of the LHC where the proton packets will collide, the ATLAS experiment aims at discovering the Higgs boson, the last missing piece of the Standard Model jig-saw puzzle. ATLAS will also look for supersymmetric particles and maybe even mini-black holes. The fundamental questions it addresses are: why do particles have a mass? What is charge? Why is there more matter than antimatter in our Universe ?[10]

3.2.1. The general frame of the ATLAS collaboration: history and key milestones

The history of ATLAS dates back to the early 1980s when the first technical concepts of the LHC were made. The scientists engaged in the successful UA2 experiment (sister-experiment to the Nobel-prize winning UA1 experiment) formed the core nucleus of several design teams for a new-generation multipurpose detector. These teams looked carefully at different particle identification mechanisms at very high energies and luminosities, for example for photon, hadron and muon identification. As a result, basic design concepts were put forward including the idea of cryogenic detectors (e.g. Liquid Argon calorimeters for electromagnetic and hadron identification) as well as large superconducting magnets for muon identification. It is important to note and understand that the technical design –and therefore selection of core competencies across the potential participating teams– follows closely from the perceived physics discovery potential and selected discovery strategies.

For ATLAS, two main detector alternatives emerged in the late 1980s and early 1990s;

[10]ATLAS Technical Proposal for a General-Purpose pp Experiment at the Large Hadron Collider at CERN, December 1994, ISBN 92-9083-067-0, CERN-LHCC-94-43, LHCC-P2, 15 December 1994, http://atlas.web.CERN.ch/Atlas/TP/NEW/HTML/tp9new/tp9.html

EAGLE and ASCOT. In 1992, the two separate tracks of technology development merged and formed ATLAS as we know it today. A Letter of Intent was formed and the foundations of ATLAS were cast solidly. Extensive R&D programs were executed in the late 1980s and early 1990s and even at the stage of the birth of ATLAS in 1992. Several key technologies and physics research strategies were pursued in parallel at the time.

As many research institutes and top physicists put their hearts and minds into conceiving the best possible detector with the available funding, fierce but friendly competition emerged between different groups. The merging of EAGLE and ASCOT had its challenges, both in terms of selecting technologies among the many promising parallel developments as well as in terms of sociology of the teams. In some cases, some institutes left the Project, then to be replaced by new ones. Another major contribution to the formation of ATLAS came from the US, as its Congress killed their own similar endeavor, the SSC in 1992. A large part of the SSC-engaged US community joined ATLAS, bringing in their skills, resources and technical knowledge; all this had to be facilitated in a manner that could maintain the best of all parties already involved in the Project.

3.2.2. A collective strategy based upon open partnership of "soft governance": the Memorandum of Understanding

The key instrument for starting the construction phase of ATLAS is the so-called Memorandum of Understanding (MoU). This document lays out, in only 7 pages, the basic rules and procedures for the entire collaboration. The document clearly states it is not a legal document, rather a "Gentlemen's agreement" in fulfilling a common goal. The document provides as an Annex a list of the detector components and which Funding Agency contributes to which element and by how much. The MoU determines a global cost ceiling of 475 MCHF using fixed exchange rates between major currencies. It does not include institute manpower or infrastructure (e.g. prototyping) costs, only direct material costs. As a financial tool it therefore offers only a partial picture of the total costs but this is accepted by the 35 contributing Funding Agencies from 150 institutes from more than 33 different countries.

The key principle in this document is the concept of technological and financial sharing of risk: as the financing Governments did not wish to grant ATLAS an explicit contingency, a tacit understanding was reached with the Funding Agencies whereby they carry the financial risk related to the deliverables they sign up to (within reasonable limits). That is, if the technical deliverables from a given country are associated with higher costs than foreseen, the respective Funding Agency absorbs the cost without making a cost claim to the Collaboration. For the technical part, the technologically very risky parts are in many cases shared by several institutes, to minimize the risk that an entire detector sub-system would fail to function as designed.

The MoU also describes the internal decision-making process of ATLAS, indicating that the responsibilities are very much decentralized and its problem-solving mechanisms are consultation-oriented and consensus-seeking. This can obviously be considered as a strength, at the same time frustrating many teams who wish to proceed with their work in an independent fashion.

The ATLAS organization diagram (see Figure 2 in the Appendix) sums up this federative structure, mainly organized by sub-systems. The ATLAS project has no formal “President” or “Chief Executive Officer”, but instead an elected spokesperson, and this fact well reflects the spirit of physics collaborations. Elected by institute vote in the Collaboration Board, the spokesperson represents the collaboration towards the external bodies (institutes, funding agencies, CERN, enterprises...). The spokesperson does not hold the power usually described in project management literature. Rather, his role is oriented towards consensus-seeking, which he must reach in bodies such like the Collaboration Board (representatives per institute), Executive Board (representatives by system) and the Resources Review Board (representatives per Funding Agency). Each sub-system is organized along a similar kind of structure.

The spokesperson is assisted by two coordinators. The technical coordinator monitors the construction progress, ensures a smooth global integration of detector elements at CERN, coordinates the installation of services (electrical cables, cooling and gas pipes etc.), the schedule and the installation of infrastructure in the experiment area. He, is also responsible for the construction of the common items (so-called Common Projects) of ATLAS such as the magnets, access structures, shieldings, cryostats, control rooms etc.). The resources coordinator manages the financial part of the experiment. He ensures the timely availability of pledged contributions as recorded in the MoU, plans, controls and reports the annual project payments. The spokesperson can also nominate deputy spokesperson(s) to help in his duties.

3.2.3. The role of CERN in the ATLAS project

The role of CERN as the host lab is two-fold in ATLAS. On the one hand, it provides the particle beams for ATLAS as well as the technical infrastructure (roads, buildings, technical services). But in parallel, it is also a participating institute and a Funding Agency among the 34 others. It contributes scientific knowledge and expertise for ATLAS in several sub-systems. It thus looks like a participating University. This dual role of CERN often generates confusion and seemingly peculiar situations: in the ATLAS project structure, a CERN employee may be in charge of a large ATLAS sub-project and at the same time, in the CERN organization, (s)he may be well down below in the hierarchy (or vice-versa)!

3.2.4. Relationships with the other experiments

ATLAS has a sister-experiment called CMS. It is of similar size and scope. As in the previous generation of experiments, the two are competitors but interact in a friendly and correct manner. Many participating institutes share their resources between ATLAS and CMS although there is basically no overlap between the participating individuals. The case of CEA (Commissariat à l'Energie Atomique) speaks for itself regarding this issue, since amongst many other contributions in the two projects, CEA is highly involved in the design and production of both the ATLAS barrel toroid magnets and the large CMS solenoidal magnet. The technical teams are partly shared in common.

ATLAS and CMS have several common technical projects, coordinated by CERN. These typically include common development work on cable and gas systems and informatics. Many teams in ATLAS and CMS have worked together earlier on during the R&D phases in the late 1980s and early 1990s. The management styles in the two experiments are perceived as being different. CMS is considered to be more centrally driven and, in the eyes of some ATLAS colleagues, more rapid in reacting to technical issues or problems. As stated above, ATLAS is by social design more decentralized and as a consequence, seemingly slower in reaching decisions (however, some CMS colleagues do state the opposite!).

3.2.5. The ATLAS Common Fund

At the time the ATLAS MoU was signed in 1998, a special mechanism was set up to fund and execute common projects too expensive or too complex for participating institute(s) to handle alone in the framework of MoU. This mechanism is the Common Fund which includes items such as the magnets, cryogenics installations, shielding and central support structures. For example, the original cost of the magnets was ca. 140 MCHF, i.e. one third of the total cost of the experiment. Their complexity and sheer size made them a technical and organizational challenge. This applies also to the cryostats & cryogenics installation, shielding and support structures. Some of these components needed to be purchased centrally by ATLAS, for example due to lack of interest in industry or missing competencies in the collaboration institutes. The original value of all of these elements in the Common Fund amount to ca. 210 MCHF or 40% of the total value of the experiment.

In order to fund the common items, each institute must contribute to the Common Fund in proportion to its detector contributions. These Common Fund contributions can be made either in hard cash or as in-kind contributions. The work carried out within the Common Fund is in practice managed by the technical and resources coordinators. ATLAS institutes or Funding Agencies wishing to make in-kind contributions, follow agreed procedures that define the MoU value of the components in question. So far, more than 60% of the 210 MCHF has been supplied as in-kind.

4. Discussion and conclusion

What elements of agglomerate collective strategy does this study case provide? We develop this question around two main lines of thought: the determinants and the forms of collective strategy. We can also address the problem by looking at the performance related to collective strategy. For us, this idea is strongly linked to the nature of the experiment and its technical success factors aiming at novel scientific discoveries. We note that economic and financial logics are here considered as inputs whereas in the industrial context, they are rather considered as output of products and markets. This interpretation leads us to examine the aspects linked with the profession and mission of public and semi-public research actors as well as their motivation in a context where knowledge doesn't represent a market gain for them but where the results of their work can instead lead to industrial developments in the economic sense of the meaning.

4.1. On the determinants of collective strategy

The determinants which lead actors to collaborate and share their resources in common lies in the extraordinary challenges which bring the actors together. In this case, such a challenge is a next-generation particle physics experiment reaching well beyond current scientific limits. This kind of project mobilizes considerable financial, technical and human resources but with high technical and organizational risks associated with it.

In order to realize this kind a project, it is necessary to find the right partners (research laboratories and governments) and an appropriate collective organizational framework. In fact, it is a question of identifying an opportunity in the unexplored research field which the community of researchers are eager to harvest. This requires setting up a strict schedule with a work plan for actors who have chosen freely to collaborate. If an idea of a new experiment is born in the minds of researchers (say, in a scientific conference), the realization of this kind of experiment requires a place, a legal and administrative framework, as well as adequate financial and human resources.

The institutionalization of the collective process described above, which we would describe as "bottom-up", requires finding a key actor with a legal statute. In this case CERN, as we already stressed, plays a particular role in this process. CERN is a legal entity which can offer a physical or tangible structure to the experiment which, instead, is not a legal body. For example, all supply contracts placed by CERN are signed and executed by CERN, not by ATLAS. In this respect, we are in the presence of a federative or agglomerate entity, which shapes and institutionalizes the collective strategy. This is a first element which determines the boundaries of collective strategy.

As for the second element, we favor a psycho-sociological explanation for the motives that have resulted in a collective strategy. These motives are not primarily financial or economic in nature but rather, knowledge-driven. In the study case of CERN activities, there is no "top-down" incentive mechanism sharing out knowledge as a response to an invitation to tender, as is often the case in national or international government programs intended to boost innovation and R&D in given industry sectors. Instead, it is rather a question defining a common ambitious program well beyond national level where the sharing of different resources is necessary in order to achieve the project goals. This requires division of work and voluntary participation of specialized research institutes and laboratories over many countries.

We favor a socio-cognitive approach (Yami, 1999, 2003) based on what is the more fundamental to the researcher as for his mission. Namely "searching" to push research frontiers beyond its limits, sustained by the presence of an active scientific community (which, in the case of particle physics, includes roughly 10 000 researchers around the world), using a common platform such as CERN. The second determinant thus consists of the existence of a public (open) platform and an expectation of collective project benefits.

4.2. On the forms of collective strategy

The flexible institutional framework of a "Memorandum of Understanding" constitutes the corner stone necessary for an adequate functioning of a collective strategy. This framework, based on "soft governance", demonstrated as essential and efficient in this study case, poses nevertheless some questions concerning its robustness and effectiveness in other sectors. Can this mode of functioning be generalized? Of course, firms in high-tech sectors are exposed to this kind of work practice while collaborating with research laboratories. However, industry, rarely runs projects like ATLAS, adventures of abnormality which generate knowledge from fundamental research, associated with risks as to the expected results of the project.

The legal problem often posed at the level of the industry is one of the precise definition of the sharing of the results and profits between partners. It is a question of spin-offs translated into new markets, customers and patents, taking also into account the relative weights and sizes of the actors as there will inevitably be initiators and followers. We nevertheless believe that an institutionalized framework of collective strategy allows a range of responses, either at the market or hierarchical level.

In our case, knowledge is an intangible asset which can not be easily assessed in marketable terms. The administrative structure of ATLAS and CERN reflects the nature of services provided for a community of researchers, but also that of governments financing the scientific programs. The hierarchy makes the decisions, evaluates and controls the system's progress; the role played by the "spokesperson" is, in this respect, crucial.

A framework such as ATLAS is not vertically integrated. The system does not absorb its components because it allows room for maneuvering at each level of the organization in order for solutions to be found where ever difficulties are met. In this system, problems are not escalated up in the hierarchy unless arbitration help is requested (typically, from the spokesperson). Every member of the collaboration, at each level, is precious collectively. This is reflected in the ATLAS publishing policy: all signed collaboration members appear as authors on the ATLAS publications (some 1 300 in 2005). Individuality is an important feature even in a large entity such as ATLAS. We see different levels of the organization overlapping continuously with each other (individual, organizational, inter-organizational). We think it is important to study this in more detail in a further study.

The question of how to stabilize the system without homogenizing its components is pertinent and also a topic for future research. Moreover, it would also be interesting to study membership modes of actors and their implications at the level of the norm and the culture present in this type of federative, knowledge producing organization (Knorr-Cetina, 1999).

Finally, the case of the ATLAS at CERN highlights the idea of managing collectively interdependences and uncertainty. In itself, this observation is not novel (see e.g. Bresser, 1988; Bresser & Harl, 1986) but contrary to expectations, we find that collective functioning is possible while maintaining a high degree of flexibility in the system. From the point of view of management research literature, we find this observation both surprising and original. In reality, the structuring and functioning mode developed by CERN has already been used a model for several other international scientific organizations (see for e.g. Kriege & Pestre, 1997).

Actors implied in the collaboration have their own parallel “individual” lives outside ATLAS and a “collective” one within. Here, the question of uncertainty refers to the experiment and not to the individual research activities of the partner/competitor laboratories. Unlike in an industrial market context, collective strategy demonstrates a strong commitment to a common, long-term goal and bringing together a pool of competences and idiosyncratic resources. This seems, on the surface at least, to suppress opportunistic behavior. We believe this observation merits also further investigation.

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Appendix

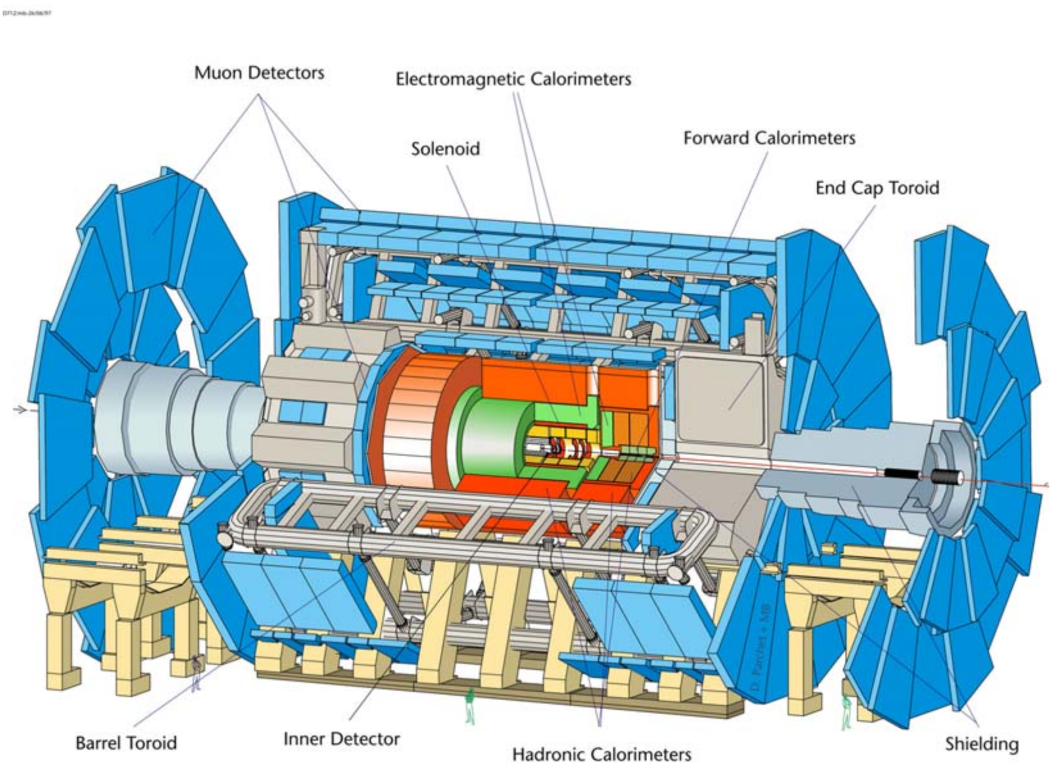

Figure 1 –ATLAS experience at CERN

Architecture of the ATLAS detector[11]

The architecture of the ATLAS detector is close to that of a Russian doll. The LHC vacuum pipe, placed along the axis of the experiment, allows the proton particles to reach the collision point every 25 nanoseconds generating the new, observed particles.
Surrounding the LHC vacuum pipe and the collision point is the inner detector (7m long, 2.3m diameter) that can reconstruct the track of all particles coming from the collision and identify many of them. The required precision is high (a few microns), and detectors must be as transparent as possible to the generated particles, hence the use of highly stable composite structures (see footnote 10; Z & Hauviller, 1994).
A strong magnetic field is needed to bend the tracks of particles in the inner detector. This is achieved by constructing a superconducting solenoidal magnet around the inner detector.
The next layer is made of calorimeters, measuring the deposited energy of particles. The electromagnetic calorimeter, situated in liquid argon cryostats, absorbs photons and electrons. The tile hadronic calorimeter (5 m radius) absorbs protons and neutrons. It is *a contrario* very absorbing (several tons of steel, intertwined with detectors and photomultipliers).
The remaining part of the detector is the muon spectrometer: a set of more than 1500 chambers, containing thousands of meters of gas-filled tubes ionized by muon particles (heavy relatives of electrons). Their tracks are bended by a strong magnetic field created by ten superconducting toroidal magnets, never built before with such large dimensions.
Numerous support structures made of amagnetic steel (in order not to distort the magnetic field) are needed as well as many services (for cables, gas tubes, cooling pipes, cryogenics feeds) and shielding elements.
The total weight of ATLAS is 7000 tons, for a length of 44m (the barrel coils are 26 m long) and a diameter of 22 m (a 5 floor building).

Complexity and technical challenges

Taking into account the required energy densities and the use of special materials, the increase in complexity (both technical and organizational) is visible with respect to previous generation of LEP experiments:

- linear dimensions have doubled, and volume increased almost by a factor of ten;
- precision in terms of dimensional stability ranges from tens to a few microns, over volumes of several tens of cubic meters. The volume of ATLAS alone is 23 000 m^3;
- more advanced techniques are now used: from the mechanical point of view, one will now operate liquid argon cryostats at 85 K made of special aluminium (class 5083), central support structures in amagnetic stainless steel weighing tens of tons;
- from technological viewpoint, there are 10 superconducting magnets, including a solenoidal magnet and three sets of toroidal magnets, cooled down with liquid helium to 4.5 K; there are electronics in rather hostile environments (high magnetic fields, particle radiation etc.);
- safety, access and maintenance constraints given that the detector is installed in a large underground cavern situated 100 meters below ground level.

[11] Idem note 4 ; cf. also : ATLAS, Technical Coordination : Technical Design Report - ATLAS Collaboration. CERN-LHCC-99-001, ATLAS-TDR-13-1999, Geneva : CERN, 598p., http://atlas.web.CERN.ch/Atlas/TCOORD/TechCoord/tctdr.html

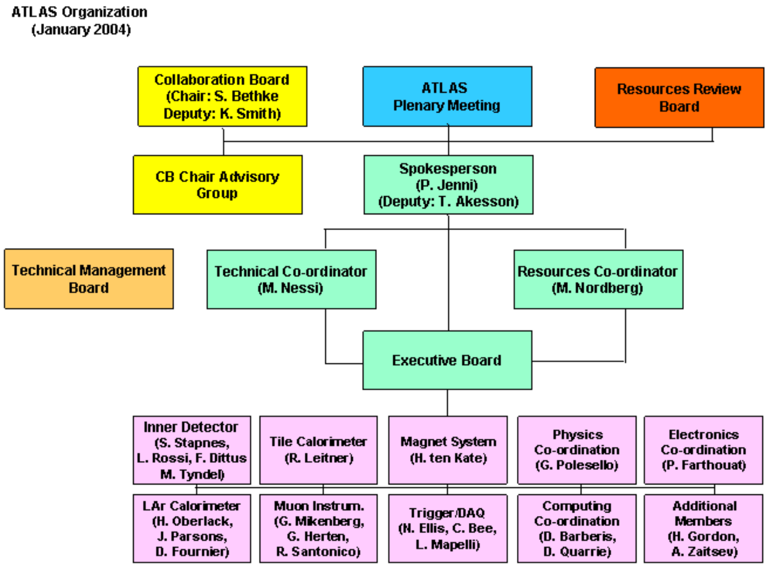

Figure 2 –ATLAS Collaboration organization

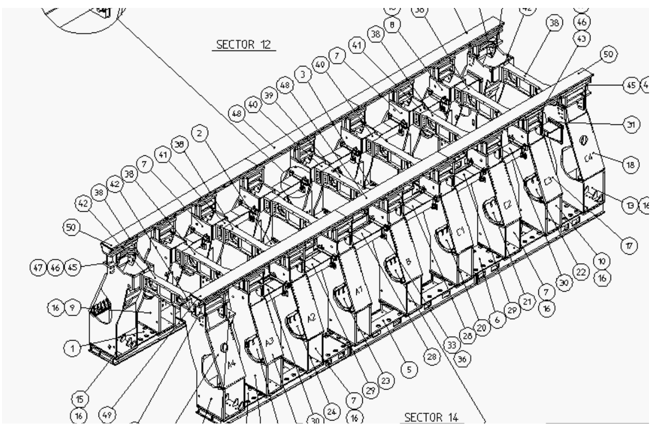

Figure 3 –ATLAS “Feet and rails” project

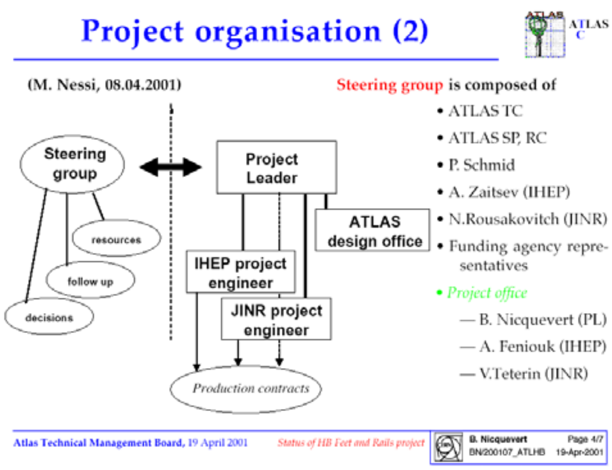

Figure 4 – Project organization