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► **To cite this version:**

Vincent Mangematin. The Simultaneous Shaping of Organization and Technology Within Co-operative Agreements. R. Coombs, P. Saviotti, A. Richards et V. Walsh. Networks and Technology Collaboration, Edward Elgar, 26 p., 1997. <hal-00424311>

HAL Id: hal-00424311

<http://hal.grenoble-em.com/hal-00424311>

Submitted on 15 Oct 2009

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THE SIMULTANEOUS SHAPING OF ORGANIZATION AND TECHNOLOGY WITHIN CO-OPERATIVE AGREEMENTS

*Vincent Mangematin**

INRA/SERD
Université Pierre Mendès France
BP 47X
38040 Grenoble Cédex 9
Phone : 33 76 82 54 41
Fax : 33 76 82 54 55
E-Mail : Vincent@grenoble.inra.fr

October 1994

Paper presented at the Advances in Sociological and Economic Analysis of Technology conference, "Technology collaboration : Networks, Institutions and States, Manchester, 21st - 23 rd April, 1993.

* The author would like to thank CSI team, SERD-INRA team and especially P.B. Joly and V. Walsh for their helpful comments on the earlier drafts. Of course, all mistakes remain my own.

Abstract

Studies in the field of sociology of innovation and economics of technical change have shown that technologies and their markets are highly intermingled. If we accept that technologies can shape the market, it leads to paying attention to how technologies are designed and developed. Indeed, the characteristics of technologies influence the nature of the competition (network externalities, increasing returns to adoption,...). The importance of co-operative R&D agreements is mostly analysed in terms of successes and failures or in terms of reduction of transaction costs. But, does the mode of development of technics have effects on the characteristics of the technical objects ? The impact of the mode of development of the technics on the characteristics of technics is still mysterious. Could it be that one of the determinants of the characteristics of technologies is the way in which technological development is organised ? The aim of this paper is to present some hypotheses about the consequence of R&D co-operation on the characteristics of the technical object in an actor network perspective. Thanks to an ethnographic study of the mode of coordination of a Eureka project, the role of technics as a mechanism of coordination is highlighted. Thus, technical choices can be analysed as the result of the identity of the actors of the cooperation, of their mutual trust and of the form of cooperation. Hence, the form and the nature of the technical object, which shapes the market, are the result of the organisation of its development.

Innovation is an occasion when products and markets are redefined. Studies devoted to it have rapidly outgrown the framework of standard economic theory and stress the simultaneous creation of technology and markets. Yet, while the market has been the object of particular attention and studied in a particular way, it has often neglected a detailed description of transformation of technologies themselves which are at the heart of the problem. In diffusion models [Mansfield, 1961, Metcalfe, 1988], the successive reduction of a technology to one dimensional variables, preferably quantifiable, is a prerequisite for analysis. In the evolutionary economics approach [Nelson and Winter, 1982, Lawrence and Lorsch, 1967] and in sociology of science and technology [Callon, 1980, 1986, Latour 1989, 1992, Law and Callon, 1987], it is the market which loses definition. From this work, I learn how designers make their choice in favour of a particular technological option and thus endow an object with a particular form. Yet we learn nothing about the details and the forms of **competition between** technologies¹. We are told that it is the environment which carries out the selection between technologies; but the nature of this environment remains a mystery, as does the way in which it operates. **Either technology is studied in detailed, but how the market makes its selection is neglected; or markets are analysed, but technology is reduced to one dimension.**

By studying information technologies (IT) [David P. 1987, Arthur B. 1989] or science based technologies [Pavitt, 1990], economists have highlighted the links between characteristics of a technology and the form and shaping of the market. They insist on self reinforcement mechanisms and irreversibility which influence the mode of competition between technologies and thus the construction of market. Is it possible in a similar way to establish relations between the mode of development and the characteristics of a technology? Can we envisage extending the observations made for production [Woodward, 1965, Tarondeau, 1982, Cohendet and Llerena, 1989] to the design stage?

What are the parameters of design of the organizational structure ? How are technical choices made? Do links between the two processes exist? If so, what are they? These are the types of questions which I shall try to answer in this article.

These issues are the result of the study of a cooperative research agreement over a three year period. Carminat is a joint research project between Philips, Renault, Sagem and TDF². The aim of the programme was to propose a system of road guidance based on

¹ Mangematin V., Rabeharisao V., 1992, "New Ways for Bridging Technology Studies and Economics of Technical Change" 4S/EASST Joint Meeting, Gothenburg, Sweden, August.

² Details are to be found in "Technological Competition, Strategies of the Firms and the Choice of the First users : The Case of Road Guidance Technologies", V. Mangematin and M. Callon, Research Policy, forthcoming or in V.

the dissemination of the most recent road information. Each party in the contract has worked on the design of such systems for a long time. Prior to the contract, Philips was working on the CARIN project which had two parts : improvement of the radio receiver so as to perfect of the Radio Data System, and development of a technique for localising vehicles. Sagem was working on the design of a navigation technology within the Minerve programme whilst Renault and TDF were carrying out research on the acquisition and broadcasting of information and services (Atlas). In 1986, these three projects were merged into CARMINAT. Each partner contributed its technical skills and knowledge of guidance systems to the consortium. The different stages of the project can be summarised as follows.

As a start, the general "architecture"³ of the system was negotiated between the partners who had to accept technical and organizational constraints. In view of the complementary nature of the technology they were pooling, the partners decided to distribute the work according to their own areas of specialisation (see fig 1). Philips was to take care of navigation, Sagem and Renault of vehicle control and diagnosis, Renault of integration into vehicles. These choices permitted each partner to develop a part of the system independently of the other partners. Each one carried out the task entrusted to it without the creation of a common laboratory being necessary. However, the **separate design** of each sub-system meant that the technology would be modular. The partners thus chose, from the multiple other technical possibilities, to design a system where the **interface** between the different sub-systems would be fixed, since the sub-systems themselves were to be developed independently.

Fig. 1. The centrality of the micro-processor and the general organization of the cooperation

insert figure 1

Source : Carminat co-operative agreement, p 39 and 40.

The main idea of the agreement is that each sub system must be developed independently by each partners while it has to be compatible with the full system at the same time. The partners thus rapidly decided on an overall "architecture" for the technical system which was in keeping with their **organizational** choices. Interrelations

Mangematin, 1993, Recherche coopérative et stratégie de normalisation, Thèse de doctorat de l'Université Paris IX-Dauphine.

³ "Architecture" means the general arrangement of the technical system.

between organization of cooperative work and technical choices are thus tightly knit. This paper discusses the determinants of these linkages.

All the sub-systems were then brought together in a test vehicle. Within this framework, the option chosen was that of installing the different parts on vehicles which would be driven from laboratory to laboratory.

In what way do organizational choices influence technical ones? It seems that I may identify three elements of choice in the organization of cooperation which clearly weigh on technical choices. Firstly, the institutional multiplicity of partners who decided to form a group to develop a new product. Secondly, the nature of the technology developed by these partners. And finally the level of trust between the partners.

I shall make two points in this paper : (i) linkages between the mode (organization) of development of technics and the characteristics of the technical objects do exist. So, I shall firstly analyse in what ways technical choices are guided by organizational choices. (ii) Technics has two faces. On one hand, technical developments have to be coordinated. On the second hand, technics is a mode of coordination. The joint development of a given technical object does not however take place without posing a number of problems of coordination, as questions of the loyalty of partners add to technical uncertainty. I shall demonstrate that technology can be a mode of coordination when the relationships between partners are stabilised. The presentation of this paper is based on the two stages of development of the cooperative research project : first, the process of stabilisation of the relations between partners taking the global architecture of the technical object as fixed; second, technological development of sub-systems when the organization of the cooperation is stabilised.

I. SIMULTANEOUS DEFINITION OF THE MODE OF DEVELOPMENT AND THE CHARACTERISTICS OF A TECHNICAL OBJECT

Research focusing on production has highlighted links between the characteristics of manufactured goods and those of the production process. The production mode structures the firm's organization; there is thus a link between characteristics of products and corporate organization. But the links between the organization of creative activity and characteristics of products remain obscure in the economic and sociological literature. This paper tries to throw some light on this, using concepts drawn from recent developments in both sociology and economics.

I.1 Questioning the influence of the designers' position in the organisation of cooperation

C. Alexander [1964] defined the design process of a product as the meeting between the form of a product and its context:

"Every design problem begins with an effort to achieve fitness between two entities: the form in question and its context. The form is the solution to the problem. In other words, when we speak of design, the real object of discussion is not the form alone, but the ensemble comprising the form and its context", [Alexander C., 1964, quoted by Clark K., 1985, p.236].

It seems that technical developments depend on both the state of the technology and the context in which the product evolves. R. Nelson and S. Winter [1982] emphasise the notion of the technological trajectory in which the product is inscribed.

K. Clark [1985], on the other hand, apprehends the form of the product by its basic functions. In the automobile industry, Clark refers for example to the power of the engine, brakes, shock absorbers, etc. The designer of the product chooses between different components fulfilling the same functions according to the perception he has of the qualities expected by the user.

K. Clark concludes that, when technical alternatives are given, the form of products will depend on the perception of qualities required by future users. These results confirm those of Von Hippel [1988]. In effect, the inclusion of users in the design and development of products transforms the technical characteristics of products.

In pursuing K. Clark's analysis, one can go even further. The form of products depends on the perception that designers have of the characteristics expected by consumers. But works on limited rationality by H. Simon [1962] as much as research on the processes of communication in firms show us that the perception which each member of an organization has, of both the organization and the environment, depends on his place in the organization. One can then logically infer that the perception of the consumer which the designers of a new product have, depends on the place of the latter in the organization. Decisions by designers between different available technologies thus depends on the way in which development is organised. It is for this reason that numerous studies stress the necessity of links between the different corporate functions and notably marketing and development research [Anderson and Tushman 1988, Xuereb 1991]. It is an opportunity to refer explicitly to the literature of different disciplines : strategy in evolutionary economics, R&D management in the management literature, network in sociology of innovation.

I.2 Links between design processes and product characteristics

In this paper, I try to propose systematic explanations of the links between organization of R&D and characteristics of technical objects. After a brief definition of variables which emerge from the case study, I shall propose a typology of the different combination of the variables.

The key variables

A series of variables were identified in the case study. They were chosen by comparison with cases taken from the literature and they seem to be relevant. However, they still have the status of hypothesis. I define three groups of variables. The first one deals with identity of the partners. The identity of partners is the result of three exogenous variables : the multiplicity of the partners, the nature of the technologies developed and the degree of *ex ante* mutual trust. The second group of variables defines technical objects developed as a result of the cooperation. This variable falls into three categories : the interconnected modular technical object, the technical object divisible into sub-systems, and the non-modular technical object. This variable is considered as endogenous to the decisions of the consortium of development. The main constraint is the availability of technological alternatives. The third group defines the organization of division of work amongst partners. Only two types of organization are taken into account : one based on pooling resources and the other based on "pooling" the developed technical object⁴. This variable is also endogenous.

Exogenous variables

Multiplicity of the partners

Carminat brings into play several partners in different firms. My study is limited to inter-firm cooperative research contracts where a hierarchical settlement of controversy is not possible, even if the impossibility results to the choice made by the partners.

Nature of technologies developed by contracting parties

I defined the nature of technologies developed by each contracting party by its degree of complementarity or similarity. The **technologies** contributed by each of the partners are **complementary**, since they want know-how they do not have. The

⁴ I use "pooling" the developed technical object in the sens of "assembling the developed technical sub-systems".

technologies contributed by each of the partners are **similar**, since they want a critical size.

I use the notions "complementary" and "similar" to describe not an agreement, but two technologies [Teece D., 1990]. The "complementary/similar" distinction conforms to the mode of analysis adopted by the partners themselves. The definition of similarity between two technologies has in fact two dimensions : the first one emphasizes the technological proximity, the second one stresses the substitutability, from the consumer point of view. Technologies are said complementary if the use of the first one requires the use of the second one, i.e. if the utility of the sum of the combination of the two technologies is greater than the sum of the individual utilities [$U(x_1;x_2) > U(x_1) + U(x_2)$].

Perceived degree of trust and mistrust

The degree of *ex ante* trust perceived by the partners is defined as follow : If the partners grant one another large credits from the outset, trust prevails in their mutual commitment. If, suspicion prevails in the contract, each having an attitude of mistrust vis-à-vis the other. The degree of trust or mistrust perceived between the contracting parties is analysed *ex ante*. In a first approach, I settle for a binary variable, trust or mistrust. It is clear that these two attitudes are the product of history [Granovetter, 1985], of past experiments, the result of the reputation or the capacity of retaliation of the cooperators. The object of the research influences this attitude. The more the output is definable and appropriable, the less will mistrust be necessary. However, at a moment *t*, the credit which the partners grant one another structures the form of organization. This variable does not take into account the effects on trust of current cooperation.

Endogenous variables

Characteristics of the technical object

The variable named "characteristics of technical objects" is completely different from the nature of the technologies developed by the contracting parties. The latter is **an exogenous input** while the former is **an endogenous output**. The latter describes the technology of each firm involved at the beginning of the cooperative agreement whereas the former defines the characteristics of the technical object developed by the co-operating partners. **Technical objects play a very complex role in the model. They are a compromise between technical and organizational constraints.** The partners choose the characteristics of technical objects constrained by available technologies. Their choice is influenced by the identity of partners. Indeed, technological constraints

must not be underestimated. **Partners determine the characteristics of technical objects conditionally upon the nature of technologies developed by contracting parties and conditionally upon their mutual trust.**

I define here three types of technical object:

An **interconnected modular technical object** (IMTO) is characterised by a modular design for the product as a whole, which permits the integration of different modules in varying numbers without the system's architecture being modified. There is a high degree of interconnection between the different sub-systems and the central one (the micro-processor in the case of Carminat). I define⁵ the concept "modularity" according to two properties : a module is a sub-set of a larger set forming the product. The product is said to be modular when it can function without certain modules even if the totality of functionality do not work. These are usually information or data processing based technologies and telecommunications play an essential role. The Carminat system is a very good example of this kind of object. The system can work even if a component is missing.

Technical object divisible into sub-systems (TODSS). These technical objects are divisible into strongly inter-connected sub-systems. The presence of all the sub-systems is required for the operation of the overall system. The technical failure of a sub-system leads to failure of the entire system. Similarly, the defection of one of the partners, if not replaceable, leads to the overall system being abandoned. This would be the case in certain complex technologies, such as the development of a vehicle for example. The main example of such a technical object is the car taken as a whole.

Non-modular technical object (NMTO). These technical objects form a whole which is not divisible into sub-systems. Developing them requires grouping together the means of research and development in one place. It is outside the scope of this paper.

The characteristics of the division of work amongst partners

Division of work amongst partners is just defined by the two extreme positions in the continuum of organization structure. Pooling resources defines the first type of organization. Common laboratory and joint venture are grouped under this flag. The common characteristic is that authority is delegated to a steering committee which is responsible for the execution of work. Creation of technical object is under its

⁵ We do not use J.C. Tarondeau's definition of modularity. He identifies "two interchangeable products as two functionally identical products [...]. The concept of modularity surpasses and includes that of interchangeability. Whilst an interchangeable product can be intended for one use only, a "module" is an interchangeable product intended for multiple uses" [Tarondeau, 1989, p.2371 and 2372]

authority. Task partitioning within each firm involved in the cooperation is second type of these extreme positions. In this framework, tasks are done in each firm and coordination of those tasks can be hierarchical. Each development group has its own hierarchy which is completely independent from the steering committee. Work is divided according to specialism. In this case, this is not a pooling of resources but a "pooling" (i.e. assembling) of the developed technical object. This is an endogenous variable. Division on work is mainly determined by partners' identity, the availability of technologies allowing or not the choice amongst various types of technical objects.

The combination of variables : a typology

H1 : The identity of the partners and their degree of *ex ante* mutual trust as well as the technology which they pool influence both the characteristics of the technical object and the organization of the cooperation.

I can specify this hypothesis as follows:

H11 : If the technologies are complementary and if the level of trust is low, then the work will be divided and regrouped by speciality.

H12 : The more the work is divided and regrouped by speciality, the more the product developed will be modular.

H13 : The more the product is modular and the work divided and regrouped by speciality, the less will hierarchical organization be a mode of coordination and the more will the need for other modes of coordination be important.

The form of the technology and the mode of organization will be the result of the level of trust or mistrust of each of the partners vis-à-vis the others, of the complementarity or similarity of the technologies pooled during the cooperation and of the internal or external nature of the cooperation. I shall ignore the latter dimension here, and limit my interest to cooperative research between different firms.

Table 3 tests out systematically the combination of the three groups of variables, trust/mistrust (T or M), complementary or similarity of technologies (C or S), characteristics of technical object (modular interconnected/divisible into sub-systems/non divisible; IMTO TODSS and NMTO) and division of work (pooling resources or "pooling" developed technical object).

I thus obtain the following table:

Table 1 : Division of work according to the partners' identity

	exogenous variables		endogenous variables	
	trust/mistrust	complementarity	technical object	division of work
1.	trust	similar	TODSS	pooling resources
2.	trust	similar	NMTO	pooling resources
3.	trust	complementary	IMTO	by speciality, possibilities of pooling resources
4.	trust	complementary	TODSS	pooling resources
5.	trust	complementary	NMTO	pooling resources
6.	mistrust	similar		no cooperation
7.	mistrust	complementary	IMTO	"pooling" (i.e. assembling) developed technical object
8.	mistrust	complementary	TODSS	"pooling" (i.e. assembling) developed technical object with high incentives for cooperation

Situations 1 and 2 : The partners trust one another, they decide to pool similar technologies. The main aim of the agreement is to attain a critical mass. The partners anticipate low risks of opportunistic behaviour. They can thus invest in the realisation of a non-modular technical object. The strong inter-connection of the different sub-sets does not present an *a priori* problem, considering the degree of *ex ante* trust between partners. They can decide on the pooling of research and development resources, whether these are in the form of a common laboratory (essential in the case of non-modular technical objects) or a distribution of tasks by speciality if the technical object is divisible into sub-systems.

Situations 3,4 and 5 : The partners trust one another, they have decided to pool their complementary technologies. This type of partnership may lead to any type of technical object. Aversion to risks of opportunism is reduced due to the initial trust of the partners. If the partners decide to pool research and development resources by constituting a common laboratory, they have more chance of ending up with a technical object which is divisible into sub-systems or with a non-modular technical object, since the grouping of research resources at the same place creates little incentive towards modularity.

Situation 6 : If the partners are suspicious of one another, cooperation on the basis of a similar technology has little chance of taking place. In effect, potential partners are in this case competitors. Risks of opportunism are all the greater as the partners are suspicious. Research on a critical scale, which would have been the basis of such an agreement, necessitates the grouping of research means. If it is possible to specify the results and to distribute the work by specialisms, cooperative research may take place. This will favour the development of a modular technical object, with each of the partners being able to work internally on a part of the final product.

Situation 7 : If the partners are suspicious of one another and if each of them has a complementary technology at its service, then the choice of an alternative technology will favour modular technical objects inter-connected to a basic component. In this case, each of the partners will try to limit the risks of opportunism. This attitude will lead them to define the scope of inter-dependence between technical systems. In fact, each one will develop modular sub-systems independently. The technical object as a whole, the object of the cooperation contract, will be conceived so as to be able to function even if one of the components is missing. In that case, the technical object will have less functionality than the complete one. The technology thus limits the advantages of opportunism for the cooperators. The division of work is carried out by specialism and large investments must be made in coordination mechanisms. In effect, if cooperation does not lead to the establishment of a common laboratory, a hierarchical organization does not appear to be a mode of cooperation since each of the partners will maintain its independence. The "pooling" of developed technical object needs a precise definition of the interface between the sub-systems to be made, as I shall demonstrate in the next part.

Situation 8 : If it proves impossible to develop a modular technology, a division into sub-systems is possible on condition that sufficiently powerful incentive mechanisms for the realisation of the contract can be found.

As I have said, the form of the technical object influences the mode of organization of the cooperation. It seems logical that the number of partners, i.e. the basis of organization, also influences the form of the technical object. In effect, during the partners' research, particularly in the case of a contribution of complementary technologies by the partners, each potential contracting party has for its part carried out research on a sub-system. Value from the investment in this preliminary research is obtained through the very modularity of the final technical object and the way in which the general architecture of the system integrates initial developments, determines how successfully this is done. I can thus make the hypothesis that the objects resulting from cooperative research will be modular.

Similarly, when trust between the partners is low, they delay specifying how much will be invested and exactly where it will go, so as to maximise their chances of obtaining value from their work in case of default or opportunistic behaviour by one of them. Thus, the complementary character of sub-systems is combined with an aim to rapidly redeploy the technology at moderate costs. Doubts about the loyalty of partners therefore orientates technical developments towards highly modular technologies.

The test of these propositions necessitates detailed case studies where each technical choice as well as rejected alternatives are analysed according to this chart. This approach requires close follow up which exceeds the limits of my analysis of Carminat.

H2 : The more the technology is modular, the more feasible is incremental innovation

The Carminat case is of course too recent to make such a hypothesis possible from observation. It does however offer us an example of the opposite. The project was maintained through the end even though the initially planned technical developments had not been realised. These technical dead-ends led to the specifications of the final product being relaxed, but they did not challenge the project itself. This observation suggests that the modularity of the technology allows for the incorporation of new developments which were not initially planned. Thus, if the incorporation of sub-systems which can function without all their components is possible, one may suppose that the integration of sub-systems with additional components is also. R. Langlois and P. Robertson [1992] emphasise, taking the example of micro-computers and electronic components, the role of modularity of the technology in incremental innovations, which tends to confirm my hypothesis.

1.3 Advantages of cooperative research agreements

Highlighting the influence of the identity of partners and their degree of mutual trust on the developed technology's characteristics, means wondering about the nature of research alliances. Models of strategic management treat decisions to form alliances as based essentially on cost/benefit analyses. The firm will take the decision to do something or have someone else do it, depending on the respective development costs. Yet this decision will affect the characteristics of the technical object developed and thus the development of its market.

Undertaking cooperative research is not only a decision to minimise costs, it is also an approach based on industrial logic. One of the participants of the CEC (Commission of European Community) DRIVE programme affirmed

"that in the final analysis, the European subsidy did not compensate for the costs involved in obtaining it, but that the principal advantages of European programmes lie in the framework of cooperative work which they allow".

The final question is which partners are to be integrated in the development. On this point sociologists of science and technology contribute a number of convergent replies. It is necessary to interest actors for them to adopt an innovation.

Going into partnership for the development of a technology also means choosing one's allies, i.e. the different developers of the technology. If the idea is accepted that potential adopters of a technology are all more or less the same, it can be recommended that firms include, from the design stage, representatives of each group of potential users.

The link between the traditional diffusion model and the shaping of the supply-side of technology is thus made. Integrated into the design process of the technology are representatives of users who inscribe within the technology the technical characteristics they want and which are accepted by the designers of the technology⁶. As the project advances, their role slides slowly from that designer to developer. The technology will then be diffused by contagion amongst similar users⁷.

This model has in particular the merit of taking the historicity of the process back to the design stages. It permits the process of recruitment of first users to be internalised, as with the degree of substitutability or decisions of hybridisation⁸.

II. THE ROLE OF THE TECHNOLOGY AS A MODE OF COORDINATION

Highlighting the advantages of cooperative research as a mode of development poses the problem of coordination of the agreements. If I show that innovation is a process of simultaneous formation of the organization of cooperation, the technology and the future users, it is necessary to question ourselves about both the parameters of the design of the organization and about the ways in which such research agreements are managed.

At the start I analysed the parallel creation of the technology and of organization (fig. 1). This study enables us to show that the level of trust and form of the technical object are linked. I have emphasised, in particular, that if the number of cooperators is high and if trust is low, then the need for coordination is great. How are the different types of cooperative research projects coordinated ? Coordinating a project means ensuring the coherence of the means employed for achieving the aim of the project. During Carminat's development, several stages are worth distinguishing. I especially focus on the mode of coordination of a project based on "pooling" the developed technical object. I do neglect to analyse the modes of coordination of project based on pooling resources. I have already shown the role of the technology as a parameter of the design

⁶ After negotiations which are more or less long, as is shown by sociologists of science and technology.

⁷ See M. Callon and V. Mangematin for a presentation of the hypotheses of this model.

⁸ Details are to be found in "Technological Competition, Strategies of the Firms and the Choice of the First users : The Case of Road Guidance Technologies", V. Mangematin and M. Callon, Research Policy, forthcoming

of organization, when the relations amongst partners are stabilised. Coordination of the project is based on the management of points of stability which are transformed with time.

I shall firstly show that technology gradually replaces hierarchy as a mode of coordination. After having analysed the conditions in which this mode of coordination can be expressed, I shall see how the different risks inherent in a cooperative research project are dealt with.

II.1 Coordinating - finding points of stability

A negotiation phase precedes the development period as such. This stage is characterised by negotiations between the contracting firms. They decide on the technical contribution of each of the members and on the general organization of the project. During this period, the technology is considered as stable, once the general architecture of the project has been determined. This first phase of the agreement is devoted to the negotiation of the financial clauses of the contract. The financial directions and management controllers of each contracting firm are mobilised by the programme managers of each firm to participate in this negotiation. What is fixed and what is in negotiation can be summarised in the following table :

Table 2 : variables of the pre-contractual phase

Fixed	In negotiation
<p>The characteristics of the future product are defined in terms of functions, target price and range.</p> <p>The technology of each sub-system is defined</p> <p>The general architecture of the system is fixed and serves as base for division of work between partners</p> <p>Authority is still internal to each firm. Steering committee is constituted by programme directors of each firm who defend their respective interests.</p> <p>Coordination based on hierarchy</p>	<p>Partners negotiate the elements integrated into contract</p> <p>The division of risks and the systems of guarantee is at the centre of discussion. At any moment a partner can default</p>

Once the contract has been signed, management of the project is officially delegated to the steering committee. Financial clauses as well as the general organization of the programme are accepted by each of the contracting parties. This stabilisation of the organizational conditions of cooperation permits the "re-opening" of the technology and the development of sub-systems, within these newly negotiated constraints.

Three principles govern the organization of this phase of cooperation. The work to be carried out is firstly **distributed to specialised work groups**. The steering committee pilots the different groups, activating or deactivating them.

The developments are then **distributed within the firms**. This principle largely includes the former, since work groups are constituted by speciality.

Finally, the **technical objects form a link between the groups**. The system's main instrument of cohesion is its modular architecture. The different sub-systems are united by a micro-processor, just as coordination between the different work groups is provided by the steering committee. Within the technical system it ensures compatibility between the different functions of Carminat without entirely determining the technology of each sub-system. The only requirements are compatibility of communication protocols and interfaces.

Each sub-system can then be developed autonomously by the work group on condition that it is compatible with the micro-processor. The need for adjustments between the partners is thus reduced, since these will have been integrated into the definition of the specifications at the start of the project. Similarly, the micro-processor represents a rule whose effectiveness requires no further coordination. In this sense, the micro-processor is a disembodied and decentralised authority which reduces the gradual erosion of the hierarchy.

It is not the steering committee or one of the partners who determines whether the quality of the developments is good or bad or whether they conform to specifications, but the micro-processor. If the development produces the required functions and is compatible with the micro-processor and communication protocols, the sub-system is integrated into the product.

The integration phase of the different sub-systems is not fully understood by the steering committee. An examination of its minutes confirms that technical discussions are totally absent during debate. The steering committee manages the progress of the different work groups, but not the content of their work. It does not decide in favour of any particular group in case of conflict and leaves the line managers to negotiate the outcome of controversy themselves. Once the prototypes of sub-systems have been designed and developed, they are mounted on test vehicles⁹ and travel from laboratory to laboratory, from Eindhoven to Paris, via Rennes and Cergy Pontoise.

These vehicles are accompanied by development engineers of the relevant sub-systems. Thus, the adjustment of the different parts of the system and their link to the micro-processor is carried out by technicians, within the test vehicles. The technical object appears to be the smallest common denominator, the link which unites. This central characteristic of coordination by the basic technology is confirmed by other case

⁹ The different sub-systems are grouped into categories and mounted onto vehicles.

studies. Y. Dubreil¹⁰, who led the development of the X06, the Twingo, emphasises the role of the technology as the element of accord between technicians.

"Two draughtsmen, looking at the same drawing, see a different object. That is why, in the body work design department, one sees small cardboard models; one communicates better with physical objects. Different departments rail at each other with bits of paper, but this is rarely the case with physical objects; objects dissolve opposition. The best language is that of objects. It is this property that we wanted to use systematically".

B. Weil and J.C. Moisson [1992] also describe this adjustment by technicians amongst themselves, using technical objects. Their description of the work of design unit draughtsmen shows that agreement between technicians is reached via the opposition of technical objects and the conformity of interfaces. The technology thus appears to establish the coherence of the project and therefore to be a true mode of coordination.

The technology thus appears from both sides, to be a parameter of the design of organization and a method of coordination of work between the partners. In a cooperative research programme where the level of trust between partners is low and where the work is distributed by speciality, the technology appears to be a method of coordination which progressively replaces the hierarchy. In effect, in the Carminat project the steering committee's prerogatives are weak. Once the rules of cooperation have been set and published officially in the contract, negotiations take place at the most decentralised level, that of technicians who conceive the sub-systems. At this stage of the project's development, the questions are mainly technical. Thus, for the technology to be a method of coordination, its network of designers must be stabilised, the borders around the agreement must be clearly defined and the rules and conventions governing the agreement be sufficiently integrated to become implicit.

Table 3 : Variables of the development phase

Fixed	In negotiation
General architecture of product is set.	Minor changes can be made by technicians who negotiate between themselves integration of final product into sub-system.
Functions, interfaces and communication protocols are set. The division of risks is fixed in the contract as well as the systems of guarantee and the general organization of the cooperation.	The sub-system is being developed.

¹⁰ Y. Dubreil, 1991, "Comment réussir un projet impossible" Séminaire vie des affaires, Report on the session of 6/12/92, edited by M. Berry.

Steering committee provides coordination between the different work groups.	Different sub-systems are grouped in test vehicles. Technical objects serve as a common language for technicians. Technology supplants the steering committee as a mode of coordination.
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Coordination by the technology appears thus as a complementary mode of coordination to that of the hierarchy. It provides for coherence between the means at work and the developments made when the hierarchy cannot ensure that function. What are the advantages of this type of coordination? What are the limits?

II.2 Influence of technical objects under development on modes of organization

Organization of the Carminat project speaks for itself in several ways. It firstly permits one to show how the partners chose to manage the risks inherent in cooperative research: opportunism, technical uncertainty, commercial uncertainty and learning.

After briefly presenting the method of managing risks in the Carminat project, I shall define the articulation between the different methods of coordination and risk management.

Response to opportunism

The struggle against opportunism within the Carminat contract is based on two principles related to its organization : (i) task partitioning between technical functions and representation functions on the one hand, and (ii) task partitioning between work groups and firms on the other. Technical functions are the prerogative of work groups and are decentralised up to the development engineers' level. Technical problems do not go as far as the steering committee. The only demands to which engineers and technical managers are subject are those of compatibility and meeting deadlines. **The steering committee manages all external relations and appears as a necessary intermediary between the "market" (technology transfer or sale of technology) and the development engineers for whom the market is not fully understood.**

This principle of separation is accentuated by the distinction between a working group and a firm. The modularity of the system permits the progressive and independent creation of specific complementary assets which are barely redeployable. Until their integration into the test vehicles, value can be obtained independently from each of the developments by the firm which developed it. Nevertheless, the complementarity of sub-systems in view of realising **the Carminat system led the cooperators to conform to certain constraints**, notably of **compatibility**. Thus, during independent

development, each partner conceived his product so as to grasp an opportunity for joint assemblage¹¹.

These two principles allow for considerable independence of developments whilst guaranteeing the partners a possible way out in the case one of them defaulting, and an incentive to cooperate as long as the terms of the contract are respected. They allow for flexible management of the appropriability of the technology. In developing modular products, the partners ensure that they do not lose everything if one of them opts out. This modularity is also a strong incentive for cooperation.

Response to technical uncertainty

A part of the response to technical uncertainty will be the same as that for opportunism. Opting out by one of the partners may in fact be due to opportunism or to a genuine technical impossibility. The independence of systems favours limiting technical uncertainty and decentralisation to work groups. Development areas have been created for each sub-system, the link with the outside being the interface. Dissociation between the different functions (managerial and technical) prevents the confusion of problems. Work group managers appear in fact as operators of **translation**¹². The steering committee only controls "management" variables; it never enters directly into the technology. On the other hand, the **dissolution of a work group signifies that the task has been executed and that the technology is stabilised. Similarly, the activation of a work group indicates the presence of a problem to be solved. For the steering committee, the work group is a black box; its variables of action are the activation or deactivation of work groups.**

The modularity of the system ensures the division of tasks, a source for limiting technical uncertainty. Furthermore, transversal work groups guarantee the integration of sub-sets and possibly the redesign of the system capable of functioning without all its components.

Response to competitive uncertainty

The separation between technical and managerial functions makes competitive uncertainty even greater. In effect, the project is carried out in a competitive sector

¹¹ The utility of each sub-system can be divided into two:

- intrinsic utility of the sub-system and its functions,
- option value corresponding to possible integration of the sub-system into Carminat. This option value can be estimated by considering the costs for development and additional tuning necessitated by the cooperation, from which is subtracted the part covered by the public authorities.

When the independent developments are complete, the realisation of the option proves to be the least costly solution considering the complementarity of sub-systems and the costs of redeploying the technology.

¹² This concept refers to actor network theory, in particular M. Callon's work.

where dynamic guidance appears as one of the strategic advantages of the automobile industry in the future. However, taking into account competitive uncertainty is without a doubt one of the weak points of Carminat's organization. This weakness cannot be imputable to the organization itself but rather to the composition of steering committee in which a technical thinking prevails on marketing one.

Management of externalities and learning

How are links between the different sub-systems managed ? How are independent developments coordinated ? Does the Carminat research programme produce synergy ? On the whole, it can be said that the organization of the project and management of learning or externalities are almost in contradiction in terms.

M. Dogson [1992] and G. Hamel [1990] show clearly that alliances are often a link in learning. They even stress that they can be an arena for what amounts to a learn. The case of cooperative development which I have examined does not support this conclusion. The organization and the technology were conceived and thought out to minimise links between firms and maximise zones of private appropriation, both of technology and of learning. No structure was set up to facilitate simultaneous learning, no formalization described the accumulation of experience and know-how. Neither of these two dimensions was measured or even mentioned during the steering committee's discussions or in its reports.

Management of the Carminat project was thus based on two principles which were intended to limit the risks of opportunism of each of the partners. Centred on the consideration of technical uncertainty, the coordination method adopted by the cooperators could also have permitted it to manage competitive uncertainty in return for some minor adjustments. In contrast, this mode of coordination remained inappropriate for the management of learning and externalities.

Management of the Carminat programme permitted the terms of decision making which took place to be highlighted. By favouring the division of work according to specialism and coordination according to the technical interfaces, the programme's partners did not benefit from the learning which G. Hamel identifies as one of the products of cooperation. The lack of consideration given to competitive uncertainty in contrast is linked to the personalities of the steering committee members.

Although the contracting firms had great weight during the negotiation of the contract, modes of coordination evolve during the course of cooperation. During the development of the technical object, the technology appeared as an essential mode of coordination. For it to play this role, it was essential that overall organization of cooperation limited the risks of opportunism and that it provided satisfactory answers to technical and competitive uncertainty. In the case of a modular project, the

independence of modules can play this role of a guarantee against opportunism. However, in contrast, in the case of a technical object divisible into sub-systems, other mechanisms must be found. Y. Dubreil¹³ sees in internal contract an additional mechanism to that of hierarchy for ensuring the viability of the project.

The following table which shows the articulation of different methods of coordination may be drawn up :

Table 4 : Articulation of different modes of coordination

technical object	Non modular	divisible in sub-system	Interconnected modular
Project coordination.	Little division of work; hierarchical coordination; constitution of a common laboratory; dominant role of the head of the laboratory; important role of partners in strategic orientation of the laboratory.	Division of work by speciality; work can be done in the contracting firms; great need for coordination due to incomplete modularity of the system. Contract, law and hierarchy are complementary to possible financial incentives to cooperation. The technology permits coordination of work of grass-roots technicians.	Distribution of tasks by speciality and by firms. The technology is a mode of coordination. Modularity of the object protects the contractants against opportunism and encourages the partners to cooperate. The dual hierarchical and ad-hoc link of grass-roots technicians are complementary to the technology as a mode of coordination.

Each organization responds in a different way to the problems which I have identified : opportunism, technical uncertainty, competitive uncertainty, learning, integration of new partners.

¹³ Y. Dubreil, 1991, "Comment réussir un projet impossible" Séminaire vie des affaires, Report on the session of 6/12/92, edited by M. Berry.

Table 5 : Response to risks

modularity	opportunism	technical uncertainty	commercial uncertainty	learning	integration of new partners
IMTO	independence of technical developments	modularity of object; partial extraction of value	separation of design and representation functions	no collective learning	easy, need only ensure compatibility of interfaces
TODSS	strong interdependence of sub-systems. Necessity of a strong hierarchy to maintain group cohesion	modularity	?	no collective learning unless pooling resources	easy if general architecture permits it
NMTO	legal and financial devices	very high due to globality of technical object	dynamic management considering technical uncertainty	much collective learning	problems of appropriability difficult to manage; technical difficulties if partners complementary

CONCLUSION

Following a development research project very closely enables one to highlight the multiple facets of the technology. Technical choices are influenced by the identity of the partners (the number and the technology which they decide to pool) as well as their respective level of trust. These parameters permit them to determine both the mode of organization chosen to develop the technology and the characteristics of the technical object developed. These characteristics are of course also determined by technological constraints. But the decisions of partners are expressed in the choice between the different available technical options. Technical choices and organizational choices are thus defined together.

During the development of the technical object, the multiplicity of partners and the organizational choices made condition the methods of coordinating the activity. If the modular nature of the technology and the absence of a common laboratory permit the effective control of opportunism and technical uncertainty, in no way are they guarantees against competitive uncertainty. It seems, moreover, that this organizational choice is incompatible with the accumulation of learning within firms.

In this organizational configuration, the technology seems like a mode of coordination which replaces the hierarchy. The latter is not an effective mode of coordination considering the few prerogatives conferred on the steering committee. The limits to its powers are moreover logical if one considers the mistrust which reigns within the consortium. Nevertheless, for the technology to be a true mode of coordination, it is

necessary for all the rules and conventions governing relations between the partners to be defined and stabilised.

By grouping in a single approach the links between the identity of the partners, characteristics of technical objects and mode of coordinating development research agreements, it is possible to envisage several approaches for constituting a typology of research-development agreements or laboratories.

If this approach provides a conceptual framework which seems coherent, empirical problems remain numerous. How does one grasp the degree of trust between partners? In the Carminat project, a range of convergent signs (numerous references to the contract in the minutes of the steering committee, absence of financing specifically for the steering committee, etc.) permit us to conclude that there is a high level of mistrust. But the definition of external indicators of trust remains to be found. Similarly, if at first approximation it is possible to define a modular technology and a non-divisible technology, the precise outline of the borders remains to be drawn.

The case was studied in an actor network perspective. Thanks to an interdisciplinary micro study, I was able to enlighten the linkages between characteristics of technical object and the mode of development. It seems to be an interesting way to produce new concepts. But stabilisation of these ideas remains to be done.

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