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Sociotechnical Constituencies as Processes of Alignment: The Rise of a Large-Scale European Information Technology Initiative

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ABSTRACT. The author discusses the recent emergence of The Open Microprocessor Initiative (OMI), a large-scale European information technology project and draws general lessons from the experience. The target of the initiative, in which many different organizations and nationalities participated, was the development of an autonomous European microprocessor capability. Using the sociotechnical constituencies approach of Organizational Behavior theory, the author describes how initially misaligned players generate the programmatic alignment of a capability-building initiative. He highlights the elements of a process of alignment that gradually and programmatically integrates the attitudes of different organizations, and shapes technology. He uses the concept of diamond of alignment to account for the several directions of social and technical alignments required in the formation of large-scale technological initiatives.

Introduction

The objective of the Open Microprocessor Systems Initiative (OMI) is to provide Europe with the capability to develop microprocessors. Reflecting the widespread concern about Europe's weakness in this critical area, many organizations from different countries were involved in shaping this project.

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These included companies, universities, laboratories, users, suppliers, competitors, and government institutions. Charting this large-scale program required close to two years of complex negotiations to complete. In the end, an agreement was reached and a document delineating the program became the first milestone in Europe's microprocessor development capability. Of course, from agreement to actual product development is a long and uncertain path and no one can guarantee success. At the present initial stage, however, the first major hurdle has been overcome.

I have argued elsewhere that "The generation of technological capabilities is a complex process in which technical and economic factors and trends interact with individual and institutional actors' expertise, visions, interests and cultural dispositions in a context of evolving market and political pressures."[1] In the process which led to the OMI, the presence of most of these elements, including the role individuals have played are present. I will begin by identifying some of its main initial features.

Several European semiconductor companies are suppliers of microprocessors, but none is a major force in world markets, which is dominated by United States based companies. The principal European companies are Inmos (U.K.) and the transputer (part of the Franco/Italian consortium SGS-Thomson); Philips (Netherlands) and Matra MHS (France), both licensees of the U.S. microprocessor architecture SPARC; Siemens, licensee of the U.S.-originated architecture MIPS; and Acorn (U.K.) and the ARM (part of the Italian computer manufacturer Olivetti). The microprocessors these companies produce are of the RISC type, an emerging architecture that has a promising future but only a small share of the market.[2] Intel and Motorola do not license their CISC architectures, thus leaving European companies with no option but to join the RISC "constituency." Thus, even though Europe was highly dependent on foreign sources, the RISC chip provided a clear "window of opportunity."[3]

While many independent institutions, from different industrial sectors and countries, have a stake in the success of the European microprocessor industry, there has been no concerted effort to pursue a single European objective. As a result, any European effort to build this capability must take into account the interests, expertise, and concerns of the major European players. A process of programmatic integration of the diverse interests and demands is necessary, especially among the institutions promoting competing technologies. But no formal relationship existed among the institutional players and there were few shared interests[4] that could facilitate a process of programmatic integration.

Given these initial conditions, it is not an exaggeration to maintain that the nature and mechanisms of the processes that lead to large-scale European initiatives are not well understood. Systematic research of these initiatives is needed. Their growing importance in the current development of the Commission of the European Communities' (CEC) policy towards ICTs in itself may be sufficient to justify such a demand.[5]

Many conceptual elements of applying the "sociotechnical constituencies" approach of several different disciplines are relevant to this problem.[6] For instance, the recognition of the critical importance of goals, perceptions, conflicts, coalitions and negotiations crosses disciplinary boundaries. It is possible to identify complementarities, overlappings, and convergences between various behavioural, sociological, historical, evolutionary economics and political science approaches. This convergence of disciplinary insights also applies to the treatment of technological and policy processes. The sociotechnical nature of technological processes,[7] their socially shaped (constructed) character,[8] the importance of community building,[9] network building,[10] system building,[11] heterogeneous engineering,[12] the importance of interpretative flexibility,[13] credibility;[14] enrollment,[15] power relations,[16] and the fact that technology also plays a role in determining the character of social networks and systems are well established.[17] A need continues to exist for further refining and developing systematic approaches to understand complex technological processes by integrating concepts in an analytically operational way.

The use of concepts such as networks, communities, and systems is a practice that is often controversial. Not only is there a great variety of meanings attached to each,[18] but most of the meanings have yet to establish a set of conceptual tools that makes them analytically operational beyond the metaphor and relevant to a general class of technological processes.[19] Similarly the concept "heterogeneous engineering"[20] is also not analytically operational beyond the metaphor.[21] The concept of "sociotechnical constituencies" (STC) while conveying a metaphorical image is derived from constituent-elements, and the complete phrase encapsulates the ensemble of all constituent-elements that play a part in the creation, production, and diffusion of technologies.[22] The relevant factor of the constituencies approach, however, is its gradual evolution towards a systematic analytical environment.[23] Constituencies can represent any technological process. It adopts relevant insights from different disciplines and attempts to develop new ones when convenient or necessary. For instance, the following discussion relies heavily on the behavioral concepts of perceptions and goals,[24] as well as on the sociotechnical tradition of conceptualizing technology. At the same time, it develops further the STC concepts of sociotechnical alignment and "diamond of alignment."

Sociotechnical Constituencies

The STC approach assumes that the processes involved in creating technological capabilities always entail the development of sociotechnical constituencies, defined as dynamic ensembles of technical and social constituents — machines, instruments, institutions, interest groups — that interact and shape each other in the course of the creation, production, and diffusion of specific technologies.

The term sociotechnical constituencies stresses the inseparability of technical and social constituents in technological development. This differentiates constituencies from communities and networks, which refer to people or institutions only. Constituencies are also different from actor-networks, which put both the animate and the inanimate in the same category. In constituencies, the parts are all constituents of the process, but it is only the social constituents who are the creators, the drivers, the purposives.[25]

Within constituencies, institutional interaction may be competitive or collaborative, or a combination of both. The interaction may involve institutions of the same type or institutions of different types and may take place at a national or international level. Institutions become constituents due to perception or expectation of benefits. In practice, they do not always have a clear idea of where their interests lie in relation to a given technology. The development of this technology does not necessarily follow the intended course or yield the results expected by the constituents. Thus, success is never guaranteed and depends largely on the quality of the process of "sociotechnical alignment."

The emergence of OMI in Europe can be viewed as an inter-institutional construction of a microprocessor-centred constituency through a process of sociotechnical alignment. Sociotechnical alignment is what constituents engage in when they are promoting the development of a specific technology either intra-organizationally, inter-organizationally, or even as an industrial standard. This may be the process of creation, adoption, accommodation (adaptation) and close or loose interaction — interrelation — of technical and social factors and actors that underlies the emergence and development of an identifiable constituency. Once achieved, such alignments are neither mere jigsaw-like accommodations of static available pieces nor complete and permanent. For this reason, the term alignment is modified by the terms misalignment and realignment, which express situations of tension and disharmony and changes or accommodations in a constituency. Nonalignment specifies situations in which the parties have not come to each other's attention, and alignment between people should not be misconstrued as consensus. Consensual alignment is only one possible form of alignment. Another is authoritarian in which alignment is enforced by one party over another through the use of power.

The Inter-institutional "Diamond of Alignment"

The concept of a "diamond of alignment" has been used to illustrate the multiple dimensions of alignment involved in the generation of large-scale inter-institutional initiatives.[26] The development of OMI provides an opportunity for the implementation of this analytical concept.

In Figure 1, the centre of the diamond denotes the evolving technology of the constituency. At no time, are specific products, solutions, and applications separate from the constituency. Rather, they are evolving technical crystallizations of the state of development of the constituency. In practice,

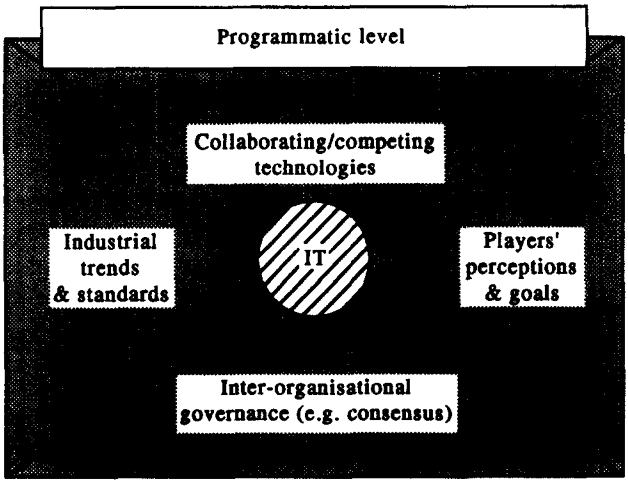

Figure 1. The Diamond of Inter-Organisational Alignment (Intra-Initiative)

large-scale initiatives tend to be built upon the foundations of existing constituencies, and the fewer the alternative technology solutions or the greater the space for alignment between them the easier the process of programmatic definition is likely to be. Successful large-scale programs are likely to involve alignments in several dimensions.

The first of these is an identifiable alignment of the programmatic solution with the governance of the organization that provides the funds for the initiative to take place.[27] This requires recognition on the part of the fostering organization that the problem addressed by the technology is highly significant to its purpose and interests. It also means that the potential technical and institutional solutions seem viable, thus meriting allocation of major resources. Of course, a programmatic solution may not fit the priorities of the fostering organization. In fact, the priorities may not even be articulated at all. In these circumstances, misalignment may develop quite easily. However, the emerging organization does not always have to align itself to the fostering organization's governance. In practice, emerging initiatives tend to generate their own internal governance, which may lead to adaptations, modifications, and new boundaries in the fostering organization. This is the case when the emerging initiative is pioneering a large-scale technical and institutional process and its development occurs within the environment of the fostering organization. In this case, creation and re-formulation — structuring and restructuring — tend to happen simultaneously in the emerging and fostering organizations.

The second dimension is an alignment between the potential technological solutions of the emerging constituency and the widely-recognized technical and market trends and standards in the targeted industrial area. Included in this alignment is an understanding of the evolution, present strategies, and likely future actions of actual and potential competing constituencies.[28]

In addition, trends and specific solutions are dynamic mutually influencing factors, and thus part of the capacity of a constituency to deliver may imply an ability to identify and generate new standards in areas not yet covered by existing standards. A mixture of standard-following, i.e. alignment of the emerging constituency's technology with existing technology, and standard-setting, i.e. alignment of other industrial players with the emerging constituency's technology — is likely to be the most pragmatic approach.

The third dimension is an alignment between the players originating the constituency-building process and between them and potential or target constituents, such as suppliers, users, and R&D institutions, and an alignment among the latter. For most, if not all of them, the aim is to become members of the broad constituency. In a large-scale programmatic context, however, this alignment does not mean that all parties work together. Often, it entails the creation or identification of "spaces" in which to manage difficult and conflictive cases such as those involving competitors. In this way, misalignments at more detailed levels become accepted aspects of alignment at broader levels, resulting in flexibility. As a result, one of the conditions for the success of large-scale programs, namely, the players' broad perceptions that the initiative is worth having is satisfied. In addition, different and even misaligned players are able to occupy different spaces while adding to the strength of the overall initiative. In this environment, the process is most likely to involve many different directions of alignment, such as expertise-based alignment between technology suppliers and users, alignment of technology solutions to users requirements, alignment of users to potential technology solutions, and alignment between interacting technologies.

The fourth dimension deals with an alignment between competing or collaborating technologies. A number of possible situations may arise:

- *Obligatory complementarity*, in which technologies need other technologies to realize their contribution and specific solutions demand strong expertise-based alignment, giving rise to processes of knowledge-integration and management of expertise.[29,30]
- *Non-obligatory complementarity*, in which technologies may contribute to an initiative's common purpose but their interaction is not a pre-condition.
- *Antagonistic competitive*, in which technologies compete for the same functional role or market and the acceptance of one may imply the rejection of others, leading to a high degree of conflict.
- *Non-antagonistic competitive*, in which technologies are either actually or apparently addressing similar functional roles or markets but they may co-exist, collaborating, and competing at different levels of the initiative; in large-scale initiatives, the boundaries between this and the antagonistic–competitive case are seldom sharply defined. They depend on the players' perceptions, negotiating stance, and approach to the initiative.

The complexity and conflict of sociotechnical alignment implied in large-scale initiatives depends on the technologies and how their respective constituents perceive their relations with others in the initiative. A fundamental factor is the players' perceptions and ambitions regarding resource building, allocation, and the scope of the initiative. Complementary technologies may lead to speedier alignment, although constituency-building is always necessary. Antagonistic cases are the most intractable, and may obstruct the achievement of successful programmatic alignment. If such cases become entrenched and do not evolve into non-antagonistic cases, survival of the initiative will require unilateral decisions. Survival will also require the chosen option to satisfice the demands implicit in the diamond of alignment. Non-antagonistic competitive cases commonly demand time-consuming negotiations and confrontations, but programmatic alignment is a matter of the players' perceptions, expectations, and ambitions.

In all technological processes, a major source of potential misalignment is the players' different areas of expertise. This is not the only source of misalignment, however, since sociotechnical alignment may also involve the human dimensions of uncertainty, suspicion, fear, and resentment. Fear and resentment often maybe inseparable from expertise-based misalignment. Furthermore, with newly emerging initiatives, different organizational players maybe uncertain about what they want or can expect from an initiative. Developers and users may have problems understanding each other's goals and point of view. Moreover, perceptions and goals are far from static, and changes in them may easily lead to misalignments. All this points to a process of human interaction that is uncertain, dynamic, and only partly rational. An awareness of how people actually perceive and understand the world around them is thus crucial.

Perception and Bounded Rationality

Psychologists define perception as "the way we look at things. . .[and]. . .the way we look at a situation will determine what we can do about it."[31] "Most of us recognize that the world-as-we-see-it is not necessarily the same as the world-as-it-"really"-is. . .[and]. . .people see things differently. Even "facts" may be seen quite differently by different people. . . .To ignore differences in perception is to ignore a major determinant of behavior."[32]

Some scholars use the term cognition instead of perception, but the notion of perceptual and cognitive processes have much in common.[33] Both recognize that the "human mind is a pattern-making and pattern-using system."[34] Concepts such as patterns, maps, mindsets, and frames of reference have been proposed to explain that what we normally see "is only part of the picture."[35] These concepts carry one simple message: people's perception is limited and selective.[36] In the field of organizational behavior, this message is summed up by the classical concept of "bounded rationality", which is a modification of the rational model of human behavior that is assumed by neoclassical economics.[37] The neoclassical economic model suggests that a firm is guided by maximizing principles — by managers who are able to weigh all the options and rationally arrive at optimal choices. Bounded rationality propounds a humbler reality of "human beings who *satisfice* because they have not the wits to *maximize*."

People are limited in their knowledge and their capabilities to learn and solve problems in a way that, "It is impossible for the behavior of a single, isolated individual to reach any high degree of rationality. The number of alternatives he must explore is so great, the information he would need to evaluate them so vast that even an approximation to objective rationality is hard to conceive."[38] Hence they mostly "satisfice" and rarely optimize.

It is not just limitations in knowledge and information, however, that play a role in bounded rationality. Members of organizations have wants, motives, drives, and passions, and these, as much as knowledge limitations, determine their frame of reference. In addition, since organizations do not exist in isolation, the cultural context also plays a determining role. "The organizational and social environment in which the decision maker finds himself determines what consequences he will anticipate, what ones he will not; what alternatives he will consider, what ones he will ignore."[39] In short, rationality is intrinsically subjective and relative, and "we can only speak of rationality relative to a frame of reference,"[40] which is culturally determined.[41]

Bounded rationality, frame of reference, and perceptions are overlapping aspects of the same behavioral process.[42] Perhaps bounded rationality can be viewed as manifesting itself through perceptions, or, conversely, perceptions can be viewed as expressions of bounded rationality. The key, however, is that both involve the total experience of people in their situational context. Other human characteristics can be added to those already mentioned: personality, experiences, value systems,[43] wishes, hopes, expectations,[44] beliefs, feelings, attitudes,[45] needs,[46] concerns,[47] and interests.[48]

Thus, the role of different types of expertise, including knowledge and skills, become part of a much larger set of variables although their centrality remains unchallenged. Some authors, for instance, have argued that "the particular set of skills and knowledge embodied in an individual can shape his perception at a subtle level in such a way that he may find it difficult to recognize the relevance and importance of other newer bodies of thought."[49] This effect is, of course, closely associated with the focusing and exclusion effect of both scientific and technological paradigms.[50] In other words, "Technological paradigms have a powerful exclusion effect: the efforts and the technological imagination of engineers and of the organizations in which they are in are focused in rather precise directions while they are, so to speak, "blind" with respect to other technological possibilities."[51]

Again, the character of expertise and its focusing effect are not behavioral properties of isolated individuals. They are influenced by the individual's organizational and social interaction. Thus, companies with close R&D and sales interaction may generate product innovations different from those produced by companies in which R&D personnel have contact primarily with R&D colleagues in other companies.[52] This is the essence of both sociotechnical alignment and of the argument that technologies represent crystallisations of the alignment of perceptions and goals of the parties shaping the development of the constituency.

Perception shapes present and future experiences, expectations, and attitudes, while being itself shaped by past experiences, expectations, and attitudes. In addition, since the basis for variety is virtually infinite, it is clear that there is considerable potential for conflict and misalignments in the area of perception and goals. For example, people from different career backgrounds are likely to have different starting perceptions, and "with different starting perceptions, perfectly logical thinking can lead to contradictory conclusions."[53] This may characterize the case of the European microprocessor initiative, in which players with different disciplinary traditions, expertise, and experiences came together to consider a joint venture.

The Social Factor: Perception- and Goal-alignment

Having established the sociotechnical character of alignment processes, one needs to focus on the social-actor dimension for two reasons: perceptions, goals, and purposive actions are created by people, as are explicit and implicit alignment strategies, or the lack of them. Within this confined focus, it is possible to see inter-organizational alignment as a process which attempts to integrate, accommodate, or modify the different stances of the participants. In other words, against a background of technology, trends, and governance, inter-institutional alignment is the process by which players evolve a positive interaction satisficing their interests and concerns.[54]

The concepts of perception-alignment and goal-alignment — misalignment, realignment — are crucial to this process. A situation of perception-alignment develops when two or more parties accept each others' interpretations of each others' motives and goals. The goals need not be the same and may even be contradictory. In contrast, goal-alignment develops when the parties come together not just in their perceptions but, in the pursuit of common or complementary aims, which typically implies a convergence of interests.[55] Perceptions and goals do influence each other, but perception-alignment is the effectiveness of communication between the different parties, while goal-alignment is both communication and coming together in a common cause which may produce mutual benefits. This alignment between people may be quite successful, yet within the overall picture of the sociotechnical constituency it may be misaligned with respect to key technical factors.

An important aspect that facilitates alignment is that normally it needs not be all-inclusive or across the board. In practice, especially for large-scale initiatives, interacting parties are certain to find that they have alignments in some areas and misalignment in others. Behavioral concepts of non-operational and operational goals and means-end hierarchy of goals are useful in this context. Non-operational goals tend to be statements of purpose that are vague or do not specify the steps leading to their achievements, such as seeking to increase an organization's profit, market share, or general competitiveness.[56] On the other hand, operational goals, or subgoals, are those that provide detailed guides for actions. Non-operational and operational goals are related to each other. Herbert Simon, for instance, describes a means-end hierarchy of goals in which each level is to be considered as an end relative to the levels below it and as a "means" relative to the levels above it. This means-end hierarchy, however, is seldom an integrated, completely connected chain. In fact, the connections between activities and ultimate goals are often obscure, leaving room for conflict and contradictions regarding both the goals themselves and the means chosen to attain them. The importance of these concepts is that they highlight both the fallacy of monolithic optimally integrated organizations, and the potential for co-existence between partial alignments and misalignments within the space of non-operational and operational goals or subgoals.

Equally important is the fact that perceptions and goals are seldom well-defined static inputs which, if they fit into a satisfactory arrangement, bring about stable and permanent alignment. Not only is a constituency's environment always changing, but also, especially at the start of a technological process, it is unlikely that all the players will have clear interests and goals. A more dynamic view acknowledges that perceptions and goals, at different levels, may in fact be altered and created along the players' interaction, thus making possible both accommodation and alignment-building. Of course, it is also likely that what started with a genuine alignment of perceptions and goals may evolve into a misalignment later on. What matters here is that a constituency-building process has two major paths to facilitate alignment:

- the space for co-existence of different goals, encompassing interactions between collaboration and competition, except in the special case in which completely antagonistic goals destroy the entire process or lead to the withdrawal of at least one of the contending parties;
- the changeable nature of goals and perceptions, potentially allowing for the generation of alignment where initially there was none.

Programmatic Alignment in the European Context

When relations of power and authority exist among players, the resulting governance may guide and even facilitate a process of alignment or decision-making. For instance, "dominant coalitions," referring "to those who collectively happen to hold most power over a particular period of time," and hence constitute "the immediate source of major structural variation in organizations," have been identified within organizations.[57,58] In large-scale constituency building, however, existing governance shows no such clear source of power and decision-making. There is no ready-made organizational model for the initiative and few formal relations between different players. The governance of the EC R&D programs has certain rules, but the organization itself can only be an outcome: something to be created and shaped through creative consensus.

This task, however, is often quite complex. For although alignment may exist on a non-operational goal, processes such as OMI's that involve competing interests generally originate in situations of misalignment in both perception and operational goals. In Europe, language differences make this process more difficult. In addition, in the broader context of R&D programs, there is the risk of effective opposition even at non-operational levels. Normally, conflicting perceptions as to how the EC's resources should be invested exist, and the larger the scale of an initiative, the greater the players' concerns, and the greater the scrutiny it is likely to invite. This makes large-scale constituency-building a very demanding and time-consuming task. Success may reward those who, within the available time and resources, are able to generate the alignment of a sizable and credible array of forces behind a program that is both technically and politically feasible.

In practice, several outcomes are possible as players engage in programmatic alignment. First, an emerging constituency-building process may fail to solve critical misalignments between potential institutional constituents, and may falter and eventually disappear. Antagonistic competitive cases are the most typical examples of such failure.

Second, an emerging constituency is able to attract many key European players who develop an interest in the initiative and try to shape it in accordance with their own perceptions, expertise, interests, and goals. In this case, the initial state of non-alignment and misalignment gives way to alignment, with the initial program changing to reflect the incorporation or alignment of new interests. The broader programmatic alignment often represents the best possible constituency-building solution available at that time.

Key aspects of the strategy and goals of an emerging constituency-building process are challenged by other European players who promote competing visions and technologies. If the emerging constituency has already established enough momentum and cannot be stopped, one of two situations may develop: Either no alignment is found and the opposition is not strong enough to impose fundamental changes, in which case the opposition drops out, or at least partial alignment is found and the competition abandons its objection and joins the constituency-building process on the basis of partial alignment, thus gaining the opportunity to shape the course of its development.

What will determine the development of one course over another is extremely difficult to predict. All constituency-building depends on specificity, idiosyncrasy, and contingency. The means, tactics, and alignment-solutions generated in one-constituency-building process will reflect this condition.

OMI Constituency-building Process: The Public Phase

Two British constituencies — the transputer and the ARM constituencies — had aligned themselves and their microprocessor technologies and were trying to mobilize a European endeavor prior to the announcement of the OMI in Brussels. Initially, most of the progress was the result of negotiations involving companies that already had cooperative ties. The perception that the effort was European was principally due to the participation of both SGS-Thomson and Olivetti. In particular, SGS-Thomson was firmly behind the transputer constituency and was willing to exercise its considerable influence in the European Commission. Contacts with the Commission had been established, and there was a willingness to support the attempt within the context of the R&D program ESPRIT. An alignment with ESPRIT's governance was then needed, requiring the acceptance of the ESPRIT rules for projects, and the opening of the constituency-building process to all key European players in the microprocessor industry. A broader programmatic alignment that would include competitors was required, since consensus was a central factor in Brussels. The mechanism that was implemented for this purpose was a series of Industrial Working Group (IWG) workshops. For the transputer/ARM constituents this was a time of considerable uncertainty. But with momentum already gathering, they expected the workshops to lead to the launch of an official EC initiative in microprocessors.

A discussion of the dimensions in the "diamond of alignment" in Figure 1 will illustrate the challenge faced by the players at the start of the workshops. Clearly, the dimensions overlap in the overall process of sociotechnical alignment.

In the industrial trends and standards dimension, the initiative was broadly aligned with the evolution of the microprocessor industry towards RISC architecture. RISC represented the immediate trend and window of opportunity in a market that was dominated by both Intel's and Motorola's proprietary CISC architectures. The embedded control market, which included products such as laser printers and automotive and telecommunications products, was of particular interest because it was growing fast and was much less subject to domination by companies that controlled huge bases in operating systems and applications software. In terms of computers, the most promising market was the dynamic workstation market, in which, in the late 1980s, the RISC architectures SPARC and MIPS were rapidly building constituencies. The strategic question for the European constituency was whether or not to target the embedded control market, the computer market, or both. A second strategic question was whether the initiative should concentrate exclusively on the current RISC architectures or on a post-RISC architecture as well.

In the collaborating and competing technologies dimension, the initiative aimed to include not just microprocessor hardware, but all technologies required to support the development of chips. These include operating system and applications software, design tools, and peripheral logic that enables the construction of microprocessor systems either on boards or on chips. Since the initiative had to support competing microprocessor architectures, the programmatic alignment involved all four types of technology issues: obligatory and non-obligatory complementarity, as well as antagonistic and non-antagonistic competitive. The most difficult alignment challenge was to achieve a meaningful accommodation for competing microprocessor architectures. This implied non-antagonistic competing technologies and required an evolution of perceptions from a mere competitive stance to one of competition and collaboration.

In the dimension of players' perceptions and goals, the initiative's most difficult alignment involved the competing microprocessor constituencies. If a European initiative was to exist at all, an evolution from a mere competitive stance to one of competition and collaboration was required. Differences in expertise, market visions, short-term pressures, suspicion, and fear all played a part in this process. For instance, the originator constituents were suspected of mounting the initiative as a ploy to obtain European resources for themselves. They, on the other hand, felt threatened by some of the criticisms and actions of other semiconductor players. These misalignments manifested themselves in the strategic issues of target markets and whether long-term work on a future post-RISC architecture should be a central part of the initiative. The originator constituents wanted to target both the embedded control and computer markets, whereas other players wanted to target the computer market only. On the issue of future architectures, the originator-constituents were strongly supportive of such work, while other semiconductor companies tended to oppose it.

As far as inter-organizational governance was concerned, the initiative had to develop its own governance in alignment with those of the EC's R&D programs. For instance, consensus, collaboration, and the meeting of deadlines were all achieved through the mechanism that threw the alignment process wide open in Brussels: the series of Industrial Working Group (IWG) workshops fostered by the Commission. "The reason for the workshops is to start making progress towards a plan but, of course, as much a reason as anything is to bring people together, and get them to talk to each other," is how one player described the purpose of the workshops.[59] In the workshops, however, the constituency-building process becomes open and every European player with an interest is entitled to participate and have his say for or against an emerging constituency. Thus, workshops can be both rewarding and risky constituency-building mechanisms and may lead to the rapid expansion of an emerging constituency, or even its demise.[60]

The entire process had to react to the ESPRIT time frame. If successful, the final program would be submitted to the Commission for approval during the first half of 1991 and would become part of the 1991 ESPRIT Work program. This would be followed by a call for specific project proposals, which was estimated to take place by mid-1991. The first projects would start around November of the same year.[61] It would be more than 2 years from the time that the originator constituents made the first contact with the Commission in late 1989. The time frame was set by the governance of the ESPRIT program and constrained by the process of consensus-building. Of course, the compensating factor was the potential scale of the initiative, which, ideally, would ensure a speedy diffusion of the technology when it reached the market. It was important not to miss the deadlines imposed by the time frame, since this would put the efficacy of the whole process in doubt.

For the emerging OMI constituency, it was no different. The series of workshops that occurred in 1990 attracted not only the support of some players, but also the scrutiny, criticism, and opposition of others. Of course, the groundwork and progress already achieved by the originators made it difficult for any alternative scenario to succeed. It was more likely that a modification of the original proposal would be found acceptable as the parties transformed pure confrontation into collaboration and competition.

The Play at the Start of the Workshops

As players' positions converged in the workshops, important pieces of the constituency-building game were in place. In particular, all players were aligned at the level of strategic goals: all wanted Europe to possess an autonomous microprocessor capability. Taking advantage of this consensus the two microprocessor constituencies of European origin joined forces, and kept control of the development of a concrete proposal.[62] A key technical element was the development of hardware and software, including design tools, to interface both the ARM and the transputer. This produced the alignment of the two initiator constituencies, with Europe potentially being able to provide silicon systems incorporating one or more of these processors at a future date.

In sociological terms, the transputer and the ARM had made the European Microprocessor Initiative (EMI) proposal an "obligatory point of passage," simultaneously ensuring for themselves an advantageous position to shape the course of the large-scale initiative.[63] Most importantly, these two aligned constituencies had succeeded in establishing two projects that were spearheading the initiative with the support of the Commission: project GP-MIMD (General Purpose Multiple Instruction Multiple Data) and project EMI-MAP (European Microprocessor Initiative Microprocessor Architecture Project). The aim of GP-MIMD was the development of a standard parallel-processing machine architecture and standard applications support interfaces. The main aim of EMI-MAP was to initiate long-term efforts by defining an architecture for scaleable general purpose parallel computing.

The other potential alternative constituencies offered nothing similar. The alternatives offered by ACRI (Advanced Computer Research Institute), a company created in November 1989 by J. Stern (ex-President of Groupe Bull), was a powerful supercomputer to be developed by 1993. ACRI argued that a single architecture was needed for the entire data processing market, totally disagreeing with the Inmos/Acorn view that a single architecture could effectively serve the entire microprocessor market.

The most powerful challenges, however, came from Philips and Matra SPARC microprocessor, and from Siemens MIPS Rx000 (R-thousand) microprocessor. These two microprocessors, both RISC architectures of U.S. origin, were not included in the original EMI proposal. The misalignment was produced by Philips wanting the SPARC microprocessor to be the central architecture for a European microprocessor initiative. Siemens wanted to protect its investment in MIPS and was hardly in a position to accept an EMI proposal centred around the interlinking of the transputer and the ARM only. Siemens, unlike Philips, had joined both EMI spearheading projects. The reasons for misalignment were clear, as was the path to alignment: spaces would have to be opened to accommodate the non-European architectures. Thus, a programmatic alignment would be based not on an EMI, but on an Open Microprocessor Initiative (OMI).

Sociotechnical Alignment through Open Systems in Microprocessors

Open systems, e.g. inter-connection and operation of systems regardless of make, is a well-established trend in the computer industry, although it has not yet reached silicon chips. Indeed, separate paths for the development and diffusion of different commercial architectures has been a central characteristic of the microprocessor industry and market. Increasing integration towards the 100 million transistor chip, however, is likely to favour the spread of open systems down to the microchip level.[64]

In 1990, the players in the misaligned positions faced each other in the IWG workshops. The complete picture is complex, including bi-lateral exchanges and the use of personal contacts and relationships in various attempts to influence the process. The aim was to achieve a workable goal-alignment within the time restrictions imposed by the governance of the ESPRIT R&D program. Thus, the misalignments had to be resolved, even though the conflicts were not minor. As to perception, the problem was one of distrust and suspicion about the ulterior motives of the transputer and ARM endeavour. Both Philips and ACRI, for instance, had come to believe that the EMI effort was more about obtaining money for the transputer and Inmos than about the pursuit of a European capability, an interpretation that key transputer and ARM proponents of course did not accept. The point is that these misalignments did exist at the start of the EMI IWG workshops, and that they did influence the attitudes of the groups towards each other. A lot depended on the constituency-building abilities of the leading players in the initiative.

As the EMI constituency-building process unfolded in Brussels, ACRI's perceptions, vision, and goals came face to face with those of the transputer/ARM constituents. At the time, ACRI was a young company and had not yet developed enough clout to create major changes in the development of a large-scale project such as the EMI. Yet this antagonistic competitive stance seems to have been preferred by ACRI. In particular, ACRI's perception that EMI was exclusively about the transputer seems to have discouraged any effective search for alignment spaces.[65]

Where ACRI publicly proposed its architectural approach as an alternative, it found that the momentum of the transputer/ARM-led proposal was too great. Most importantly, ACRI had done little grassroots constituency building and their alternative received almost no attention in IWG workshops. Since even a discussion in a workshop would have, at least momentarily, derailed the constituency-building already established, nobody objected when members of the transputer and ARM constituency argued that ACRI could not expect to redirect the discussion at such a late stage in the process. Not surprisingly, ACRI representatives did not play any noticeable part in the few Brussels IWG workshops that followed the presentation of their alternative.[66]

Constituency-building in Brussels attracted a variety of players with a variety of motives. Some found that they wanted to transform an emerging constituency, others eventually found it antagonistic to their own aims. As one participant stated, "I'd be looking at the process in its own right, how can that initiative be useful and successful, or, how can it be killed if it's not going to be?"[67]

Whether a person plays the role of constituency-killer or constituency-builder depends on the perception he or she develops as to the potential benefit of the constituency. Some players may change their perceptions in the process. In the case of the EMI, one of the most revealing occurrences was the conversion of a very active player from a potential constituency-killer into a forceful constituency-builder. The initial perception of this player was similar to that of Philips and ACRI: the Franco-Italian semiconductor company SGS-Thomson, after acquiring Inmos, wanted money to fund Inmos and the transputer through ESPRIT.

However, as contacts were made with the EMI constituency-building process in Brussels, it became clear that he "could not go against history, or to kill this activity because politically, there was too much force behind it."[68] Furthermore, he began to develop a positive perception of the benefits that a European microprocessor initiative would provide. A process of goal and perception alignment had begun.

"I saw a lot of people who were actually very interested in doing something. I felt that if I could convince them that if they could produce something really useful, they could actually make even more money."[69] This "something really useful" was also an opportunity to advance the interest of his own organization. As another EMI participant observed, "I think he just decided that the power of a constituency like the EMI forming would give him enormous sort of leverage to the kind of work they were doing."[70]

An important contribution by the new constituent was that he perceived and promoted the critical importance of involving microprocessor users in the early shaping of the initiative. He felt that the original proposal was about just another microprocessor. He tried therefore, to steer the plan into a much more application-driven direction.

In retrospect he believes that the initial perception and reaction of the ARM and transputer constituents to his efforts was not favourable. They were afraid that he was trying to realign the initiative away from their own goals.

"I think there was fear in the minds of Acorn and Inmos that they couldn't see anything else. If I went to a meeting, or something, they were very happy if somebody else went in my place. It was real fear."[71] Although there was a misalignment of perceptions, there was no real misalignment of goals. Thus, "Out of all of the people, Inmos was the company who I saw wanted to make money in this thing. It meant moving them away from transputer to something else. That was my goal, and I think after a lot of hassling, and heated discussions, and so on, they really did come around to that concept."[72]

An important element in eliciting this alignment was the position taken by the many other players in the process. In effect, once the initiative went to Brussels, consensus was going to be the dominant decision-making mechanism. Thus, aligning a majority behind a particular position would almost certainly oblige other players to give careful consideration to the benefits of that position.

"So what we did, a few of us, I got in touch with a few people in the systems company. And a lot of these people started saying the same thing, and people from the business world, office and business systems, were saying the same thing. And so, this is how this activity started moving away."[73]

Of course, Inmos and Acorn may have a different account of the evolution of the EMI process. Indeed, it can be argued that they were interested in the participation of users from the very beginning. This particular player, however, strongly promoted the "embedded-control" side of the Initiative, and, from this viewpoint, his account seems to fit the evolution of the original proposal towards embedded-control applications.

The most critical case of misalignment involved all of the European semiconductor manufacturers. The change of a word in the Initiative's name from European to Open reflected a major realignment of the strategic direction and its technology.

The beginnings of open systems go back to the first meeting between the transputer and ARM constituents with the Commission in October 1989. It was clear that the original proposal had little in it to align the interests of Siemens and Philips. Following this meeting, a new section was added suggesting technical paths for interfacing the transputer and ARM with both SPARC and MIPS. Basically, the same solution linking the ARM and the transputer was being extended to link the European to the U.S.-originated architectures. Admittedly, the alignment still revolved around the transputer and the ARM. But, an opening was made and further evolution was possible. Siemens and Philips approached this situation differently, particularly because Philips' vision of an EMI was more narrow and short-term. Siemens, on the other hand, was able to be more flexible and allowed room for alignment.

As the largest electronics company in Europe, Siemens is involved in many European projects. In the case of EMI, however, Siemens' involvement was not without difficulties, given their position as a MIPS constituent. Siemens had considered the transputer in the past and had taken the decision "not to cooperate on the transputer, mainly because it was not Unix compatible."[74] Siemens' position was made clear in the following quote:

We explained that if EMI is only transputer, we will not participate in the future. It never will be a European solution. It's a company specified solution, with all its advantages, but, if we say it is a European Microprocessor Initiative, then it cannot be only a transputer one, because SPARC, or MIPS, or DEC Alpha, whatever, are well established in very important European systems equipment, and they have essential advantages in some applications. EMI is never acceptable to us if it is really one or two systems.[75]

This left Inmos with little choice. If they wanted to encourage Siemens' alignment they had to respond to this concern:

I suggested to them that, in terms of the shorter term activity, there would be no harm at all, and potentially quite a lot of benefit, from having interfaces between Inmos links and MIPS processors because, again, just like the ARM they are logical. And there are very, very few applications for which you'd actually have difficulty deciding whether to use MIPS or a transputer.[76]

In other words, the technical links acted as the political bridges through which Siemens could join the EMI process, while still being a member of the MIPS constituency. For Siemens, this techno-political solution was reasonable: it incorporated the company's shorter-term interests, and the work on the future architecture offered the possibility of a more powerful processor by the late 1990s. In addition, the features being envisaged for this longer-term processor fit well with the trends in the microprocessor industry. At the same time, none of this precluded Siemens from licensing any new processor that was developed in the meanwhile.

As a result, Siemens did join very early in the activities leading to the formulation of the Initiative. Of course, in EMI-MAP, the microprocessor work is led by an Inmos/ARM team. Thus, although Siemens' involvement clearly reflects a degree of alignment between the parties, Siemens would be more comfortable if the work for the next generation architecture was in the hands of a more neutral party. Indeed, during an OMI workshop in October 1990, Siemens did put forward the proposal that "Research/university institutes investigate system requirements and architectural concepts for a new, post-1995 ("next generation") microprocessor."[77] This proposal, however, never became a serious issue. Siemens was in misalignment with the goals of the transputer and ARM constituency and with the purpose of the EMI-MAP project itself. By playing the MIPS card Siemens was simultaneously in a position to consider, and even promote, this architecture as an alternative for the microprocessor of the future.

The same solution that allowed for the technical interface of the MIPS microprocessor and the political alignment of Siemens was suggested to Philips in relation to the SPARC and the future processor. But Philips' perceptions and vision were at the time dominated by a crisis mentality in which longer-term concerns had little place. Understandably, Philips representatives tended to stick to their short-term strategy, trying to make the

SPARC architecture the centre of the initiative. The problem was that this approach was plainly antagonistic, offering no space for alignment, particularly to the originator constituencies. Philips contended that the proposed initiative's next-generation microprocessor was nothing but a continuation of the transputer, and hence a misguided activity as far as the RISC workstation market was concerned.[78] The perception was that Inmos had already cornered the EMI-MAP project for the transputer and, consequently, the new architecture was almost bound to be shaped in the direction of this technology.

The E1 (code name for the future microprocessor) is totally directed towards the transputer, which is a waste of money for me. OMI is actually putting on silicon the design idea of what OMI-MAP would say. So, it's all locked. This is of no interest for us. (And as far as influencing OMI-MAP is concerned) I would say wishful thinking. Yes, we have no power, they get the contract, they do what is written on the contract, they get the money, they do what they please.[79]

Of course, unlike Siemens, Philips had remained outside EMI-MAP altogether. The feeling of exclusion, then, was probably strong. On the other hand, the company was promoting a shorter-term strategy and effectively excluding itself from the process of shaping any longer-term future microprocessor. Not surprisingly, Philips was much more comfortable with the idea that the OMI should not be concerned with future microprocessors since this was a decision best left to each company. "It is up to everybody to try to have their own solution, be it transputer, be it SPARC, be it MIPS. I don't want to pay for a microprocessor of another kind."[80]

This position was not much of a base for rapid programmatic alignment within the emerging constituency. Unlike ACRI, Philips did carry a great deal of clout within the Commission, and there was a tacit acceptance that the company could not be left out. Seemingly, Philips realized this as well and tried to move the initiative their way. Philips grassroots work, however, was not as effective as that of the transputer/ARM constituencies and, indeed, tended to rely on the company's political clout. The result was a protracted argument in one IWG workshop after another until the process was exhausted by the end of 1990. SPARC failed to capture the Initiative but became one of its important constituent processors. Unlike Siemens, however, Philips stuck to its shorter-term goal. Their alignment was in the area of inter-processor communication between existing architectures. In this respect, a new component called Heterogeneous Inter-processor Communications (HIC) became for Philips the critical technical constituent allowing for the accommodation of all players within the Initiative.

The only thing which should be funded by Brussels is the inter-processor communication, because that's the only thing which is unifying people. A common viewpoint would be to have all C1 [code name for the HIC] and zero E1, that would be the ideal, that would be the most constructive part, because it is not paying for anything else than the exchange basis for everybody's solution.[81]

Obviously, this would be too narrow a viewpoint, and not likely to keep the emerging OMI constituency together. Eventually, Philips representatives accepted this reality and accepted the development of a new-generation architecture, proposed early on by the transputer and ARM constituency although they did not become involved in its development.

The protracted negotiations with Philips interfered with the process of programmatic alignment of the initiative. At times, it was clear that the players were beginning to be impatient with Philips and its position, particularly the transputer and ARM constituents. Philips was perceived as delaying and threatening the Initiative. Later Philips' representatives became increasingly isolated in the workshops.[82] Philips, however, believed that it was articulating the unspoken feelings of those who remained silent.[83] Philips representatives eventually realized that they were in the weaker group which may be why they dropped their antagonistic positioning of SPARC and their objection to work on the future microprocessor.

It was widely known that the deadline for consensus was late 1990. If this deadline was missed, the Initiative would lose a year and, in all probability, would fail altogether. In this context, it was the chairman of the task force, entrusted by the Commission to steer the OMI process, who drove home the message. "[He] concluded one meeting by saying that unless the main parties could reach some accord, then the whole thing was about to die — it was a very serious moment!"[84] This choice of align-or-perish had a positive effect. Nobody, including Philips, wanted the OMI to die. Thus, when the chairman of the task force presented this choice towards the end of 1990, everybody realized that time for antagonism was over and that consensus had to be achieved.[85] The programmatic alignment achieved in late 1990 satisfied the goals of all key European microprocessor constituencies.

Had the role of Philips' representatives then been a futile exercise? Not necessarily. Philips played the role of the devil's advocate by questioning the wisdom of the transputer and ARM initiative. This may have caused delay, and even hostility at times, but it also raised many difficult and important questions that any Initiative has to face. Ultimately, it only strengthened the quality of the Initiative. Philips did embrace the Initiative in the way Siemens did. In the process, the change of the EMI into the OMI was reinforced.

Implicit in the acceptance of non-European architectures such as MIPS and SPARC was the strategic re-alignment from a European to an Open initiative. The first step was Inmos' proposal to use the Inmos links to interface the non-European processors to the transputer, thus expanding interprocessor communication beyond the ARM and, hence, Europe. However, this solution did not prove to be the final aligning factor. It was still centered around Inmos and the transputer. During the IWG workshops, it became apparent that players such as Groupe Bull were also in possession of very advanced link technology. An alignment was found in the definition of the new HIC, which would support the Inmos links as one option among several others. The HIC was to take the concept of inter-processor communication to a new level by enabling communication among all processors, not just around the transputer.[86]

The HIC is a European aligner component and, in this respect, an example of technology through European integration and vice-versa. It was not contained in the original proposal. Its purpose is not only to bridge the present architectures, but also to build bridges between the present architectures and those of the next generation as well. As described in the final OMI proposal, the objective of this aspect of the initiative is "to specify and promote an overall architecture and a high performance interface standard to allow interworking between existing *accessible* microprocessor architectures, as well as the O1 [previous E1 code name for the new generation architecture]. The connection architecture may have several different physical implementations."[87] In this definition, the term accessible is an important one, since some architectures now on the market (e.g., Intel's 80 × 86) are not licensed. As a result, the technical details necessary to establish the interface are not readily available.

In contrast, technical details of both SPARC and MIPS are readily available through licensing by Philips and Siemens. This explains why the HIC is about these two existing non-European architectures.

For the time being, the HIC technically crystallizes the state of development of the OMI constituency. It is a revealing reminder of the Initiative's strategic evolution — its interactions, conflicts and alignments — towards technical as well as institutional openness.[88] It is an evolution that would enhance the OMI constituency's chances for success in several ways. In addition, OMI user-constituents stood to gain a great deal. They would eventually have a choice of components and the capability to combine them into customized chips, giving them the best functional performance for their specific needs. For European producers of microprocessors, this was also an opportunity to build the technical bridges that might eventually become the paths facilitating the migration of institutional members. Of course, bridges may lead in two directions and emigration rather than immigration is also a possibility. Such a threat was expected to spur the European constituents on to better performance, thus energizing the development of the initiative as a whole. Finally, the Initiative truly became the first declared attempt to take the concept of open systems down to the level of the silicon chip; this had the potential to induce a radical shift in the global microprocessor market. Now, Europe is taking the lead towards an open-systems capability that could potentially combine different architectures on a single chip.

Conclusions

The primary conclusion one could draw from the OMI experience is that it was a consensual alignment case of constituency-building. No dominant coalition was present to facilitate the process of alignment and the success of the initiative could only be created and achieved through negotiation and consensus.

Second, the entire process of programmatic alignment is multi-dimensional in the sense illustrated by the "diamond of alignment." OMI provided *satisficing* solutions to all of the diamond's dimensions. Thus, there was identifiable alignment with the governance of the fostering organization on three counts.

The third recognizable aspect pertains to possible outcomes of constituency-building processes in Brussels. The Initiative was able to attract many European players who developed an interest in carrying it out and, simultaneously, tried to shape it in accordance with their own perceptions, expertise, interests and goals. At the same time, the early strategy and goals of the constituencies that originated the Initiative were challenged by other European players who promoted competing visions and technologies. The result was a substantial evolution of the original proposal reflecting the sociotechnical alignment of a much broader set of interests.

A fourth lesson that can be drawn from the OMI experience is that, from start to finish, a range of constituency building factors played a key part in the successful evolution towards programmatic alignment. These factors are mostly behavioural in character and are part of a more general process of effective constituency-building of large-scale initiatives.

All these constituency-building efforts contributed to the OMI's successful evolution towards programmatic alignment. The achievement however, demanded the implementation of a more concrete set of alignment tactics and techniques, particularly during the workshop phase of the OMI. The key is to generate a climate of positive thinking. There seems to be a subtle psychological transition from making positive contributions to the discussion to becoming active members of the constituency. As a rule, the more the expertise/visions/interests of contributors become part of the program, the more the program is likely to become part of the contributors. The difficult part is to make the contributions converge into a manageable and realistic program, while staving off negative and diversionary moves.

The OMI successfully reached programmatic alignment in mid-1991 and entered the difficult stage of delivering its promise. The first call for proposals for the initiative was issued in the last quarter of 1991. All major players submitted proposals filling the aligned spaces that they had created for themselves during the formulation of the program. The expert evaluation took place in late 1991 and the first projects started in earnest in the first half of 1992. The OMI was off the ground with an EC funding of ECU65 million (about U.S. $80 million).[89]

About a year later, in mid-1993, The OMI issued a second call for proposals, which generated a fairly high response. As a result, in 1994 the membership of the OMI constituency increased substantially to over 140 companies and universities grouped around more than 40 projects. The total commission funding for the Initiative had increased to over ECU100 million. With the start of the EC's Fourth Framework Program at the end of 1994, the OMI attracted a further ECU172 million of EC funding for the period 1994-1998. Most significantly, the Initiative also established a strong reputation for policy success in European R&D programs. As a result, other large-scale, targeted initiatives have developed and may benefit from the model established by the OMI.

Notes

1. A. Molina, "In Search of Insights into the Generation of Techno-Economic Trends: Micro- and Macro-Constituencies in the Microprocessor Industry," *Research Policy*, Vol. 22 (1993), pp. 479-506.
2. Today, microprocessors come in two broad classes known as CISC (Complex Instruction Set Computer) and RISC (Reduced Instruction Set Computer). CISC architectures grew with the computer industry and over the years have become very complex as designers added more and more instructions to the microprocessor's instruction sets. In contrast, RISC microprocessors came on the market only in the mid-1980s. The RISC concept reduces to a minimum the number of instructions. Infrequent instructions are generated through a combination of the simple instructions available. Technically, the overall expected result is a more efficient and faster computation by RISC as compared with CISC. RISC is a challenge to the well-established dominance of the market by CISC.
3. "In 1988, European imports of microcomponents (i.e. general purpose microprocessors, microcontrollers and peripheral logic) totalled $992 million (representing 82% of the European market)." ESPRIT Industrial Working Group, *Open Microsystems Initiative, 1991 Workprogramme* (IWG Plan December 5, 1990, ESPRIT, Brussels), p. 4.
4. European IT collaboration started in earnest with the launch of ESPRIT (European Strategic Programme for Research and Development in Information Technology) in 1984. Experience in large-scale initiatives, however, was limited to programs such as RACE (Research and development in Advanced Communications Technologies in Europe), started in 1987, and JESSI (Joint European Submicron Silicon Initiative), started in 1989. Unlike RACE's focus on the entire telecommunications network and JESSI's on process technology, the focus of OMI is primarily on product technology.
5. M. Carpentier, "After Maastricht: Filling in the New Electronics Policy Framework," *XIII Magazine*, Vol. 5 (March 1992), p. 3; Commission of the European Communities (C.E.C.), *The European Electronics and Information Technology Industry: State of Play, Issues at Stake and Proposals for Action* (Brussels: C.E.C./DGXIII, 1991).
6. A. Molina, The Socio-Technical Basis of the Microelectronics Revolution: A Global Perspective, Ph.D. Thesis, 2 Vols (Edinburgh: Edinburgh University Press, 1987). A. Molina, "Transputers and Transputer-Based Parallel Computers: Sociotechnical Constituencies and the Build-Up of British-European Capabilities in Information Technologies," *Research Policy*, Vol. 19 (1990), pp. 309-333. Molina, *op. cit.* (1993).
7. The sociotechnical school of thought has a long tradition that can be traced back to Marx and his dialectical materialist analysis of the development of productive forces/social relations of production within capitalism. Since then, many scholars have understood technology not only as a social process involving devices (i.e. tools, machines, products), people, organization, and procedures, but also as a process inseparable from society at large. In this view, society and technology reciprocally influence each other's development. For Marx's conceptualization of science and technology, see D. MacKenzie, "Marx and the Machine", *Technology and Culture*, Vol. 25 (1984), pp. 473-502; R. Mishra, "Technology and Social Structure in Marx's Theory: An Exploratory Analysis," *Science and Society*, Vol. 43 (1979), pp. 132-157; and N. Rosenberg, "Marx as a Student of Technology," *Monthly Review*, Vol. 28 (1976), pp. 56-77. A brief review of some important contributors to the sociotechnical tradition is found in Molina, *op. cit.* (1987). The work of the Tavistock Institute in the 1950s is often associated with the concept of socio-technical systems as an attempt to deal with the relations between the technical and human aspects of work organization. See E. Trist and K. Bamforth, "Some Social and Psychological Consequences of the Longwall Method of Coal Getting," *Human Relations*, Vol. 4 (1951), pp. 3-38.
8. W. Bijker, T. Hughes and T. Pinch (eds), *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology* (Cambridge, MA: The MIT Press, 1987); W. Bijker and J. Law, *Shaping Technology/Building Society: Studies in Sociotechnical Change* (Cambridge, MA: The MIT Press, 1992); D. MacKenzie and J. Wajcman (eds), *The Social Shaping of Technology* (Milton Keynes: Open University Press, 1985).

9. D. Marsh and R. Rhodes (eds), *Policy Networks in British Government* (Oxford: Clarendon Press, 1992). M. Wright, "Policy Community, Policy Network and Comparative Industrial Policies," *Political Studies*, Vol. 36 (1988), pp. 593-612.
10. B. Elzen, B. Enserink and W. Smit, "Weapon Innovation: Networks and Guiding Principles,"*Science and Public Policy*, Vol. 17 (1990), pp. 171-193; B. Latour, "The Prince for Machines as well as for Machinations," in B. Elliot (ed.), *Technology and Social Process* (Edinburgh: University of Edinburgh Press, 1988), pp. 20-43. J. Law and M. Callon, "The Life and Death of an Aircraft: A Network Analysis of Technical Change," in Bijker and Law (eds), *op. cit.* (1992), pp. 21-52. Marsh and Rhodes (eds), *op. cit.* (1992). K. Mulder and P. Vergragt, Social Networks as an Explanation for Different Technological Strategies, paper presented to 4S Conference (Irvine, CA: November 1989). Wright, *op. cit.* (1988).
11. T. Hughes, *Networks of Power: Electrification in Western Society, 1880-1930* (Baltimore, MD: The John Hopkins University Press, 1983); T. Hughes, "The Seamless Web: Technology, Science, Etcetera, Etcetera," *Social Studies of Science*, Vol. 16 (1986), pp. 281-292. W. Shrum, "Scientific Specialties and Technical Systems," *Social Studies of Science*, Vol. 14 (1984), pp. 63-90.
12. See J. Law, "The Anatomy of a Socio-Technical Struggle: The Design of the TSR2," in B. Elliot (ed.), *Technology and Social Process* (Edinburgh: Edinburgh University Press, 1988), pp. 44-69.
13. See T. Pinch and W. Bijker, "The Social Construction of Facts and Artefacts: or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other," *Social Studies of Science*, Vol. 14 (1984), pp. 399-441.
14. See D. MacKenzie and G. Spinardi, "The Shaping of Nuclear Weapon System Technology: U.S. Fleet Ballistic Missile Guidance and Navigation: Part I: From Polaris to Poseidon," *Social Studies of Science*, Vol. 18 (1988), pp. 419-463; and "Part II: Going for Broke — The Path to Trident II," *Social Studies of Science*, Vol. 18 (1988), pp. 581-624.
15. M. Callon, "Some Elements of a Sociology of Translation: Domestication of the Scallops and the Fishermen of St. Brieuc Bay," in J. Law (ed.), *Power, Action and Belief: A New Sociology of Knowledge?* (London: Routledge & Kegan Paul, 1986), pp. 196-233.
16. R. Kaplinsky, *Automation: The Technology and Society* (Longman, London, 1984); D. Noble, *Forces of Production: A Social History of Industrial Automation* (New York, NY: Alfred Knopf, 1984).
17. Hughes, *op. cit.* (1983). D. MacKenzie and J. Wajcman (eds), *The Social Shaping of Technology* (Milton Keynes: Open University Press, 1985). Law, *op. cit.* (1988), pp. 44-69. N. Rosenberg, *Perspectives on Technology* (Cambridge: Cambridge University Press, 1977).
18. C. Raab, "Taking Networks Seriously: Education Policy in Britain," *European Journal of Political Research*, Vol. 21 (1992), pp. 69-90. For C. Freeman, network activities are not new, they have long been part of industrial practice. The difference is the much wider scale of the networking processes of recent times due to the diffusion of the information technology techno-economic paradigm. See C. Freeman, "Networks of Innovators: A Synthesis of Research Issues," *Research Policy*, Vol. 20 (1991), pp. 499-514.
19. In a special *Research Policy* issue on networks, DeBresson and Amesse argue for the incorporation of transaction-cost analysis in network approaches. See C. DeBresson and F. Amesse, "Networks of Innovators: A Review and Introduction to the Issue," *Research Policy*, Vol. 20 (1991), pp. 363-379. For transaction cost analysis, see O. Williamson, "Transaction Cost Economics: The Governance of Contractual Relations," *The Journal of Law and Economics*, Vol. 22 (1979), pp. 233-261. On the other hand, Law and Callon, *op. cit.* (1992), have distinguished between global networks and local networks in their analysis of the shape and fate of technological projects. And Callon *et al.* have distinguished several types of techno-economic networks: incomplete or chained, convergent or dispersed, and short or long networks. See M. Callon, P. Laredo and V. Rabeharisoa, "The Management and Evaluation of Technological Programs and the Dynamics of Techno-Economic Networks: The Case of the AFME," *Research Policy*, Vol. 21 (1992), pp. 215-236.
20. Law, *op. cit.* (1988).
21. The point has been made that it is necessary to move beyond just demonstrating heterogeneity. See K. Sörensen and N. Levold, "Tacit Networks, Heterogeneous Engineers, and Embodied Technology," *Science, Technology and Human Values*, Vol. 17 (1992), pp. 13-35.
22. The term "constituencies" is often found in the literature. By and large, however, it is used to refer to groups of people who are actual or potential players in the process of developing a technology.
23. It must be noted that the development of conceptual tools for the "sociotechnical constituencies" approach is a continuous process. In this sense, the approach is an unfolding program of research. For instance, other work has developed concepts to enable an integrated analytical treatment of techno-economic trends from product to industry. Also, initial work has been done to conceptualize

the role played by the specific nature of technology in the evolution of technological processes and industries. See Molina, *op. cit.* (1993). Also, A. Molina, ***The Formal Methods Constituency: Diffusion of an Emerging Technology into a High-Volume Industrial Environment*** (Edinburgh: RCSS, The University of Edinburgh Press, 1993a).

24. See R. Cyert and J. March, ***A Behavioral Theory of the Firm*** (Englewood Cliffs, NJ: Prentice-Hall, 1963). J. March and H. Simon, ***Organizations*** (New York, NY: Wiley, 1967) (1st edn, 1958). H. Simon, ***Administrative Behavior*** (New York, NY: The Macmillan Co., 1957).
25. Mulder and Vergragt, *op. cit.* (1989).
26. A. Molina, Technology Diffusion and RTD Programme Development: What can be Learnt from the Analysis of Sociotechnical Constituencies? *DGXII Occassional Paper* XII-378-94 (Brussels: C.E.C./DGXII-A/5, 1994).
27. Williamson uses the term "governance structure" to refer to "the institutional matrix or framework within which transactions are negotiated and executed. . .", Williamson, *op. cit.* (1979), p. 239. Governance is used here in the similar sense of the organization's framework guiding or influencing individual and collective interactions and associated program definitions.
28. The development of a given technology is not simply the result of an insular, intra-constituency process. It is also the result of that sociotechnical constituency's interaction with other sociotechnical constituencies. It is influenced, for example, by legislation and regulation and technical and market standards and trends which are themselves the result of interaction between sociotechnical constituencies (i.e. an inter-constituency process). Thus, technical and market standards (trends) are not really exogenous to constituencies: sociotechnical constituencies themselves create and alter them according to the extent of their relative strengths, dynamism and growth. On the other hand, it is true that once these trends gather momentum, they are likely to appear to many social constituents as an external force, a technology-shaping environment influencing the development and products of the constituency. This impression may be particularly strong where, for instance, institutions are trying to establish new products and standards in fields already occupied by strong competing constituencies. See A. Molina, *op. cit.* (1990).
29. S. Collinson, "Managing Product Innovation at Sony: The Development of the Data Discman," *Technology Analysis and Strategic Management*, Vol. 5 (1993), pp. 285-306.
30. J. Fleck, "The Effective Utilisation of Robots: The Management of Expertise and Knowhow," *Proceedings of the 6th British Robot Association Annual Conference* (Birmingham, May 16-19, 1983), pp. 61-9.
31. E. de Bono, *De Bono's Thinking Course* (London: BBC Books, 1991), pp. 38-39.
32. H. Leavitt, "Perception: From the Inside Looking Out," in D. Hampton, C. Summer, R. Webber (eds), *Organizational Behavior and the Practice of Management* (Glenview, ILL: Foresman & Co., 1968), pp. 155-161. Quotations on pp. 155 and 161.
33. Gleitman sees perception as one of the three domains of cognition-perception, memory and thinking, but it is clear that "[t]here are no clear boundaries that demark these three domains. In describing perception, we often cross over the border into memory. . . .But perception also shades into thinking. . . .Nor is it clear where memory leaves off and thinking begins," in H. Gleitman, *Psychology* (London: Norton & Co., 1991), p. 330.
34. E. de Bono, *Teaching Thinking* (Middlesex, Harmondsworth: Penguin, 1978), p. 95.
35. R. Evans and P. Russell, *The Creative Manager* (London: Unwin, 1990), p. 104.
36. Dearborn and Simon conducted a study on selective perception and found support for the hypothesis that industrial executives will perceive those aspects of a situation that relate specifically to the activities and goals of their department. "Selective Perception," in D. Hampton, C. Summer, R. Webber (eds), *op. cit.* (1968).
37. H. Simon, "A Behavioural Model of Rational Choice," *Quarterly Journal of Economics*, Vol. 69 (1955), pp. 99-118. J. March and H. Simon, *op. cit.* (1967). Also Cyert and March, *op. cit.* (1963) and Simon, *op. cit.* (1957).
38. Simon, *op. cit.* (1957), p. 79.
39. March and Simon, *op. cit.* (1967), p. 139.
40. *Ibid.*, p. 138.
41. "The way in which an individual perceives a technological problem and constructs an appropriate solution is a function of their culturally embedded cognitive framework and consequent subjective expectations about future states of the world." [M. Farmer and M. Matthews, "Cultural Difference and Subjective Rationality: Where Sociology Connects with the Economics of Technological Choice," in G. Hodgson and E. Screpanti (eds) ***Rethinking Economics*** (Cheltenham: Elgar, 1991), pp. 103-116. Quotation on p.114.]

42. "The frame of reference serves just as much to validate perception as the perceptions do to validate the frame of reference." [March and Simon, *op. cit.* (1967), p. 152].
43. See A. Filley, R. House and S. Kerr, ***Managerial Process and Organizational Behavior*** (Glenview, ILL: Scott, Foresman & Co., 1976). "It is more than just our thinking that it is conditioned by the past, the whole of our perception is unconsciously determined by what has gone before." Evans and Russell, *op. cit.* (1990), p. 89.
44. "In addition to perceiving what they expect to perceive, people also have a tendency to perceive what they want to perceive." Filley *et al., op. cit.* (1976), p. 62. Likewise, "Expectations are by no means independent of such things as hopes, wishes, and the internal bargaining needs of subunits in the organization." Cyert and March, *op. cit.* (1963), p. 81.
45. "As social psychologists use the term, an attitude is a rather stable mental position held toward some idea, or object, or person. Examples are attitudes toward nuclear power, the legalization of marijuana, school integration, or packaged breakfast food. Every attitude is a combination of beliefs, feelings, and evaluations, and some predisposition to act accordingly." Gleitman, *op. cit.* (1991), p. 459.
46. "People's perceptions are determined by their needs. . .[and]. . .both wishes and fears are important to one's needs." Leavitt, *op. cit.* (1968), p. 157.
47. According to Law, concerns may be quite detached from profit or market return, and they may be connected with a variety of discursive forms such as love, duty, fear and impossibility. Law, *op. cit.* (1988).
48. "As the name "inter-esse" indicates, "interests" are what lie in between actors and their goals, thus creating a tension that will make actors select only what, in their own eyes, helps them reach these goals amongst many possibilities." in B. Latour, *Science in Action* (Milton Keynes: Open University Press, 1987), pp. 108-109.
49. Fleck *op. cit.* (1983), p. 67.
50. T. Kuhn, *The Structure of Scientific Revolutions* (Chicago, ILL: The University of Chicago Press, Chicago 1962); G. Dosi, "Technological Paradigms and Technological Trajectories," ***Research Policy***, Vol. 11 (1982), pp. 147-162.
51. *Ibid.*, p. 153.
52. March and Simon, *op. cit.* (1967).
53. de Bono, *op. cit.* (1978), p. 41.
54. Satisficing is used here in Simon's meaning of the term.
55. Of course, there is always the possibility that some interacting parties may mistakenly perceive that they have an alignment of goals when this is not the case. Conversely, the possibility also exists that they may mistakenly perceive a mis-alignment of goals when, on closer scrutiny, this is not the case. The latter mis-alignment tends to occur when, for instance, distrust and suspicion about the ulterior motives of certain players color the perception of others.
56. March names them superordinate goals. See J. March, "The Business Firm as a Political Coalition," *The Journal of Politics*, Vol. 24 (1962), pp. 662-678.
57. A similar problem is identified by Nelson and Winter in relation to the firm, ". . .to understand the behavior of the firm as a whole in terms of the divergent interests of various constituencies and the specific procedures by which those interests interact to produce the actions of the firm as such." R. Nelson and S. Winter, *An Evolutionary Theory of Economic Change* (Cambridge, MA: Harvard University Press, 1982), p. 57. The authors suggest, however, that, in empirical application, this sort of theorizing would suffer from "limitations of access to data on the nature of constituent interests and on the structure of the internal political process — and also, when such access is possible, on the complexity of the phenomena and relative remoteness from the crude and aggregative measures of overt form of behavior with which the economist typically wants to deal." (*Ibid.*, pp. 58-59) Nelson and Winter themselves take a different path into their evolutionary theory of economic change.
58. J. Child, "Organizational Structure, Environment and Performance: The Role of Strategic Choice," *Sociology*, Vol. 6 (1972), pp. 2-22. J. Kotter, "An Interactive Model for Organizational Dynamics," in L. Schlesinger, R. Eccles and J. Gabarro (eds), ***Managing Behavior in Organizations*** (New York, NY: McGraw-Hill, 1983), pp. 413-428.
59. Interview with D. May, Inmos (1990).
60. For the Commission workshops are a useful device both technically and politically. They help to test the validity of an idea by subjecting it to a public-consensus process which, at the same time, represents an opportunity for all European players to participate. Thus, if a successful alignment occurs, workshops tend to act as "fishing nets", catching the best that European institutions may

have to contribute. Also, by their very nature of consensus-building mechanisms, workshops tend to protect the Commission against such common charges as being involved in "picking winners." In practice, the winners are simply those who are more successful in building alignment around their own constituencies. Such a process is beyond the control of the Commission itself. True, the Commission may provide, at a certain point, the arena, the opportunity, and the catalytic lure of funding and prestige for emerging constituencies. But only the players promoting the technology can truly make it happen.

61. As it happened, the first projects only started around May 1992, following a longer-than-envisaged period of evaluation and funding negotiations.
62. The Inmos' transputer and the Acorn RISC Machine (ARM) are the main European microprocessors currently in the market. They are of British origin, but now much more pan-European as Inmos has become part of the Franco-Italian company SGS-Thomson and Acorn part of the Italian company Olivetti. Although the ARM and the transputer belong to the general class of RISC (reduced instruction set computers) microprocessors, they show significant technical differences, since they were conceived to address different sectors of the microprocessor market. Thus, the ARM provides support for conventional general-purpose sequential processing and it was created by Acorn for use in its low-cost workstations. Whereas, the transputer was created by Inmos to compete in the general purpose 32-bit microprocessor market, and, in contrast to the ARM, the objective was the production of a high-performance chip for single or multiprocessor applications. Much has been written on the transputer over the years. For an examination as well as bibliographic references, see Molina *op. cit.* (1990). The ARM received much less attention than the transputer initially, but this has changed in recent years as a result of ARM successes in securing many licences. For an architectural review of the ARM, see S. Furber and A. Wilson, "The Acorn RISC Machine — An Architectural View," *Electronics and Power* (June 1987), pp. 402–405.
63. "Obligatory point of passage" would relate to the process whereby technologists and institutions succeed in making their products a necessary reference for other people. See Callon, *op. cit.* (1986) and Law and Callon, *op. cit.* (1992).
64. Today, Intel's most advanced chip, the Pentium, contains just over 3 million transistors.
65. For instance, as late as October 1990, after a workshop in Brussels, ACRI concluded that "there was no way to discuss anything else than the Inmos transputer technology at all." (Interview with J. Stern, ACRI, 1990.)
66. Later on, after the workshops, ACRI began to change its perception and, indeed, a common space enabling a degree of goal-alignment did develop between ACRI and the transputer/ARM constituency. Eventually, they both became part of an OMI project working on the development of future microprocessor architectures.
67. Interview with M. Chesney, Meiko (1990).
68. Interview with an OMI player who wished to remain unidentified.
69. *Ibid.*
70. Interview with another OMI player.
71. Interview with OMI player who wished to remain unidentified.
72. *Ibid.*
73. *Ibid.*
74. Interview with Konrad Pöbl, Siemens AG, Components Group.
75. *Ibid.*
76. Interview with D. May (1990).
77. Siemens AG, *OMI-Meeting* (OMI, Brussels, October 1990, mimeo), p. 3.
78. This opinion was shared by Matra MHS, another European semiconductor company which had licensed the SPARC architecture. According to Matra, they had a good understanding with Philips, "first because they [Philips] were in the SPARC camp and, second, because they fully agreed with us that EMI was a scandal in terms of the scope of what was supposed to be funded. I would say that Philips was much stronger than we were in criticizing the project. . . .We opposed it but it was a tactical move so that we would be invited to share our part of the cake." Interview with representative from Matra MHS.
79. Interview with J. B. Theeten, Philips, 1990. E1 was the codename used during the workshops to refer to the long-term future microprocessor. The interviewee's use of OMI-MAP, and not EMI-MAP, reflects the change of name of the overall initiative (from EMI to OMI) by the time of the interview.
80. *Ibid.*
81. *Ibid.*
82. "With Philips the whole thing really started to backfire on them. I think most people think that,

because they started sending representatives along who were clearly trying to sort of kill the thing and undermine it. But, of course, by that time there were far too many people in the room. . . .They got themselves into a position where really they are now attracting hostility from the community that's being built." Interview with D. May (1990).

83. "I think what is interesting is that every time one of the key Philips' guys stands in front and plays the bad guy in the formal sequence of the discussion, at the tea-break or the coffee-break, most of the other silent people come and say: "I am glad you said so, and why don't you shout more because it's a realistic viewpoint." Interview with J. B. Theeten (1990).
84. Personal communication with C. Whity-Strevens, Inmos (1992).
85. "At the beginning there was all the fighting, most of them against the idea to start with, but they were patient, at the same time they accepted the rule of consensus-building." Interview with Pierre Aigrain, Chairman of the OMI Task Force.
86. This openness "was a big help to everyone because that was the only way to convince the political people that there was something to do all together." Interview with representative from Matra MHS.
87. Note that the codename of the future generation architecture has changed from the E1 used before to O1. This is a reflection of the change from European to Open in the whole initiative. *Background Material to the 1991 Esprit Workprogramme*, Vol. 3 (C.E.C., Brussels, June 12, 1991).
88. "In the process, the interests, expertise, conflicts, visions, etc., became 'fossilised' in the shape of the machines." Molina, *op. cit.* (1990), p. 321.
89. ECU (European Currency Unit) is the common currency of the European Community and it is not traded in the money markets. All activities funded by the EC are paid in ECU and conversion then takes place into respective national currencies. At present the ECU exchange rate stands at approximately 1ECU = 1.2 US dollars.