DOCUMENT RESUME

ED 478 093 IR 058 687

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TITLE	Leveraging Knowledge: Impact on Low Cost Planetary Mission Design.
PUB DATE	2002-06-00
NOTE	11p.; In: SLA 2002: Putting Knowledge to Work. Papers Presented at the Special Libraries Association Conference (Los Angeles, California, June 9-12, 2002); see IR 058 674.
AVAILABLE FROM	For full text: http://www.sla.org/content/Events/ conference/2002annual/ confpap2002/papers2002conf.cfm/ .
PUB TYPE	Reports - Descriptive (141) -- Speeches/Meeting Papers (150)
EDRS PRICE	EDRS Price MF01/PC01 Plus Postage.
DESCRIPTORS	Access to Information; *Corporate Libraries; *Electronic Libraries; Engineering; Engineers; *Information Management; *Information Services; Library Development; Scientific and Technical Information ; Space Exploration; Special Libraries; *User Needs (Information); World Wide Web
IDENTIFIERS	*Electronic Resources; Intranets; *Knowledge Management

ABSTRACT

This paper discusses innovations developed by the Jet Propulsion Laboratory (JPL) librarians to reduce the information query cycle time for teams planning low-cost, planetary missions. The first section provides background on JPL and its library. The second section addresses the virtual information environment, including issues of access, content, and online requests. The third section discusses knowledge management projects, including: the Information Providers Directory; JPL Know Who, a directory of skills and knowledge at JPL; JPL Taxonomy for the Portal (i.e., a replacement for the JPL Intranet Web site); JPL Stories series, a monthly story-telling event; several small projects to capture and communicate tacit knowledge; metadata standards; a catalog of JPL authors and publications; and the Document Information Management System. The fourth section describes the relationship between the JPL Technical Library and the Flight Systems Engineering Section, including a survey to identify the information needs of systems engineers, organizing the collection in the Flight Systems Section electronic library, and implementation of the library. (MES)

Leveraging Knowledge: Impact on Low Cost Planetary Mission Design

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INTRODUCTION

In January 1991, Dr Edward Stone became director of the Jet Propulsion Laboratory and undertook the transformation of planetary mission design from large, complex and expensive missions to low-cost planetary missions. The Jet Propulsion Laboratory Technical Library has been involved in a transformation of its own responding to the challenges of a changing environment. This paper discusses innovations developed by the JPL Librarians to reduce the information query cycle time for teams planning low-cost, planetary missions. The information query cycle time was reduced through changing the process of the query and the tools by which information is acquired

BACKGROUND

The Laboratory

When Dr. Edward Stone became Director of JPL, NASA was trying to recover from "serious and embarrassing problems with the space shuttle and the space telescope."[1] The White House and the NASA Administrator, Admiral Richard Truly, disagreed on the approach to space exploration. The White House wanted Admiral Truly to "scale back plans for large, expensive, and long duration space science programs."[2]

By March 1992, Admiral Richard Truly had been replaced by Daniel S. Golden who had many years of experience at TRW managing industrial space company. One of his first acts was to visit all the NASA Centers. At JPL "he declared that he wanted to see smaller space projects that could be launched quicker and cheaper."[3] Beginning in 1992, JPL senior management began significant changes: reduction of the work force; descoping the complex Cassini project to save time and money; and designing an innovative Mars Program comprised of smaller, less complex projects.[4]

The change in mission design necessitated changing the way technology was developed at JPL to meet mission requirements. The large projects of the past had had the time and resources to develop the new technology needed during the course of the mission. The new strategy was to develop organizational structures to "advance their [technology] capabilities in chosen areas and integrate those capabilities into the flight projects."[5] For example, the X-2000 program provided "technology development in avionics, communications, and power systems."[6]

The Library

The JPL Technical Library went through a serious review in 1993, both from within and a peer review from colleagues at Caltech. The Library had a Marketing Committee who decided to conduct an extensive survey of our customers as a "first step toward developing a long-term marketing plan for the Library."[7] The survey asked a variety of questions about the collections and the services. The survey packet also had free-text comment areas. The Marketing Committee made ten recommendations in its report. The clearest statements were to "improve customer access to online databases;... reduce the turnaround time for book, document and serial orders;...develop customer outreach and education programs"...[8]

We also had a peer review in 1993 by a colleague at Caltech that was commissioned by the Science Division at JPL. In certain areas there was a confluence of thought: the Library needed to "provide users with direct electronic access to databases with document delivery capability"; and [9] "purchase the electronic version of information resources...;" [10] Evaluation of the changing JPL environment, the Library customer survey results, and the Caltech study led to the evolution of our Virtual Information Environment known as BEACON, extensive participation in Knowledge Management Projects; and consulting with the Flight Systems Engineering Section.

VIRTUAL INFORMATION ENVIRONMENT

The JPL changed environment meant that we had to develop an improved process and new tools to shorten the time for acquiring information. We decided to focus on online tools in the users' workspace for self-service inquiry.

The development strategies included a continuous improvement of the online environment. From 1993 to 2002 we have addressed and continue to address the issues of access, content and online requests.

We began with global access to content through local Internet Service Providers and JPLNet, the remote access service at JPL. JPL has improved remote access since our initial rollout by implementing a Virtual Private Network (VPN) technology, which has dramatically increased the speed of remote access but necessitated ongoing negotiations with the publishers to enter their IP addresses into the VPN "tunnel."

The content was selected for ease of use, technical quality, reliability, relevance and query cycle time. Organizing and presenting the large number of full-text journals and books has brought us more deeply into the world of information architecture. We began with a manageable list of 300 full-text journals, but now have over 800 titles. To increase the "findability" of titles by subject and title, we have entered titles into the catalog and added subject pages for online resources to the web site. Working on ease-of-use issues and reducing the query cycle issue caused us to spend considerable time on navigation, labeling, site indexes and maps to the BEACON web site.

Online requests for titles not linked to full-text files has been critical to improving our turnaround time. We have refined our processes for filling requests and worked on the technical issues of the online request mechanism. We discovered just how many different platforms and browsers are being used when we implemented online request forms. We resolved problems for the most commonly used platforms and browsers, but also established an email address dedicated to online requests.

The BEACON web site and full-text journals and books have been well received, but most of the content was formal publications rather than unpublished and often ephemeral information created within JPL which was quite often the missing piece needed by the engineer or scientist.

KNOWLEDGE MANAGEMENT PROJECTS

Internal information, both tacit and explicit, has always been the most elusive information to try to provide the customer. Developing innovative tools and processes to shorten the cycle of getting information has been a challenge. JPL had repositories for documents, technical drawings and product data, but retrieval was difficult without the numbers assigned to the item. The JPL Technical Library had been allocating staff resources for twenty years to index documents placed in the central file and identified only by a document number. These documents were microfilmed and available to the Laboratory. However, the repository was not part of the Library and the indexing was extremely labor intensive. The activity and the database was eventually turned over to the Engineering Document Group who managed the repository

As demand for collaborative work space and access to shared electronic information grew, numerous electronic project repositories were created. The repositories were home grown and not standardized. It was difficult to discover their existence, much less what was in them.

Finding a solution to the electronic repositories documentation requirements of the increasing number of projects was one of the main business drivers for knowledge management at JPL. The Knowledge Management Program at JPL was centered in the Information Technology Sections. The JPL Librarians library became involved in several of the official Knowledge Management Projects as well as initiating activities later recognized as knowledge management. We needed tools to access the content and networks of people who could connect us with the information we needed in a timely fashion. Following is a brief description of our activities:

Information Providers Directory: The Information Provider Directory was compiled by Teresa Bailey, one of the Technical Librarians, to help audit the available information on the Laboratory, provide contact information and a brief description of the content of each repository. The initial effort developed into a loosely affiliated group that meets quarterly to network and make presentations. Last year the Library organized an Information Provider Fair in the lobby of the Library. We are fortunate to have a large open space where we can have activities. Each participant had a poster or an online demonstration of some product. The Information Providers Directory has become an extremely effective tool for the librarians to get access to obscure collections and for us to provide leadership in developing a community of interest.

JPL Know Who: JPL Know Who is a directory of skills and knowledge at JPL. I became Co-Team lead with someone from the Chief Scientist's office. The project was funded by Knowledge Management and was the first in which a Librarian was a recognized Team Lead. This product will be used as a directory by the Reference staff and a networking tool. Participating in an IT development project with requirements reviews and readiness reviews was useful to gain credibility in the community. It will also be a tool for the Librarians to network with technical experts willing to share their skills and knowledge.

JPL Taxonomy for the Portal: The JPL Portal project was conceptualized by the Knowledge Management Program as a replacement for the JPL Intranet web site. A key feature of the Portal was a taxonomy. Robert Powers, a JPL Librarian, led the taxonomy development effort. The Portal is being rolled out to the Laboratory in phases and is not yet in full use.

Process owner for "Develop Knowledge": The Library Group Supervisor, Barbara Amago, is process owner for "Develop Knowledge" under the Knowledge Management Process Domain, which has been important as a structural element as JPL tries to reshape itself as a process-based organization.

JPL Stories series: The JPL Stories Series is a monthly story-telling event that was organized by a Technical Librarian, Teresa Bailey. Teresa has been able to communicate to the storytellers that the goal is not just colorful yarns. For example, one of the storytellers was able to bring the JPL Design Principles to life by telling stories to illustrate such things as "test as you fly and fly as you test."

Knowledge Capture—Teresa has also been working on several small projects under this general project title to capture and communicate tacit knowledge. Among the activities of the Knowledge Capture Team are interviews of significant retiring JPL senior staff; an underground orientation (what goes on in what buildings); JPL 101 a series of questions about JPL designed to help new hires understand the culture and unpublished information about JPL.

Metadata Standards—I also contributed information on the Dublin Core Standard and its evolution as a standard accepted by JPL

Catalog of JPL Authors and Publications. The Library Supervisor, Barbara Amago, has chaired a team to create a bibliographic database of JPL Authored Publications. It will be used for bibliometric data, specialized bibliographies, and links to full text when possible.

Document Information Management System (DIMS): In this case the Library contributed its bibliographic database of JPL documents to one of the largest repositories which formerly only had access by document number. The collection was mostly on microform. This collaboration enabled location of some of the older documents by author, title, keywords as well as report numbers. This is becoming an increasingly valuable collaboration because the documents are beings scanned and digitized as they are requested which speeds the cycle time.

FLIGHT SYSTEMS ENGINEERING SECTION

The relationship between the JPL Technical Library and the Flight Systems Engineering Section began in August 2000 when Rob Kocsis, a senior member of the Technical Staff in the Flight Systems Engineering Section approached the Library for a consultant to help establish a digital collection for young engineers, new to JPL. JPL had decided that the Xerox product, Docushare, would be used for the project digital collections. The Docushare system itself was managed as a project in the Knowledge Management Program. It provided an infrastructure for digital document repositories for the numerous flight projects and sections.

The Flight Systems Engineering Section leads and supports the spacecraft systems design at JPL. This includes the subsystems (e.g. thermal, power) functional requirements definitions and the interface designs between the different subsystems. They also become involved in launch vehicle integration and spacecraft design verification requirements. [11] Management of these activities subcontracted out to industry has become an increasing part of the job.

The newly hired engineers find themselves quickly assigned to a project and expected to produce deliverables in a relatively short period of time. To complicate matters, they might be co-located in different buildings with other Project Team members or working in a virtual team Environment with partners from industry or universities.

The management of the Section was responding to the cultural and paradigm shift mentioned by Philip Barnett in his thesis. Prior to the 'better-faster-cheaper' era, "performance was the independent variable and cost the dependent variable."[12] Having cost become paramount over performance to the degree that a cost overrun of 25% would mean cancellation of the project meant that senior management had to find means to control costs and mitigate risk. This was the business driver for management to ask the library for help in developing innovative approaches because "project system designs had to be tailored to ensure development times reduced from five to six years or more down to three to four years."[13]

When Rob Kocsis approached the Library, he was uncertain about both the content and the organization of the digital collection. I was the Librarian who became the consultant. We began with a meeting of two senior engineers; four engineers young enough to remember the challenges of being a "newbie" but experienced enough to have discovered solutions to some of the problems; two engineering students from Cal Poly and two new engineers who were to be able to use the team to get answers in real time.

We developed a questionnaire that was sent to all systems engineers in the section. Some of our questions were similar to those used in Wilda Newman's study at APL.[14] Her questions were clustered in three groups: "focus on information in your current environment; focus on knowledge in your current work environment (how do you know something that you don't know)."[15] Newman's third group was beyond the scope of our project because the questions ask about a future work environment ten years down the road. We sent out the following questions:

1. What Projects are you currently working on?
2. What phase is the project in?
3. What are your current responsibilities in supporting the project?

4. What products are you responsible for producing?
5. What reviews are you going to have to support and with what products/information?
6. How and where do you get information on your responsibilities and deliverables?
7. Does your project have a library? [Docushare repository]
8. What information/references/aids would help you do your job better?
9. What other information (project related, Laboratory related, NASA related, etc) would you like to be able to access to help you?
10. What are the three most important organizational features of an on-line library/reference for you?
11. What are the top five types of reference material/information most important to you?

Our questions were most effective in gaining insight into what types of information were most valuable at different phases of a project. They were least effective eliciting responses to Newman's second type of question which is how do you know when you know something you don't know. In other words, how would we establish the pedigree of the information?

Most of the content requirements were JPL gray literature, organizational information:

Fault Protection Requirements
Functional Block Diagrams
Requirements, level definition, content and structure
Flight rules
Review materials (Presentations, Preliminary Design Reviews etc.)
ATLO (Assembly, Test and Launch Operations) plans, schedule, tasks, timing with rationales
Margins (settings, assessing, reporting)
Resource utilization as a function of time
Lessons Learned
Stories providing context to Lessons Learned
Ease-of-use requirements for the library were keyword and full-text searching and browsing.

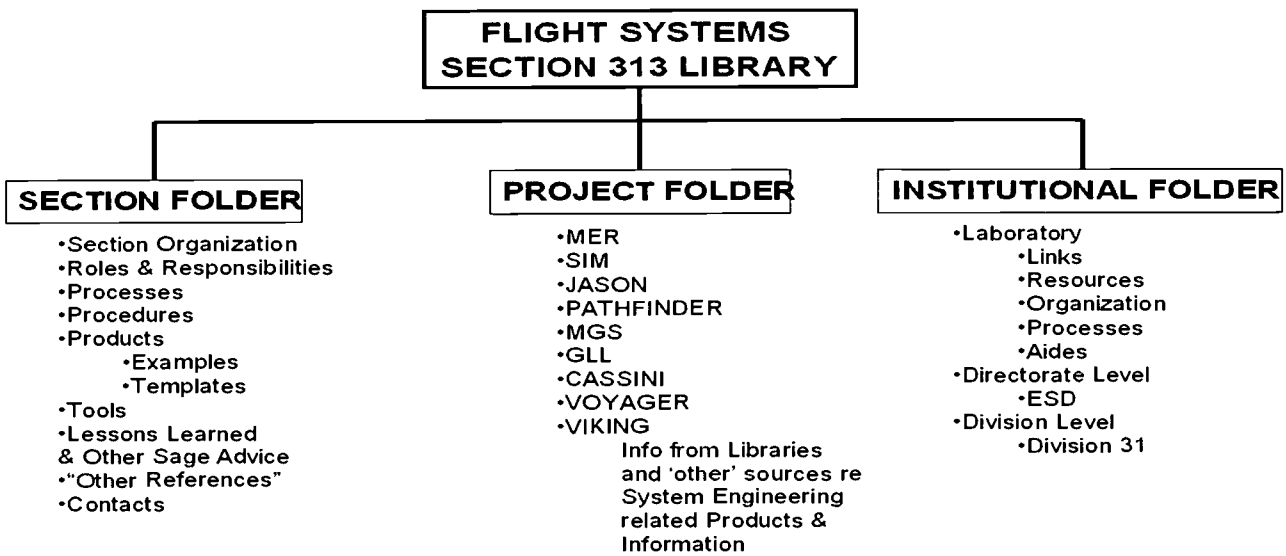
The team decided to stick to the business drivers helping the new engineers shorten the query cycle with a new tool that could be rapidly deployed. The content was divided into high, medium and low priority. The high priority material included: Functional Requirements; Mission plans; Functional Block Diagrams; Flight Rules and Constraints; Preliminary Design Reviews; Critical Design Reviews and Launch Readiness Reviews. The criteria for high priority was material based on JPL design principles where quality examples and templates would significantly reduce development time and reduce risk of diminished performance.

The medium priority material included: Fault Tree Analysis; Fault Protection Design Description Documents; Launch Vehicle Interface, Requirements and Controls Documents,

Interface Control Documents and System Requirements Reviews. The low priority documents included: Launch/Hold Criteria Documents; Pre-Ship Reviews; and Flight Operations Reviews.

Organizing the Collection

Organizing the collection sounded a lot like system engineering to the team, and it was their favorite part of the project. We played dueling diagrams and eventually settled on one



The resulting structure bore little resemblance to the identified content groupings. It seemed more productive to make extensive use of metadata for document types, such as functional requirements documents, and include an alphabetical list of documents.

The JPL Library was to be linked under the Institutional Folder, but it was clear from discussions that many of the young engineers were unfamiliar with the range of on-line resources at our site such as the wealth of full-text handbooks or databases beyond the one available at their university. Many were also only familiar with the particular information architecture design of the web site at their university library. It was clear that a fresh look at presentation of the JPL Technical Library's resources in their environment would be beneficial.

Currently, one of our technical librarians is experimenting with a different group JPL in innovative ways to communicate and present narrowly focused selections from digital collections for which we have paid site licenses.

Implementation and Population

The plot thickened—seriously. JPL's authentication and authorization system development team had been sent back to the showers after one of their design reviews. The Library project has been put on hold because all of the content must be reviewed for restricted access for proprietary information and export controlled information. JPL has a diverse workforce that includes contractors who may be in competition in certain circumstances and foreign nationals who are entitled to certain information but often restricted on other information. It appears that some of the technical problems will soon be resolved and perhaps the project will resume.

Populating the library will still contain challenges because the content will have to be reviewed as though it were going to be published or sanitized into more of a template. The documents will also have to be reviewed for quality if they are to be used as training and resource material. The level of collaboration will be complicated, but I think the development of a core collection could be of great benefit. Another part of "plan" would be to have some of the senior technical staff have "office hours" to provide context and guidance to the young engineers. Because I am working on this project, and the JPL Know Who Directory which has close ties to the mentoring program, I do see possibilities of a Flight Systems Engineering Section Support Program for the rapid deployment environment.

CONCLUSION

The JPL Library successfully developed strategies to meet the goals of JPL to design low-cost planetary missions by changing the process, the tools and developing the networks to leverage knowledge at JPL.

ENDNOTES

[1] Barnett, Philip M. *The evolution of a federally funded research and development center: an analysis using four theoretical frameworks* [dissertation]. Claremont Graduate University : Claremont, California., . 2000 p. 316.
[2] Ibid., 318
[3] Ibid., 322
[4] Ibid., 319
[5] Ibid., 339
[6] Ibid.
[7] *The JPL Library Customer Survey: report to management. February 12, 1993,* p. iii.
[8] Ibid., 15-16
[9] Douglas, Kimberly. *JPL library study and executive summary. December 17, 1993 p. 63*
[10] Ibid.
[11] Flight Systems Section 313, http://eis.jpl.nasa.gov/sec313/
[12] Barnett, p. 321
[13] Ibid., 323
[14] Newman, Wilda B."Some research results on knowledge management and end user work environments in 2010" in *Independence to inter dependence, the next phase in the information revolution : 91st annual conference,* Philadelphia, 2000, p.69
[15] Ibid.

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