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## Developing an advanced environment for Collaborative Computing

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### Abstract

Knowledge management in general tries to organize and make available important know-how, whenever and where ever is needed. Today, organizations rely on decision-makers to produce "mission critical" decisions that are based on inputs from multiple domains. The ideal decision-maker has a profound understanding of specific domains that influence the decision-making process coupled with the experience that allows them to act quickly and decisively on the information. In addition, learning companies benefit by not repeating costly mistakes, and by reducing time-to-market in Research & Development projects. Group-decision making tools can help companies make better decisions by capturing the knowledge from groups of experts. Furthermore, companies that capture their customer's preferences can improve their customer service, which translates to larger profits. Therefore, collaborative computing provides a common communication space, improves sharing of knowledge, provides a mechanism for real-time feedback on the tasks being performed, helps to optimize processes, and results in a centralized knowledge warehouse. This paper presents the research directions of a project which seeks to augment an advanced collaborative web-based environment called Postdoc, with workflow capabilities. Postdoc is a "government-off-the-shelf" document management software developed at NASA-Ames Research Center (ARC).

The addition of workflow capabilities, is an important component of allowing version control in the collaborative development of documents, (i.e., change requests, document reviews, and proposal writing). By tracking changes in the state of the document, such as Proposals, documents could be drafted and submitted, then later reviewed, voted on, and totals tallied all in a virtual collaborative environment. By combining Postdoc's ability to maintain revision control with the added ability to notify users via e-mail based on the document status, dispersed groups can benefit from a true dynamic, collaborative environment.

### Knowledge Management and the Organizational Context

A number of definitions for Knowledge Management abound in the literature today, among them:

1. "Getting the knowledge from 'people who have done it' documented and available across the enterprise...as it was done by the team who did it" (Gundry & Metes, 1996).
2. An important new business movement that advocates the creation, sharing, and leveraging of knowledge within an organization to maximize business results (Milagro, 1997).
3. Creating the opportunities for private knowledge to be made public and tacit knowledge to be made explicit (Stewart, 1995).
4. Creation, acquisition and transfer of knowledge and modification of organizational behavior to reflect new knowledge and insights (Garvin, 1994).
5. Knowledge management in general tries to organize and make available important know-how, wherever and whenever it is needed (Becerra-Fernandez, 1998b).

Important organizational know-how includes processes, procedures, patents, reference works, formulas, "best practices", forecasts, and fixes. Technologically, Intranets, groupware, data warehouses, networks, bulletin boards, and video-conferencing are key tools for storing and distributing this intelligence (Maglitta, 1996). Today, organizations rely on decision-makers to produce "mission critical" decisions that are based on inputs from multiple domains. The ideal decision-maker has a profound understanding of specific domains that influence the decision-making process coupled with the experience that allows them to act quickly and decisively on the information. This profile of the ideal decision-maker usually corresponds to someone who has lengthy experience

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and implicit knowledge gained from years of observation. While the profile of today's ideal decision-maker does not mark a significant departure from past practices, the following four underlying trends are raising the stakes in the decision-making scenario:

1. **Increasing Complexity:** The complexity of the underlying domains (internal, external, competitive, process, technology, etc.) is increasing;
2. **Accelerating Volatility:** The pace of change (volatility) within each domain is increasing;
3. **Speed of Responsiveness:** The time required to take action based upon subtle changes within and across domains is decreasing; and
4. **Less Experience:** Individuals with decision-making authority potentially have less tenure with the organization than ever before, due to such factors as high employee turn over rates.

The principal effects of these trends include the following:

1. **Maturity Intuition:** Decision makers are less likely to understand the nuances of domain inputs due to the complexity of specific domains and to their own tenure within an organization;
2. **Responsiveness:** The timeliness of responses due to external pressures is more urgent due to competitive pressures such as shortening product development cycles; and
3. **Accuracy:** The swiftness of implementing an action after a decision has been made allows little market tolerance for inaccurate responses

For example, corporate downsizing is a well-known feature of the economic landscape of the late 20th Century. The dominant driver of downsizing in most organizations is well understood: rapidly reduce costs in order to survive against competitors. Among the many side effects of downsizing, the most destructive is the dissipation of the "Knowledge Resources" within the organization; hence, organizations end up devitalized (e.g. decreased morale, commitment, quality, teamwork, productivity and innovation) (Eisenberg, 1997). Current literary reviews show that companies are typically not prepared for downsizing, and few take any steps to prevent the escape of knowledge that usually follows the downsizing. For example, BellSouth's recent reengineering of their Engineering Department resulted in a 75% reduction of their engineering workforce. These jobs were primarily out sourced to a vendor that absorbed many of the engineers that were laid-off, but not all of them. Unfortunately, the company did not put any mechanisms in place to capture the knowledge of the employees that were leaving the department. A two-month review of the results following the reengineering effort shows that certain quality indicators are not being met (Becerra-Fernandez, 1997). To minimize the impact of downsizing, a company must first identify what skills will be needed to meet mission critical objectives. This requires a strategic planning process that envisions what each department will be doing in the future. This, in turn, will allow the company to identify the skills and information resources required to meet its objectives. Therefore, effective tools to capture knowledge are essential for a company to maintain its competitive edge.

Supporters of the Knowledge Management movement say "effective knowledge management pays off in fewer mistakes, less redundancy, quicker problem solving, better decision making, reduced research development costs, increased worker independence, enhanced customer relations, and improved services. In effect, the advantages resulting from Knowledge Management add up to keep the company at least a few steps ahead of its competitors" (Stuart, 1996). Since Knowledge Management tools provide access to explicit company knowledge, it is easy to learn from previous experiences. "Learning" companies benefit by not repeating costly mistakes, and by reducing time-to-market in Research & Development projects. Group-decision making tools can help companies make better decisions by capturing the knowledge from groups of experts. Companies that capture their customer's preferences can improve their customer service, which translates to larger profits" (Becerra-Fernandez et. al. 1998a). Organizations and businesses must learn to effectively manage their knowledge, including how to efficiently catalog it and then reuse it. Organizations are now concentrating their efforts not only in gathering documentation, but also in mining the tacit knowledge and experiences of their employees (knowledge harvesting). The context of Knowledge Management (KM) is to capture and re-use the investments in research and development as a vital part of a project. Eliciting and harvesting knowledge changes a normal organization into a "learning" organization capable of quickly and efficiently finding solutions to new problems, as well as, reusing and adapting previous solutions.

#### **Assessing areas of intellectual capital at NASA**

A functional Knowledge Management System requires that knowledge be elicited/created, shared, managed, and leveraged by a balanced combination of: people, process, Information Technology Applications, and organizational culture. In order to assess the areas of intellectual capital for Kennedy Space Center, a Knowledge Management Assessment (KMA) for KSC was designed and implemented between February and April, 1998 (Becerra-Fernandez, 1998c). The following is an excerpt from the summary of the results from the Knowledge Management Assessment of KSC's Knowledge Management (KM) needs and possible enhancements to the current KM Environment:

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1. **Center-wide Lessons Learned Repository:** Five of the eight interviewed groups expressed the need for a Center-wide Lessons Learned Repository which would include a synopsis of why certain decisions were made, rather than simply which decisions were made.
  2. **Collaborative Tools:** Of the 8 technical groups interviewed, 6 expressed a need for Internet/Intranet based collaborative tools that capture knowledge as teams create it. Implementation of appropriate collaborative tools would also address the need to enhance virtual communication among departments and teams; as well as between KSC and other government agencies and universities. Collaborative tools allow linking functional teams to integrate support, troubleshooting, and engineering initiatives.
  3. **Knowledge Management Procedures to Harvest Knowledge:** Five of the eight interviewed groups expressed the need for procedures to harvest organizational knowledge. The Knowledge Management procedures to harvest knowledge within the organization would keep track of details of processes. These details include the who, the where, and the why of the processes' decisions and details.
  4. **Electronic Document Storage:** Four out of the eight interviewed groups addressed the need for proper electronic document storage that would allow departments and teams to share work files and relevant data. This system should allow intuitive access of required information.

From these observations, a list of recommendations was developed. The following is an excerpt of the recommendations:

1. **Meeting common needs:** Preliminary observations from the Knowledge Management Assessment state that, while all the functional groups at KSC are to a large extent disjoint, they still have common needs. One of those needs is to have centralized repositories of lessons learned, best practices, and unstructured documents accessible to all employees in an intuitive fashion.
2. **Reorganizing:** The Learning Organization of the 21st Century will also require the implementation of tools that will enhance the collaboration across functional organizations. Collaborative computing software is an effective way to enhance team collaboration, particularly that of virtual teams whose members work within the spectrum of "same time/same place" to "different time/different place".
3. **Establishing a centralized knowledge repository:** All of the KSC groups interviewed expressed the need to facilitate intra-departmental linkages, particularly aimed at enhancing access to information archived in isolated departmental databases.

#### **Project Description: Augmenting the capabilities of Postdoc**

One tool frequently touted under the auspices of Knowledge Management is document management. At the core of a document management system is a centralized repository, an electronic storage medium with a primary storage location that affords multiple access points. Document management builds upon the central repository by adding support to the classification and organization of information, unifying the actions of storage and retrieval of documents instituted over a platform independent system. A document management system unifies an aggregate of relevant information conveniently in one location through a common interface. The document management collaborative application increases communication, thus allowing the sharing of organizational knowledge. The document management system essentially stores information.

A workflow tool provides a method of capturing the steps that lead to the completion of a project within a fixed time frame, and in doing so, provides a method of illustrating such steps. Currently Postdoc does not support a workflow tool. Workflow systems can be useful for projects by enacting its elemental tasks, as well as by providing a mechanism, for the analysis and optimization of the entire processes detailing the project. Another benefit of using a workflow system is that it provides the user with an audit of necessary skills and resources prior to project initiation. Workflow systems also provide a template for the replication and reuse of stored processes. Finally, workflow tools can also serve as a training tool since they provide a broad overview with detailed operations of tasks as well as identification of "weak links" in a process.

A collaborative environment, which allows the informal exchange of ideas, combined with a detailed workflow, which captures process steps, is an efficient method of streamlining business practices. A document management system unifies an aggregate of relevant information conveniently in one location through a common interface. Categorizing and processing information for search purposes provides a detailed knowledge warehouse. The collaborative application increases communication, thus allowing the sharing of organizational knowledge. Although there are benefits of using these three tools (document management, workflow, and groupware), independently of each other, their integration augments their individual contributions. The document management system essentially stores information. The electronic documents are usually organized and relevant to its hierarchical structure. The workflow, which details the steps involved in completing a project, combined with a central repository that contains information relevant to a project, provides added benefits. The most important benefits, according to Knowledge Management theory, is the elicitation and capturing of organizational know-how that typically is not captured by most information systems, as well as an obvious user

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interface to access and reuse this organizational know-how. Collaborative computing provides a common communication space, improves sharing of knowledge, provides a mechanism for real-time feedback on the tasks being performed, helps to optimize processes, and results in a centralized knowledge warehouse.

Postdoc is a "government-off-the-shelf" document management software developed at NASA-Ames Research Center (ARC). Postdoc required a development effort of 5 person-years of software coding and testing, beginning with the New Millennium Electronic Documentation Project in the Computational Sciences Division at NASA Ames Research Center. The New Millennium Electronic Documentation Project was the first NASA web-based intranet defined for a very large program involving six Deep Space Mission, three Earth Orbiting missions and six technology teams in 1995. This project was a semi-finalist in the 1996 NII Awards. This effort involved studying how widely dispersed teams interact and what web-base tools are most effective for overcoming their geographical differences and varying computational environments.

Postdoc is a multi-user, web-based application primarily for the storage and retrieval of documentation (i.e., word processing documents, spreadsheets, slides, illustrations, images, video, audio, software archives, or others). Unlike a traditional web site where the webmaster alone constructs it, a Postdoc web site is \*easily\* constructed by its users who can login to the site to add, delete, and organize documents the way they want. Users need not have any specialized web site construction knowledge or skills such as HTML or programming. Users create documents on their own computer using many popular applications (such as Microsoft® Word, Excel, and Powerpoint) then easily upload them to the Postdoc server. The server can then automatically convert them into PDF, enabling them to be viewed by anyone without the creating application. By virtue of being a web-based application, Postdoc can be used by anyone, anywhere. The only requirements to use Postdoc are a computer (be it a Macintosh®, PC, or a Unix workstation), a browser (such as Netscape® Navigator or Microsoft® Internet Explorer), and an Internet connection. Although Postdoc works well for small co-located teams, by being web-based it also works very well for geographically dispersed teams, including members on travel using a laptop computer with a cellular modem. Postdoc is available for free for government use. NASA-ARC supports the deployment of this innovative tool, not only within NASA centers but also at other government agencies.

This project seeks to augment the current Postdoc environment with workflow capabilities. The addition of Workflow capabilities is important in the context of allowing version control in the collaborative development of documents, such as change requests, document reviews, and proposal writing. By tracking changes in the state of the document, Proposals could be drafted and submitted, then later reviewed, voted on, and totals tallied all in a virtual collaborative environment. By combining Postdoc's ability to maintain revision control with the added ability to notify users via e-mail based on the document status, dispersed groups can benefit from a true dynamic, collaborative environment. Figure 1 is a representation of the collaborative computing underlying technical architecture. The expanded workflow capability will allow setting e-mail notifications for specific changes in the state of a document. An advanced feature for automated processing of the document will also be provided in the workflow process. Figure 2 is a representation of the integrated workflow environment.

### **The Evolution of Postdoc**

Postdoc has been very effective in meeting the targeted scope of a document management system, and continues to be used today to manage thousands of documents across many divisions of NASA. However, Postdoc's ability to support Knowledge Management is limited by this initial scope and by the (dated) design and implementation. A plan is in place to rearchitect the Postdoc system with a larger, more generic scope, in order to meet Knowledge Management needs, as well as the growing needs of other projects throughout NASA that are looking to expand Postdoc's functionality into (often drastically) different applications.

Of key concern, to Knowledge Management, is the ability to manage metadata about documents (often making the metadata more critical than the actual document itself) and to enable users to create workflows to manage the collecting and manipulation of this metadata and to manage the state of the document's workflow as it transitions. The core Postdoc development team will address these needs and others by rearchitecting Postdoc--utilizing an access-controlled, user-extensible, object-oriented data model. Postdoc will be redesigned with a decoupled, hierarchical design, providing a "sandbox" application programming environment (APE) for end-users to develop workflow and knowledge management functionality while ensuring security by preserving data access-control.

This decoupled design also enables Postdoc components to be exchanged for alternative, often quite different components. For example, by adding an alternate communication and presentation layer, a command-line interface, 'chat' interface, or WebDAV document publishing client interface could all be supported simultaneously. Alternatively, an entirely different database architecture could be leveraged, allowing for Postdoc's adoption of object-oriented and/or distributed database technologies without application modification.

The Postdoc redesign will also incorporate the most current, applicable technologies, standards, and protocols

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for web-based collaborative environments (primarily working towards compliance to and utilization of XML and WebDAV standards and technologies.)

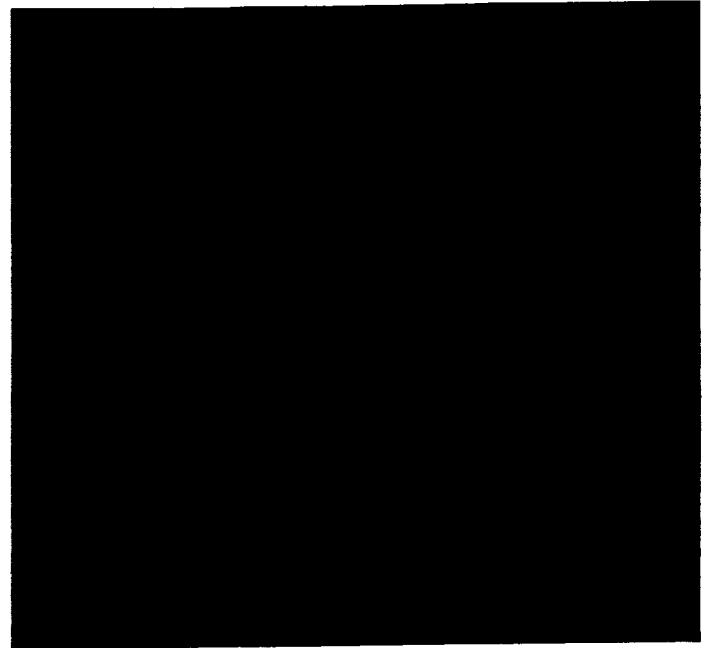
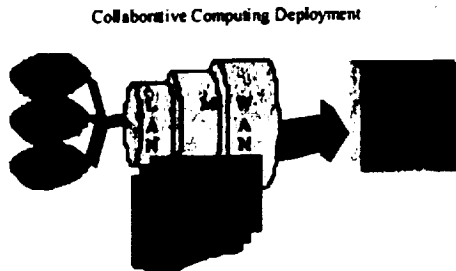


Figure 1 Collaborative Computing Deployment Structure      Figure 2 Workflow for Collaborative Computing

#### Future applications of this research

A potential application of this research is the implementation of a collaborative environment within the context of the software change request process. In the current environment, Postdoc notifies users of any changes in the document. In the new developed environment, notifications will be set for specific changes that modify particular states of the document. The new expanded capabilities of Postdoc will be tested in the Software Change Request (CR) process. It is anticipated that the new process would consist of:

1. CR Document is inputted into Postdoc.
2. Input notifies the System Engineer via email.
3. The System Engineer updates the CR with a log number and other data
4. This update notifies the originator and Software Change Board Members
5. The workflow system then automatically assigns the CR to the Software Board Calendar automatically
6. Software Change Board reviews and dispositions the CR
7. Software notifies everybody concerned
8. CR is closed and appropriate notifications are sent

In addition, the automated processing feature of Postdoc will be tested, including batch database updates, integrity checks, and vote tallies. The prototype, implemented through the integration of workflow, document management, and groupware tools, can be applied to other domains that rely on group collaborations within NASA. This application provides a mechanism for virtual team collaboration that can be made available both inside and outside of NASA-ARC. Moreover, user access is provided through an intuitive underlying web structure. The application can also be easily replicated within NASA.

The new augmented features of Postdoc would prove invaluable to other key process in NASA, for example in the Payload Processing Customer Support Process. The augmented Postdoc environment with workflow/document

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management/groupware capabilities would be useful to develop a prototype for collaborative computing ideal for the NASA-KSC Payload Processing Directorate. This application would be aimed at improving the Payload Processing Customer Support process, by combining a central repository of information and a workflow system through a common web interface. This application would improve and streamline business processes and the sharing of organizational knowledge.

The Postdoc collaborative computing environment described here could provide the NASA-KSC Payloads Processing Directorate with a detailed audit of resources. It would allow the observation and capture of a project plan as it is being created through the document management, and provide a means of assessing the effectiveness of completed project plans with the integrated workflow analysis tools. The Postdoc collaborative computing environment would also provide an audit of hours necessary for the completion of a project through the time-framed process layout. This collaborative computing application would be able to capture organizational knowledge, including how to complete a process flow, why a process flow is performed the way it is, and what information is needed to complete a process flow. The Postdoc collaborative computing environment would enable informal as well as formal suggestions for projects, akin to an electronic suggestion box, to provide process feedback. It would also provide a method of reusing captured knowledge as a training tool.

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