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ENABLING INNOVATION AND COLLABORATION ACROSS GEOGRAPHY AND CULTURE: A CASE STUDY OF NASA'S SYSTEMS ENGINEERING COMMUNITY OF PRACTICE

Daria E. Topousis
Jet Propulsion Laboratory, California Institute of Technology, USA
daria.e.topousis@jpl.nasa.gov

Keri Murphy
Jet Propulsion Laboratory, California Institute of Technology, USA
keri.s.murphy@jpl.nasa.gov

Greg Robinson
NASA Headquarters, USA
gregory.l.robinson@nasa.gov

ABSTRACT

In 2004, NASA faced major knowledge sharing challenges due to geographically isolated field centers that inhibited personnel from sharing experiences and ideas. Mission failures and new directions for the agency demanded better collaborative tools. In addition, with the push to send astronauts back to the moon and to Mars, NASA recognized that systems engineering would have to improve across the agency. Of the ten field centers, seven had not built a spacecraft in over 30 years, and had lost systems engineering expertise. The Systems Engineering Community of Practice came together to capture the knowledge of its members using the suite of collaborative tools provided by NEN. The NEN provided a secure collaboration space for over 60 practitioners across the agency to assemble and review a NASA systems engineering handbook. Once the handbook was complete, they used the open community area to disseminate it. This case study explores both the technology and the social networking that made the community possible, describes technological approaches that facilitated rapid setup and low maintenance, provides best practices that other organizations could adopt, and discusses the vision for how this community will continue to collaborate across the field centers to benefit the agency as it continues exploring the solar system.

1.0 Introduction

In 2004, the National Aeronautics and Space Agency (NASA) faced major knowledge sharing challenges due to geographically isolated field centers that inhibited personnel from sharing experiences and ideas. Mission failures and new directions for the agency demanded better collaborative tools. Two major events drove the need for improved knowledge sharing across the agency: the loss of Space Shuttle Columbia and the U.S. President's vision to return astronauts to the moon and begin human exploration of Mars.

FOLLOWING the loss of NASA's Space Shuttle Columbia and crew in 2003, the Columbia Accident Investigation Board was convened to identify underlying causes of the accident. After extensive review, the Board determined that "NASA's organizational culture and structure had as much to do with this accident as the External Tank foam." [1] This uncovered an endemic problem across the Agency: that the full body of NASA's existing knowledge and resources are not sufficiently accessible or utilized to solve engineering problems. [2] The Columbia Accident Investigation Board also discovered that while most NASA Centers capture lessons learned, they tend to keep knowledge of problems contained within their Center. [1] In the end, the Board determined that "NASA has not demonstrated the characteristics of a learning organization."[1]

Less than one year later, President Bush announced his vision to send astronauts back to the moon and to Mars. NASA recognized that in order to achieve this vision, systems engineering would have to improve across the agency. Of the ten field centers, seven had not built a spacecraft in over 30 years, and had lost systems engineering expertise. In addition, some centers would face major restructuring to change focus from aeronautics research to being more centrally involved in the new generation of human spaceflight vehicles. Central to enabling cross-center collaboration is a strong systems engineering base.

In response to these needs, the NASA Engineering Network (NEN) was formed to provide a multi-faceted system for overcoming geographic and cultural barriers. The NEN integrates communities of practice with a cross-repository search and the Lessons Learned Information System, allowing expertise captured in communities to be shared with a larger audience.

The NEN provided a secure collaboration space for over 60 practitioners across the agency to assemble and review a NASA systems engineering handbook. Once the handbook was complete, they used the open community area to disseminate it. By using NEN, the community was able to forego costly face-to-face sessions or the confusion of passing multiple Word files around and instead focus on the online community as a means of gathering input and guidance from practitioners.

This case study explores both the technology and the social networking that made the community possible, describes technological approaches that facilitated rapid setup and low maintenance, provides best practices that other organizations could adopt, and discusses the vision for how this community will continue to collaborate across the field centers to benefit the agency as it continues exploring the solar system.

2.0 Background

2.1 Communities of Practice

Communities of practice are "groups of people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis." [3] They have existed throughout history, through such organizations as guilds and professional societies. Because they are an effective means for capturing, sharing, and using knowledge, communities of practice provide a means for collaboration and innovation, and have become a more prevalent component of knowledge management strategies at many major organizations. [4] In fact, communities of practice are increasingly seen as "the best way to bring about the long-sought goal of creating a 'learning organization,' getting people to share their knowledge, and creating a pool of collective organizational intelligence." [5]

The community of practice concept at NASA grew out of early work in the idea of innovation at NASA and research from Kuhn's study that innovation occurs at the "edges" of communities—for example, when thermal engineers and mechanical engineers are brought together to work a complex problem. [2]

Etienne Wenger's early work in the field provides a foundation for the steps of identifying and cultivating communities. [3] Cultivating communities follows seven basic principles: designing for change, opening dialogue, inviting varying levels of participation, developing public and private spaces within the community, focusing on value, combining familiarity and excitement, and creating a rhythm for the community. [3]

Over the past decade, much research has been published describing success factors beyond these seven principles. One central concept is that intentionally-formed communities, that is, those communities an organization's managers create rather than one that arises organically, is that they must be focused on the central problems facing the organization. [6]

Most organizations also found that strong leadership is key to a successful community. A leader must be respected by practitioners and act as champion for the community, but they also must have time available to devote to leadership tasks such as "balancing member interests and agendas; identifying priorities; attending inclusiveness; drawing contributions; facilitating interactions; and encouraging a culture of egalitarianism and co-operations." [7]

In addition to having a strong leader and a focus on the central business areas, face to face meetings are often central to cementing relationships and building trust among members. [8] For organizations with funding that inhibits face-to-face meetings, teleconferences are often an acceptable second choice.

Once formed, most communities that survive past the initial launch phase were successful because participants had something meaningful to work on. "Activity becomes meaningful when focusing on things that matter to community participants." [9]

While communities of practice have existed since ancient times, the advent of online or virtual communities is a relatively new concept. As portal technology and collaborative tools have improved, organizations have been forming online communities to enable members of geographically distributed organizations to collaborate and interact. These online or virtual communities provide a means for more participation from a wider range of practitioners. In addition, using online tools means content can be easily stored, retrieved, and reused. [10] However, because members are not always online at the same time, and are not able to see what people are reading, it can take more effort to remind users of the community's existence and to encourage members to ask for help and share ideas. [3]

Online communities face other challenges as well. While they are relatively easy to create, organizations must be sure to remove barriers to participation, acknowledge individual uniqueness, and connect that uniqueness to the larger community purpose. [11]

2.2 Impetus to Form the Systems Engineering Community

In the summer of 2006, the Systems Engineering Working Group which consisted of members from various centers, were facing the challenge of trying to incorporate input from 60 experts across the agency into one document: the Systems Engineering Handbook. Following the release of NASA Procedural Requirement 7123.1, NASA Systems Engineering Processes and Requirements, it was clear that an improved handbook would help engineers understand and implement the requirements and lead to a more consistent and effective implementation of systems engineering practices across all centers. Although a handbook had existed for several years, no one was sure where the official version was stored, and most agreed that it needed updating.

Soon after embarking on updating this document with content contribution from 60 experts, the team realized it needed a central space to store the document and a means of gathering review comments. After seeing a demonstration of the NASA Engineering Network, which offered online communities of practice that included a centralized portal with an integrated portlet for content from DocuShare, a content management system, the team decided to create a community of practice.

DocuShare is a document repository system that allows users to upload or access content in various formats (MS Office, PDF, HTML, etc.). Each library can be configured to allow different levels of access to selected personnel. The secure login was one key feature that the community was interested in. In addition, DocuShare provides a configuration control mechanism whereby only one user at a time can edit a document, thus preventing confusion and lost content.

2.3. The NASA Engineering Network

The communities of practice sit within the NASA Engineering Network, a suite of information retrieval and knowledge-sharing tools specifically aimed at facilitating communication among engineers at all of the NASA centers and affiliated contractors. The network includes a metasearch capability, the Lessons Learned Information System, communities of practice formed along engineering disciplines, and a portal to integrate these components. Figure 1 illustrates the NASA Engineering Network.

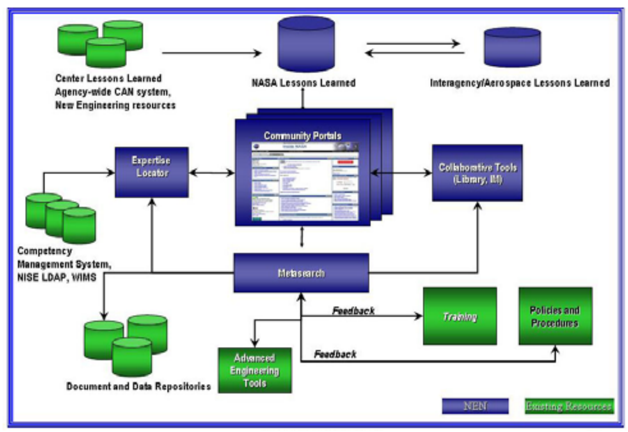

Figure 1: NASA Engineering Network

Following extensive benchmarking with organizations such as the U.S. Navy, U.S. Army Company Command, the U.S. Department of Commerce, and Boeing, it became clear that effective engineering communities of practice are aligned with the Office of the Chief Engineer. In addition, because the NASA Office of the Chief Engineer was responsible for overseeing the goals of sending astronauts to the moon and Mars as well as resolving issues that arose in the Columbia Accident Investigation Report, this office was most interested in implementing communities of practice.

NASA underwent a series of core competency exercises from the late 1990s through the present, looking at the areas of expertise that would be needed to operate existing NASA projects and build a new human capability to the moon and Mars. These competencies were initially instantiated into NASA's Competency Management System (an online system that maps individuals to their competencies). The Office of the Chief Engineer and NASA Engineering Safety Center (NESC) later identified a smaller list of

25 key engineering disciplines that are at the heart of NASA's work. This list comprises the communities in the NASA Engineering Network. At the core of the NESC is an established knowledge base of technical specialists pulled from the ten NASA Centers and from a group of partner organizations external to the Agency. This ready group of engineering experts is organized into 25 disciplines areas. Similar to Orr's study of photocopier repair technicians, where the "construction of their identity…occurs both in doing the work and in their stories" [12], engineers at NASA are accustomed to identifying themselves by their discipline. Engineering disciplines include: structures, systems engineering, environmental test, materials and processes, software engineering, and nondestructive evaluation.

These communities build upon existing virtual, programmatic, or traditional groups to the maximum extent possible to enhance already existing social networks and build others where necessary. Such online communities have as underpinnings innovative search capabilities to provide access to key information, discussion areas, and collaborative tools to allow engineers from all of NASA's partners and centers to seamlessly share ideas and work together. These communities are a natural fit for engineers, since it is in their nature "to share knowledge, to work jointly on finding solutions for complex problems." [11]

The NASA Engineering Network facilitates communities of practice through an online portal that contains contact lists, discussion boards, announcement portlets and blog and wiki capabilities. The system is built on Vignette software.

3.0 Method

3.1 Analysis approach

One gap in the literature has to do with how communities of practice change over time. [10] The research in this paper includes both qualitative and quantitative date, since in communities of practice it is critical to address both the human and data sides of the equation. [13] Reports reflecting qualitative community activity were submitted on a weekly basis to NASA Headquarters, and these were culled for major changes between January of 2007 when the community launched and August 1, 2008.

Quantitative data was culled for a one year time period between August 2007 and August 2008. This was done for two reasons. First, system metrics were not available until April 2007, and community activity, as seen in the weekly reports, began to grow in August 2007. Available metrics included page hits to the main community landing page, which is within the NASA Engineering Network's portal, and portlet hits to major pieces of content such as key documents and community announcements. In addition, wiki metrics were gathered via the wiki tool.

An analysis was conducted not just of how the community worked together beginning with the task of updating the handbook, but also how other features of the NASA Engineering Network enabled the handbook to be stored in DocuShare and distributed as part of the engineering search.

The community is open to all personnel, thereby providing a forum for experiences to be shared, leading to equally competent levels of systems engineers across all centers. However, for the most part during the research window, the community was used exclusively by the Systems Engineering Working Group. As noted in the discussion below, beginning at the end of the 2008 fiscal year, a push to the entire systems engineering community at NASA will begin.

3.2 Community Implementation

The systems engineering community followed the implementation model established for all communities of practice within the NASA Engineering Network. This process including selecting a community leader, building content, and rolling out the community.

Any sort of complex community requires a leader who will align interests and perspective and guide conversation. [14] An engineer's trust in the appointed leader is key to the success of the communities; as Nahapiet and Ghoshal wrote, "where relationships are high in trust, people are more willing to engage in…cooperative interaction." [15]. The leader's role is to align the community with strategic and operational goals, energize the community, and organize meetings and events. [16] The leader makes final decisions about how to communicate about the community as well as how individual portlets will be used. For example, some community leaders ban anonymous posting to discussion boards.

As described earlier in this paper, the engineering communities are led by Technical Fellows. Steve Kapurch is the fellow for systems engineering, but he delegated leadership in the first year to Ross Jones, a recognized leader at the Jet Propulsion Laboratory.

Once the community was identified and leadership was arranged, a facilitator on the NEN team was assigned to assist in building content and managing the community. This person is a member of the NEN team who has technical proficiency to provide expertise on layout and communication approaches. He or she also conducts behind-the-scenes maintenance on Vignette and any associated electronic libraries, wikis, or blogs. The facilitator works with the leader to integrate standards and key lessons learned within each community. the facilitator also trains new community members as needed.

Because the facilitator is a member of NEN, lessons learned from other facilitators are easily shared and new technology developed for one community can easily be implemented for another. This also creates consistency across the communities, so that users who are members of more than one community of practice will have a frame of reference when moving from one community to another.

Following the identification of discipline, leader, and facilitator, the initial stage in establishing a community includes identification and collection of key information for each community. In this case, the facilitator worked with the leader to build a DocuShare library and connected it to the community's main page.

All communities are implemented using Vignette Portal software, version 7.2. This tool was selected because it adhered to IT security policies within NASA and provided a range of tools useful to engineers, including discussion boards, calendars, resources links, and web connectors into DocuShare.

To enable seamless transition from any given community to NASA resources that require authentication, the NEN team added the ability to pass the encrypted username and password. This was particularly useful when working with secure login for DocuShare. It allowed a user to seamlessly transition with one click from a NEN community into the document repository.

5.0 Discussion

In the first few months, as the handbook was being developed, much of the focus in the community was on the DocuShare portlet, called "Key Documents." Meetings were held on a weekly basis with 30-plus working group members, the community leader, and the NEN facilitator, who trained users on the system and answered questions as needed.

In the first few months page hits to the community were relatively consistent, with on average less than 100 hits per month. As seen in Figure 2, page hits were high going into August as the community was working on the handbook. Those hits subsided until February 2008 when the handbook was released. In the first month following its release, 45 users downloaded the handbook. Since the release of the handbook, hits have averaged near 200 per month. Of all the other active engineering communities within NEN, systems engineering is consistently the most active.

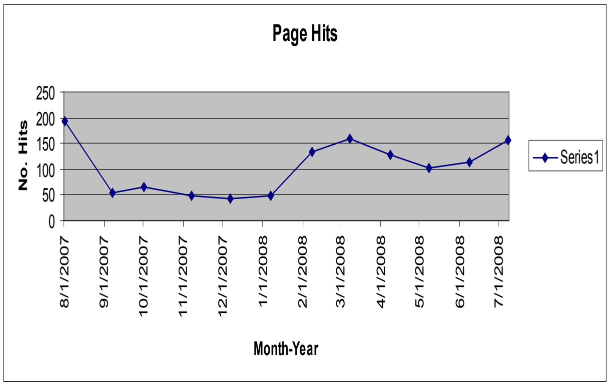

Figure 2: Page hits to the Systems Engineering Community landing page

In addition to weekly meetings, the community also had regular face-to-face meetings. The community had a face-to-face meeting at Kennedy Space Center in April, and page hit counts spiked before and after that meetings. Another meeting is planned for September, and it is expected another increase in activity will be seen in the metrics.

By far the most used portlet within the page was the Key Documents portlet, which reflected the DocuShare document repository collection. Figure 3 shows a screenshot of the key documents portlet.

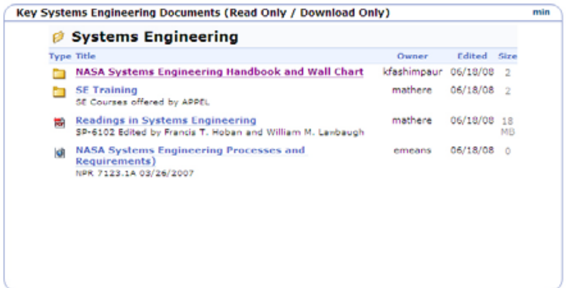

Figure 3: Key Documents

As seen in Figure 4, hits to the key documents portlet also increased from February through April as the team prepared for its face-to-face meeting. The library is often used before, during and after meetings to collect and share presentations and other files. In addition, users were accessing and downloading the handbook during that timeframe, and this activity may have accounted for the increase in activity. Hits dipped again following the face-to-face and leading into the summer months, a time when many employees take vacation and are less active.

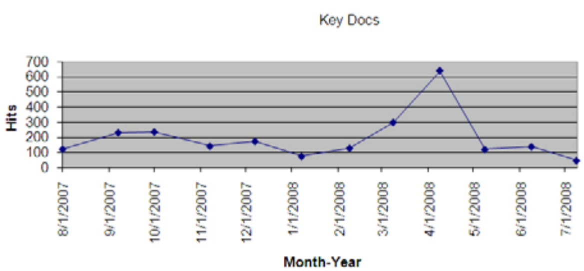

Figure 4: Hits to the Key Documents portlet

Other portlets were difficult to measure in terms of hits. For example, the announcement portlet, seen in Figure 5, consistently showed activity, but for the most part practitioners may be reading the content from the landing page and never clicking the portlet.

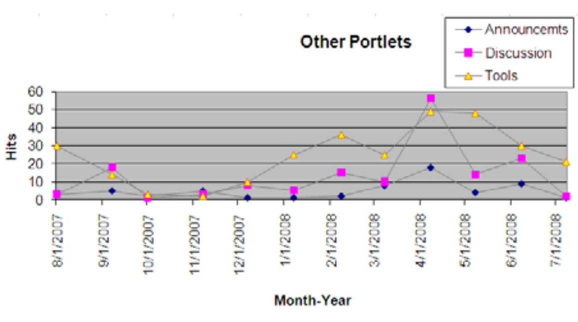

Figure 5: Announcement, Tools, Discussion Board Hits

See Figure 6 for a screenshot of the announcement portlet, which at the time of capture was promoting a forum on systems engineering held at Johnson Space Center.

Figure 6: Screenshot of the Announcement portlet

The tools page within the community provides a list of popular tools both inside and outside the agency that practitioners have found useful in their work. This sub-page also gets consistent hits each month, though nowhere near the hits seen by the Key Documents portlet. The discussion board also gets a handful of hits, but is not used for discussions. Its only content is a welcoming message to new participants. See Figure 5 for metrics on these portlets.

Most community of practice experts agree that one way to increase participation is to include as many content resources as possible. [17] In addition, because of the suite of resources available through the NASA Engineering Network, tools could be delivered with a short turnaround to community members. As practitioners used the community to build and deliver the handbook, they began requesting other features. While they liked the secure features of DocuShare, participants requested a simpler way of collaborating on less formal documents.

In October 2007, a systems engineering wiki was rolled out using an open source tool called TWiki. A link to the wiki was placed on the systems engineering home page. The wiki metrics match the page hits to the Systems Engineering community, and use is increasing as the community builds more content. Currently, a spike has been seen in wiki usage as the community restructures the wiki in preparation for a major revamping of the systems engineering community. See Figure 7.

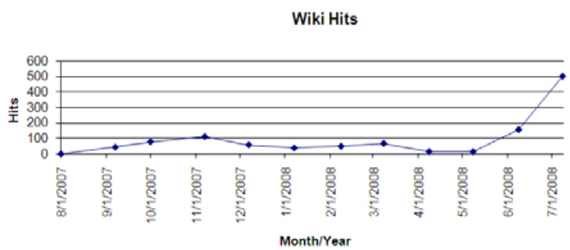

Figure 7: Systems Engineering Wiki Hits

The main Systems Engineering Working Group had sub-divided into smaller groups that would focus on training and deployment. These groups also requested pages where they could collaborate. Following Wenger's principle about having both public and private spaces for communities [3], these subgroups were given secured spaces so that they could have work in progress that would not be reviewed until ready.

One major factor in the success of this community was that it hired a part-time coordinator to oversee the content and ensure the working group interacted smoothly. Because the leader's time was in demand, he appointed a person who could dedicate a set amount of time during her week to be sure that the community moved forward. This content coordinator was able to oversee day-to-day operations and plan for outreach activities to increase participation in the community.

The other major success for this community was in the distribution of the handbook. Not only were 60 experts able to collaborate on the content, but once it was completed, they were able to store it using the DocuShare library and then make it available through the NASA Engineering Search. This ensures that the handbook can be retrieved either through a direct query or through search-related browsing. In addition, the engineering search has wider availability than NEN because it is also a part of InsideNASA, the employee portal for the agency.

6.0 Next steps

Now that the handbook is complete, the Systems Engineering Working Group is looking to expand membership and usage of the community. Community leaders, including Ross Jones, Steve Kapurch and the content coordinator have begun restructuring the community so that instead of focusing on tasks just for the working group it will become the central site for all content related to systems engineering at NASA. The team, including the community leader, NEN facilitator, and content developer are developing a framework by which users will be able to find online resources, policies, training, and interactive pages.

Once that rollout has occurred and membership is widened to include all system engineers across the agency, the authors will conduct surveys with participants to determine who they use the community and why. This survey will then inform how other communities of practice within NEN are cultivated.

The community continues to drive the need for new technology. Endeavors have focused on integrating existing NASA directives into the community's culture and improving communication mechanisms among practitioners. As new communities are established in NEN, they are able to take advantage of the best practices and technical innovations developed by the Systems Engineering Community of Practice.

Between the handbook release, and the new framework, systems engineering is now a strong discipline at all centers. The cohesion of all NASA field centers around this discipline will continue to grow as the new framework is released and publicized.

7.0 Acknowledgements

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