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I.T. R&D Agenda for the '90s and Beyond

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Abstract. *The exploitation of technology in organizations is ubiquitous today. More and more, information technology (IT) proponents have to grapple with the question of bringing next waves of technological advances into organizations, rather than the easier question of merely automating manually-operated organizations. This paper explores a deep concern facing IT R&D strategists today: realization of a long term, sustainable agenda that would ride the future waves of advances in organizations and capitalize on the usage of technologies to lead such advances. The relevance of this agenda in the Singapore context is discussed.*

1. Introduction

Technology, including information technology (IT), is fast coming to full circle. As user organizations catch up with the leading edge in IT, the marginal utility of further technological advances continues to decline. In other words, it is becoming increasingly difficult for the benefits of each new technological advance to justify the costs of its deployment. Complicating this problem further is the fact that some of the high-profile areas in computing research, for instance artificial intelligence, have fell short of the many promises stated in the sixties and seventies on how the technologies will revolutionize the way people live.

The development of an appropriate IT R&D agenda is therefore highly nontrivial today. This paper provides a critical analysis of the issues surrounding the development of a practical R&D agenda that may be sustained into the 21st century. The notion of *sustainability* is central because in today's climate it is highly possible for IT R&D strategists to get trapped in vicious planning-replanning circles without achieving a steady rate of advancement in deployment.

The foremost concern in the analysis is the mission statement. It is necessary that the mission statement provide a view of the end goal that is long enough to drive a sustained R&D programme. In this paper, the following long term view of the role of IT is proposed: *To catalyze continuous improvement in the quality of life.* Under the setting of such a long term view, multiyear milestones can then be identified clearly in the R&D agenda. We envisage that the R&D agenda will run along a time frame of 10 years or so, into the middle of the next decade.

This paper argues that the engineering (and reengineering) of systems must be attacked formally and holistically in the R&D agenda if technological change is to be introduced successfully. In this light, we present arguments that: (i) There is an urgent need for technologists to drastically widen their understanding of an *operating system* in the real world; (ii) There is a need to formalize the models and their linkages in technology development; (iii) The notion of the use of information, though seemingly obvious, can be exploited much more in IT R&D; and (iv) Standards for information exchange should support the proliferation of freedom and change in operating systems.

The research reported in this paper has been an input into the long term R&D agenda for the author's institute, and as a basis for specific reengineering and system deployment methodologies applied to Singapore's IT2000 projects (Yap, 1994) and various industry IT initiatives. For instance, we have developed methodologies for technology change feasibility studies (Khoong & Ku, 1994), methodologies for process reengineering (Khoong, 1995), and systematic approaches to the development of computer applications frameworks (Khoong, 1994b) in support of the R&D agenda. This agenda is also a basis for a long term R&D strategy in decision support systems (Khoong, 1994a).

2. Systems

What is a *system*? As technologists, we immediately associate the term with computerized systems and technologies. This view is unfortunately myopic. An operating system in the real world is a complex network of people, materials, technologies, processes, and other organizational mechanisms of both tangible and intangible nature. Information technology is but a cross-sectional perspective on the workings of the operating system. Do we understand the linkages of IT to people, materials, and processes? Do we even understand the linkages of IT to other technologies in operating systems? It is only through a holistic, end-to-end process view of the operating system that we would understand how the various components of the operating system come together. The cross-sectional view that has become a habit of technologists suffers from the Orwellian '1984' syndrome: "*I know how, but I do not understand why.*"

If we agree that technology is fast coming to full circle, then it is clear that a purely technological orientation in the IT R&D agenda is unlikely to stand the test of time. We should broaden our definition of innovation to encompass the entire operating system, and reposition IT as but a subset of the technological tools in the innovator's toolbag. It is no longer acceptable to think of IT as the first or only avenue for innovation in operating systems. We also have to think of innovating people, materials, and processes, which really provide cornerstones for taking systems into the 21st century. Only then can we say that we have fully understood, and practised, what it means to deploy practical

technological advances. This discussion leads us into the next section.

3. Models

How can we understand systems and workplaces? How does the understanding lead to a sustainable R&D agenda? We need to create and manage robust models that translate into implementation. Without models, terms and statements that we articulate are vacuous.

Necessary models fall into the following classes: process models, decision models, user models, communications models, information models, and systems engineering models. Process models provide the starting point in understanding the mechanics of the operating system. Decision models are crucial because they explain why processes are carried out - the business policies and goals of the individuals, groups, organizations, and the government in the system. User models address not only the human-technology interface issues but also the expertise of users in interacting with the technology and reasons for the interaction. Communications models must not only treat the networking issues at the implementation level, but also the dynamics of user group interaction at the design level. Information models are discussed in the next section. Note that systems engineering models, which encompass the software engineering practices in the deployment of IT, are really transparent to the operating system and are therefore at the lowest level of the operating system modelling framework. The proposed modelling framework is further explained in Figure 1.

The notion of *change* deserves special consideration in the models. Operating systems change over time. Management of such changes is subtle, but powerful. We need models that help us understand and manage change, and that facilitate the use of IT to lead the change. *Those who lead changes win.*

4. Information

Nobody disputes the importance of information. But why do organizations collect, store, and use information? Unless this issue is properly understood, the '1984' syndrome would continue to haunt us. Information is utilized by organizations in one or more of the following fundamental ways:

(i) For problem solving, such as planning;
(ii) As a means of communication to coordinate processes or to implement decisions;
(iii) As a service resource that can be sold or exchanged for other benefits; and
(iv) As a weapon to gain strategic advantage in competitive or hostile situations.

Information requires much innovative management to support operating systems in the next century. The view of information as passive repositories (despite intelligent retrieval mechanisms) is myopic. Three propositions are raised here:

(i) We shouldn't just store information, but also *transform* the information intelligently, continually to improve its value with each future use;
(ii) Information should be managed as active, intelligent agents (Riecken, 1994) that *self-navigate* to the people or machines that need them at any place, any time, for anybody, and for any activity; and
(iii) Information should also come *alive* – not just online – when presented to the users. *Make information dance before the users' eyes.*

The key application of the viewpoints in this section is that information structures in an organization should take advantage of the multiple facets in the use of information and optimally exploit possibilities of giving information structures lives of their own. This is illustrated in Figure 2. The structural network has two very important uses. It is *analytical* in that it generates both internal and external understanding of the workings of the organization, and facilitates the reengineering of processes in the organization. It is *computational* in that automated organization support tools can use the network to intelligently implement the processes in the organization, thus minimizing human intervention in tasks that from the organization's viewpoint are considered as overheads (i.e. do not contribute directly to the betterment of the core business of the organization).

5. Standards for Freedom and Change

Standards for document and information management are essential ingredients for promoting maintainability and shareability of information. This perspective is accepted in information engineering. A more subtle perspective is the role of standards in business process reengineering. Much on documentation standards (e.g. SGML) and business reengineering have been discussed in recent years, but the discussions have taken place in two separate communities. We need to establish constructive connections between the standards and reengineering perspectives.

Two particular dimensions of such connections may be emphasized – *freedom* and *change*. The freedom dimension is the utility of standards in "virtualizing" the organization into one of independent, empowered units of knowledge workers. There is a possibility of the dangerous "standards ⇒ control" effect taking place, although the effect actually needed is "standards ⇒ freedom." The change dimension is the utility of standards in facilitating change in the structure and role of people, technology, and processes in the organization. There is a possibility of an equally dangerous "standards ⇒ ossification" effect taking place, although the effect actually needed is "standards ⇒ change." While avoidance of the adverse effects along these two dimensions may appear to be common sense, it is easy to end up with such effects if the information engineering effort is not managed in light of the broader business reengineering objective.

6. Engineering (and Reengineering) Toward the Long Term View

Mission statements of IT R&D organizations articulate futuristic scenarios made possible by leading edge technologies that they intend to push. The popular target for advanced IT applications has been, and continues to be, workplaces – for instance, the mission statement may focus on the makings of the intelligent office. We first take a

look at workplace innovation, and then extend the innovation horizon further toward a long view for the IT R&D strategy.

Office automation is no longer a mystery in workplaces today. Desktop personal productivity tools like word processors, spreadsheets, and database management systems have become the staple in workplaces around the world. So what are the avenues for continued technological advancement? Three major trends are developing:

(i) Time windows for performing work are becoming increasingly wide and flexible, for such reasons as conducting businesses across several time zones and for personal convenience. In other words, the following movement is emerging:

sometime workplaces → anytime workplaces

(ii) Workplace boundaries are becoming increasingly extended or transparent, as business partnerships continue to streamline and break down barriers. In other words, the following movement is emerging:

somewhere workplaces → anywhere workplaces

(iii) Workplace efficiency and effectiveness concerns are transcending personal productivity issues toward the support for collaborative group and organizational work. In other words, the following movement is emerging:

somebody workplaces → anybody workplaces

Point (iii) merits further elaboration. The view that the operating system serves only the interests of a single individual or group is myopic. A system can serve the interests of numerous groups within an organization, or even the interests of a constellation of organizations. The common habit is to define the boundaries of an operating system based on the interests of an individual or a small, cohesive group. Other interests not covered by the system are assumed to be independent and possibly conflicting. These assumptions often fall apart when the boundaries of the system are extended.

The ultimate in workplace innovation is one that is space-time-people optimal. This vision is illustrated in Figure 3. The two major needs to realize this vision are:

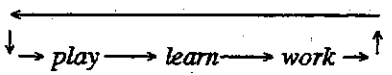
(i) Tools that facilitate such quality workplaces; and
(ii) Methods that transform current workplaces into such quality workplaces.

It is not difficult to see that (ii) presents a far greater challenge and pressing need than (i). Need (i) is to a large extent a technological endeavour, whereas need (ii) encompasses many other fields of enquiry, such as organizational dynamics and socio-economic issues.

To further underline the intrigue surrounding the transformation need, we consider the case of anywhere workplaces. Do automated tools like centralized multimedia information repositories and teleconferencing systems sufficiently support an anywhere workplace? It is not difficult to see that while such innovations do indeed facilitate an anywhere workplace, the workplace is by no means transformed from being somewhere to anywhere by such tools. Therefore, it is important to view such an innovations as mere starting points in the R&D agenda to transform somewhere workplaces into anywhere workplaces.

To reiterate, making workplaces that are already anywhere (like users which are already geographically separated before the birth of IT) more efficient is a far cry from studying how we can transform somewhere workplaces into anywhere workplaces. This is where a holistic analysis of the operating system plays a central role, and in particular the analysis of processes. The expanded interest in transforming workplaces is undoubtedly of much greater impact and lasting value.

The transformation process can be extended even further. How can we transform sometime workplaces into anytime workplaces? How can we transform somebody workplaces into anybody workplaces? Perhaps the most intriguing is the notion of a *place*. We have looked at workplaces. What about play-places? Rest-places? Can we envisage places in the future where work, play, and rest are seamlessly integrated with no adverse social effects? Such a vision is exemplified by the following emerging *"edutainment"* movement:



Places may thus exist on the some-activity - any-activity dimension. How can we transform some-activity places into any-activity places?

So what should the ultimate mission statement be? To achieve an anywhere workplace? An anywhere, anytime workplace? An anywhere, anytime, anybody workplace? Or an anywhere, anytime, anybody, any-activity place? Perhaps the most appropriate long term view is:

To catalyze continuous improvement in the quality of life

This long term view is illustrated in Figure 4. Under this setting, concrete milestones running into the next century can be placed in the R&D agenda. For instance, the first concrete milestone may be to achieve the anywhere workplace. This may be followed by the total quality workplace vision, then the quality work/play-place vision, and finally the quality living vision.

7. The Singapore Scenario

IT R&D in Singapore has been a fairly recent phenomenon. The National Computer Board, a government body promoting and coordinating computerization in the country, was established in 1981. Two IT R&D institutes (Information Technology Institute and Institute of Systems Science) were established a few years later. These institutes focus on developing applications of advanced technologies, bridging the gap between academia and industry. Through the collective efforts of the Board, the two institutes, local universities, and polytechnics, IT R&D in Singapore has attained a level of maturity comparable to efforts in the USA, Europe, and Japan. The rapid explosion of information flows between Singapore and the rest of the world over the years has also eliminated cultural differences in the application of advanced IT.

Concrete developments are underway in Singapore, under the umbrella of the IT2000 national masterplan, to transform the country into an intelligent island of quality living. The R&D agenda suggested here captures the essence

of the masterplan. The core component of IT2000 is the development of the National Information Infrastructure (NII) for communications internetworking and information exchange across the nation (Yap, 1994). The NII would provide information at the fingertips ("info@fingertips") of users and information processing systems. The info@fingertips mechanism is the key enabler of the anywhere workplace (AWP) paradigm.

At our institute, we are developing technologies for info@fingertips and AWP – for instance, computer-supported cooperative work (CSCW) tools (Grudin, 1994a). In support of the AWP, we have also outlined the R&D agendas for the various models that are needed to form the AWP operating system. For instance, a 10-year R&D agenda for decision models has been proposed (Khoong, 1994a), including elements such as group decision support systems (GDSS) (Nunamaker, 1989) and intelligent agents (Riecken, 1994). In preparation for AWP deployment, we have also developed methodologies for high-level process reengineering (Khoong, 1995) and technology change (Khoong & Ku, 1994). Furthermore, we are developing frameworks for automated management systems, namely Manpower & Service Management Framework (MSMF) and Logistics Management Framework (LMF) (Khoong, 1994b). These frameworks provide suites of generic decision support tools.

Figure 5 summarizes the abovementioned activities in the R&D agenda.

8. Waves of Change

As the IT R&D agenda takes its course in the years ahead, a host of unprecedented societal phenomena will emerge. It is of utmost importance that such phenomena be thoroughly addressed in multidisciplinary research, so as to prepare the public for major changes in work and lifestyles. We mention some of the more intriguing phenomena below.

The emergence of information superhighways, exemplified by Internet, is redefining the concept of wealth. Increasingly, as is already observed now, the gap between rich and poor nations is defined not so much by access to material goods, but by access to information. Exotic cultures and civilizations will emerge and interact on the information superhighways. In a sense, the entire history of human evolution is being repeated on such superhighways.

This leads to further questions. For instance, should we let history repeat itself, or patrol the information superhighways with controls and policies? While it makes sense not to repeat mistakes of the past, there is also some deep possibility that unnatural intervention in the evolutionary process will seriously harm the "ecological balances" on the superhighways.

Another question borders on human existence itself – increasingly, people will know each other not through physical interaction but through interactions on the information superhighways. Virtual humans and virtual organizations will roam the superhighways, coexisting with biological humans. Boundaries of reality become blur.

Work and lifestyles will evolve in intricate ways. Telecommuting, for instance, would become more of a necessity and less of a choice, given factors such as the emergence of anytime work and people transportation costs arising from traffic congestion. A blurring of the boundary between work and home arises. The costs and benefits of this phenomenon needs to be studied. In all likelihood, the benefits are to the work, but the costs are to the home. There is a notion of *lifestyle reengineering* that should soon be taken seriously.

Today, organizations define who gets connected on the information networks. In the road ahead, those who connect on the networks will define the organization. Organizations will become rapidly evolving, mutating, metamorphosing organisms, alternating between the real and virtual realms. Organizations will appear to be increasingly chaotic in the short term, with order emerging in the long term (Stacey, 1993). Employees may experience what may be called the *Prisoner-Consultant Oscillation* – oscillating between the feeling that the organization needs him (the Consultant feeling), and the feeling that the organization traps him (the Prisoner feeling). In the long run, order emerges from this chaos when *the employee becomes the organization.*

These waves of change are intertwined with waves of change to IT itself. IT R&D will have to examine through field studies the social impacts of IT and, in a sense, go back to the basics of human-human interaction (HHI). After all, the purpose of the computer is ultimately to aid HHI; if IT R&D only focused on the problems of human-computer interaction, some crucial elements of the purpose for solving such problems may be lost. Ultimately, IT should be used *everywhere*, and yet *nowhere* to be seen – it should get out of the way of users.

9. Concluding Remarks

We have presented in this paper key issues influencing a long term IT R&D agenda, some concrete developments based on the agenda, and some aspects of the agenda's ramifications. At the author's institute, research programs are now rapidly evolving in accordance with such an agenda, with strong initial emphases on information models, user models, process models, and their linkages. The impact of the agenda is beginning to be felt with the emergence of multidisciplinary R&D efforts.

As is common with technology projections, it is easy to overestimate the impact of the R&D agenda in the short term, but underestimate it in the long term. It is therefore hoped that the issues raised in this paper would trigger IT R&D strategists to devise courses of actions that can quickly take users to the edge of the future.

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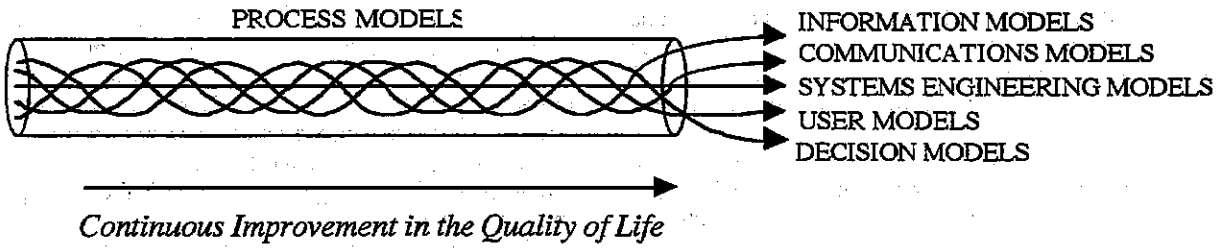

Figure 1. In the path of continuous improvement in the quality of life, innovations in information, communications, user, and decision models are intricately intertwined. Systems engineering models provide fundamental support for these innovations. All of these models are in turn integrated through innovations in process models.

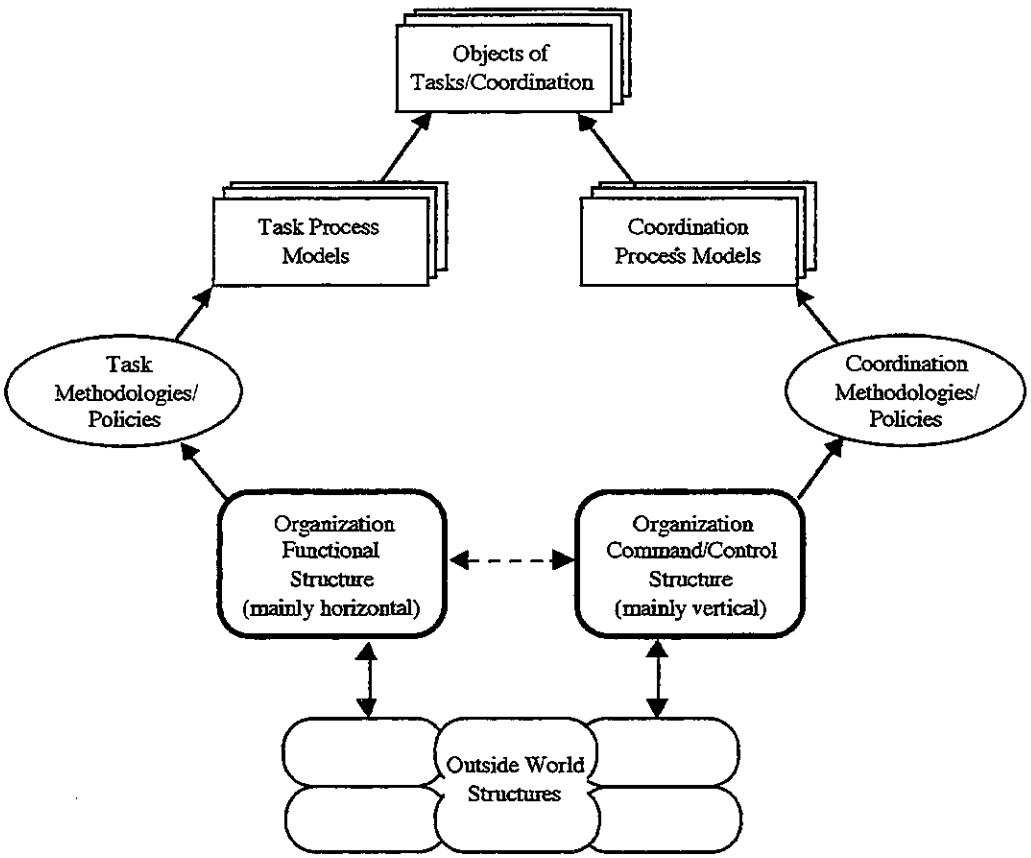

Figure 2. Information structures in an organization. The functional structure of the organization provides specialist skills in distinct tasks, and is therefore mainly horizontal. The command and control structure of the organization provides managerial skills in broad departmentalizations, and is therefore mainly vertical. In many organizations, the link between the horizontal and vertical structures (indicated by the dashed arrow) is rather poorly understood. Yet elements of the horizontal and vertical structures often converge at the level of objects of tasks (e.g. specific products or services of the organization) or during interactions with outside world structures. The structural network can expose many opportunities for reengineering of the business processes in the organization and for studying the exploitation of future technological changes.

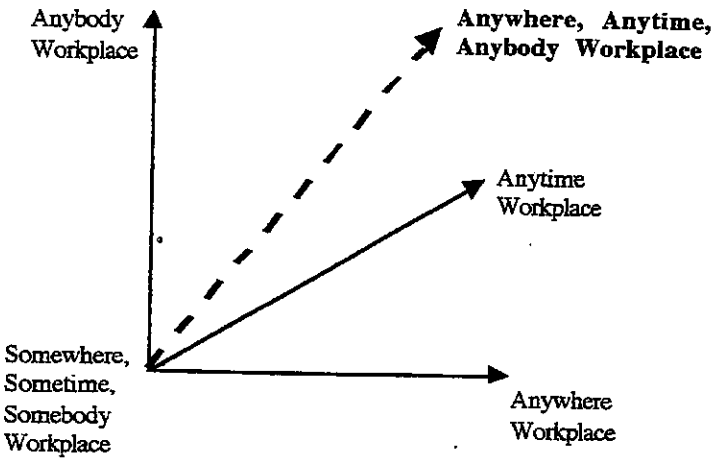

Figure 3. Workplaces may be defined based on the dimensions of space, time, and people. The ultimate quality workplace is one which is space-time-people-optimal, which is at the end of the dashed line.

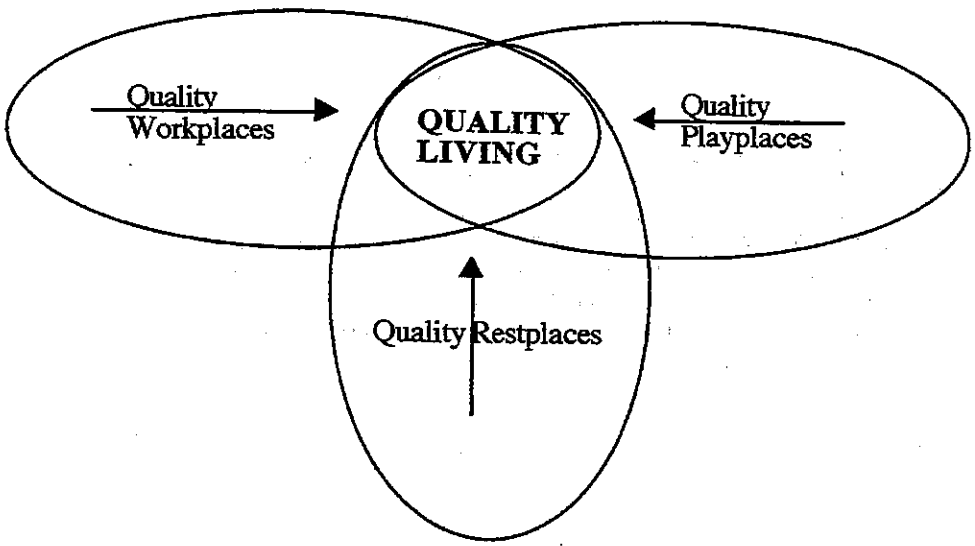

Figure 4. The ultimate long term view of innovation is toward quality living. This entails the ha· ·vergence of quality workplaces, quality playplaces, and quality restplaces.

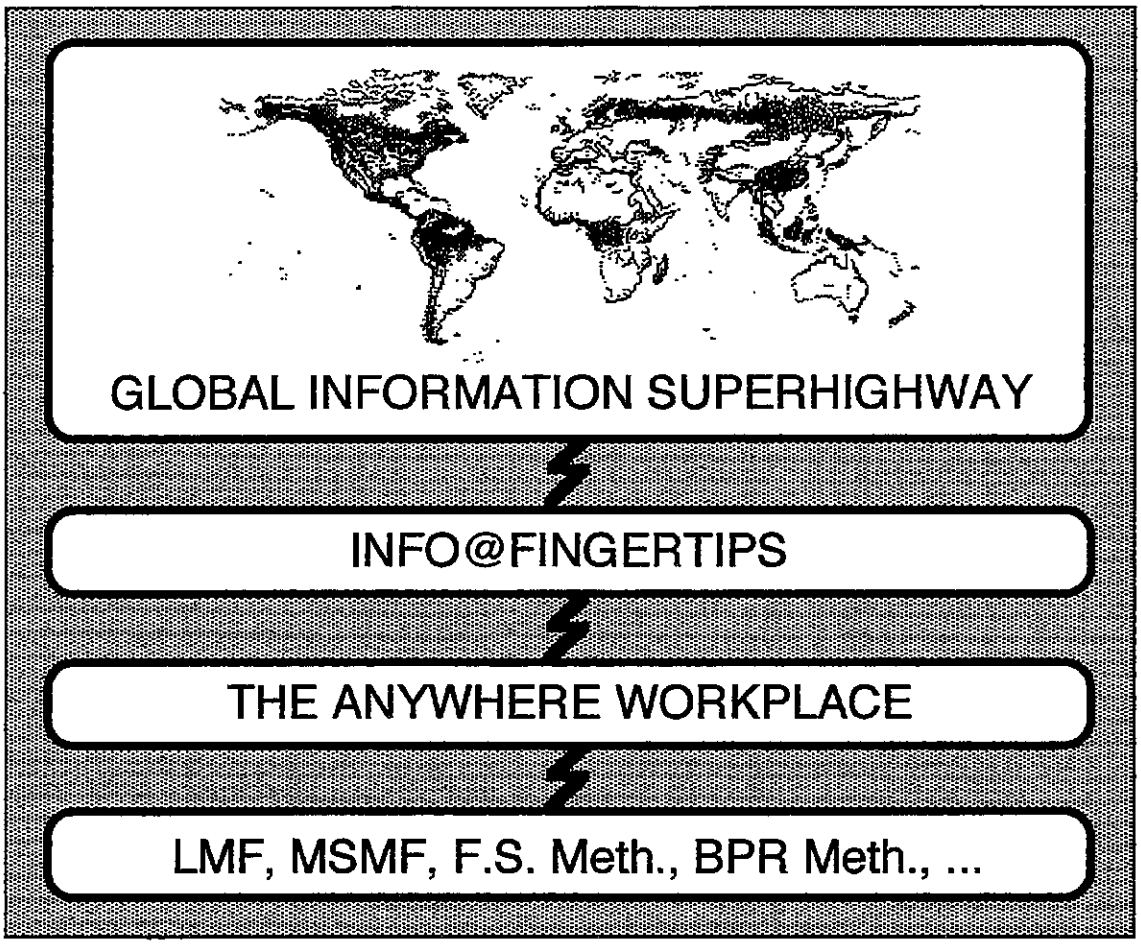

Figure 5. *Some initiatives in the I.T. R&D agenda.*