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Trends and determinants of managing virtual R&D teams

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In the past years we have witnessed a strong decentralization of R&D to local customers and centers-of-excellence. Facilitated by modern information and communication technologies, „virtual project teams“ have been formed. With their boundaries expanding and shrinking flexibly with changing project necessities, virtual teams are believed to be an important element in future R&D organization. Based on 204 interviews with R&D directors and project managers in 37 technology-intensive multinational companies we identify four forms of virtual team organization for the execution of R&D projects across multiple locations. Ordered by increasing degree of central project authority, these four team concepts are: (1) decentralized self-organization, (2) system integrator as a coordinator, (3) core team as a system architect, and (4) centralized venture team. Our contingency approach for organizing a transnational R&D project is based on four principal determinants: (1) the type of innovation (radical/incremental), (2) the systemic nature of the project (systemic/autonomous), (3) the mode of knowledge involved (tacit/explicit), and (4) the degree of resource bundling (complementary/redundant). According to our analysis the success of virtual teams depends on the appropriate consideration of these determinants.

I. Project Management within Virtual R&D Teams

A. Trends in International R&D

The nineties have seen the largest expansion of international R&D ever. Consequent power decentralization to divisions and the endeavor to be more market oriented have led to a 'jungle growth' of dispersed R&D activities. Additionally, corporate R&D is trying to tap into local knowledge pools with dedicated research laboratories. This internationalization of R&D has reached more than 50% in small countries such as the Netherlands and Switzerland, 30% in all of Western Europe, and about 10% in the United States (e.g., Dunning, 1994; Patel, 1995; Roberts, 1995; von Zedtwitz, Gassmann 2002 a). While strategic guidelines for identifying and evaluating potential R&D locations are well established, the real challenge for management is to integrate new R&D units so that they become productive partners in the company's global R&D network. In parallel with the rise of international R&D, inter-unit R&D collaboration increases and cross-border innovation projects become more common. But these projects have a notorious reputation for being difficult to manage, costly to execute, never on-time, and ineffective towards their goal. Regarding transnational R&D projects, R&D managers are thus divided into two groups: one believing in the additional potentials offered by multiculturalism and multiple perspectives, and one balking at the extra costs and inefficiencies incurred.

Virtual teams organization have been hailed as a flexible and modern solution for international project management (see e.g., O'Hara-Devereaux and Johansen, 1994; Howells, 1995; Boutellier et al., 1998, 1999). But what are virtual organizations? During the past decade, the term 'virtual' has been used differently in a number of management concepts. For instance, Goldman, Nagel and Preiss (1994) define the virtual organization as an opportunistic alliance of core competencies distributed among a number of distinct operating entities within a single large company or group of companies. Other notions of virtual organization include temporary networks linked by information to share skills, costs and access to one another's resources. Some authors exclude the presence of central coordination or supervision, often denying hierarchy and vertical integration (see e.g. Handy, 1995; Chesbrough an Teece, 1996; Harris et al, 1996; Upton and McAfee, 1996; Chiesa and Manzini, 1997).

For the scope of this work we define the concept of a virtual R&D team as a goal-oriented group of organizational units or individuals. The team's expanding and shrinking boundaries depend on specific requirements of the task it is trying to achieve. A virtual R&D team, spanning several companies, does not necessarily rely on modern information and communication technology (ICT), although this is becoming the norm; and its members may pursue their own rationales, although they contribute to a shared goal.

Table 1. Short overview of relevant literature on factors affecting managing virtual R&D teams.

Project determinants	**References**
Power of the project manager.	Burgelman (1984), Katz and Allen (1985); Wheelwright and Clark (1992); Thamhain and Wilemon (1987); Roussel, Saad, and Erickson (1991)
Funding mechanism	Madauss (1994), EIRMA (1994), (1995); Ellis (1988); Szakonyi (1994a, b); Borgulya (1999); Wyleczuk (1999); Crawford (1992)
Project goals	Roussel, Saad, and Erickson (1991); Dimanescu and Dwenger (1996)
Project Owner	Rubenstein et al. (1976); Katzenbach and Smith (1993a); Leavitt and Lipman-Blumen (1995)
System interdependencies and knowledge	Madauss (1994); Henderson and Clark (1990); Nadler and Tushman (1987); Nonaka and Takeuchi (1995)
Project coherence	Roussel, Saad, and Erickson (1991); van de Ven (1986); Thamhain and Wilemon (1987)
Cross functional integration	Burgelman (1983); Imai, Nonaka, and Takeuchi (1985); Szakonyi (1994a, b); Nadler and Tushman (1987); Wheelwright and Clark (1992)
Communication tools	Allen (1977); Tushman (1979); Dimanescu and Dwenger (1996); Albers and Eggers (1991); Jensen and Meckling (1996); Gassmann and Zedtwitz (1999)
Organizational structures and processes	Cooper and Kleinschmidt (1991); Madauss (1994); O'Connor (1994); de Meyer (1991); Gassmann and Zedtwitz (1998); O'Hara-Devereaux and Johansen (1994); Bartlett and Ghoshal (1990); de Meyer (1991); Ancona and Caldwell (1997)
Globalization and externalization of R&D	Rubenstein (1989); de Meyer and Mizushima (1989); von Boehmer, Brockhoff, and Pearson (1992); Ridderstråle (1992); Beckmann and Fischer (1994); de Meyer and Mizushima (1989); Campagna and Roeder (1999); Howells (1995); Gassmann (1997); Gassmann and Zedtwitz (1998); Naman, Dahlin, and Krohn (1998); Reger (1999); Zedtwitz and Gassmann (2002a, b).

B. Review of Project Management Literature

Despite substantial research in project management, R&D managers acknowledge the inadequacy of traditional project management training for managing transnational innovation processes. In literature, few authors present descriptions of transnational R&D project organization, and even less authors provide an guiding framework for project execution. In our analysis, we have considered ten characteristics describing project management and organization: Power, funding mechanism, goals, ownership, system interdependencies and knowledge, project coherence, cross-functional integration, communication tools, organizational structure and processes, globalization and externalization of R&D (Table 1 lists important literature devoted to these factors). Our empirical research indicated that virtual projects differed substantially in these factors (see Appendix). The four typical forms of virtual projects that we suggest in the next chapter therefore pay special attention to these fundamental project characteristics.

C. Aims of this Paper

Today, no one would argue that the world of R&D has not become a global one. But high project costs, travel intensity, weak international coordination tools and project incertainties make international R&D projects challenging. Therefore the decision to use a virtual team is a necessity because of global R&D and technology centers not a choice; being 'virtual' is in most cases not a strategy but an operational reality. Modern information and communication technologies do reduce the necessity to collocate project activities, but they cannot solve problems related to trust building, team spirit, and the transfer of tacit knowledge. What is missing is a guiding framework that adequately considers the many additional challenges and constraints of international R&D projects.

Based on our analysis, we observe four typical team structures for the execution of international R&D projects: 1) Self-organizing decentralized teams; 2) teams with a system integrator; 3) teams with a core coordination team; and 4) centralized venture teams.

There is no single optimal solution for all projects and companies; therefore we have chosen a contingency approach. We identify four principal determinants for transnational project organization: 1) the type of innovation pursued; 2) the systemic nature of the project; 3) the modes of knowledge conversion; and 4) the degree of resource bundling. We conclude with five trends that we observe as shaping the future of virtual R&D organization.

II. Research Methodology

The focus of our investigation was the virtual R&D project. The data for this research was gathered in 204 semi-structured research interviews with senior R&D representatives of 37 technology-intensive companies between 1994 and 2000. Interview data were complemented by desk research, namely the analysis of corporate annual reports, company journals, internal memos, reports and presentations. Moreover, in follow-up sessions with our interview partners, we confirmed our interpretations at each company (Yin, 1988).

In the set of the 37 companies, 21 had their home bases in Europe, 5 in the USA, and 11 in Japan. All companies are highly internationalized and operate in the electrical, telecommunications, automotive, machinery, chemicals, and pharmaceuticals industries. These industries rank among the highest in terms of average R&D to sales ratio; ranging between 4.2% for motor vehicles and 12.6% for telecommunications (Schonfeld, 1996). Furthermore, they are characterized by a high degree of international division of labor.

Some of the investigated companies carried out almost 90% of their R&D abroad. Typically, companies with high degrees of R&D internationalization are the results of mergers of their parent companies. The acquisition of foreign R&D units increases their international R&D dispersion but not necessarily the degree of transnational R&D collaboration. Many strongly decentralized companies aim to take advantage of distinct competencies in local R&D units by trying to link the process of knowledge creation across many R&D sites.

III. Four Types of Organization for Virtual R&D Teams

We identified four principal concepts of organizing virtual R&D teams (Fig. 1). Ordered by increasing degree of centralized control in dispersed project teams, these are

1. Decentralized self-coordination,
2. System integration coordinator,
3. Core team as system architect,
4. Centralized venture team.

We present these concepts in this order. Each concept is explained in reference to the major project descriptors identified by our literature review. Particular emphasis is placed on interface management, both technical and interpersonal, as well as project management and project organization.

A. Decentralized Self-Coordination

In decentralized self-coordinating teams there is no strong central project manager, and no single authority enforces a rigid time schedule (Fig. 2). Project objectives are not vital to the company's business and hence receive only casual management attention. Due to the high degree of

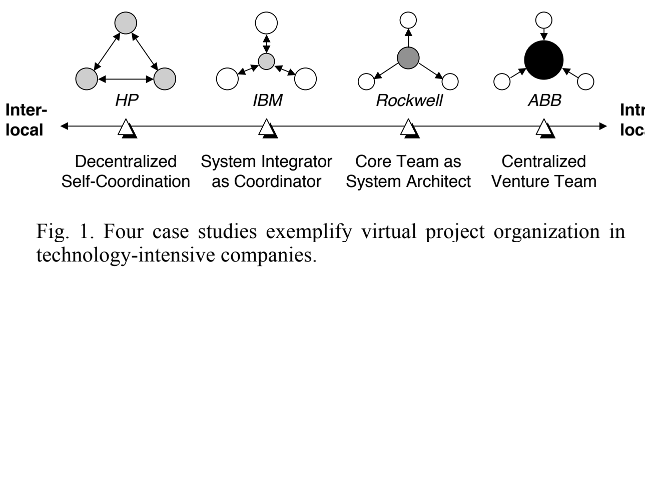


Fig. 1. Four case studies exemplify virtual project organization in technology-intensive companies.

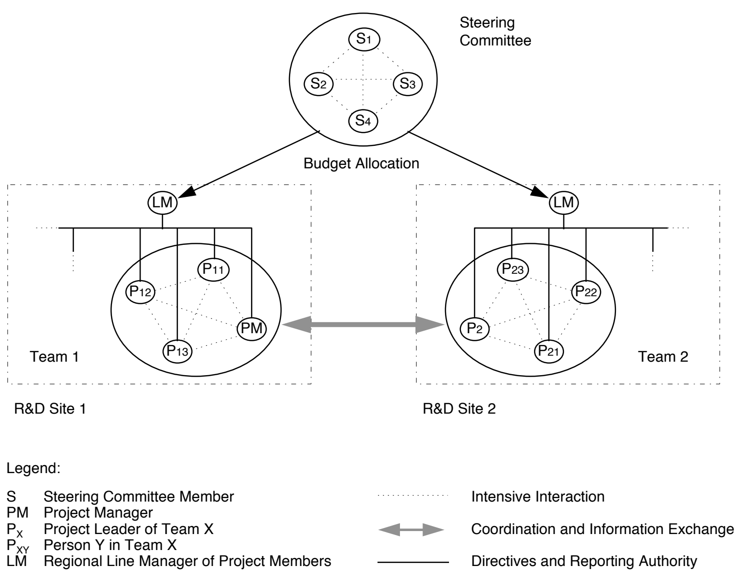
decentralization, communication and coordination is primarily based on modern information and communication technologies such as the Internet, shared databases, groupware, as well as telephone and fax. A strong corporate or professional micro-culture sometimes compensates for the absence of team or project spirit found in traditional project teams. Intrinsic motivation is important. The team itself must come up with a bracket for balancing potentially diverging individual interests and relatively weak forms of coordination. Company-wide soft management practices and company culture provide guidelines for project members.

Because of the lack of a formal project authority, self-organized teams often start out as part of a bootlegging R&D activity. But decentralized self-coordinating teams may also be set up by a superior manager who later yields project control to the group (e.g. collaborative basic research projects). Once initiated, only some administrative support is necessary (see Kuwahara, 1999). In research, the goal of such projects is to stay in touch with leading scientists around the world and draw on their ideas and insight for the benefit of related internal R&D projects. In these very early stages of R&D, system integration is often not an issue as it is still unclear what systems, technologies, and products are affected.

Decentralized self-coordinating teams in development can only emerge if standards for interfaces between locally developed modules are already available and clearly defined, i.e. IBM's established VSE and MVS system. Such modules result in relatively autonomous products with low specificity and can be produced and distributed independently. This is the case in dominant design industries in which the overall product architecture is shared by all major parties and the focus of innovation is on process improvement, i.e. elevetor industry. In the computer industry, dominant designs have emerged at the OEM level: Independent providers of memory modules, integrated circuits, software, peripheral components, and system integration compete in a highly contested market.

Decentralized self-coordination is well suited for organizations with independent business units that have a high self-interest in the development of the product component they manufacture. The overall project is supervised by a steering committee that approves and assigns the project budget. Regional line managers assume control over local module development. Such an independent and multilateral coordination of teams succeeds best in incremental or highly modular innovation. The system or product architecture not only has to remain unchanged but must be explicitly known and understood by all participating R&D teams from the onset of the decentralized project, in addition to all applicable standards and norms. Since technical interfaces are well defined, potentially diverging project objectives for component development have only a limited impact on the entire project.

Since there is relatively little interaction between remote decentralized self-coordinating teams, no integrated problem solutions will be found. Moreover, there is no central project coordination with strong authority and decision power. Should critical project situations arise and priorities need to be set, overall project goals may be sacrificed at the expense of local interests (e.g. resources, local over global design, local autonomy). A possible escape is to endow the steering committee with directive



Gassmann (1997)

Fig. 2. Decentralized self-coordination between remote project teams.

power over line managers in regional R&D units.

„Mirror organizations“ in the involved R&D site help to identify required specialists in more complex settings (Galbraith, 1993: 48). Such a symmetrical organization of teams greatly supports direct communication between corresponding specialists at the operative project level without expanding administrative project chores.

Decentralized self-organizing teams emerge if a more powerful central project organization is prevented by market forces (e.g., autonomous web developers) and company-internal principles (e.g., inter-divisional competition). However, if a decentralized self-organized project rises in importance to the company and managerial problems are expected, an individual will be vested with formal coordination authority to ensure more efficient system integration.

Case Study A: Decentralized Self-coordinating Teams - Hewlett-Packard's Technology Transfer Project

The Technology Transfer Project at Hewlett-Packard (HP) was initiated by a HP scientist because he was discontented by the serious challenges that research labs faced when trying to impact HP businesses with new technologies divisions (see Wyleczuk, 1999; Fig. 4). He raised the interests of colleagues, the support of his management, and the financial commitment of the WBIRL grant committee. The product he envisioned was a management tool-base for project leaders and scientists. As such, this product had to be created with the help of a multitude of HP managers, scientists and engineers. As the project initiator, he identified supporters in HP Labs research centers in the US, England, and Italy; these participants in turn recruited new members.

The workload was highly distributed, and most of the communication took place by e-mail or videoconference, except for some daylong face-to-face meetings that were critical to developing a common vision. The early attempts to „get going on the work" failed because the distributed team members had not yet established common goals and objectives. These early difficulties and frustrations disappeared after the crucial goal-setting meeting, when all members met face-to-face for two days. The team could then proceed with briefer monthly video or telephone project meetings.

The team experienced great support from other HP scientists, who offered their advice and experience on best-practice tools. based on this know-how pool and an external benchmark on existing industry practices, the team came up with a technology transfer toolbox. Most of their work and the final product were supported and dependent on Internet technologies. The team selected some pre-existing process reference documentation templates for packaging the findings as it was considered important to reuse any tools available; this template was already a de facto standard internal to HP for capturing best practices.

B. System Integrator as R&D Coordinator

Interface problems that occur in self-organizing teams can be reduced if a system integrator assumes a coordination role. A system integrator harmonizes interfaces between modules, defines work packages, and coordinates decentralized R&D activities (Fig. 3). Interface management encompasses four aspects:

1. A system integrator harmonizes physical, logical and process interfaces between modules and supervises overall system integration (*technical interface management*).
2. The system integrator is also responsible that the work packages in a project are completed on time (*temporal interface management*).
3. The system integrator tracks and controls the contribution of all participating profit centers (*administrative interface management*).
4. Moreover, the system integrator must build a common project understanding between different functional and regional units in the project team (*social interface management*).

The system integrator has a central role in an otherwise highly decentralized project. Several system integrators or a dedicated project integration office may supervise particular complex or collaborative decentralized projects. The integrator facilitates the coordination between integrated product management teams and local teams, and he ensures coherence of individual project team aims. These teams act highly independently, but as long as they fulfill previously agreed specifications the system integrator is reluctant to interfere. Often, this project organization is used to tap locally available expertise for product upgrades or refinement work.

As a 'global knowledge engineer', the system integrator is responsible for managing knowledge transformation processes (between explicit and tacit knowledge) and the aggregation of the locally created knowledge. He must translate between teams of different contexts: languages, business vs. technical aspects, and culture. In order to overcome functional differences, a system integrator must opt for system thinking in favor for local technological optimization.

Although project coordination is considerably aided by modern information technology, an initial workshop with principal team members and subsequent regular face-to-face contacts are crucial for system integration. A central location of the integrator's office is hence important in order to reduce the otherwise significant travel burden, and to facilitate meetings between teams and integrator.

Differing interests of project teams can endanger project success, since the system integrator has still only little decision authority over the decentralized teams. Through intensive communication, strong personal commitment and frequent travel the system integrator aims to build an informal network and some form of team spirit. If conflicts still cannot be handled this way, he will summon team leaders to meet face-to-face in order to settle the dispute or solve the problem. Integrating diverging interests in a multi-cultural background demands high inter-personal skills from the system integrator who cannot rely on top-management support or directive power over the dispersed teams. Much patience, sensitivity and experience is required to align the individual objectives of each partner team, making sure that they agree on a shared understanding of what is to be achieved and how each partner would contribute to this goal. Mutual demonstrated appreciation of each other’s work (e.g. in top-management reviews) is crucial for continuous motivation in an extremely complex international environment.

Case Study B: System Integrator as an R&D Coordinator - VSE Development at IBM

The development of IBM's Virtual Storage Extended (VSE) system software is distributed over eleven R&D units. For reasons of compatibility, each release requires mostly incremental improvements in specific functions (90% is reused). Project management and system responsibility reside in the German R&D unit at Böblingen near Stuttgart. Acting as a steering committee, the Investment Review Board is located in New York (Gassmann, 1997: 92-108).

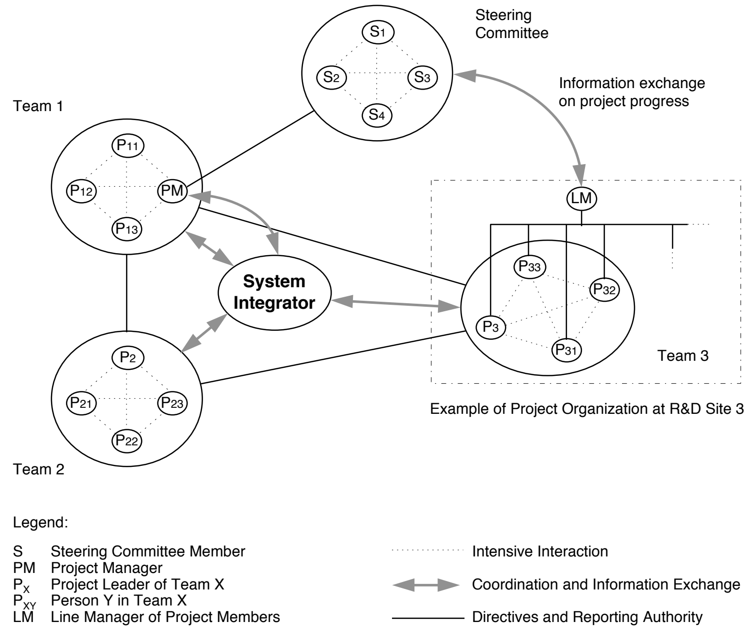
Coordination requirements and interaction between project teams are dependent on the degree of interdependencies of VSE product components. As a rule, they are relatively low. Not every unit participates by default in a new release, only the four R&D units in Böblingen, Hursley, Santa Theresa and New York developing vital components are involved in each release. The high degree of platform management and system compatibility with MVS reduces parallel development, system complexity, interface mismatches and product maintenance costs.

There is a substantial potential for conflict between teams since each development team is part of an independent profit center. Direct instructions from one team to another team are usually not possible. The overall project manager wields relatively low authority. Although this empowerment promotes self-coordination, a unit's autonomy is limited by IBM-internal integration. The system integrator must rely on the readiness to cooperation of the other R&D teams, often relying on softer forms of persuasion. If no agreement can be reached, Böblingen considers internal development or outsourcing. This often results in complex profit distribution schemes and intellectual property conflicts.

System integration is located in a project office in Böblingen. Four integrators coordinate all development work of 20 VSE components. Their responsibilities include the collection and technical evaluation of new project ideas, technical system design, project supervision and coordination, project documentation and VSE product planning. Ideas for completely new functions and products (leading to radical innovation) are also reviewed, considered for potential development in Böblingen, or assigned to a better-suited IBM R&D location.

After many years of VSE development experience, project planning is a highly standardized process with clearly defined project goals, interfaces and abundant boundary conditions. The project office tends to restrict developmental freedom in project teams. Once the VSE development reaches a predefined checkpoint, the specifications are 'frozen'. Component design is almost completely entrusted to local R&D units, but the project office also supervises and coordinates the entire development process (including system design, implementation, code scaffolding, module integration, customer testing).

C. The Core Team as a System Architect



Gassmann (1997)

Fig. 3. System integrator as coordinator of decentralized R&D teams.

Companies whose R&D teams work closely together control their product development processes better (Takeuchi and Nonaka, 1986: 78). Studies on communication and team performance suggest a physical collocation of R&D in one place (e.g. Allen, 1977; Katz and Allen, 1985; Takeuchi and Nonaka, 1986: 40; Katzenbach and Smith, 1993b). But the advantages of intralocation are in fundamental contrast to the many multi-site necessities in R&D projects (Lullies et al., 1993: 193).

Collocating all project members and equipment may be very costly and sometimes impossible. The second-best solution is to form a core team of key decision-makers who meet regularly in one location to direct decentralized R&D work (Fig. 4). In comparison to the concepts of decentralized self-coordination teams and system integrators, this approach is characterized by the highest intensity of interlocal communication, and most integrated problem solution.

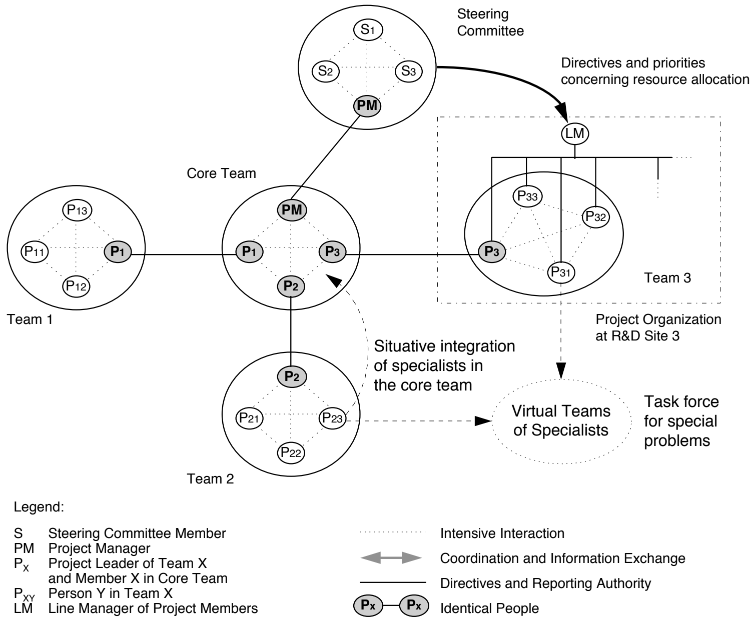
The core team typically consists of a project manager, team leaders of decentralized projects teams, and internal business customers. External customers as well as consultants have been seen to be part of core teams, although their involvement in the project is on a part-time basis. The size of a core team usually does not exceed 10 to 15 people.

The core team develops the system architecture of a new product and maintains coherence of the system during the entire project duration. Essentially, it assumes the role of a system architect and integrator (interface management) but has the directive authority to enforce its instructions. Hence the core team is better prepared to resolve diverging interests of functional and local organizational units and to translate between differing cognitive contexts ('cognitive bridging', Ridderstråle, 1992: 14). Day-to-day management takes place through the use of collaborative tools such as intra- and internets, groupware, videoconferencing, significantly reducing the requirement, frequency and costs of face-to-face meetings.

Good linkages between the core team and the supervising project steering committee are a must: They guarantee direct information flow between project teams and the product champions. In strategic projects, the steering committee should also have direct influence on the line managers concerning the prioritization of projects and resource allocation, as to resolve the many responsibility conflicts occurring in a complex matrix organization.

Since core teams can address problems on a more integrative level, new solutions can be found outside predefined concepts and frameworks ('architectural' or 'radical innovation', Henderson and Clark, 1990: 9). Problem solving in core teams differs substantially from independent search paths of self-coordinating teams or the mediation by system integrators. Core teams are inevitable if highly innovative products are to be developed and intralocal project execution is not possible because of restricted resources.

If the core team is unable to solve a specific problem, specialists from other R&D units or local teams will be temporarily included. The boundary of the project team expands and shrinks according to the project tasks and



Gassmann (1997)

Fig. 4. Core team as a system architect.

project difficulties, although the size of core team must not exceed an upper limit in order to guarantee operational efficiency. The core team may address limited and clearly defined problems by contacting specialists of participating R&D units directly for joint problem solving. Tele- or videoconferences may suffice to bring together the input from specialists, but if the problem is particularly complex and involves several modules, specialist's teams are created and supervised by the core team.

Case Study C: The Core Team as a System Architect - Intelligent Machine Development at Rockwell Automation

Rockwell Automation has built a reputation for developing intelligent machinery and machinery diagnostics. In January 1996, representatives of 18 major customers were invited to establish a business need and technical requirements for a variety of applications of intelligent machines. As competition was perceived to catch up, Rockwell Automation decided to initiate an ambitious 18-month program to develop an intelligent motor product (see also Discenzo, Schaefer, and Marik, 2000). The product specification outline was based on customer input and Rockwell Automation's experience with several earlier concept systems, integrating existing experience as well as novel, yet-to-be-developed technologies.

A core team of three senior staff members from marketing, R&D, and engineering was formed. A senior vice president sitting in the review committee 'owned' the project. As the core team did not want to afford the risk of failure with unproven resources or the delay for learning new technologies in-house, new team members were included in the team as needed. Often the best staff was found in another Rockwell division, hence expanding the project boundary again. A one-page, graphic product brochure was created which served to motivate and communicate a clear and common objective to the team. The projects internal visibility, strong customer-drive and a keen sense-of-urgency ensured team coherence, although only one person was employed full-time and everyone else had other responsibilities to attend to as well.

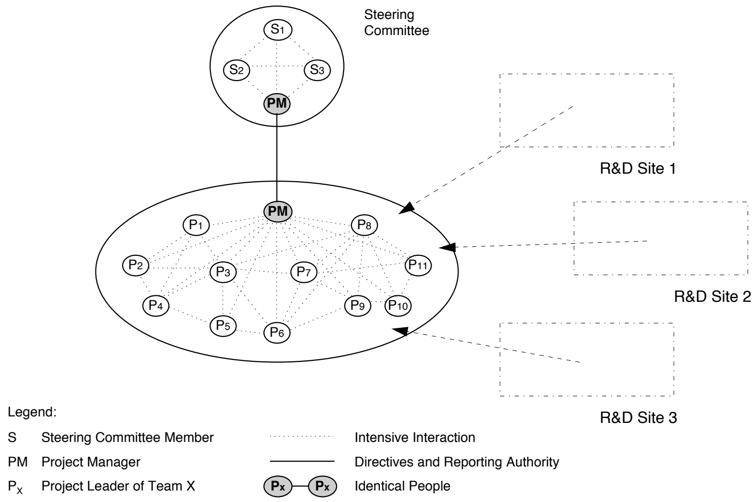
Formal project management tools were introduced to support communication and reporting. A concise project reporting format and tracking form was developed specifically for this project, including a one-page summary that graphical project status representations. A standard repository uniformly maintained the timely validity and accuracy of technical information; software code revision and document control were administered by the core team.

Still, a key success factor was the considerable amount of informal communication. During the day-to-day development activities it was customary for team participants to contact anyone in the project as needed. E-mail, intranet, video-conferencing, and telephone conference calls were heavily used. Issues and results from this semi-formal communication were copied easily to the appropriate core team leader responsible for the area of activity.

The most critical element, however, was the selection of dedicated, communicative and trustworthy people: Just professional competence alone was not sufficient for decentralized R&D work. Many segments of the team had collaborated previously, resulting in a high degree of trust and open communication. Individual team members from remote locations spent time at other team member sites performing joint R&D tasks. Ensuring trust and transparency of leadership to project management was also highly important. The R&D representative in the core team spent up to 25% of his time travelling and coordinating R&D activities with local team engineers, contractors and customers. Competent and empowered team leaders in each location helped align local activities with the overall project objective. Despite the adversities of geographical separation, the project turned out to be very successful: The overall development time was shortened from the projected 18 months to 12 months while staying within the predefined budget. A testament of the novelty of this accomplishment is multiple trade industry awards and patent awards for this work.

D. *Centralized Venture Team*

Spatial distance between R&D employees decreases the likelihood of communication significantly (Allen, 1977): Coordination and know-how exchange become more problematic in international R&D settings. Physical collocation of scientists, engineers, and project managers thus tend to make the execution of R&D projects more productive. Due to high costs of relocating dispersed R&D personnel and resources in one location (and the resulting local overcapacity once the project is concluded), the centralized venture team is used only for strategic innovation projects of utmost importance (Fig. 5).



Gassmann (1997)

Fig. 5. Centralized venture team: collocation of all participating R&D teams under heavyweight project management.

The geographically centralized venture team is responsible for planning and execution of an R&D project, including idea generation, product system definition, technology and product development, testing, and often even the product’s market introduction. In order to justify the magnitude of expenses and efforts, a sense of urgency is required. A heavyweight project manager wields unrestricted command over the resources assigned to him, and he employs all available tools of project coordination. To effectively implement his decisions, he is fully empowered to pursue new and original solutions without repeatedly asking for approval. Full technical and business responsibility is likely to lead to radical new product and process concepts. Due to its strategic importance, project funding is often provided from corporate sources. One or several steering committees supervise the project.

Through physical proximity and intensive project-internal communication, the centralized venture team seeks to implement integrated solutions. Physical collocation for face-to-face communication and good informal linkages between team members (preferably in the same building or room) are regarded as the principal factors for effective and short-time development. Simultaneous engineering (rugby team approach) is possible if cross-functional collocation overcomes compartmental thinking.

Known as „High-Impact-Projects“ at ABB, „Top projects“ at Bosch, or „Golden badge projects“ at Sharp, centralized venture teams can be extremely expensive and therefore only used for strategic projects. Staying within project budgets is less of a priority than achieving technical goals and time-to-market. Frequently, such projects are crucial for developing attractive business opportunities or for closing gaps to fast-moving competitors. Being dispatched to the central project location, the project members are exempted from their line duties in other R&D locations. Specialists are often intensively engaged in such activities, and their removal from their parent location imposes great opportunity costs for venture teams. Direct costs are less important compared to the opportunity costs of collocating the team. The development of a strong project culture complicates the reintegration of the project members into their previous line functions.

Although the centralized venture team is pulled together in one place, this location is not necessarily the corporate R&D center. The venture team's separation and independent organization from its original research department is often considered critical. Removed from the company’s line organization, a venture team allows the unrestricted cooperation of specialists from several functional areas. As in Daimler-Benz's 'Project-House Necar', the team settled in Nabern, about 30 km away from the headquarters in Stuttgart, but close enough to other Mercedes-Benz development units in Ulm and Friedrichshafen. R&D teams of cooperation partners (DBB Fuel Cell Engines and others) are collocated with the Project-House, such that almost 200 R&D people are working on fuel-cell development in Nabern. Similarly, ABB's GT24/26 development took place in rural Gebenstorf, but still within a short ride from either the Research Center in Baden or the R&D headquarters in Zurich (see ABB case for more details).

Despite their strong centralization, these venture teams are increasingly international. Even very large companies do no possess all technological capabilities to pull off a high-risk high-impact project all by themselves. Strong international partners help in setting technical and market standards. Technological cooperation with lead customers, specialized suppliers and research partners require the integration of teams from across the border.

Centralized venture teams are the most costly approach to virtual R&D teams and result in difficult overcapacity situations during the termination of the project. But centralizing research teams may be the only way to achieve challenging goals under intense time pressure until information and communication technologies used in transnational R&D become more powerful. Especially when information can easily be converted to code and team members know each other already from previous projects, a substantial amount of cost-intensive centralization can be reduced to kick-off and review meetings. Yet, modern information and communication technologies cannot replace face-to-face contacts for extended periods of time.

Case Study D: Centralized Venture Teams - ABB's Think-Tank for the Gas Turbine Development GT24/26

With several international R&D units involved for component development and testing, the GT24/26 gas turbine development at ABB is an example for a strongly centralized yet transnational R&D project. The GT24/26 project represented a breakthrough innovation in gas turbine development—for instance, more than a hundred patents were filed. In the 1980s, ABB reduced its commitment and R&D engagement in high-power turbines, until a 1991 market analysis indicated a multi-billion-dollar market for turbines generating more than 130 Megawatts ('high end turbines'). Lagging three to five years behind General Electric, Siemens and Westinghouse, ABB had to catch up with its competitors in terms of quality, time, and price.

The short development time in particular seemed unattainable, since technological foundations had still to be developed. Because market entry timing was paramount, new management methods were called for to ensure fast-cycle development time, competitive advantage and customer orientation. An R&D project team of several hundred people from 20 nations was created (Fig. 10). Specialists from basic technologies, such as material and environmental sciences, but also from different functional departments, such as production, assembly, and service formed a highly interdisciplinary team; the know-how gathered was highly complementary.

The project structure was characterized by high international division of labor. The ABB Research Center in Baden, Switzerland, provided the new combustion technologies, and Baden researchers were subsequently engaged in integrating these technologies in the new turbine. The main share of the turbine development took place in Baden, including the development and production of the combustion chamber and turbine blades as well as final assembly of the turbine. ABB Mannheim was responsible for R&D and production of rotors, requiring profound technological know-how. Less technology-intensive components were developed in locations with cost advantages. In addition to ABB R&D units, external companies participated in the turbine development through contract R&D, development cooperation, and integration as a lead user.

All project members were concentrated in a single open-space office in a two-story building in Gebensdorf, a village near Baden, Switzerland. Since ABB had enlisted many contributors outside ABB for integrating external know-how, the central project location of this 'think-tank' facilitated cross-functional communication and helped to keep critical know-how inside the project. The strategic importance, the high-flying objectives, and the seal of confidentiality supported the creation of a common project spirit and innovation culture. ABB was cautious not to accidentally release any information to competitors: All project members were sworn to secrecy, and even the Gebensdorf building retained an innocent residential housing exterior.

The GT24/26 development project enjoyed high priority within ABB's Power Generation unit. The project leader reported directly to the head of development and the general manager. The steering committee met once a month. In critical phases of the project, even the Board of Management was involved. Most of the project members were completely assigned to the project and reported only to the project manager. The project manager was responsible for all activities between research, development and production, including the completion of the first two gas turbines and their installation at the customer sites. The strong position of the project manager facilitated his access to critical and limited resources, such as functional specialists in particular technical areas.

The design of production tools was started before the product development phase was concluded. Even more acute than in sequential development projects, the parallel execution of the turbine development in combination with the spatial distances between product and production tool development units created serious coordination challenges. For instance, the rotor development team and its manufacturing personnel were relocated from Mannheim to Baden in order to ensure the necessary intensity of communication.

Due to high R&D costs and urgent time pressures, ABB deployed the concept of innovation marketing: the close interaction of R&D, marketing, and innovative product users. Innovation marketing aims to aligning internal and external technological constraints by coordination among the main innovation participants, improving technology transfer, cross-functional communication, and market introduction times. The principal management approach combines heavyweight project management, design-for-manufacturability, benchmarking, and simultaneous engineering.

GT24/26 was the first simultaneous engineering project at ABB. Since vital technological know-how was lacking and the pressure to reduce development time was enormous, ABB engaged in this project before the necessary materials research was completed. In order to simultaneously develop end-product components while fundamental research was still under way, research and development was collocated in one building in Gebensdorf, Switzerland.

The main success factors of the GT24/26 development were the centralization of the project team in one location, or think-tank, the coordinated parallelization of activities and cross-functional cooperation, strong top-management commitment, and the integration of potential and lead customers. ABB's top management fully supported the project, yielding considerably authority and decision power to the GT24/26 project manager. Cross-functional teams, lead users, researchers, and development engineers collaborated during the entire project. The GT24/26 generation was a technological breakthrough and moved ABB from a late follower into a technical leader in the field of high-end turbines within a short time frame. Compared to previous projects, time-to-market could be reduced by 60% and the number of modules by nearly 50%.

IV. Determinants of Transnational R&D Organization

In the previous section, we have outlined four paradigmatic forms of project organization: self-organizing decentralized teams, R&D teams coordinated by a system integrator, core-team guided R&D projects, and centralized venture teams. These four concepts differ in various ways, the most visible differences being the power of the project manager and the geographic location of the main part of the team.

However, these differences do not explain *why* a particular organization of virtual R&D project execution was chosen—they only highlight *how* an organization prefers to address more fundamental determinants and constraints of transnational R&D work. The question remains, *what* are these fundamental determinants for virtual R&D projects?

In this section we suggest four determinants that shape virtual R&D project organization. Our propositions are based on our empirical investigation and analysis of the project descriptors that we used in the above concepts, complemented by literature relevant to R&D, project management and knowledge creation. In total, we identified four determinants as relevant for choosing a specific organizational form of transnational R&D organization.

1. Type of innovation: Incremental versus radical;
2. Nature of the project: Systemic versus autonomous;
3. Knowledge mode: Explicit versus tacit;
4. Degree of resource bundling: Redundant versus complementary.

A. Type of Innovation: Incremental versus Radical

The novelty of an innovation is given by the number, extent, and predictability of deviations from the experience and know-how base of a company. If the affinity of an R&D effort to existing technology and processes is strong, we speak of incremental innovation. Incremental R&D projects are characterized by higher continuity, routinization, and more gradual improvement. Examples for strong process affinity are efforts to reduce tolerance levels or improve pass-yield quotas; products with a high affinity to existing technologies are e.g. software application updates such as Word 6.1 or platform-based car derivatives.

Radical innovation is typically the result of a break-through project in a new technology or process, involving completely new markets, new technological designs, or the integration of formerly unrelated technologies for novel applications. Since the affinity to existing technology or processes is weak, project dynamics and hence uncertainties concerning attainability and execution are higher. For example, the pharmaceutical industry is currently embracing drug-by-design processes and other revolutionary approaches to drug development. Products that opened new markets or involved novel technologies are ABB's GT24/26 or Daimler's Smart mobile.

Incremental innovation is better suited for decentralized execution as the required technologies are known and system interfaces are defined. R&D is more likely to target module-internal innovation, leaving the overall product system intact. While incremental innovation is often a sine-qua-non condition for maintaining or expanding an existing line of business, its R&D projects usually do neither enjoy the same visibility nor attract the same attention from top-management.

B. Nature of the Project: Systemic versus Autonomous

The systemic nature of the innovation project depends on the interdependence and structurability of individual project work tasks. Highly structured projects with separable work tasks are examples of autonomous innovation projects. Structure implies a defined input-output process as well as cause-and-effect knowledge about individual tasks. Work is split up into work packages with well-defined interfaces. The execution of a project can easily be planned in advance; clear tasks and responsibilities are assigned to all project participants. Work tasks that are highly separable from the development of the product system are, for instance, personal computer components such as memory chips, disk drives, and integrated circuits. The rigorous testing and research process established in many academic and industrial R&D laboratories is a good example for highly structured innovation. In pharmaceutical R&D, this is embodied e.g. in well-maintained laboratory manuals and rigid guidelines for clinical development.

Highly interdependent work tasks indicate a systemic nature of innovation. Interdependence occurs often in the early phases of R&D projects, when technical and procedural concepts have not been fully defined yet. In product development, wide tolerances between functional parts also reduce separability.

Thompson (1967) describes four types of interdependence relevant for R&D projects: pooled, sequential, reciprocal, and team-oriented. Pooled interdependence is based on restricted access to shared resources. Sequential interdependence links the output of a work package with the input of another work task. Reciprocal interdependence implies mutual coordination of temporal and logic dependencies as in technical specifications of highly integrated products. In team-oriented interdependence, high module-internal interdependencies require a strong coordination and mutual integration of work package goals within every team. We have found these constraints e.g. in laptop development, where tightly packed modules require close physical and functional alignment which makes a clear separability of module development impossible. Also, highly creative processes such as brainstorming perform best when structural rigidities are removed.

First-of-a-kind development projects are often systemic since there is little previous relevant experience available by which the project should be structured. With increasing knowledge and experience, work tasks and interdependencies are delineated better and better. In complex R&D projects, however, many technical design interfaces are initially unknown and emerge only in the course of the project (see also Sosa, Eppinger, and Rowles, 2000). Systemic innovation is better approached with cross-disciplinary teams not only because their input may be more diverse but also because they are believed to adapt faster to unexpected change. System integration is tedious and conflict resolution is difficult: they are inevitable and take place between multiple stakeholders. This requires strong interpersonal and superior coordination skills. In autonomous innovation, system integration occurs at a lower level and is typically not time critical. Coordination and communication is asynchronous and determined beforehand by technical and managerial constraints.

Hence, the separability of a project decreases with the diversity of information, communication frequency, and unpredictability of communication. High interdependence and systemic projects are unsuited for interlocal execution, whereas autonomous work packages and highly structured projects may be decentralized to remote but higher qualified R&D units.

C. Knowledge Mode: Explicit versus Tacit

The pooling and transfer of knowledge among team members is crucial, particularly in international projects which aim at exploiting specific location advantages. In the context of knowledge exchange across great distances, the distinction between tacit and explicit knowledge becomes even more important (see Nonaka and Takeuchi, 1995; Polanyi, 1966). Explicit knowledge is easily articulated and documented, but tacit knowledge is difficult to communicate.

We further discern two types of knowledge: individual knowledge and social knowledge.

Social knowledge is knowledge shared among a group of individuals, its interpretation being subjective to the composition of this group. Nevertheless, there is a high degree of redundant knowledge that provides identity to this group. Individual knowledge is specific to every human being; it is present and producible without other people having to be around.

In R&D projects, individuals as well as teams engage in knowledge creation and knowledge transfer. Learning occurs both at the individual level as well as at the team level. The codifiability of knowledge defines learning modes and knowledge exchange patterns. Highly codifiable individual knowledge is fact-based accounts or low-context-specific results. Codified social knowledge is found in laws and written norms and standards, as for instance in R&D project manuals, ISO certifications, or password-recovery functions. Difficult to codify individual knowledge are many individual 'how-to' skills at the border to what we may call art or intuition; it may also be more trivial knowledge that an individual is unaware of and assigns little relevance to be articulated. Hard to codify social knowledge is at the base of group dynamics and the success of assembling the 'right' team.

Tacit knowledge includes both individual knowledge and social knowledge. Examples are decisions based on intuition and 'coordination without words'. The transformation of knowledge (socialization, externalization, internalization, combination) from one mode to another is not trivial and crucial for effective learning and know-how transfer. In the start-up phase of an R&D project, mutual agreements and procedures must be established (socialization). This tacit knowledge is eventually externalized (i.e. codified and transformed into standards and specifications). The processing of explicit knowledge into more explicit knowledge (combination) is increasingly supported by modern information technologies, particularly multimedia-based means of context-rich communication.

These transformations are highly affected by the cultural and behavioral background of the project members. Project coherence may be based on shared cultural or social knowledge, or that mutually shared social knowledge can be established in order to reduce difficulties resulting from cultural differences. Interlocal project execution presupposes that tacit knowledge can be externalized and communicated over distance. It is the project manager's responsibility to facilitate the transformation of individual know-how to knowledge available to the entire team.

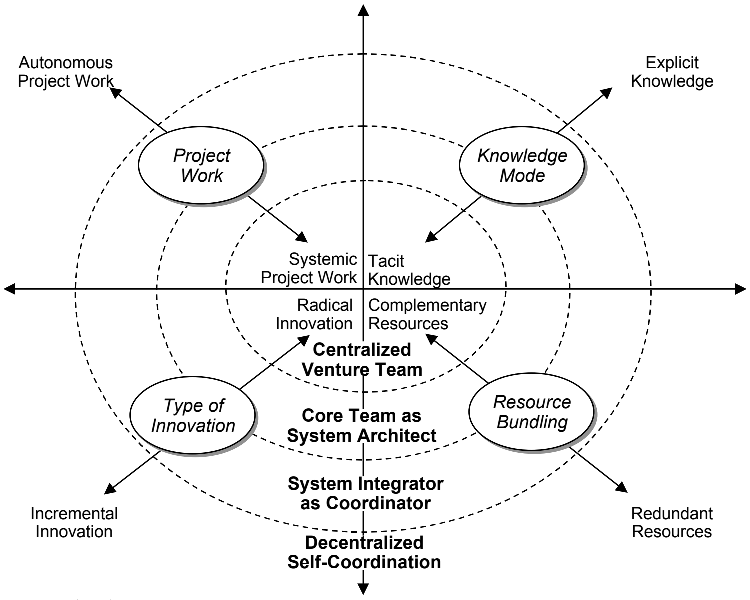
D. Resource Bundling: Redundant versus Complementary

In international R&D projects, resources such as capital, equipment, and people are pooled over a number of locations. Within a project, the deployment and bundling of these resources can be either redundant or complementary.

We consider bundling of resources both in functional as well as technological capacities. Strong functional redundancy is present in projects with team members performing similar functions. Project-internal communication then tends to be less problematic since all members use the same terminology and share the same referential framework. Functional redundancy is low if different functions are involved, such as R&D, suppliers and lead users. As their contexts are not strongly related, communication tends to be more complicated and requires more face-to-face contact and externalization. Strong functional redundancy occurs when subteams are deployed in parallel to prepare competing solutions to the same problem; cross-functional teams are typically characterized by low functional dependency.

If only few technological areas are involved in an R&D project, redundancy in technology is relatively high: All participating teams or R&D units share similar technological competencies. Researchers of the same scientific discipline also share the same cognitive base and terminology, which, as with functional redundancy, helps low-context ICT or telephone communication by making reference to well-understood frameworks. An example for strong technological redundancy are projects in clinical drug development, where a specific drug candidate is being tested in similar circumstances across a multitude of hospitals. Low technological redundancy is given if many different technologies are to be combined and only few experts are available. This is the case in cutting-edge R&D where the number of experts is limited such as in intelligent machine design or laser research.

Redundancy is often associated with the duplication of R&D efforts and the waste of available resources. However, redundancy in resources and competencies (usually tied to people or teams) provides a buffer against the unforeseeable loss of key people or the elimination of technical alternatives. Epistemological redundancy thus improves the knowledge creation process in R&D projects. Redundant and overlapping knowledge improves the parallelization of R&D work and cross-functional collaboration. Interlocal projects are more difficult to carry out if there is little or no functional and technological redundancy.



Gassmann (1997)

Fig. 6. Four fundamental project determinants and their fit with the four concepts of virtual R&D project organization.

V. Towards a Contingency Approach to Organizing Virtual R&D Teams

We have started our discussion with a review of some important characteristics of project organization and project management. These project descriptors guided us through four concepts of virtual R&D organization, spanning highly centralized to self-organizing decentralized projects. We have argued that four fundamental determinants are responsible for the observed spatial distribution of project teams and their organization. These four determinants are the type of innovation (radical vs. incremental), the systemic nature of the project (systemic vs. autonomous), the knowledge mode conversion (tacit vs. explicit), and the degree of resource bundling (redundant vs. complementary).

The four fundamental determinants demarcate spatial organization of R&D projects (Fig. 11), establishing whether centralization is necessary or decentralization is possible. We suggest two propositions of virtual R&D project organization:

P1: The centralization of R&D projects is necessary for radical innovation, systemic project work, prevalence of tacit knowledge and the presence of complementary resources.

The centralization of projects is necessary if the needed know-how is still tacit or difficult to externalize. The more tacit knowledge abounds, the higher are the interdependencies between teams and between product components. Frequently recurring interface issues make unproblematic and straightforward face-to-face communication imperative. The project's complexity is large and not discernable into smaller subsystems. Resources are thus bundled and subjected to centralized management. If successful, such projects make significant contributions to knowledge-building, i.e., radical innovation.

P2: The decentralization of R&D projects is possible for incremental innovation, autonomous project work, prevalence of explicit knowledge and the presence of redundant resources.

Decentralized projects are possible if technical data and project information are easy to share among subteams, leaving little ambiguity of interpretation. Work and technical interfaces are predefined and need not be negotiated beforehand. Each team enjoys high work and technical autonomy. Teams have access to their own resources, without the need to share them with other project subteams. Project complexity in its entirety may still be significant; however, specific module complexity of each decentralized team is relatively low and requires no intensive coordination with other project teams.

We want to reiterate that all four described concepts are in fact *virtual* project organizations. Even centralized venture teams are often transnational R&D projects, integrating local lead-users or outsourcing clearly defined subtasks. Like in any other virtual R&D team, the scope and size of centralized venture teams change and adapt with the project tasks at hand. As we remember, expanding and shrinking team boundaries are at the core of the definition of virtual R&D teams.

VI. Conclusions and Future Trends

The use of virtual teams, especially in international R&D projects now seems well established and likely to continue. Powerful information and communication technologies, growing experience with managing transnational R&D processes, and the globalization of technology are harbingers of a new standard in international R&D organization. In this paper we proposed four concepts of virtual R&D project organization, describing principal management responsibilities and organizational pitfalls. We also suggest specific conditions and circumstances that must be in place in order to determine the appropriate degree of spatial and organizational decentralization.

In the centralized venture team, all project members are collocated in one place. In the core team as a system architect, all relevant team leaders and project managers meet in one centralized location. The system integrator moves between geographically dispersed R&D teams trying to coordinate them. There is little face-to-face contact between self-coordinating teams.

The fundamental determinants that we identified as critical in transnational R&D projects were the type of the innovation pursued, the systemic nature of the project, the necessary knowledge conversion mode, and the degree of resource bundling. In their entirety, these determinants and concepts may serve as a guideline for the conception of virtual R&D organization.

Looking ahead we observe the following trends in organizing virtual R&D teams:

Trend 1: As the internationalization of R&D continues, the importance of virtual R&D teams increases.

The internationalization of research, development and technology will continue. Decentralized structures of research, development and knowledge creation will become the standard in companies of all sizes and technological concentration. The accumulation of technological know-how in centers-of-excellence, in association with increasing returns-to-scale in knowledge production, necessitate the establishment of local R&D units and technology listening posts. Ethnocentric and geocentric centralized R&D organization will need to open up and outsource R&D on a global scale in order to secure technological competitiveness. Profit center thinking leads to more empowerment of decentralized business units, carrying out more designated activities along the entire value creation chain. This is the paradigm of market orientation in product development. In pulling these dispersed R&D capabilities back together into targeted innovation projects, virtual R&D teams play a vital role.

Trend 2: Transnational R&D projects follow talent in new industrialized countries.

The rise of transnational R&D projects is carried forward by the availability of talented engineers and scientists in an increasing number of centers-of-excellence around the globe-and our awareness of their existence. Company clusters and local governments create the bases for new technical knowledge in regions formerly insignificant to international R&D; multinational companies try to tap these bases with local R&D offices in regions such as Eastern China, India, Taiwan, Korea, Singapore, Eastern Europe, Mexico, and parts of South America. Students and scientists who have gone to the US and Europe for training and education return to their home countries. Being highly computer-literate and proficient in English, the dominant language in international science and business, they can translate between explicit ICT-based communication and their often context-rich local cultures. Particular industries with modular product development processes (e.g., software) already exploit the possibilities of 24-hour laboratories and local wage advantages. Furthermore, since the virtual integration of dispersed teams can take place from anywhere, ICT-based R&D offers great opportunities for customer-oriented R&D.

Trend 3: Better ICT enhance the functionality of virtual R&D teams.

Besides the conventional telecommunication support such as telephone, e-mail and fax, the best ICT current virtual R&D teams support systems that use are groupware, videoconferences and real-time multi-site simulations. During the short time period of our interviews (1994-2000) we have experienced fast progress in new state-of-the-art iinformation and communication technologies. Future communication technologies are expected to convey a sufficient amount of tacit information to create the illusion of virtual presence. Haptic as well as holographic technologies are being developed. The internet expands both in reach (net-periphery and backbone) as well as in information throughput (bandwidth). Advances in microelectronics, data transmission and information processing are pulling down the barriers project managers today have to overcome with time-consuming long-distance travel. Project management tools are developed with decentralized work execution in mind. Already today many scientists and engineers have gained a familiarity with conventional internet tools that go beyond the expectations of yesterday's communication researchers. Not only will ICT become more powerful, but also their perceived disadvantages will become less of a burden.

Trend 4: Relative costs of running virtual R&D projects will decrease due to learning curve effects.

Like any other group effort, teams will become better at doing virtual R&D projects the more they get engaged in international R&D. Once a company has moved up the learning curve, we see a reduction of time-to-market and of R&D costs. Project participants become increasingly savvy in utilizing ICT and working in a diverse team environment. Project leaders and R&D management enhance their understanding on how such projects should be set up and run. Moreover, overall coordination costs fall as the most competent local companies are integrated in global R&D processes in order to optimize the use of external resources.

Trend 5: Highly decentralized virtual R&D teams gain importance in open system architectures such as internet-based applications.

With the advent of the Internet and the World Wide Web, a powerful and highly transparent standard has emerged. In internet-based industries, technical interfaces define social interfaces. Hardware and software specifications as well as web development tools are publicly available, making the Internet a product development platform par excellence. Web-integration means system integration. Already today, companies of the new economy use the Internet as their main referential fix-point for establishing a network of worldwide R&D competence. Software engineers and programmers are highly independent of actual locus of work; some of them work on a purely contractual basis for faraway headquarters. Knowing that their skills are highly contested in a dry labor market, they chose to pursue professional challenges that match their individual interests. But this is only possible because software engineers are highly ICT-literate people, being accustomed to communicate via E-mail and other means of ICT.

Todays success of open source products, such as Linnux, Apache web server or sendmail, have triggered an academic discussion on virtual and open organizations (Gassmann 2001). New ways of incentive systems and operating modes have avised in these user and hacker communities. Research agenda on this empirical phenomenon is just starting to evolve.

Decentralization is generally justified by the need to tap local resources and talent. This is certainly a major driving force in virtual R&D projects. However, the dispersion of R&D work is also motivated by finding adequate assistance for 'the few great minds' in an R&D organization, top-notch scientists and researchers with exceptional productivity and creativity. Virtual

R&D teams cater both needs: tapping local diversity as well as supporting central creativity. The boundaries between virtual R&D projects become blurry—some members are key experts in several teams. Hybrid forms of virtual teams, one overlaying the other, become possible.

With this contribution we hope to have added to the understanding of spatial distribution of R&D teams and its effects on project management. Especially in emerging technologies or large and costly projects, virtual R&D can help to spread the risk and distribute costs among a network of stakeholders. It is crucial to identify appropriate target technologies, project members, and modern support tools. Nevertheless, traditional coordination methods and tools are still required. Not every project or innovation is suited to virtual execution. The decision whether a project should be carried out by a virtual R&D team must be made case by case.

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Appendix — Case Studies

Case Study D: Centralized Venture Teams - ABB's Think-Tank for the Gas Turbine Development GT24/26

With several international R&D units involved for component development and testing, the GT24/26 gas turbine development at ABB is an example for a strongly centralized yet transnational R&D project. The GT24/26 project represented a breakthrough innovation in gas turbine development—for instance, more than a hundred patents were filed. In the 1980s, ABB reduced its commitment and R&D engagement in high-power turbines, until a 1991 market analysis indicated a multi-billion-dollar market for turbines generating more than 130 Megawatts ('high end turbines'). Lagging three to five years behind General Electric, Siemens and Westinghouse, ABB had to catch up with its competitors in terms of quality, time, and price.

The short development time in particular seemed unattainable, since technological foundations had still to be developed. Because market entry timing was paramount, new management methods were called for to ensure fast-cycle development time, competitive advantage and customer orientation. An R&D project team of several hundred people from 20 nations was created (Fig. 10). Specialists from basic technologies, such as material and environmental sciences, but also from different functional departments, such as production, assembly, and service formed a highly interdisciplinary team; the know-how gathered was highly complementary.

The project structure was characterized by high international division of labor. The ABB Research Center in Baden, Switzerland, provided the new combustion technologies, and Baden researchers were subsequently engaged in integrating these technologies in the new turbine. The main share of the turbine development took place in Baden, including the development and production of the combustion chamber and turbine blades as well as final assembly of the turbine. ABB Mannheim was responsible for R&D and production of rotors, requiring profound technological know-how. Less technology-intensive components were developed in locations with cost advantages. In addition to ABB R&D units, external companies participated in the turbine development through contract R&D, development cooperation, and integration as a lead user.

All project members were concentrated in a single open-space office in a two-story building in Gebensdorf, a village near Baden, Switzerland. Since ABB had enlisted many contributors outside ABB for integrating external know-how, the central project location of this 'think-tank' facilitated cross-functional communication and helped to keep critical know-how inside the project. The strategic importance, the high-flying objectives, and the seal of confidentiality supported the creation of a common project spirit and innovation culture. ABB was cautious not to accidentally release any information to competitors: All project members were sworn to secrecy, and even the Gebensdorf building retained an innocent residential housing exterior.

The GT24/26 development project enjoyed high priority within ABB's Power Generation unit. The project leader reported directly to the head of development and the general manager. The steering committee met once a month. In critical phases of the project, even the Board of Management was involved. Most of the project members were completely assigned to the project and reported only to the project manager. The project manager was responsible for all activities between research, development and production, including the completion of the first two gas turbines and their installation at the customer sites. The strong position of the project manager facilitated his access to critical and limited resources, such as functional specialists in particular technical areas.

The design of production tools was started before the product development phase was concluded. Even more acute than in sequential development projects, the parallel execution of the turbine development in combination with the spatial distances between product and production tool development units created serious coordination challenges. For instance, the rotor development team and its manufacturing personnel were relocated from Mannheim to Baden in order to ensure the necessary intensity of communication.

Due to high R&D costs and urgent time pressures, ABB deployed the concept of innovation marketing: the close interaction of R&D, marketing, and innovative product users. Innovation marketing aims to aligning internal and external technological constraints by coordination among the main innovation participants, improving technology transfer, cross-functional communication, and market introduction times. The principal management approach combines heavyweight project management, design-for-manufacturability, benchmarking, and simultaneous engineering.

GT24/26 was the first simultaneous engineering project at ABB. Since vital technological know-how was lacking and the pressure to reduce development time was enormous, ABB engaged in this project before the necessary materials research was completed. In order to simultaneously develop end-product components while fundamental research was still under way, research and development was collocated in one building in Gebensdorf, Switzerland.

The main success factors of the GT24/26 development were the centralization of the project team in one location, or think-tank, the coordinated parallelization of activities and cross-functional cooperation, strong top-management commitment, and the integration of potential and lead customers. ABB’s top management fully supported the project, yielding considerably authority and decision power to the GT24/26 project manager. Cross-functional teams, lead users, researchers, and development engineers collaborated during the entire project. The GT24/26 generation was a technological breakthrough and moved ABB from a late follower into a technical leader in the field of high-end turbines within a short time frame. Compared to previous projects, time-to-market could be reduced by 60% and the number of modules by nearly 50%.