# Development and Leadership of R&D Consortia: Lessons learned and possible road ahead for continued innovation[1]

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The objective of this presentation is to discuss issues involved in the formation, and successful operation of research consortia. As an example, the Complex Interactive Network and Systems Initiative, CINSI, is a program that aims to develop tools and techniques that will enable national infrastructures to self-heal. EPRI and DOD are jointly funding the project for about $30 million over five years. From the very start, the funding partners appreciated that the research challenges were beyond the scope of any single contractor or university department; thus CINSI was organized on a consortia basis. The kick-off for the program was held in May 1999. There are six consortia, each comprising about three to six universities and, in a few of the consortia, an industrial partner.

I provide my "off the cuff" observations on the creation and leadership of interdisciplinary multi-university/industry/government/NGO organizations, primarily based on lessons I have learned after creating (in 1998) and leading (during 1998-2001) large R&D multi-disciplinary consortia of scientists, engineers and economists. These consortia consist of 108 professors and over 240 graduate students, researchers and postdoctoral researchers in 28 US universities, who are working on modeling, simulation and analyses of complex interactive systems. One of the 24 key technologies that has already emerged from this is what is called the "Smart Self-healing Grid." I shall provide an analysis of the funded consortia and discuss issues based on models of (i) creativity and innovation and (ii) successful knowledge management projects. Pertinent issues and some thoughts on successful team formation and continued innovation include:

- Why form consortia? Is collaboration and teaming worthwhile? Does it lead to elitist "us vs. them" attitudes instead of open communication leading to creative work? How to identify and prevent such tendencies? Identify potentially divisive issues including allocation of resources among consortia members.
- Setting the theme very early on and up front, before the actual work begins, to clearly examine assumptions, re-visit a groups' vision and re-examine their responsibilities after their selection and at an on-going basis.
- Communication: How would the consortia participants share their progress reports inter-/ intra-consortium? How would the consortia participants share their progress reports with funders? How often, and in what form? Also does this satisfy the associated milestones and time-lines?
- Develop an ecology of networked collaboration: Avoid "micro managing"; encourage researchers' own feeling of excitement for their innovative work and of their control over their activities and contributions. A good opportunity to enhance this, for example, would be to ask each team to develop its own methods of effectively communicating between its various

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members. The culture and chief researchers' attitudes could play a key role in success or failure of graduate student interactions both within a university and within this wider context of culture. Charging the members to develop their own communication processes, make it their responsibility/goal to be successful rather than "micro-managing" this process. They may come up with exciting and effective ways of communicating. There may be other areas where management can enhance their performance by charging them to develop solutions, rather than giving them directives.

- Face-to-face meetings with follow-up regular interfacing would create inter-dependence: Workshops, formal sets of meetings as well as opportunistic forms of interaction among them.
- Facilitate mechanisms (and allocate budgets and rewards) for collaboration at "lower levels" including graduate students and faculty working together; developing as much familiarity with each other as possible. E.g. graduate student symposia: Request each consortium to provide a few (say 2) challenging problems before the meeting and then have them work on it for three days and present the results; follow-up efforts and results (and provide funding for their travel).
- Identify and set clear go/no-go points. Also be aware of the ever-present conflict between managing a project to enhance creativity, and managing a project to optimize the chances of success; go/no go is part of this, as is regular reporting of progress.
- Clearly and explicitly address/discuss the role of the overall consortium manager: Many of the points indicated depend on a strong and consistent unifying presence provided by the overall consortium management team. In particular, one of the challenges faced is managing the program to its overall goals while balancing varying (or even conflicting) interests of stakeholders that include other commitments and sources of funding. Assembling and managing the consortium has to recognize and plan for these somewhat competing agendas. Also, this issue underscores the points made about communication, and how to optimize handling this issue effectively, since it is present in almost all consortia. Another aspect of the communications that have proven absolutely essential to effective management of this "competing agenda" issue is consistent and frequent external communication to the various stakeholders regarding the purpose, progress, and characteristics of the consortium. This not only builds consensus, but to some degree it supersedes the competition between various agendas because the external expectations and image would take precedence.
- Conflict is a natural part of consortia on many levels. Although permanent resolution may prove futile, it can be managed and even leveraged for improved teaming and performance. Human interaction creates conflict, adding strong minded, intelligent people in business and technology amplifies this conflict. The key is how to use it as an opportunity for leadership, which begins from within and fundamentally depends on values like courage, decency, honesty, empathy, care. Those values are independent of the course we choose in life. They apply to whatever position we hold and in whatever situations we may be in. However, in our interdependent networked systems, while excellence at this micro level is necessary, it alone is insufficient and requires meso- and macro- levels that constitute an ecology of networked innovation and collaboration. In addition, conflict can provide stimuli for positive change. It is a point of bifurcation with potential options and new opportunities. Effective leaders are also highly skilled negotiators. If you aspire to leadership, know the road ahead, park your ego at the door, and cultivate a quiet mind. Humility is fundamental.

These observations can be analyzed using models of (i) creativity and innovation and (ii) knowledge management (KM). These two are linked themes, as they are potential synergies in creating knowledge, then leveraging it to develop a potentially positive feedback loop.

"Creativity" drives the steps in which knowledge is created and built: the discovery of research results as the development of innovations are creative processes. Although each result and innovation is useful in its own right, the discipline of knowledge management enables them to be leveraged. KM does this by revealing the synergies in the results and innovations; by cross-fertilizing the outputs of that first creative step and enabling researchers to combine the existing knowledge in new ways, thus prompting fresh innovation and discovery. In summary, KM provides a feedback mechanism for the creation of further knowledge.

Before we focus on the macro organization of multi-university consortia, it is pertinent to consider a "smaller" example.   Let us view a school or even a department as a "learning consortium". As we know the core competency of a research university is not transferring knowledge but creating it—a shared responsibility of faculty and students. This requires inversion of the top-down faculty-centered view to a learning community where students are coupled with other students, faculty, outside professionals and research communities, employers, and funding agencies. In addition, students naturally cross-departmental lines and create novel connections. Student feedback on teaching, direction of research and internal structure of the school can be valuable.

Since faculty are the key to making any university design work, a new approach to faculty selection is also called for. Thus the criteria for faculty selection in a school that plans to focus the energy of its students and faculty on challenges posed by nature, society, and technology must go beyond the usual criteria. Traditional criteria of research and teaching excellence within a single disciplinary context will need to take into account potential larger impact and trans-disciplinary interests and experiences. These may include demonstrated record of being innovative, interactive, integrative, and a willingness to be involved. Creation of new curricula and courses need to be considered involving courses that mix "bottom-up" learning (which builds up a broad base of general competency and works toward tackling topics at the frontier) with "top-down" learning (starts with a frontier problem and works its way down, working at picking up knowledge required to understand a frontier problem or solution). Also mix single discipline courses taught by one professor, with trans-disciplinary courses, taught by a team of professors representing different departments. Remain adaptive and avoid predetermined rigid curricula and encouraging students' feedback and learning from one another. Encourage teams of students to work on key questions and develop ways for them to share their results with other teams and even other schools—e.g. through the Internet.

Establish problem-oriented entities, Centers, which cut across departmental boundaries and create bridges between departments and disciplines (historically departments of material science, bio-medical engineering and even earth and planetary sciences were created in this way). Such centers can be an inspiration for new courses, seminars to address challenges posed by nature and society. In addition, these centers can be devoted to nurturing "pre-centers" with the responsibility of exploratory and strategic research on a wide range of trans-disciplinary problems. This may even be a Center of Centers and as it matures, the university can consider spinning it off into a new and more specialized Center (which may over time become a Department). But to keep this as a living and thriving system, it is important to keep this Center of Centers small, adaptive, flexible and innovative, rather than becoming a school or college.

**Creativity**

Over the last 15 years, studies of creativity have paid increasing attention to the issue of *climate*. This can be discriminated from culture in that it refers to the more accessible and observable behaviors and attitudes – culture usually refers to deep-rooted beliefs and values. A widely cited study is that of Ekvall (1991). He considered climate as a moderating force on communications, problem solving, decision-making, learning and motivations. He studied 35 Swedish and US organizations and classified them into two groups: innovative and stagnated. He showed that 10 factors (in his nomenclature, dimensions) discriminated them, as shown in Table 1: Creative climate dimensions

| *Dimension* | *Creative climate* | *Uncreative climate* |
|---|---|---|
| Challenge | Enjoyable and energetic | Alienated and indifferent |
| Dynamism | Excitedly busy | Boringly slow |
| Idea time | Off task play | Little off task play |
| Playfulness | Happy, humorous | Dull, serious |
| Conflict | Debated with insight | Warfare |
| Openness | Trusting, failure accepted | Suspicious, failure punished |
| Support | People listen | Critical, negative comments |
| Freedom | Independent initiatives | Passive, rule bound |
| Debates | Contentious ideas voiced | Little questioning |
| Risk taking | Act on new ideas | Detail and committee bound |

**(source: Ekvall, 1991)**

Looking at Ekvall's dimensions it is clear that there is a tension between the freedom required for creativity and the control needed for properly administering a large project[2]. This paradox is recognized but can be resolved:

> "bureaucracy and formalism are enemies of creativity and innovation, but nevertheless we do need formal procedures and routines to be able to utilize the creative potential existing in the organization"
>
> --Ekvall, 1991

Indeed we have found that it pays to have both a disciplined, structured environment with long breaks that allow time for creativity (innovation requires blocks of discretionary time[3]).

**Knowledge Management (KM)**

Definitions of knowledge abound. In the knowledge management (KM) literature, a typical definition is "information combined with experience, context, interpretation and reflection" (Davenport, de Long and Beers, 1998). Similarly, there are many definitions of knowledge management, but they all seem to come down to the same question: how can organizations use knowledge more effectively?

KM is a key step in realizing additional value from the initiative. By establishing methods of easily sharing and accessing each others data, information and knowledge, the consortia will be able to

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[2] This is not just about being a "nice" person, but the goal is to create and sustain a positive, respectful and collaborative work environment -- highly productive and conducive to a climate of achievement and performance. This makes business sense, as the cost of incivility is just too high (and includes low morale and loss of good talented people).

[3] One of my colleagues pointed out that while the above ideas are great, throughout history, some of the best creativity has come right after warfare, dark ages or other tragic events.

exploit synergies that would not otherwise have been apparent. In my opinion, this would greatly enhance the prospect of uncovering truly radical innovations. Knowledge management was an explicit part of the CINSI Request for Proposal. I think it is therefore reasonable to evaluate the consortia against the criteria that are indicators of successful KM projects. Just as there are many definitions of KM, there are many lists of criteria by which to establish quality. A typical list is that provided by Davenport *et al. (ibid.*). Although their paper focuses on large KM projects, many of their factors are transferable to a situation such as CINSI, where there is a relatively small budget available for such issues. Relevant success factors are:

- Technical and organizational infrastructure and boundaries
    - Organization structure and design
    - Accountabilities (who owns what)
    - Critical Interdependencies
    - Decision making rights about how the work gets done
    - Services and processes to execute the work effectively
- Performance Measures:
    - Results and Management Metrics: What operational or "milestone" metrics do we need to monitor and manage monthly progress?
- Clear purpose and language.
    - Information and Communications
    - Information necessary to do the work
    - Communications requirements within/between functions
- Multiple channels for knowledge transfer.
    - Critical tasks and activities required to build a product and/or deliver
- Senior management and stake-holder support.

Does any of this actually matter? The consortia are producing knowledge, so does it matter if they only interact and actively share this knowledge once a year or more? I believe it does, in the sense that the consortia are missing a major opportunity. Referring to Nonaka's work on knowledge management (1991), we see that one of the crucial elements is already in place: redundancy. For Nonaka, the process of creating new knowledge depends on "tapping the tacit and often highly subjective insights, intuitions and hunches of individual employees and making those insights available for testing and use by the company as a whole." And this requires redundancy:

> "Redundancy is important because it encourages frequent dialogue and communication. This helps create a 'common cognitive ground' among employees and thus facilitates the transfer of tacit knowledge. Since members of the organization share overlapping information, they can sense what others are trying to articulate"
>
> -- Nonaka, 1991

The EPRI/DoD CINS program has plenty of redundancy, as is clear from the (type of challenge *vs.* type of solution) matrix that has been used to analyze the CINSI portfolio. However without open and effective communication channels between these overlapping parts, all the benefits of redundancy will be lost. Effective collaboration and other related areas were discussed throughout this initiative:

"Only three things happen naturally in organizations:
*friction, confusion and underperformance.*
Everything else requires leadership."
-- Peter Drucker

**Bigger picture**

"The empires of the future," said Winston Churchill, "are the empires of the mind". Echoing this in his 1981 book, *Investing in people: The Economics of Population Quality*, Economist and Nobel Laureate, Theodore Schultz, argued that the wealth of nations is not limited by land or minerals, it comes predominantly from "the acquired abilities of people, their education, experience, skills and health." What are we doing about this?

Nations have been slow to heed this wisdom, and what is needed is not done. Children's education, particularly for girls, is not a high priority for many governments. In many industrialized countries educational systems remain troubled, teachers don't enjoy the respect they once enjoyed and investments on development of "human capital" are minimal (Nichols 1999).

In the U.S. scientist and engineers working in R&D make up about 75 out of every 10,000 people employed, about 80/10,000 in Japan, 50/10,000 in UK, 30 in Italy and fewer than a handful in most developing countries. US spending in R&D accounts for 2.5% of the GDP, yet the results rippling outward from the investments in technology—and its related educational base—accounts for "perhaps 50% of the past growth of the American economy. I don't mean to overstate the roles of science and technology. But nations that invest in those fields of human capital do better economically than those nations that do not."

In more developed countries, competition for funds and jobs is often fierce, and the need to account for every penny on shortening deadlines saps the energy out of every R&D team; hence the young investigators see the future as both tempting and frustrating. Even worse, many scientists feel the "chill of attitudes" noted 20 years ago by an English immunologist Sir Peter Medawar, in his book Advice to a Young Scientist. "One of the worst forms of snobbism in science is that which draws a class distinction between pure and applied science." How much time and energy is squandered simply because investigators find it necessary to defend the rationale for, the existence of excellence in activities that are economically motivated?

In addition, during difficult economic times and low funding cycles, the scarce resource environments that researchers get thrown into, adds another level of difficulty -- there is an old African proverb along the lines "when the watering hole gets smaller, animals get meaner." During such periods, the increased level of stress permeates nearly everywhere we turn. Therefore being mindful of the shadow we cast on others is critical, and the old saying that the ladder-climbers often "kiss up, but kick down and kick sideways" applies more so than in periods of abundance. Regardless of these cycles, leaders strive to keep their environments (e.g., laboratories and classrooms) to remain clean and safe havens for being positively challenged, and for professional growth and learning. What you permit, you promote!

Difficult times provide an opportunity to reinvigorate collegiality and collaboration, getting off the pedestal, and realizing that we are in this together, and to learn and grown as a team.

"We may have all come on different ships, but we're in the same boat now."
– Dr. *Martin Luther King Jr.*

While being conscious of such hurdles, there is a synergy when researchers, their ideas and teams work together; innovation is most often achieved when ideas and objects/tools are brought together in novel ways as never before. The prevailing paradigm for the analysis and optimization of system operations, as well as for engineering design itself, uses a "top down" approach through mathematical programming. It is based philosophically on the prevailing scientific methodology of "reductionism." Although this scientific method has been remarkably successful in reducing, say, chemistry to physics, it has not been able to completely reduce biology to chemistry or sociology to biology.

Indeed, throughout most of our civilization, scientific explanation by reduction has given rise to a subdivision of the natural and engineered systems into smaller and smaller bits and areas of specialization. While specialized innovation has given us and our societies many comforts of modern life, a new mode of interaction and collaboration has risen in the last few decades by the use of information technology including the earlier ARPA Net and the WWW. To quote from the special section of the December 4th, 2000 issue of TIME on Innovators and Inventions of the Year:

> "… One consequence might be that we finally recognize history's Great Innovators for what they were: the products of a culture of scarcity that taught us to regards them and their talents as rare. That they were (and are) especially talented is in no doubt here. But semi-intelligent information technology and the transition of a culture from one of information scarcity to one of abundance may for the first time allow all of us into the invention game. Then technology will provide the nuts-and-bolts backup to give shape to whatever any imaginative brain can conceive. And there are more than 6 billion imaginative brains out there across the planet waiting for opportunity…"

Closer to our discipline, as engineers we all learn that "if you measure it, you manage it;" I submit to you that is only a prerequisite to "<u>if you Price it, you will manage it even better</u>." With that in mind:

Do you Know what you Do, Does? As you know the Noble prized economist Prof. Robert Solow at MIT quantitatively showed the power of engineering and technology in the economy—"Technology drives over 60% of the US economy."

Engineering enhances the quality of human life, produces growth in our economy, and serves our society. The 20th Century, in particular, marked a period of technology triumphs. Electrification, telecommunications and the Internet, fast and efficient transportation, modern medicine, scientific agriculture, and other advances changed—and continue to change—the conditions of human life all around the globe.

In little more than 100 years, the average human lifespan nearly doubled. Many times greater still have been the new opportunities and possibilities afforded by technology to each individual during that longer life.

Engineering and its impact on societies around the globe are Immense. Having recently visited India and China — two ancient civilizations that are increasing leverage in their science, engineering, and leadership base to power economic growth-- have realized their aspirations toward societal progress with positive economic impact.

Speaking of scientists and engineers rising to positions of leadership, did you know that India's President is a physicist, and is coupled with a former World bank economist who is the prime minister? Also we all have seen China's rise in World economy. Almost twenty years after embracing science and technology and market mechanisms in 1979, the nearly 3,800-year-old

Chinese civilization has been emerging in its global impact in leveraging technology and innovation to grow businesses and its economy.

Although China's investments in S&T development began long before the current highest tier in the Communist Party came to power, for the first time ever, all nine members of China's elite Politburo Standing Committee, are engineers. These leader engineers face several fundamental challenges:

• Can a booming economy that is networked globally and driven by engineering and technological revolution be sustained without intellectual property rights and free speech, particularly now with the Internet?

• Assuming that in the next decade or later as China reaches toward its aspirations and achieves its economic goals, can its citizens drink the water and breathe the air?

During the last two decades, China has gone from a nearly third world or developing communist economy to a dynamic growing competitive market. The country's science and engineering vision and policy has driven a historically unprecedented economic growth. Overall, the Chinese economy has grown nearly 10 percent per year for the last few years and this trend is accelerating. Almost 11 percent of their GDP growth emanates from their S&T base. It is clear that science and engineering and its effective management is a major driving force in shaping global society.

Because the pace of global change is accelerating, the long-term strategic view of leadership, S&T, policy, markets and business become a vital consideration. Rather than a traditional focus on maximizing short-term profits, the long-term view allows leaders to better consider the impact of emerging trends. They then can make the necessary course corrections to remain a viable player.

As the world opens, the value of education continues to rise, and knowledge will play an even greater role in development of technological innovations and in the success of businesses. For leaders, the importance of knowledge means pursuing learning with a passion, since understanding the changing environment demands a constant stream of information and a tolerance for ambiguity.

Companies that make the investment in research and development are in the position to advance and launch technological innovations. Increasingly, leadership in science and technology developments will emerge from collaborations among coalitions of companies, universities, national labs, and government agencies. This "open research model" allows companies to leverage assets. If you are innovative, you will find new directions.

As scientists and engineers, we need to be able to see past product specifications and ask what it means to the customer. Just a few years ago, I didn't know how many Apples and new iPods we needed!

In a broader context, the need for engineering and our capabilities is to strategically enhance our quality of life and to provide an indispensible enabler of great opportunities for a bright future-- a few nuggets for you to consider this evening:

1. Plastic cards at the movies by the time the movie Mission Impossible 5 (MI-5) is released, with over 2000 movies that you'll select to have on it;
2. Pinpointing evolution: Point your cell phone to a can or box at the supermarket and the service provider has your secure confidential medical data and knows whether the food is medically OK for you or not. Push buy/Not buy… alternatives

3. Processing evolution: On a single fiber optic you can carry all the information in the World! Shannon's theory applies to single channel, not to a cellular fiber optic network. N+1 receivers are separated by ½ a wavelength, you can separate the interference, it's just a matter of processing power-- features include transparency, alternatives/choice, and breadth.
4. Powering evolution: Batteries, Nanotech… plastic batteries with up to 8 times its nominal capacity charged in less than a minute…

We live in a very promising time. Scientists and engineers have major contributions to make — and must play a leadership role in these and many other innovations that continue to enrich and improve our lives. As engineers, scientists, designers and architects, we are problem solvers-- the greater the challenge the more relevant and innovative our contributions become -- we must ask "why not?"

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