THE COORDINATION STRUCTURE OF INTERNATIONAL COLLABORATIVE TECHNOLOGY ARRANGEMENTS

Antonio J. Bailetti and John R. Callahan

Both authors hold joint appointments in the Department of Systems and Computer Engineering and the School of Business, Carleton University
Ottawa, Canada K1S 5B6

***R&D Management*, 23 (2), April 1993.**

ABSTRACT

As the pace and breadth of technological progress increases around the world, companies both large and small are forming international collaborative arrangements as the basis for developing competitive advantage from technology. Management of these arrangements requires the creation and maintenance of a wide variety of strategic and operational interdependencies within and between companies. The paper introduces a method for developing a representation leading to a system level understanding of the coordination structure of international collaborative arrangements. The method is based on recent advances in coordination theory and object oriented domain analysis. We apply the method to represent four international collaborative arrangements. The representations that result are then used as data to identify five basic modules of the coordination structure of international collaborative arrangements: strategic management, intra-firm management, joint management, technology exchange and customer interaction. The proposed method leads to increased organizational learning of the goal oriented coordination processes for which managers are responsible when establishing international collaborative technology arrangements.

THE COORDINATION STRUCTURE OF INTERNATIONAL COLLABORATIVE TECHNOLOGY ARRANGEMENTS

INTRODUCTION

The management problems of collaborative arrangements include the selection of partners, the development and evolution of the strategic intent of the arrangement, the negotiation of a contract which forms the legal basis of the arrangement, the organizational design of the collaboration, the maintenance of clear and effective communication between the firms involved, the coordination of the internal activities in the firm with those related to the collaboration, and the evaluation of its performance. These issues must be addressed by managers within a complex set of interdependencies among a variety of actors.

Methods which assist a manager in acquiring an understanding of the overall structure of these interdependencies so that decisions are not based on a localized segmented logic have not been developed in the research literature on collaborative technology arrangements. The literature has focused on the categorization and strategies of international collaborative arrangements.

There are two different approaches to the management of complex interactions such as international collaborative technology arrangements. The first is to specify the tasks deemed necessary to make the interaction a success and partition these tasks among the relevant task groups. Coordination mechanisms are established subsequently to manage the transfer of output from one group to another. In the second the structure of the coordination processes involved in the interaction is specified first. Only then are the tasks to be carried out specified and allocated. For interactions such as collaborative technology arrangements which have high task uncertainty and high coordination intensity, we argue that the second approach is more appropriate. However, implementation of the second approach requires that managers understand the coordination structure of the interactions that they are charged with.

The paper introduces an innovative method for developing a representation leading to an overall understanding of the coordination structure of international collaborative arrangements. The method is based on coordination theory and object oriented modeling. The method is applied to four case studies. The representations that result are then used as data to identify the basic modules of coordination structure that are key to the management of such arrangements.

INTERNATIONAL COLLABORATIVE TECHNOLOGY ARRANGEMENTS

A collaborative technology arrangement is a technology driven exchange between two or more companies in which collaboration replaces arms length market exchange to a significant extent. These arrangements are known by a variety of names including strategic partnerships, strategic alliances and cooperative agreements (Balakrishnan and Koza 1990, Ghemawat, Porter and Rawlinson 1986, Hagedoorn 1990, Olleros and Macdonald 1988, Root 1988, Tyebjee 1988). They may or may not involve equity positions of one company in another. For the purposes of

this paper we can also include joint ventures in which two or more companies actually form a new company which embodies the collaboration between them. International collaborative technology arrangements last a relatively long time and centre on the deployment of technology. Distance, time, language, culture and national jurisdiction affect both the reasons for establishing the collaboration and its operational form.

Collaboration is now an integral part of the strategies of most technology driven companies. Companies use collaborative arrangements not only for direct access to technologies, but also as a means to facilitate organizational learning (Huber 1991) and the creation of absorptive capacity (Cohen and Levinthal 1990).

The specific factors which are driving technology based firms to use collaboration in place of more standard arms length transactions include the significant technological discontinuities taking place in such areas as electronics, software and biotechnology; the convergence of technologies and markets in fields such as communications and computing; the rise of technological standards which lead and significantly affect product markets; and the scale increases required for doing research and development for global markets.

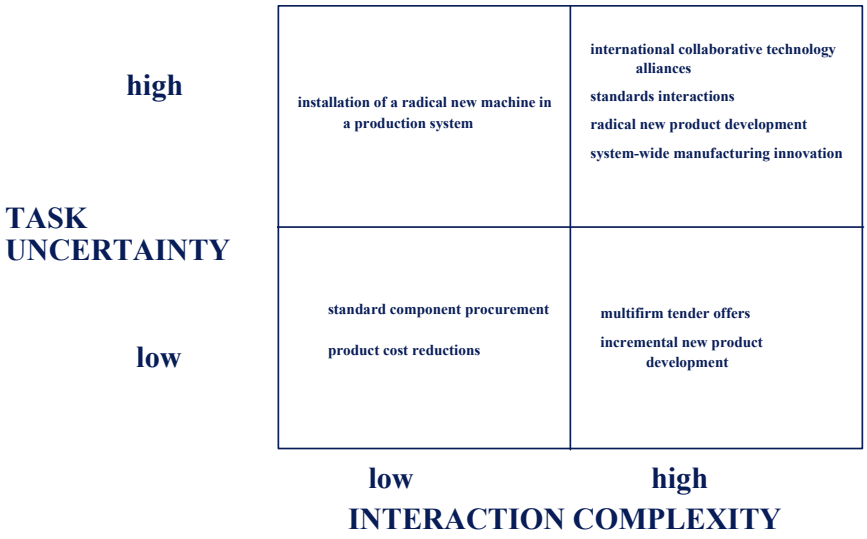
The pace of technological change has accelerated noticeably in recent years. Technologies can be sold or licensed. However, transferring a technology from one organization to another is often a complex and subtle process, especially if the technology is new. Collaborative arrangements can facilitate the process of technology transfer so that the organization with the technology can take fullest advantage of it by working together with another organization with the required complementary assets for the mutual advantage of each organization.

Economic analysis has been used by a number of authors in the study of technology based collaborative arrangements (Contractor and Lorange 1988, Hennart 1988, Mowery 1983, Pisano 1990, Pisano and Teece 1989, Teece 1986, 1988). Collaboration is viewed as a form of exchange intermediate between self liquidating open market transactions and those supported by hierarchies internal to a single firm. This research has centred on the analysis of the economic motivation for collaboration, in particular for the substitution of collaboration for vertical integration. The collaboration between companies has also been approached by a number of organization theorists at a theoretical level (Borys and Jemison 1989, Fombrun 1986, Oliver 1990, Van de Ven 1976, Van de Ven, Delbecq and Koenig 1976). Business strategy is the basis for other research based for the most part on surveys and case analyses (Porter and Fuller 1986, Hamel, Doz and Prahalad 1989) which concentrates on the strategic rather than managerial aspects of technology collaborations. Collaboration between small and large firms has been the focus of a number of studies (Doz 1988, Forrest and Martin 1992, Hull, Slowinski and Collins 1988). Again, the focus of this research has been on the strategy and the reasons for entering a collaboration rather than on their management. The normative literature on the management of technology collaborations tends to be case based, informal and anecdotal in nature (Lewis 1990).

Collaborative technology arrangements generally have high task uncertainty and high coordination intensity (Killing 1988). Task uncertainty refers to uncertainty in the specification of the tasks to be carried out, the skills and resources required, and the sequencing, timing and duration of the tasks. Coordination intensity is related to the number and character of the common objects linking task groups, together with the frequency, importance and routineness of

the coordination interactions that take place. Figure 1 categorizes some example management situations on the basis of task uncertainty and coordination intensity.

Figure 1:
Task Uncertainty and Interaction Complexity



REPRESENTING COORDINATION ENSEMBLES

We argue that the understanding of collaborative technology arrangements with both high task uncertainty and high interaction is best approached through an analysis of their coordination structure. We argue further that modeling this structure can increase managerial effectiveness. During the life of a collaborative technology arrangement a manager charged with making the arrangement a success must manage a wide variety of interdependencies between activities undertaken by others and those that they themselves undertake. Specifying the coordination structure of the arrangement prior to specifying the actions required to manage these interdependencies can reduce the structural problem of managing part-whole relationships. A shared vision of the system level representation of the associations that must be created and managed will result in better decision-making and communication.

We integrate coordination theory and object-oriented modeling to develop an understanding of the coordination structure of international collaborative technology arrangements. This structure can provide the basis for a systematic view of the interdependencies involved in such arrangements. The coordination structure of an interaction is modeled as a coordination ensemble.

Previous research studies define coordination structures in terms of patterns of decision making and communication among a set of actors who perform tasks in order to achieve goals (Baligh 1986, Malone 1987, Malone and Smith 1988). Advances towards an interdisciplinary theory of coordination focus explicitly on the aspects of working together that are unique to coordination problems and define coordination as the act of managing interdependencies between activities (Crowston 1991, Malone and Crowston 1990, 1991).

We define a coordination ensemble as a configuration of actors (e.g., firm executives, operational groups within firms, joint groups established by firms to carry out activities essential to the success of an arrangement) that interact by creating, modifying and using an array of shared objects (e.g., contracts, technology know how, specific deliverables). This definition captures the essence of the base layer that underlies the coordination processes involved in a collaboration. The base layer supports the upper layers of the interaction in much the same way that the physical layer of the Open Systems Interconnection Model supports its other six layers (Stallings 1989).

We build on studies that have found it useful to describe coordination in terms of layers of successively deeper underlying processes. These studies describe coordination processes such as goal selection and decomposition, resource allocation and timing management in terms of four layers: coordination, group decision making, communication and perception of common objects (Crowston 1991, Malone and Crowston 1990, 1991). The study of situated action in organization theory, theories of common knowledge in economics and the study of shared variables and databases contribute to our understanding of the base layer upon which all other layers of goal oriented coordination processes are built (Malone and Crowston 1991). The layered representation of coordination conceptualizes the base layer as comprised of two components, actors and shared objects. It focuses on actors' ability to see and manipulate shared information.

We focus on associations between actors and shared objects and exclude those that link two objects. The interdependence between two actors' responsibilities is represented in terms of the shared object that the actors either create, modify or use. A second important characteristic of our specification of coordination ensembles is that it focuses on a systems level view of coordination structure. This highlights the fact that each association must be considered in relation to the whole ensemble. This approach is different from those which study interdependencies between actors or objects taken a pair at a time (Crowston 1991). We emphasize representing the coordination ensemble around objects rather than procedures or data. This is a third important characteristic of our coordination ensembles. Both actors and objects are objects in the sense used in object-oriented analysis and design.

Thus, coordination ensembles can be thought of as forming a base layer for network models such as those developed by Hakansson (1987, 1988) to model intercompany relationships. Hakansson's models feature actors, interconnected in a network, which perform activities and control resources.

Object oriented approaches to modeling use objects, not algorithms, as their fundamental building blocks (Booch 1991, Coad and Yourdon 1991 a and b, Rumbaugh et al. 1991, Shlaer, Ohlsen and Hywari 1988). Alternative approaches apply algorithmic decomposition, using principles from the more traditional top-down procedural analysis, and data-driven analysis. A data driven approach describes a horse in terms of its parts: head, tail, body, legs, etc. A procedural driven approach describes it in terms of the operations the horse performs: walk, run, trot, bite, etc. In contrast, the object oriented approach describes the horse in terms of its responsibilities: carry things, maintain its living systems, communicate, etc. (de Champeaux and Faure 1992).

An object is an entity that can be observed in the problem domain--something you can do things to. An object combines both data structure and behavior in one entity. Booch (1991) describes an object as something that can be distinguished from other objects (has an identity), can be characterized in terms of dynamic values of a set of properties (has a state) and can perform operations upon other objects or can have another object perform operations upon it (has behavior).

Object oriented approaches appeal to human cognition (Booch 1991) and as a result can reduce the gap between the complex real world system and the model used to represent it (Jeffcoate et al. 1989). An object oriented representation of coordination ensembles provides managers with a better appreciation of the complex system they work into, a common vocabulary of discourse to effectively communicate the nuances of their responsibilities to others, and a tool to continuously improve the management of the part-whole relationships embedded in the process of coordination for which they are accountable.

Object-oriented representations are more stable over time than those based on top-down structured analysis and data-driven analysis (Booch 1991, Coad and Yourdon 1991a). Our representation of coordination ensembles developed in this paper provides managers with a stable framework for improving the process of continual organizational and individual learning. A stable framework facilitates the incorporation of previous results into current analysis.

Our object oriented representation of coordination ensembles provides a continuum of representation for a systematic transition from analysis to specific action (Coad and Yourdon 1991a). The manager can use it to capture the essence of their specific problem domain as well as to design implementation strategies and tactics.

Recently several authors (Booch 1991, Coad and Yourdon 1991 a and b, Gibson 1990, Lee and Carver 1991, Odell and Martin 1992, Rumbaugh et al. 1991, Shlaer and Mellor 1988, Shlaer et al. 1988, Wirfs-Brock et al. 1990) have specified approaches to object oriented analysis to describe what a target system is supposed to do. For purposes of this paper we selected the approach detailed in Rumbaugh et al. (1991) because of its elaborate specification of the sequence of steps to follow, greater care placed on identifying and specifying associations between objects, emphasis on front-end conceptual analysis, and wide use in industrial object-oriented applications.

We shall now describe four cases of international technology collaboration and model the coordination ensembles which form the basis for their management. Coherent subsets of objects and their associations which we term modules will be identified for each case. These modules will then be used to draw conclusions about the general nature of the coordination structure of such arrangements.

FOUR CASES OF TECHNOLOGY COLLABORATION

Quadra Logic Technologies and American Cyanamid

Quadra Logic Technologies (QLT), a small entrepreneurial startup, and American Cyanamid (AC), an American based international pharmaceutical firm, have a collaborative technology agreement built around the commercialization of a cancer treatment called photodynamic technology (PDT). To generate profits from PDT, QLT requires clinical test capability, production facilities capable of producing in volume, management experienced in the regulatory approval process together with marketing, sales and distribution. AC has the required skills and resources.

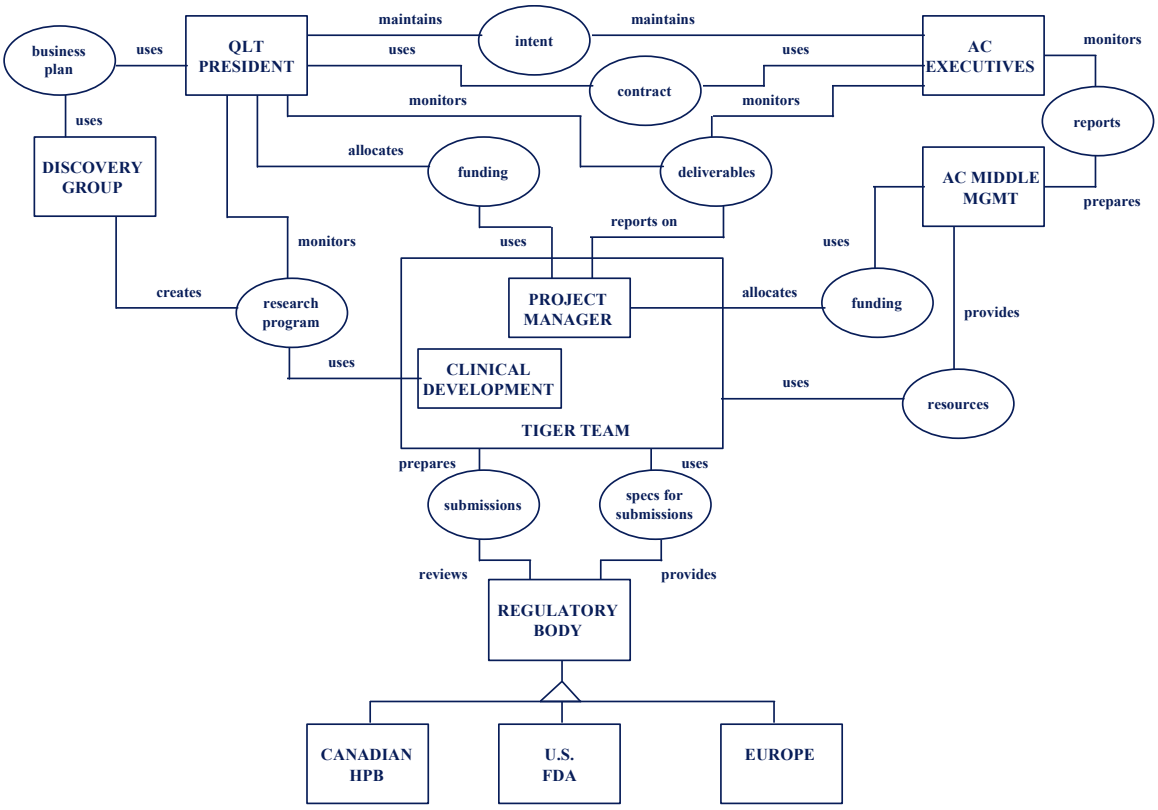
As part of the arrangement, AC took a minority equity position in QLT. AC also received world wide marketing rights for a specific set of PDT products for use in the treatment of a specific set of cancers. In return QLT will get a fixed percent of all revenues from the eventual sales of these products. Costs incurred during development, clinical testing and FDA approval are shared equally. The downstream costs of production, marketing, distribution and sales are to be charged to AC. Both sides worked hard to develop a clear understanding of the intent of the agreement. Such an understanding was regarded as essential for the collaboration to work.

The project to bring the PDT drugs to the point of commercial viability is driven by a "tiger team" made up of personnel from both QLT and AC. The overall control of the tiger team is exercised by the president of QLT. The tiger team contains individual champions for all parts of the process: clinical research, regulatory approval, manufacturing, and marketing both North American and international.

The medical director in charge of clinical development on the tiger team also manages QLT's Discovery Group which works with a network of clinical research associates drawn from a variety of universities. In this way QLT maintains control of its technology development process.

Figure 2 is the ensemble which models the coordination structure of the collaboration between QLT and AC from the point of view of the president of QLT who is responsible on the QLT side for making the relationship work. In each of our analyses of coordination structure we will take the viewpoint of a manager or group of managers charged with the success of the relationship being analyzed.

Figure 2:
Coordination Ensemble for Quadra Logic and American Cyanamid



There are a number of identifiable modules in the coordination ensemble of the collaboration between QLT and AC. They include:

- the coordination relationship between the QLT PRESIDENT and the DISCOVERY GROUP around two shared objects, QLT's business plan and research program;
- the reporting relationship between the AC EXECUTIVES and the AC MIDDLE MANAGEMENT;
- the coordination of the QLT PRESIDENT and the AC EXECUTIVES around the intent and the contract of the collaboration;
- the coordination between the TIGER TEAM and QLT around the FUNDING allocated by the QLT PRESIDENT and the research program brought to the TIGER TEAM by the person in charge of CLINICAL DEVELOPMENT on the team. Note here that the two actors, CLINICAL DEVELOPMENT and PROJECT MANAGER, are nested or contained within the actor TIGER TEAM;
- the coordination between the TIGER TEAM and AC MIDDLE MANAGEMENT around FUNDING allocated by the PROJECT MANAGER and the resources provided by AC MIDDLE MANAGEMENT; and
- the coordination between the TIGER TEAM and the various REGULATORY BODYs around the specifications for the regulatory submissions and the submissions themselves.

Figure 2 makes use of the concept of inheritance used in object oriented modeling. The actor REGULATORY BODY is a class of organizations each of which have a coordination relationship with the TIGER TEAM around the specifications for submission and the submissions themselves. There are three principal REGULATORY BODYs of importance to QLT and AC: the CANADIAN HPB (Health Protection Branch), the U.S. FDA (Food and Drug Administration) and regulators in EUROPE.. Each has the same type of coordination relationship with the TIGER TEAM, but not around the same specifications nor around the same submissions.

DY-4 and Ferranti

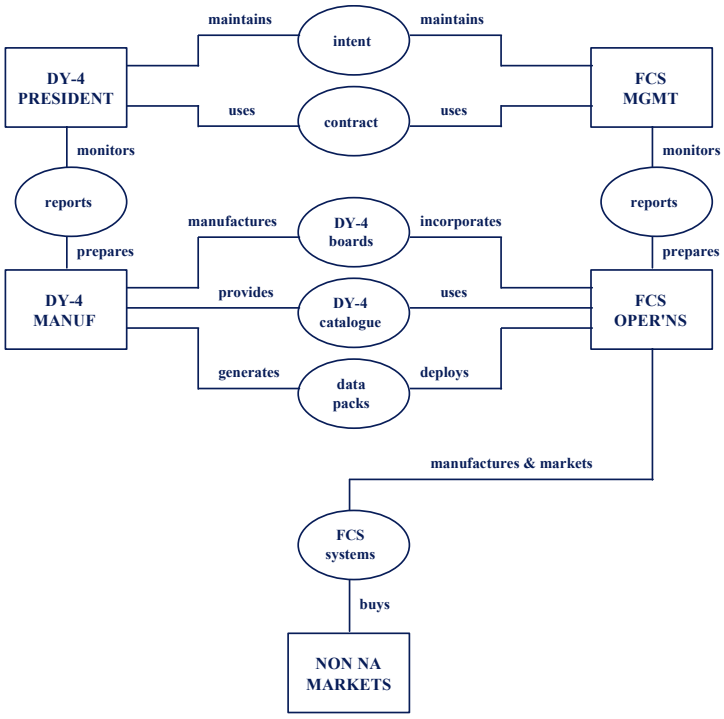
DY-4 is a mid-sized Canadian manufacturer of Versa Modular Europe (VME) based boards for computing systems requiring military levels of reliability and ruggedness. VME is a non-proprietary architecture standard for the bus or interface between processors in a computer. Ferranti International Signal plc is a major international technology systems contractor. Ferranti Computer Systems Limited (FCS), one of Ferranti's 23 subsidiary operating companies specializing in real time systems and associated products for both military and civilian applications, approached DY-4 seeking their expertise in VME. At the same time, DY-4 had been looking for a partner to help with distribution into the fragmented British market.

In a contract negotiated in 1986, Ferranti received manufacturing and distribution rights for specified DY-4 products exclusive in the U.K. and non exclusive in the rest of the world except for North America. Ferranti was restricted from selling DY-4 products in the U.S. and Canada except as components in Ferranti systems. DY-4 also received a license to produce and sell some Ferranti products, exclusive in North America and non exclusive in the rest of the world with the exception of the U.K. The agreement specified an up front payment by Ferranti to DY-4 and manufacturing royalty payments. The two companies also committed to do joint development work although this never became a major part of the operations of the collaboration.

During the collaboration which lasted until the end of 1991, the purchase and manufacture of DY-4 boards by Ferranti formed the major part of the collaboration. Figure 3 models the coordination structure of the collaboration from the viewpoint of the president of DY-4 for this part of the relationship. The ensemble is made up of four modules:

- those internal to DY-4 and to FCS built around reporting relationships;
- the coordination of the DY-4 PRESIDENT and the FCS MANAGEMENT around the intent and the contract of the collaboration;
- the coordination between DY-4 OPERATIONS and FCS OPERATIONS around DY-4 boards, the DY-4 product catalogue and DY-4 data packs as shared objects; and
- the relationship between FCS OPERATIONS, principally manufacturing and marketing, and their customers in the NON NORTH AMERICAN MARKETS into which they were principally selling their systems.

Figure 3:
Coordination Ensemble for DY-4 and Ferranti



There was a natural tendency for management in both DY-4 and FCS to push the operation of the relationship down in their respective organizations as far as possible. However problems between the two firms, when not solved at the operational level, moved up to the executive level. A recurrent problem was the lack of a mutually accepted interpretation of the state of development of products listed in DY-4's product catalogue.

The DY-4 PRESIDENT recognized that the cycling of concern with the FCS collaboration up and down in the firm was not a good sign since solving operational problems at the executive level is always expensive. The problem was addressed in two ways. First, the relationship between the DY-4 catalogue and DY-4's ability to deliver was more tightly controlled so that the DY-4 catalogue became a real "shared object" for coordination with FCS. Second, the DY-4 PRESIDENT took a more proactive role in the relationship than he had up to this point so that the intent of the relationship was more continuously maintained with FCS MANAGEMENT.

Intent rather than the contract was the guiding force of the arrangement. In the words of a DY-4 manager: "If you have to look at the contract, then the deal is not working. You must have an ongoing willingness on both sides to solve problems as they arise". This was particularly important for DY-4 given that the contract was written for administration in British courts so that DY-4 felt that it would lose any legal action based on the contract.

The IRIS Project

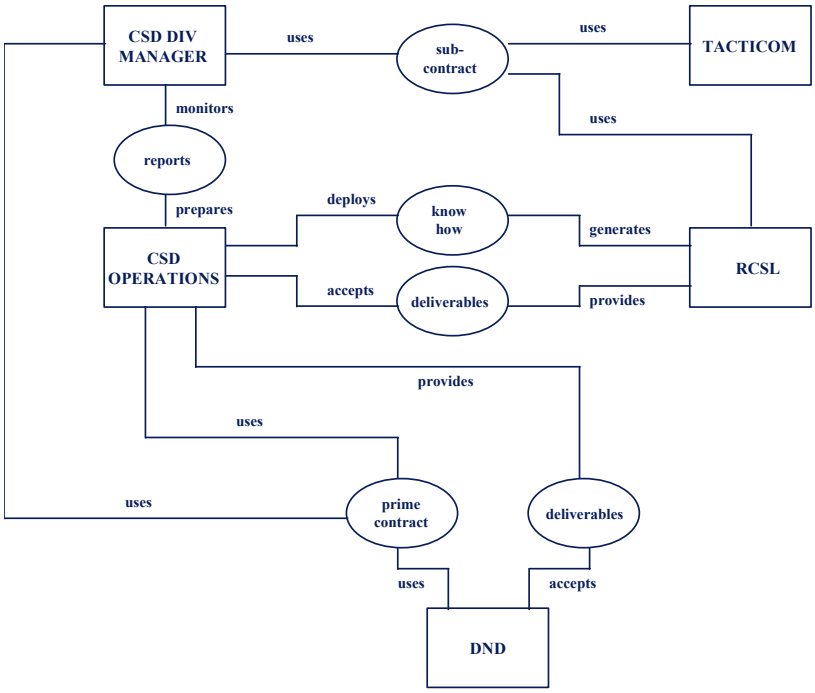
The IRIS project is designed to bring the Canadian army up-to-date in communications technology - to replace 1950s era radio equipment so old that it must be entirely replaced. A second objective of the project is to bring military communication technology into Canada, particularly into Western Canada.

The prime contractor for the project is Computing Devices of Canada (CDC), a division of Control Data Corporation of the United States. An important partner is Racal Electronics plc. Racal, a large publicly owned, diversified electronics company based in the U.K., provided its radio technology as the technological basis of the CDC lead bid. Other international partners in the consortium include: TRW Inc., a large American multinational, the Government Electronics Group of Motorola, and SD-Scicon plc, a British firm. The four other participants in the consortium are smaller regional Canadian companies: Atlantic Research Canada, Frontec Logistics Corp., Westbridge Computer Corp. and SED Systems Ltd.

The core of the consortium is the technology transfer arrangement between CDC and Racal. CDC established a teaming agreement with Racal-Tacticom in anticipation of the IRIS project. Tacticom is a marketing subsidiary of the Racal Radio Group (RRG) of Racal. The actual performing organization for Racal is Racal Communications Systems Ltd. (RCSL), another RRG subsidiary.

CDC and in particular its Communications Systems Division (CSD) which is responsible for the IRIS project, coordinate their activities around the Racal subcontract as do Tacticom and RCSL of Racal. CSD and RCSL also coordinate around the Racal know-how and deliverables specified in the subcontract. Figure 4 outlines the coordination structure of the CDC relationship with Racal from the point of view of the CSD DIVISION MANAGER who is charged with making the relationship work for CDC.

Figure 4:
Coordination Ensemble for CDC and Racal



There are again a number of identifiable modules in figure 4:

- the coordination between the CSD, TACTICOM and FCSL around the sub-contract;
- the reporting relationship between the CSD DIVISION MANAGER and CSD OPERATIONS;
- the transfer of know how and deliverables between RCSL and CSD OPERATIONS; and
- the coordination of the CSD DIVISION MANAGER and CSD OPERATIONS with the CANADIAN DND (Department of National Defense) around the prime contract and the CSD deliverables.

The fact that there is a single external actor in this relationship, the CANADIAN DND, and the nature of this actor as the sole purchaser of the deliverables causes differences in the coordination structure of this relationship. Intent is not a significant shared object in the coordination structure of the collaboration between CDC and Racal. The contract, and the derived sub-contracts, are very specific about the nature and timing of the deliverables.

Nordion and TRIUMF

Nordion, originally part of Atomic Energy of Canada, has a large share of the world reactor based radioisotope market. Accelerator generated radioisotopes provide complementary products which build on Nordion's core competencies. Nordion had the technological infrastructure to develop the capacity to operate an accelerator for production of radioisotopes. However, it chose instead to establish a collaborative arrangement with TRIUMF, a joint venture of the four universities of Alberta, Simon Fraser, Victoria and British Columbia, which runs a

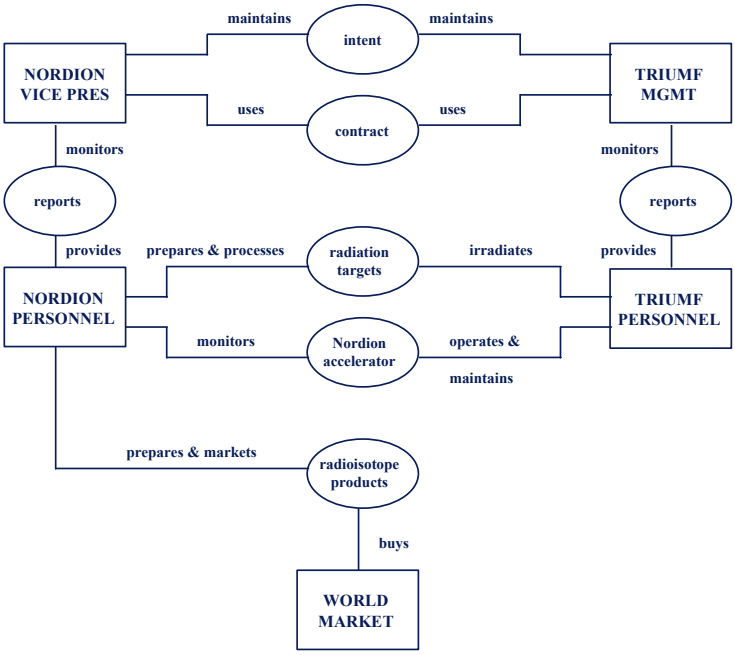
large cyclotron for experiments in subatomic research on the grounds of the University of British Columbia.

Nordion paid for the installation of a small accelerator and related equipment together with a building to house it adjacent to the main TRIUMF facility. Nordion also pays for the costs of the operation of radioisotope production including the salaries of their own and of TRIUMF personnel. TRIUMF runs the Nordion accelerator, and this expertise remains within TRIUMF.

Nordion provides the targets used in the production of radioisotopes to TRIUMF personnel. Once irradiated, the targets are returned to Nordion which processes and packages the material for shipment to medical clinics and hospitals around the world.

The coordination structure of the principle operations of the collaboration from the point of view of the NORDION VICE PRESIDENT who is charged with making the collaboration work for NORDION is outlined in figure 5.

Figure 5:
Coordination Ensemble for Nordion and TRIUMF



There are five identifiable modules in figure 5:

- the coordination around intent and contract between the NORDION VICE PRESIDENT and TRIUMF MANAGEMENT;
- the two reporting relationships between management and operations in both NORDION and TRIUMF;
- the coordination between NORDION PERSONNEL on the TRIUMF site and TRIUMF PERSONNEL around the operation of the Nordion accelerator and irradiation of targets; and

• the coordination between the NORDION PERSONNEL on the TRIUMF site and their customers in the WORLD MARKET around the preparation, marketing and sales of Nordion accelerator generated radioisotope products.

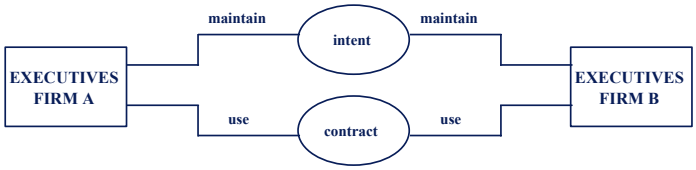
ANALYSIS OF THE COORDINATION ENSEMBLES

An analysis of the coordination ensembles for the four cases leads us to conclude that they are made up of combinations of five different basic types of modules.

The Strategic Management Module

The Strategic Management Module encompasses the coordination of the executives of the firms in a collaboration around the maintenance of the intent of the collaborative arrangement and the use of the contract.

Figure 6:
Strategic Management Module



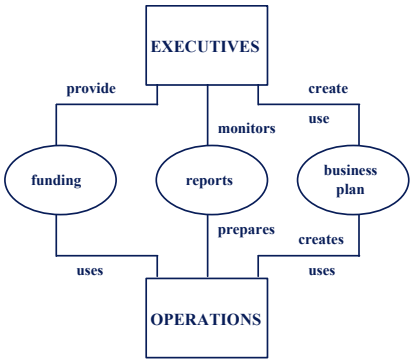
Intent is the common understanding about the purpose of the collaborative arrangement and the mutual benefits to be derived from it. It is essential for strategic collaborations. It may not be an important part of collaborations which are operational or have become so, i.e., in which task uncertainty and coordination intensity are low. Thus, for example, intent is not an important shared object for the IRIS project because it is operational and based on the specifications laid down by the Canadian DND. Intent was a very important part of the DY-4 collaboration with Ferranti in the initial stages, but less so towards the end as Ferranti became more of a conventional distributor for DY-4 product. Intent is often revised and frequently relearned as new managers become involved. In international arrangements, differences in language, culture and organizational practices can make the establishment and maintenance of intent as a shared object particularly difficult.

A contract will embody the intent of the collaborative arrangement as well as the financial and operational details, deliverable schedules, etc. The contract is updated infrequently, generally when the differences between the current contract specifications and the actual requirements of the arrangement diverge significantly. In international arrangements, the contract must be based in some specific jurisdiction. In this case, the legal specification of the contract and its enforcement become significant problems for at least one of the collaborating firms;

The Intra-organizational Module

The Intra-organizational Module models the coordination between the executives and the operations (e.g., R&D, manufacturing and marketing) of a firm around the shared objects such as funding, reports and a business plan.

Figure 7:
Intra-organizational Module

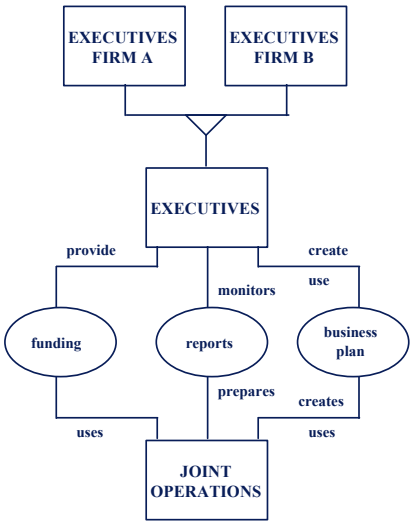


This module captures the normal management coordination interactions which take place within a firm irrespective of whether or not it is in a collaboration.

The Joint Management Module

The Joint Management Module is present in those collaborations which have joint actors such as the TIGER TEAM in the collaboration between QLT and AC. Here the executives of both collaborating firms coordinate with each other and with the joint actor around the same sorts of shared objects used in the Intra-organizational Module, funding, reports and business plans.

Figure 8:
Joint Management Module



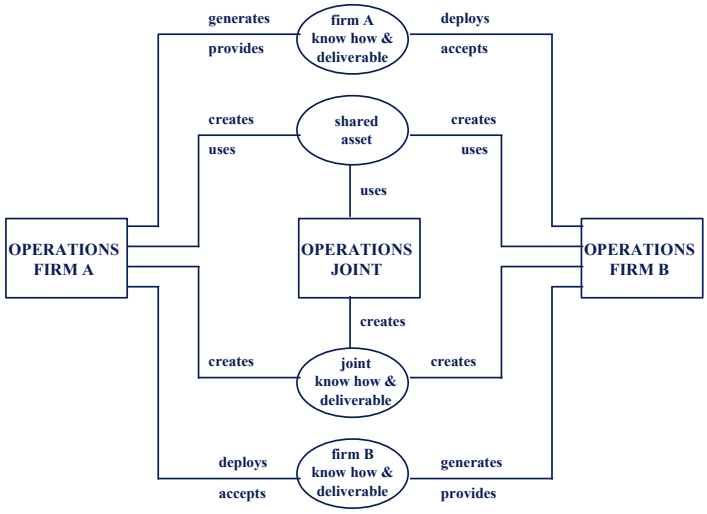
The diagram for the Joint Management Module uses the concept of inheritance introduced earlier. In the diagram, the EXECUTIVES FIRM A and the EXECUTIVES FIRM B belong to the class EXECUTIVES. This idea is easily generalized to include more than two firms in a collaboration.

The Joint Management Module introduces a particularly difficult aspect of collaborative arrangements, whereby the operational management of both firms is in a sense joined so that executives in one firm interact with the operations of another.

The Technology Exchange Module

The Technology Exchange Module models the coordination between the operations of the two firms and any joint operations that the firms have set up around the know how, deliverables and shared assets which form the basis of the collaboration.

Figure 9:
Technology Exchange Module

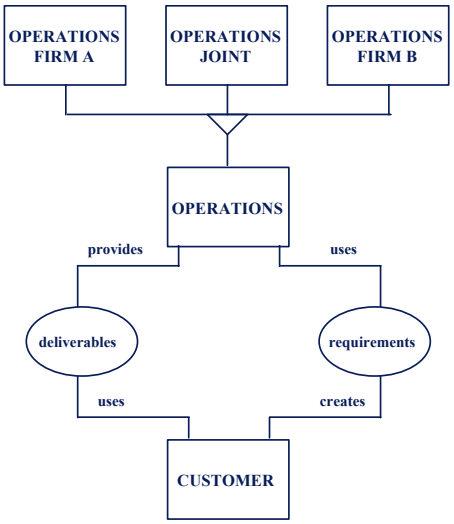


Know how is generated and deployed. Deliverables are provided and accepted. Shared assets are created and used. Joint know how and deliverables are created in the collaboration. Again this module can be easily generalized to include the operations of more than two firms.

The Customer Interaction Module

The Customer Interaction Module models the coordination of operations with the customers of the firms. These customers can include agencies such as the U.S. FDA which use the output of the joint operation of QLT and AC which is the TIGER TEAM. Inheritance is used here for both the operations of the firms and for the customers. There will commonly be a whole variety of customers, represented by the class CUSTOMER.

Figure 10:
Customer Interaction Module



The requirements and deliverables of this module are the fundamental generators of a collaborative arrangement. They are most often products and/or services to be marketed by the collaborating firms to global markets.

IMPLICATIONS FOR INTERNATIONAL COLLABORATIONS

Modular Representation

The coordination ensembles of the four cases can be expressed in terms of configurations of the five modules identified in the previous section. The coordination ensemble of the QLT and AC arrangement (Figure 2) is a combination of the Strategic Management, Intra-organizational, Joint Management, Technology Exchange, and Customer Interaction modules. The coordination ensembles for both the principal part of the DY-4 and FCS collaboration (Figure 3) and for the operational part of the Nordion and TRIUMF collaboration (Figure 5) are a combination of the Strategic Management, Intra-organizational, Technology Exchange and Customer Interactions modules. The CSD and Racal Radio Group ensemble (Figure 4) contains the Intra-organizational, Technology Exchange and Customer Interactions modules. The Strategic Management module is not used to model the ensemble because of the importance of the prime contract and the derived sub-contracts as the principal shared objects within the coordination structure, and of the two company structure of the Racal Radio Group in the collaboration.

Distinct Aspects of International Collaborations

Intent and contract are two shared objects which are very different in international as opposed to domestic collaborative arrangements. Intent provides the basis for a powerful coordinating mechanism in complex and uncertain interactions. The difficulties inherent in managing this coordination mechanism are compounded in international collaborations by

differences in language, culture and business practice. To be successfully used for coordination as a shared object, intent must be maintained by frequent, preferably face to face, communication. It is hard to capture the intent of an international collaboration completely in written form. Managers must interact with each other. This makes managerial turnover particularly problematic in international collaborations where intent is a necessary and important coordination mechanism.

Differences in business law and jurisdiction make international contracting more difficult than domestic. This is particularly true for most collaborative technology arrangements which are not, in general, impersonal arms length deals. Collaborative technology arrangements are a flexible form of organizational relationship which facilitate organizations working together to create competitive advantage by using each others know how and resources. In a sense, an organization which enters into a collaboration can obtain the use of some of the assets of another organization not through a cash transaction but by providing in return the use of some of its own assets.

Williamson (1986, p. 103) contrasts classical and relational contracting. Classical contracting occurs when "all future contingencies pertaining to the supply of a good or service are described and discounted within respect to both likelihood and futurity". In classical contracting the identity of the partners is irrelevant, the nature of the agreement is carefully delimited, more formal written features of the contract govern over informal oral features when the contract is contested, and remedies for dispute are narrowly prescribed. In relational contracting, the relationship underlying the contract is complex and of long duration. The relationship takes on the properties of "a minisociety with a vast array of norms beyond those centred on the exchange and its immediate processes" (Williamson 1986, p. 105).

Relational contracting is required for many international collaborative technology arrangements in which the transactions are of a recurring and non-standardized kind. Developing a contract for this type of arrangement and using it as a shared object for managing interdependencies is difficult even without the additional problems of differences in business law and legal jurisdiction found in international collaborations.

As pointed out above, the coordination structure of technology collaborations can entail the executives of one firm coordinating with the operations of another firm around shared objects such as funding, reports and business plans. Managing such an interaction in an international context is made more difficult, for example, by the use of different financial reporting conventions. However, dealing with such differences is rapidly becoming a standard part of doing business internationally. The same may be said for the interaction of the operations of the collaboration with international customers - such interactions are standard in most businesses irrespective of whether or not they are involved in technology collaborations.

In the four cases of technology collaboration analyzed, the shared objects which form the basis of the collaborations, technology based know how and deliverables, do not seem fundamentally different when situated in an international context. Moreover, it would seem likely that purely domestic collaborations would have similar overall coordination structures. The coordination structure of the QLT/AC arrangement is likely typical of small firm/large firm collaborations in which the small firm supplies technological know how and the two firms establish a joint task group to execute a major part of the collaboration. The coordination

structure of the principal parts of the DY-4/Ferranti and Nordion/TRIUMF arrangements is also likely typical of collaborative arrangements built around the transfer of technology based know how and products without the establishment of a joint task group. Thus, based on an analysis of the four case studies, we conclude that the principal differences between the coordination structure of international collaborative technology arrangements and those which are purely domestic occurs because of the effects of international factors on the use of the intent and contract for the arrangement as shared objects.

DISCUSSION

We have used an innovative method of representing systematically the coordination structure of international collaborative technology arrangements to analyze the coordination structure of four case studies. The method models coordination structure in terms of ensembles of actors, shared objects and associations between actors and shared objects. Shared objects and associations specify the interdependencies between actors which form the basis of coordination structure. The coordination ensembles derived were then used as data to draw general conclusions about the coordination structure of international collaborative technology arrangements.

This paper makes three contributions. First, it demonstrates the use of coordination ensembles for analyzing complex interactions of actors around shared objects in a real problem domain. This method of representing interactions with high task uncertainty and high coordination intensity has potential application in other areas of R&D management such as pre-development activities in new product development, management of design systems and the interaction of a firm with anticipatory industry standards.

Second, the paper makes a contribution to the literature on the management of collaborative arrangements which has for the most part focused on categorization and strategy rather than management issues. The method used allows managers to focus on the relevant attributes of the shared objects of an interaction. It makes apparent the importance to strategic and operational management of structuring the appropriate shared objects and their associations to actors.

Third, we bring together two streams of research, coordination theory and object oriented modeling, which have to this point been isolated from each other. This paper provides a starting point for further research into the general structure of coordination ensembles which can add to both the coordination theory and object oriented modeling literature. A second opportunity for further research lies in the integration of structure theory with the concept of coordination ensembles (Fombrun 1986, Gersick 1986, Tushman and Romanelli 1985).

A number of avenues for future research suggest themselves. The coordination ensembles described in the paper give a view at a point in time of the coordination mechanisms used in strategic partnerships. Longitudinal studies could add to our understanding of the evolution of coordination ensembles over time and to the power of the coordination ensemble technique for management decision making. The case material that

forms the basis for the paper is being used to pursue this. Research on the effectiveness of the technique is also being pursued. Companies are now using coordination ensembles for the initial design of strategic partnerships. Data on the effectiveness of the approach is being gathered for subsequent analysis. A third issue is the "user friendliness" of the coordination ensemble diagrams themselves. They can be challenging to work with, especially at the initial stages of modeling when a manager is grappling with the complexities of his or her problem domain. Automation of the modeling process could contribute significantly. Efforts are currently underway to adapt industrial strength programs for the graphical representation of system designs, for use in developing coordination ensemble diagrams on a personal computer.

REFERENCES

Balakrishnan, S. and M.P. Koza (1990) "Patterns of Cooperative Competition in Global Industries", in M.W. Lawless and L.R. Gomez-Mejia (Eds.), Strategic Management in High Technology Firms, Greenwich, Conn., Jai Press.

Baligh, H. H., (1986) "Decision Rules and Transactions, Organizations and Markets", *Management Science* 32, 1480-1491.

Booch, G. (1991) Object Oriented Design with Applications, Benjamin Cummings, Menlo Park, CA.

Borys, Bryan and David B. Jemison (1989) "Hybrid Arrangements as Strategic Alliances: Theoretical Issues in Organizational Combinations", *Academy of Management Review*, 14(2), 234-249.

Coad, P. and E. Yourdon (1991a) Object-Oriented Analysis, Yourdon Press, Englewood Cliffs, NJ.

Coad, P. and E. Yourdon (1991b) Object-Oriented Design, Yourdon Press, Englewood Cliffs, NJ.

Cohen, Wesley M. and Daniel A. Levinthal (1990) "Absorptive Capacity: A New Perspective on Learning and Innovation", *Administrative Science Quarterly*, 35, 128-152.

Contractor, Farok J. and Peter Lorange (1988) "Why Should Firms Cooperate? The Strategy and Economics Basis for Cooperative Ventures", chapter 1 of Farok J. Contractor and Peter Lorange (eds), Cooperative Strategies in International Business (Joint Ventures and Technology Partnerships between Firms), Lexington Books, 3-30.

Crowston, K. G. (1991) Towards a Coordination Cookbook: Recipes for Multi-agent Action, Ph.D. Thesis, Alfred P. Sloan School of Management, Massachusetts Institute of Technology, Boston.

de Champeaux, D. and P. Faure (1992) "A Comparative Study of Object-Oriented Analysis Methods", *Journal of Object-Oriented Programming,* 2, 21-33.

Doz, Yves L. (1988) "Technology Partnerships between Larger and Smaller Firms: Some Critical Issues", chapter 18 of Farok J. Contractor and Peter Lorange (eds), Cooperative Strategies in International Business (Joint Ventures and Technology Partnerships between Firms), Lexington Books, 317-338.

Fombrun, Charles (1986) "Structural Dynamics Within and Between Organizations", *Administrative Science Quarterly*, 31, 403-421.

Forrest, Janet E. and M.J.C. Martin (1992) "Strategic alliances between large and small research intensive organizations: experiences in the biotechnology industry", *R&D Management*, 22(1), 41-53.

Gersick, C. (1986) "Revolutionary Change Theories: A Multilevel Exploration of the Punctuated Equilibrium Paradigm", *Academy of Management Review*, 16, 10-36.

Ghemawat, Pankaj, Michael E. Porter and Richard A. Rawlinson (1986) "Patterns of International Coalition Activity", chapter 11 of M.E. Porter (ed), Competition in Global Industries, Harvard Business School Press, 345-365.

Gibson E. (1990) "Objects--Born and Bred", *BYTE*, October, 245-254.

Hagedoorn, John (1990) "Organizational modes of inter-firm co-operation and technology transfer", *Technovation*, 10(1), 17-30.

Hakannson, Hakan (ed) (1987) Industrial Technological Development, Croom Helm, London.

Hakannson, Hakan (1988) Corporate Technological Behaviour, Routledge, London and New York.

Hamel, Gary, Yves Doz and C. K. Prahalad (1989) "Collaborate With Your Competitors - and Win", *Harvard Business Review*, 67(1), Jan-Feb, 133-139.

Hennart, Jean-Francois (1988) "A Transaction Costs Theory of Equity Joint Ventures", *Strategic Management Journal*, 9, 361-374.

Huber, George P. (1991) "Organizational Learning: The Contributing Processes and the Literatures", *Organization Science*, 2(1), February, 88-115.

Hull, Frank, Gene Slowinski and Paul Collins (1988) "Entrepreneurial Strategies for Effectively Partnering with Corporations in High-Technology: A Preliminary Analysis", in Luis R. Gomez-Mejia and Michael W. Lawless (eds), Proceedings: Managing the High Technology Firm, University of Colorado at Boulder, January 13-15, 200-207.

Jeffcoate, J., K. Hales and V. Downes (1989) Object-oriented Systems: the Commercial Benefits, Dudley Ltd, London.

Killing, J. Peter (1988) "Understanding Alliances: The Role of Task and Organizational Complexity", chapter 3 of Farok J. Contractor and Peter Lorange (eds), Cooperative Strategies in International Business (Joint Ventures and Technology Partnerships between Firms), Lexington Books, 55-67.

Lee, S. and D.L. Carver (1991) "Object-oriented Analysis and Specifications, A Knowledge Based Approach", *Journal of Object-Oriented Programming*, 5, 35-43.

Lewis, Jordan D. (1990) Partnerships for Profit, The Free Press.

Malone, T. M. (1987) "Modeling Coordination in Organizations and Markets", *Management Science*, 33, 1317-1332.

Malone, Thomas W. and Kevin Crowston (1990) "What is Coordination Theory and How Can It help Design Cooperative Work Systems?", *ACM CSCW 90 Proceedings*, October, 357-370.

Malone, T. M. and K. G. Crowston (1991) Toward an Interdisciplinary Theory of Coordination, Technical Report #120, Center for Coordination Science, Massachusetts Institute of Technology.

Malone, T. M. and S. A. Smith (1988) "Modeling the Performance of Organizational Structures", *Operations Research*, 36, 421-436.

Mowery, David C. (1983) "The Relationship Between Intrafirm and Contractual Forms of Industrial Research in American Manufacturing, 1900-1940", *Explorations in Economic Thought*, 20, 351-374.

Odell, J. and J. Martin (1992) Object-Oriented Analysis and Design, Prentice Hall, Englewood Cliffs, NJ.

Oliver, Christine (1990) "Determinants of Interorganizational Relationships: Integration and Future Directions", *Academy of Management Review*, 15(2), 241-265.

Olleros, Francisco-Javier and Roderick J. Macdonald (1988) "Strategic Alliances: Managing Complementarity to Capitalize on Emerging Technology", *Technovation*, 7, 155-176.

Pisano, Gary P. (1990) "The R&D Boundaries of the Firm: An Empirical Analysis", *Administrative Science Quarterly*, 35, 153-176.

Pisano, Gary and David J. Teece (1989) "Collaborative Arrangements and Global Technology Strategy: Some Evidence from the Telecommunications Equipment Industry", in Research on Technological Innovation, Management and Policy, Vol 4, Greenwich, JAI Press, 227-256.

Porter, M.E. and Mark B. Fuller (1986) "Coalitions and Global Strategy", chapter 10 of M.E. Porter (ed), Competition in Global Industries, Harvard Business School Press, 315-343.

Root, Franklin R. (1988) "Some Taxonomies of International Cooperative Arrangements", chapter 4 of Farok J. Contractor and Peter Lorange (eds), Cooperative Strategies in International Business (Joint Ventures and Technology Partnerships between Firms), Lexington Books, 69-80.

Rumbaugh, James, Michael Blaha, William Premerlani, Frederick Eddy and William Lorensen (1991) Object-Oriented Modeling and Design, Prentice Hall.

Shlaer, S. and S. J. Mellor (1988) Object-Oriented Systems Analysis: Modeling the World in Data, Yourdon Press, Englewood Cliffs, NJ.

Shlaer, S. , S. J. Mellor, D. Ohlsen and W. Hywari (1988) "The Object-Oriented Method of Analysis", in Proceedings of the 10th Structured Development Forum.

Stallings, W. (1989) Handbook of Computer Communications Standards, Howard W. Sams, Indianapolis, Indiana.

Teece, David J. (1986) "Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy", *Research Policy*, 15, 285-305.

Teece, David J. (1988) "Capturing Value from Technological Innovation: Integration, Strategic Partnering, and Licensing Decisions", *INTERFACES*, 18(3), May-June, 46-61.

Tushman, M. L. and Elaine Romanelli (1985) "Organizational evolution: A metamorphosis model of convergence and reorientation", in Barry M. Staw and Larry L. Cummings (Eds.), Research in Organizational Behavior 7, JAI Press, Greenwich, CT, 171-222.

Tyebjee, Tyzoon T. (1988) "A Typology of Joint Ventures: Japanese Strategies in the United States", *California Management Review*, Fall, 75-86.

Van de Ven, Andrew H. (1976) "On the Nature, Formation, and Maintenance of Relations Among Organizations", *Academy of Management Review*, October, 24-36.

Van de Ven, Andrew H., Andre L. Delbecq and Richard Koenig, Jr. (1976), "Determinants of Coordination Modes within Organizations", *American Sociological Review*, April, 322-338.

Wirfs-Brock, R. B., B. Wilkerson and L. Wiener (1990) Designing Object-Oriented Software, Prentice-Hall, Englewood Cliffs, NJ.

Williamson, Oliver E. (1986) Economic Organization: Firms, Markets and Policy Control, Wheatsheaf Books.