Exploiting Expertise and

Knowledge Sharing Online for the Benefit of NASA's

GN&C Community of Practice

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In 2004, NASA faced major knowledge sharing challenges due to geographically isolated field centers that inhibited engineers from sharing their experiences, expertise, ideas, and lessons learned. The necessity to collaborate on complex development projects and the reality of constrained project resources together drove the need for ensuring that personnel at all NASA centers had comparable skill sets and that engineers could find resources in a timely fashion. Mission failures and new directions for the Agency also demanded better collaborative tools for NASA's engineering workforce. In response to these needs, the online NASA Engineering Network (NEN) was formed by the NASA Office of the Chief Engineer to provide a multi-faceted system for overcoming geographic and cultural barriers. NEN integrates communities of practice with a cross-repository search and the Lessons Learned Information System. This paper describes the features of the GN&C engineering discipline CoP site which went live on NEN in May of 2008 as an online means of gathering input and guidance from practitioners. It allows GN&C discipline expertise captured at one field center to be shared in a collaborative way with the larger discipline CoP spread across the entire Agency. The site enables GN&C engineers to find the information they need quickly, to find solutions to questions from experienced engineers, and to connect with other practitioners regardless of geographic location, thus increasing the probability of project success.

Nomenclature

CoP	=	Community of Practice
GN&C	=	Guidance, Navigation, and Control
NASA	=	National Aeronautics and Space Administration
NEN	=	NASA Engineering Network
NESC	=	NASA Engineering and Safety Center
NRB	=	NESC Review Board
TDT	=	Technical Discipline Team

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I. Introduction

From 2003-2005 major changes were under way at the National Aeronautics and Space Administration (NASA). In 2003, following the loss of Space Shuttle Columbia, an accident investigation board found that NASA was not exhibiting the behaviors of a learning organization, and that while each center was capturing its own Lessons Learned, it was not sharing those lessons with other centers[1]. When NASA was founded in 1958, it inherited some of aeronautical research labs such as Langley Research Center and Ames Research Center that had previously been under its predecessor NACA. Over time, NASA took in Navy and Army research centers such as Marshall Space Flight Center and the Jet Propulsion Laboratory. Some of these centers had their own culture before NASA formed and brought that with them to the new Agency. In addition, the centers have different purposes. Some are research labs, some are robotic space flight centers, and some are human space flight centers. For the most part, until very recently, work was done within the center itself and collaboration across centers was less frequent. All of this has resulted in each center having its own unique culture, and little or no need to interact with other centers other than on the occasional project. Most knowledge stayed within the center and never rose to an Agency level. It was clear from the Columbia Accident Investigation report that this would have to change.

Figure 1. NASA Field Centers

In 2004 when President George W. Bush announced the Vision for Space Exploration, this included a mandate that the Shuttle Program be retired in 2010. The Agency shifted its focus to developing a replacement vehicle. The new vehicle would not just be a one-for-one replacement of Shuttle, which was a cargo spacecraft primarily developed to transport people and equipment to the International Space Station. It would be a new type of vehicle that would be able to go to the moon and eventually Mars. This effort would require unprecedented collaboration from almost all of the centers and that personnel from those centers have comparable skill sets. It quickly became clear that knowledge sharing would play a vital role in this collaboration and in ensuring that NASA could continue developing innovative technologies.

Technical innovation was not the only challenge facing NASA at this time. Its workforce was aging, and the gap between the incoming younger generation and the generation nearing retirement was growing. As with most organizations, there was concern about the loss of institutional memory, but of even greater concern was that there were not enough engineers in a broad range of career levels to meet the challenges of newer and more complex missions. In Fiscal Year 2010, the average age of NASA civil servants was 47. There were 3 times more people over-60 than under-30 at NASA in certain job classifications[2]. In engineering, the changing demographic is alarming. As shown in figure 2, which compares workforce age of engineers in FY 1993 with that existing at the start of FY 2010, the number of engineers under 35 has dropped precipitously. According to the U.S. Government Accounting Office, if the workforce continues aging, not enough engineers will have moved up the ranks in time to acquire the requisite skills to enable NASA to meet its vision for space exploration[3].

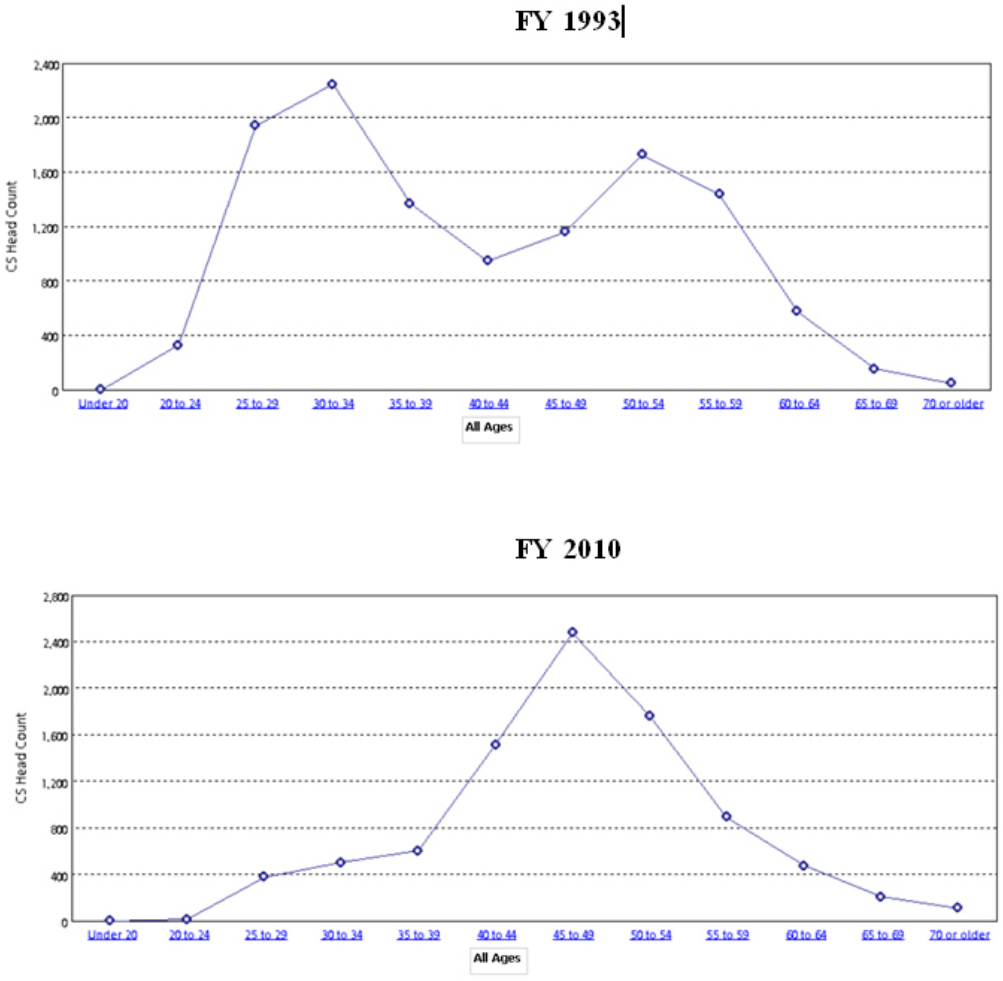

Figure 2. Average age of NASA engineering workforce[4]

If it was to meet its goals of developing a new generation of vehicle to support human spaceflight to the moon and Mars, the Agency had to engage and retain younger generations of workers and bridge the gaps between the different generations working today. Knowledge sharing among the generations is more critical than ever. While the traditional model for passing experience and ideas from one generation to the next is often done through mentoring or apprenticeships, this information is rarely recorded for future use[5]. In addition, the different generations of workers have distinct communication styles and expectations of their work environment. For example, while the older generations might feel most comfortable communicating in person or via telephone, younger generations tend to prefer instant messaging or interfacing through social networking tools[6].

In response to these needs, the NASA Chief Engineer established the NASA Engineering Network (NEN). NEN is 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. The search system is a single interface into 43 repositories from the various field centers and external sources such as the Department of Defense and Department of Energy.

II. Overview of NASA's Engineering Communities of Practice

On NEN, a community of practice (CoP) is a group 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."[7] Communities have existed throughout history, through organizations such as guilds and professional

societies, but until recently they were not formally and strategically established within the aerospace industry. 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[8]. 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[9]," exactly what NASA was seeking.

A note on terminology: A community of practice is a group of people with a shared interest who engage with each other to solve problems, learn, or innovate. The term is often used sinuously with technology that supports this interaction; on NEN that means online sites. For this paper, we have tried to clearly indicate when we are referring the GN&C community of practice site or the community of practitioners looking to improve NASA's capabilities and skill sets.

A. Communities on the NASA Engineering Network

When establishing communities on NEN, several things were clear from the beginning. First, the team would establish strategic communities built along NASA's engineering disciplines rather than having communities self-select. Strategic communities would allow the Agency to focus on improving in engineering disciplines central to its overall mission of space exploration. Following the method laid out by Hubert St. Onge and Debra Wallace in *Leveraging Communities of Practice for Strategic Advantage,* communities were aligned with NASA's core competencies[10]. Beginning in the 1990s, NASA had been conducting a set of core competency exercises to determine what the Agency would need to build a new human capability to travel the moon and Mars. When NEN was formed, NASA Office of the Chief Engineer (OCE) required that communities be aligned with the NASA Engineering and Safety Center's (NESC) Technical Fellow program. Disciplines include GN&C, Propulsion, Structures, Materials, Life Support, Avionics, etc.

Second, peer-to-peer relationships among engineers was key to fostering trust in the site, so that users would see it as a place to seek information and solve immediate problems[11]. The communities would require leaders who would provide content that was useful and current and be a champion to rally other practitioners to use the sites. To have this credibility and access to practitioners, they would have to be recognized leaders in their field. The NESC provided this leadership through their Technical Fellow program. See the next section for details on this program.

Third, the technology underpinning all of NEN would have to enable collaboration, discussion, and posting of content. Younger generations in particular expect to participate in an online environment with current and dynamic content, so it would be critical to create community sites that would encourage their participation while also ensuring older generations would also feel comfortable and welcome on the site. Formal vetted documents such as standards and requirements would be centrally shared along with informal discussions and networking. This allowed the sites to capture both tacit and implicit knowledge in one place.

Community sites on NEN have the additional benefit of being hosted within the system that houses the NASA Lessons Learned Information System and a search that queries multiple repositories both internal and external to the Agency. Search queries for key lessons can be established specific to community interests and ensure that search results always get the latest results. For example, on GN&C saved search queries include terms like "star tracker" and "gyroscopes" within the Lessons Learned system. When a user clicks the query, the system runs a search and retrieves a complete and up-to-date set of lessons.

The NASA Technical Fellows, together with their Technical Discipline Team members, serve as the champions for their CoP websites. They determine the structure and technical content of the website and are available to collaborate, answer questions and be involved in online discussions. Efforts are underway to more broadly inform the NASA engineering workforce about these new online CoP resources and to encourage community participation at all levels of engineering experience. The Technical Fellows also strongly encourage all members of each community to contribute their individual knowledge, lessons learned and other discipline expertise to the CoP websites. Feedback on the structure, content, features and capabilities of each CoP website is welcomed and should be directed to the appropriate NASA Technical Fellow.

Communities of practice have several stages of development. When creating a new community site, the NEN team meet initially with the Technical Fellow and his or her team. The NEN team member, called a facilitator, provides direction and best practices on how to establish a site, works with the technology to create and manage the online interface, and helps train users as needed. Most communities have started by collecting content. This content includes standards, NASA Policy Requirements, conference information, papers and publications relevant to the discipline, and images and videos. In the early stages of the community, the facilitator and Technical Fellow have very active roles and are engaged in collecting content and maintaining the site. As time goes on, and practitioners

begin to use the site more, the content will come from the members more and more. Figure 3 shows the stages of community development.

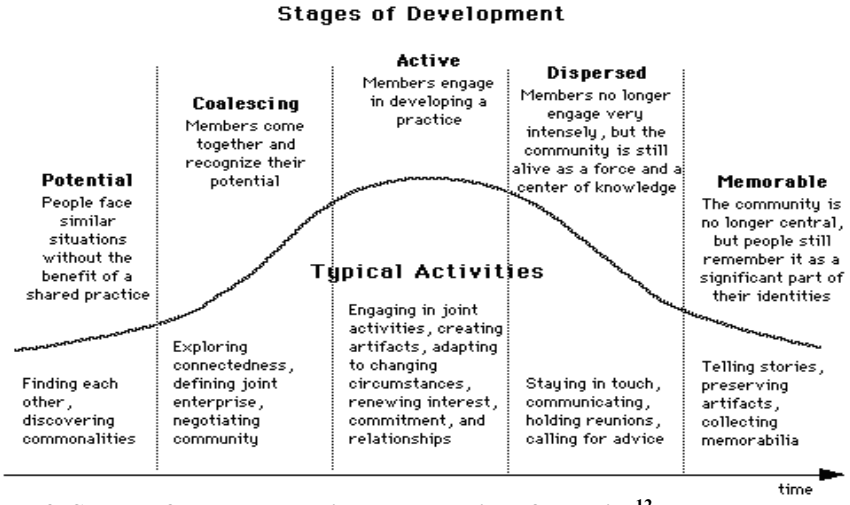

Figure 3. Stages of development in a community of practice[12]

As of May 2010, thirteen engineering communities were live with five being planned and developed. GN&C was one of the first communities that rolled out, along with Structures, Nondestructive Evaluation, and some special communities specifically approved by the NASA Chief Engineer. These special communities were for the Systems Engineering Working Group and the Software Working Group. Some management specific disciplines were also live, including one for Program/Project Management and one for Knowledge Management. Currently most of the live communities are still in the coalescing phase. In FY2011, the NEN team will focus on helping move the communities toward a more active state. The CoP websites can be visited and seen by all personnel with NASA Intranet access at the following location: *http://nen.nasa.gov.*

B. NESC and the Role of NASA Technical Fellows

On July 15, 2003, Administrator Sean O'Keefe announced plans to create the NASA Engineering and Safety Center (NESC) at Langley Research Center with the purpose of providing a central location to coordinate and conduct robust, independent engineering and safety assessments across the Agency.

One of the tenets of an effective safety philosophy is to provide an avenue for independent assessment of the technical aspects and risks of critical systems. NESC offers this alternate reporting path for all NASA programs and projects. Rather than relieving NASA program managers from their responsibility for safety, the NESC complements the programs by providing an independent technical review with adequate technical expertise and funding. The vision that NESC has for itself is to serve as the independent and objective deep technical resource of choice for NASA Programs and other government agencies. As its fundamental mission the NESC strives to set the example for engineering and technical excellence within NASA. Its primary purpose is to increase safety through engineering excellence. A resource for all the Agency, the NESC is a unique and valuable asset for the high-risk programs that NASA undertakes.

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 15 discipline areas called Technical Discipline Teams (TDTs). TDT members are drawn from NASA, industry, academia, and other government agencies. By drawing on the minds of leading engineers from across the country, the NESC consistently solves technical problems, deepens its knowledge base, strengthens its technical capabilities, and broadens its perspectives, thereby further executing its commitment to engineering excellence.

The organizational structure of the NESC is predicated on maintaining a diverse and broad base of knowledge, keeping informed and engaged with each center and the Agency's major programs, responding efficiently to requests for assistance, and retaining a high degree of independence. There are some 60+ full-time NESC-badged employees, many of whom are located at NASA's Langley Research Center in Hampton, Virginia. Others are affiliated with Langley but may reside at another center. The Technical Fellow for GN&C, for example, is affiliated with Langley but resides at Goddard Space Flight Center. Over 700 other engineers nationwide are employed part-time by NESC as members of the 15 TDTs. This distributed organizational model purposefully positions the

technical experts at their centers where the problems are so that they stay engaged and technically sharp. More than 200 NASA-external TDT members are drawn from industry, academia, and other government agencies.

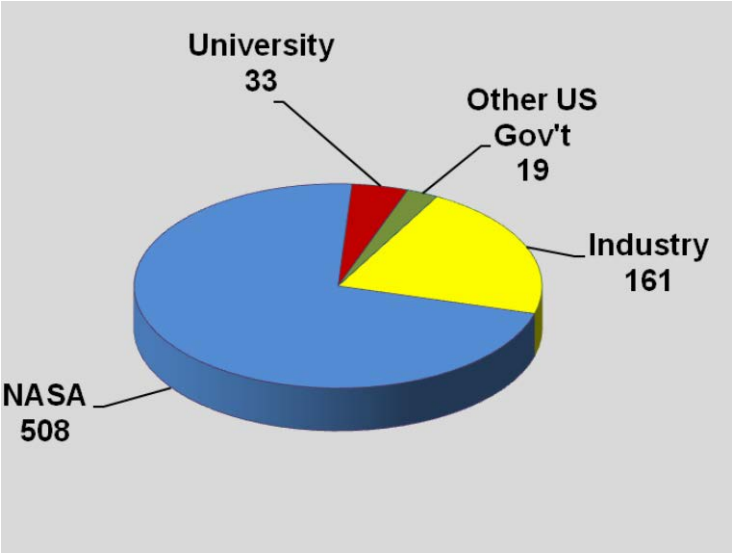

Figure 4. Over 700 top caliber engineers support the NESC nationwide.

NASA Technical Fellows assemble, maintain and provide leadership for the TDTs and are stewards for their disciplines. The Technical Fellows serve as the senior technical experts for the Agency in support of the Office of the Chief Engineer and the NESC. They are an independent resource to the Agency and industry to resolve complex issues in their respective discipline areas.

The NASA Technical Fellow cadre is modeled after the technical fellows typically found in the aerospace industry. Several large, widely distributed, research and development-intensive corporations formally appoint a small number of their senior engineers and scientists to be Fellows in specified technical areas or discipline-specific roles. In most of these organizations, the title of "Fellow" is the most senior rank an employee can achieve on a technical career path or "ladder" as it is often referred to. Specifically, the Technical Fellows are responsible for: 1) fostering consistency of Agency-level standards and specifications, 2) promoting discipline stewardship through workshops, conferences and discipline advancing activities, and 3) ensuring that Lessons Learned are identified and incorporated into Agency processes.

The 12 original NASA Technical Fellows were appointed after successfully completing a rigorous selection process. The specific engineering disciplines these Technical Fellows represented were deemed to be those most relevant to ensuring NASA's successful Return to Flight on July 26, 2005 with the launch of the Space Shuttle Discovery (STS-114) ending a two-and-a-half year wait for the historic return to flight after the Columbia accident. One additional Technical Fellow was added in 2008 (Flight Mechanics, split from original Flight Sciences discipline) and then two more Technical Fellows were added in 2009. These were for the disciplines of Electrical Power (split from original NESC Power and Avionics discipline) and Passive Thermal Control/Thermal Protection (split from the original NESC Life Support/Fluids/Thermal discipline). Traffic analysis of the problems and issues coming to NESC were used to determine the need to offer new Technical Fellows from existing disciplines in order to more evenly balance the workload.

C. The GNC& TDT

The GN&C Technical Discipline Team (TDT) is a technical resource that supports the NESC and the independent assessment teams approved by the NESC Review Board (NRB). The primary purpose of the GN&C TDT is to engage in the resolution of GN&C related issues throughout the Agency when directed by the NRB or by NESC senior leadership. A secondary purpose of the TDT is to proactively identify Agency-wide GN&C engineering discipline issues and problems.

The GN&C TDT is assembled, maintained and managed by the NASA Technical Fellow for Guidance, Navigation & Control. The resources (subject matter experts, tools, and test facilities) required to support the assessment teams and other GN&C-specific NESC activities come from the TDT. The TDT is cognizant of all GN&C related assessments to ensure adequate and timely expertise support. This is accomplished via bi-weekly teleconference meetings and also with annual face-to-face meetings. These and other communication mechanisms (e.g., a NESC-internal secure website to post team news and other information) are used to unite the TDT members located across NASA.

The GN&C TDT consists of individuals who are experts in a wide range of sub-disciplines including GN&C systems, GN&C analysis, GN&C components and hardware systems (sensors, actuators, interfacing hardware systems), GN&C software, flight dynamics, mission design, flight operations, launch vehicle flight mechanics

analyses, and launch vehicle guidance systems. As mentioned above, this team of experts collectively serves as a discipline "think tank" to identify potential GN&C issues and problems to address proactively by the NESC.

Given the wide breadth and depth required to adequately staff the TDT as well as to support multiple assessments simultaneously, a staffing model has been developed to recruit and staff the team. This staffing model requires skill sets representing discipline systems experts, sub-discipline specific experts, and technical team support personnel. The GN&C TDT consists of a "core" group of approximately 20-30 discipline systems experts. It also consists of an extended team of about 5-6 specific experts from each of the sub-discipline areas of expertise that encompass the broad scope of the GN&C discipline at NASA. These sub-discipline experts are on call-up to the NASA Technical Fellow and to the core team. Approximately 100 GN&C experts, the majority of them being NASA Civil Servant employees from across the Agency, currently comprise the entire NESC GN&C TDT. When the operational function of the GN&C discipline TDT is constrained by limited Agency in-house staffing resources, additional discipline expertise from outside the NASA community (e.g., industry and academia) are exploited to augment the TDT membership.

The members of the "core" group are senior level individuals from across the Agency that have broad but expert knowledge. These senior experts have in-depth knowledge of one, or several, GN&C expertise areas, but probably not all the GN&C areas of expertise. The individuals who make up the TDT's "core" group possess exemplary leadership and teamwork skills since they both represent their center's GN&C engineering organization and also serve as the GN&C leadership interface to the NESC's assessment teams.

The sub-discipline specific experts are individuals that have in-depth experience and expertise in a specific GN&C area. These specific areas are defined by the TDT core group. For example, on the GN&C TDT, there will be sub-discipline experts in the following areas: inertial sensors, GPS navigation, spacecraft attitude determination and control, stellar/celestial sensors, formation flying, flight dynamics, aeronautical vehicle flight control, inter-planetary navigation, flight mechanics, reaction wheels, control moment gyros, controls structures interaction, mission design, launch vehicle guidance and control, etc.

The technical support group is the third and last major component of the GN&C TDT. The technical support group is a small (about 3-5 people) contingent of individuals that support the NASA Technical Fellow for GN&C in the day-to-day management and operation of the TDT. These are typically GN&C engineers with perhaps 5-8 years of professional work experience. They contribute routine administrative and technical support (e.g., recording teleconference meeting minutes, providing logistics for the annual face-to-face meeting, updating the TDT's internal website, etc.) while at the same time benefiting from the mentoring experience of working with the other TDT members. The technical support group, by virtue of their role on the TDT, has exposure to a wide range of GN&C problems from across NASA as well as the opportunity to witness firsthand the problem solving skills of some the Agency's senior GN&C engineers. This has turned out to be a win-win situation that benefits the operation of the TDT and the technical support group personnel.

Since the TDTs started working, some observations have been made regarding steps toward breaking down geographic barriers and encouraging knowledge sharing. TDT members find that working within the NESC organizational structure permits an exposure to other NASA programs, projects, cultures, methods, and business practices from across the Agency. Typically this allows experiences to be gained outside one's normal work area within a single NASA center organization. The experience broadens one's horizons. Exposure to engineers from other centers helps shift preset expectations of the abilities or attitudes of other center personnel; work on the TDT has built respect and a more open environment for interaction and collaboration in the future.

III. Establishing the Guidance, Navigation & Control Community of Practice

In the course of doing their day-to-day work the Technical Fellows have come to an increased realization of the serious impact that lost engineering knowledge (and engineering lessons not being learned) has on maintaining NASA's engineering capabilities. Clearly lost GN&C knowledge can also saddle missions with the undesirable impact of unnecessary costs and risks. A recent paper on NASA's lost lessons learned[13] discusses the need to recover 'lost" GN&C knowledge and lessons learned and provides examples of this. In the view of the Technical Fellows the engineering CoPs are part of a multi-faceted solution to avert accidents, mishaps and failures; to generally improve engineering quality; to improve efficiencies in allocation of scarce resources; and to improve the rate of project success, all occurring with the attendant, but less tangible, benefits of improved morale and confidence within the NASA engineering workforce.

One of the most critical Agency-level needs that all the Technical Fellows feel strongly about is the requirement to ensure technical continuity across generations in their respective engineering disciplines. At NASA, as in other technology-driven 'learning' organizations, there is a critical need to focus on capturing and transferring knowledge

from personnel who work on complex systems made up of sophisticated hardware and software. As NASA transfers its hardware and software systems from one generation of engineers to the next, we need to ensure the current workforce also passes along their knowledge to their successors and leave detailed documentation for future personnel. Obviously this situation is exacerbated by the current engineering workforce demographics as was discussed in Section I above. The current initiative to create online engineering communities of practice within the Agency is seen by the Technical Fellows as a positive step to facilitate knowledge transfer between senior experienced NASA engineers and those engineers that have only recently entered the NASA engineering workforce.

A. Goals in Creating the NASA GN&C Community of Practice

The fundamental objective of the CoP site is to provide an online environment that connects NASA's engineers to both the experts within their particular discipline and to the collective body of discipline expertise. Through these online communities, engineers from all the NASA centers can ask experts questions, collaborate on solutions to common problems, find standards and references related to their engineering discipline, take part in online discussions, and find contacts at each center. The CoP websites enable engineers to find the information they need quickly, to find solutions to questions from experienced engineers, and to connect with other practitioners regardless of their geographic location within the Agency. The expectation is that these CoP websites can help solve NASA's twin problems 1) lost engineering knowledge as many of its most experienced engineers retire from the workforce and 2) the syndrome where its costly real-world engineering lessons are most often merely catalogued and not truly "learned" by the next generation of NASA engineers. In this spirit NASA management also anticipates that the use of CoP websites will contribute to improvements in engineering quality, efficiencies and rates of success as well as reductions in mistakes, rework, anomalies, accidents, and mishaps. Lastly, it is quite possible that the morale of NASA's engineers will increase by virtue of their being able to clearly identify with, easily collaborate with, and professionally benefit from their counterparts across NASA in their chosen discipline.

IV. Results

The GN&C community went live in May 2008, the fifth engineering community on NEN (after Structures, NDE, Systems Engineering, and the Software Working Group). The site was developed by the GN&C Technical Fellow, his deputy, two members of the community, and two facilitators from the NEN team over the course of approximately two months. The team developed links to conference information; links to content of interest; a document repository to house papers, mishap reports, and other documents; and a "reading room" where members of the team listed books they would recommend to GN&C practitioners. Eventually this reading room capability would be mimicked by other communities and become a popular feature.

The Technical Fellow, deputy Technical Fellow, and NEN facilitator met regularly after the site was live to continue updating content. We created an "In the News" section on the home page to share GN&C related current events. Several months after the site went live, a Find an Expert page was added which listed the core TDT members with a picture, brief biography, and contact information. This took longer than expected to develop due to reluctance by some engineers to provide a photograph. The picture was considered important by the site development team because it created a more personable and approachable feel that text alone could not have done. Once this page was live, some community members commented that Find an Expert page was not all-inclusive; that there were many more experts around the Agency than were listed. As a result, the page was relabeled "Core Discipline Team."

A. Metrics

Metrics are captured as page hit and reported to community leads on a monthly basis. Each click by a user is a hit, so if one user goes to the home page then clicks two sub-pages, that will be counted as three hits. Since the community rolled out, the metrics have had ups and downs but have not shown dramatic growth in site usage overall. The largest spike was in July and August of 2009, when Harlan, Brown & Company conducted a survey amongst GN&C practitioners. Users were asked to look at the community and provide feedback. Growth in usage began again in February of 2010 following a presentation given at NASA's Project Management Challenge event, and continued through April 2010, when a video page was added to the site and an email list was created to begin notifying users about changes. In FY 2011, metrics overall will be reevaluated to determine if page hits is the right measure of community activity or if there are better and more informative metrics.

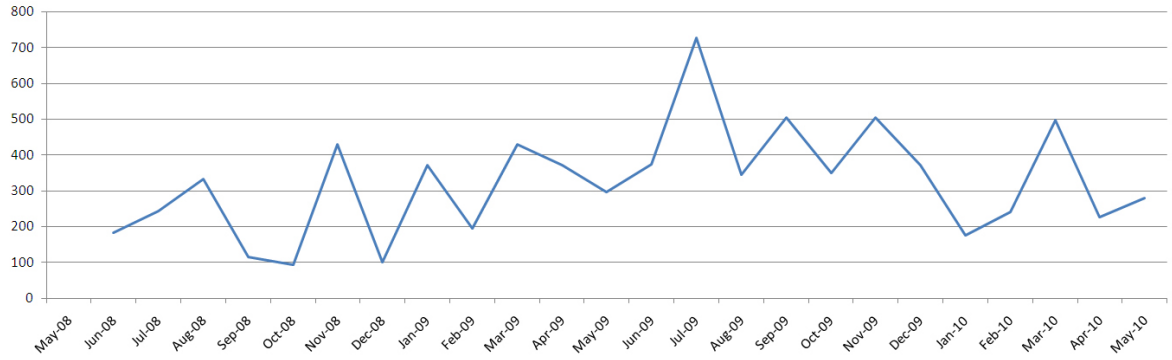

Figure 5. GN&C monthly page hits, May 2008-May 2010.

B. Survey Results

In July and August of 2009 Harlan, Brown & Company (Brown) was brought in the GN&C Technical Fellow through the NESC to conduct a survey of the GN&C discipline. The purpose of the survey was to gather unbiased opinions by practitioners outside the TDT on the discipline on recent trends, technical challenges, and other issues. Brown had conducted this survey once before, in 2007, but at that point the CoP site was not up. When they returned in 2009, Brown added a few questions about the community of practice site. Of those surveyed 64% were not aware of the site until the survey, and 85% had never used the site before. Clearly the Technical Fellow, TDT, and NEN team would have to undertake a communication campaign to raise awareness that the site was available.

Practitioners were asked to look at the site, indicate what its best features were, what should be improved, and how to draw people to the site. Once they looked at the site, 73% felt that it was a good start. Respondents particularly liked the document library and the information on conferences and workshops. See Figure 6 for responses on best features.

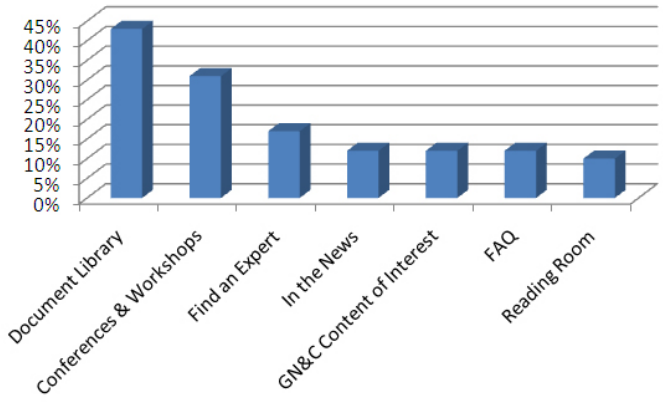

Figure 6. Survey Response: Best features of the site[14]

Respondents also indicated they thought the site was too focused on Goddard Space Flight Center, and should be broadened to include information on other centers (77% of respondents stated this). They noted that almost no information was found on the site about Johnson Space Center, the Jet Propulsion Laboratory, Langley Research Center, and Marshall Space Flight Center. They suggested that each center could contribute a highlight story, and a different story could be featured every month. Several users (36% of respondents) thought the site should be made available to the non-NASA community. Currently the site is only open to personnel behind the NASA firewall, to encourage open participation.

When asked how to draw people to the site, a large majority of respondents thought it was critical to keep the content fresh and be sure it was valuable information so that practitioners would want to spread the word amongst each other. They also suggested that emails and marketing materials be distributed to targeted groups. A breakdown of suggestions is captured in Figure 7.

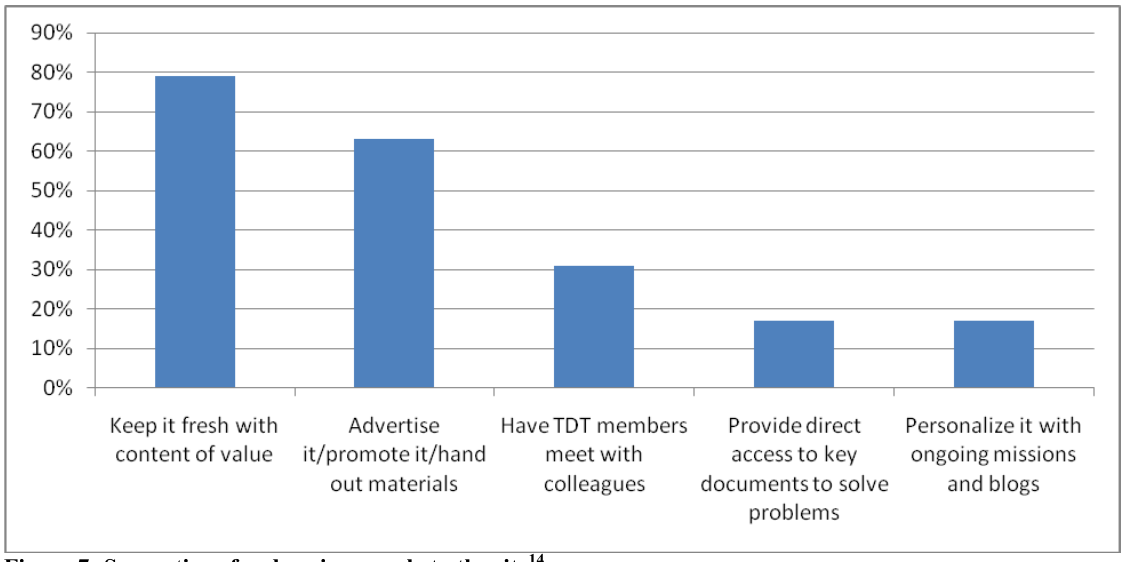

Figure 7: Suggestions for drawing people to the site[14]

When asked about the website, some liked its look but others felt that it was too much information. Originally the site was laid out so that most of the content was on the home page. The intention was to make everything available quickly and easily, but the result was a page that was so cluttered with content that nothing stood out.

Specific comments on the site included people expressing concerns about how to overcome distinct cultures at each center, suggesting that centers get more involved in contributing content about missions they're involved in, and with mixed reviews on NASA's current ability to collaborate.[14]

C. Changes Based on User Feedback

In addition the Brown survey, the NEN team conducted informal surveys with college students doing internships at JPL and student summer hires to get their input. Most commented on the welcome area of the home page for GN&C and other community sites, which included the official NASA picture of the Technical Fellow. The students thought, based on the formal picture with the Technical Fellow in a suit and tie and an American flag behind them, that the site was intimidating, too formal, and not one where they would likely seek to get input or exchange ideas. As a result, the NEN team decided to encourage Technical Fellows and other community leads to change the formal picture for a more casual one, preferably one where the practitioner is smiling. This change in photograph on GN&C can be seen in Figure 8 and 9 below.

When the Brown survey was completed, the GN&C and NEN teams met to review comments and determine if any changes could be made immediately. They reviewed the content and set up a GN&C @ NASA page to give a forum for centers to exchange information about the latest projects or undertakings that might be of interest to other practitioners. Each center's section includes a link to relevant center-specific websites and/or information about what that center was working on. The GN&C Technical Fellow and NEN Facilitator met with division and section management at Johnson Space Center to solicit input and encourage their participation in the community site. Other center visits are planned as well. To date center participation is still low.

Based on surveys and other input, the NEN team also changed the layout of communities. The previous layout philosophy had been to put as much information on the home page as possible so users could scroll through it and see everything at a glance. This clearly became unwieldy and instead of helping users find information it overwhelmed them. Instead of putting all the content on the home page, each major category of content was collected on separate pages so that the home page could have welcoming information, a news area, and clear and simple navigation that would allow users to get to the content they sought quickly. The first change was to move content off the home page and instead create navigation using icons that would allow users to quickly assess the kind of content available on the site. A new page was added to highlight work going on at each center. See Figures 8 and 9 for a before and after screenshot.

Figure 8. GN&C site before the survey

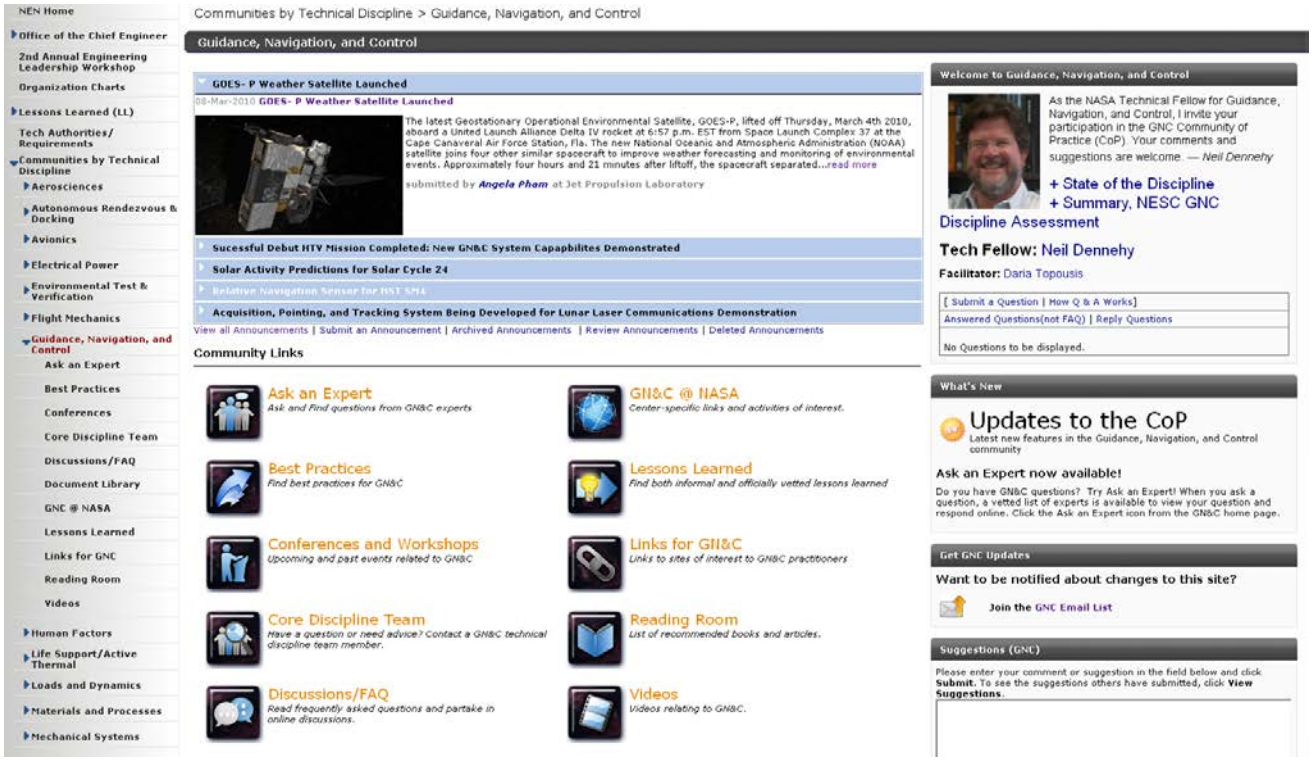

Figure 9. GN&C site after the survey

D. Knowledge Sharing

Peer-to-peer knowledge sharing began happening in late August of 2009, when an early career engineer from Wallops Flight Facility asked a question on the discussion forum about stability analysis for a highly nonlinear thruster-based attitude control system. One member of the Technical Discipline Team provided a response, and another collected responses from experts he knew at his center. Without the community site, the engineer might have asked someone at his center about this question, and might have received a perfectly good answer, but that knowledge would have stayed between the engineer and the expert he asked. Instead, he received three responses to his question, and all that information is captured on the website for others to see and benefit from.

A rotating spotlight on mishap reports and lessons learned was added as well. Engineers post information on a mishap report or lesson learned and comment on its relevance to current NASA work. This is a way to capture both implicit and tacit knowledge and record it as well. Two recent items that were highlighted in this area included an X-43A mishap report with findings and images and a clear and succinct writeup, and a pitot-static system failure with a brief write-up and video. By including this area on the site, the knowledge is captured and disseminated, which hopefully stimulates interest in it and reminds people of the lessons learned.

One other feature was added to highlight interesting news items relevant to the discipline. This appears on the home page as the top-left item, so it has a place that is highly visible to engage users. Because this content changes regularly, practitioners who visit the site get a sense that there is fresh and current content. Topics for this In the News feature have included solar activity cycle predictions for Solar Cycle 24, relative navigation sensors on Hubble Space Telescope Servicing Mission 4, and the successful firing of an attitude control motor. These news features often include pictures and elaboration on the event as it related to GN&C. The purpose of this feature is not just to share news items, but to raise awareness across the Agency about the latest happenings related to guidance, navigation & control and to give practitioners a broader view into the discipline and how it's used in projects they might not be familiar with.

E. Challenges

While the community site has had an auspicious start, there have been challenges as well. Spreading the word to practitioners that the site is available has been slow, and it has been difficult to engage center management in providing content to share. Most practitioners are so busy with their day-to-day work that finding time to contribute a small news items or write-up about the project they're working on. The NEN team is working on strategies for raising awareness about communities of practice and encouraging users to see that spending time contributing knowledge is value-added for NASA.

Activity on the discussion forums has been minimal as well. In part this may be due to the antiquated discussion board on NEN. It is cumbersome to create a thread, and users must have a login to post content. The login is unique to NEN and users often forget their username or password, and by the time it's reset they've moved on to another task and have lost interest in contributing to discussions.

Some of these problems may be the result of technological infrastructure. The NEN system is currently on a portal system called Vignette. While it provided excellent ability to build out the site, it has limited Web 2.0 capability that would allow practitioners to participate more. If Web 1.0 was pushing content out on website in a one-way direction, Web 2.0 includes the capability for users to post their own content easily for others to comment on this (think of blogs, social networking sites, etc.) For example, the discussion board is outdated and difficult to use, there is no wiki capability, and users must rely on the NEN team to upload any kind of content outside the discussion board. To fix these problems and build a more modern site, the NEN team is replacing Vignette with a more robust and flexible system that meets the growing requirements of the communities. In August 2010, the Vignette system will be replaced by this new system, called Liferay.

Some challenges have been more difficult to overcome. Industry and academic partners, who in some cases are part of the NESC Technical Discipline Teams, have limited access to the communities through a read-only extranet site. This impedes those users from sharing their knowledge and answering practitioner questions. In addition, the extranet is simply a mirror of actual content, and it has to be manually updated every time a change is made on the regular internal site. Because the Office of the Chief Engineer set the requirement that NEN be internal to the Agency, a request will have to be made to them to review this, and determine if it is appropriate to change. There is some concern that if the sites are opened, NASA personnel will feel less willing to share information.

Overall, the community of practice is not self-sustaining, but is still in the coalescing phase of development. A handful of people contribute content on a regular basis, and must intentionally set time aside to do so. This is part of a larger cultural change that is just starting at the Agency; to see knowledge sharing and capture as a critical part of our work.

F. Next Steps

In the coming months, more changes are planned for the community site. In May, a new feature called Ask an Expert was rolled out. This system aligns vetted experts with a workflow such that when a practitioner has a question, an email is sent to experts in preselected categories (e.g., estimation and filtering, modeling and simulation, launch vehicle GN&C). The experts respond online and their answers are stored and made available to all users across the Agency. This tool was developed to provide a bridge between the different generations of workers and the different skill sets so that engineers have a means of getting quick and useful information in a timely manner. As Ask an Expert is used more and more, we will have a searchable compendium of GN&C knowledge. Over the coming months, we expect to add more experts to the list and to conduct an advertising campaign so users know the system is available and awaiting their questions.

The team is asking seasoned engineers to tell us what advice they would give to a young engineer just starting to work in the discipline. Once this is collected from a handful of people, it will be made available on the site. Other engineers will be able to add their own advice online.

When the system underlying NEN is replaced by Liferay, this will provide better forums, wiki capability, and the ability for end-users to upload content and comments on the site. Users will be able to suggest books for the reading room. Centers could be given their own blog capability and assign someone to regularly update the news from that center. Users will also be able to rate content, and over time this might shape how the site develops.

Clearly the biggest obstacle that must be overcome is lack of awareness that the site exists at all. Over the coming months, plans are under way to communicate about the site, particularly at those centers with a strong GN&C presence. The goal of this communication activity is to encourage users to visit the site, but also to engage more experts and center personnel in providing information so that the site stays relevant to work being done.

VI. Conclusion

In conclusion, the NASA Engineering Network and its communities of practice, including that for Guidance, Navigation & Control, have been making slow but steady progress in establishing and strengthening engineering communication and knowledge sharing. This is one of several efforts that is helping mitigate the challenges NASA faced beginning in 2003 due to geographically isolated field centers, an aging workforce, resource constraints, and a new direction for the Agency. The community has attempted to build an online site for practitioners to find relevant information and share their own knowledge. It is still in its early stages, but over time as it grows from the coalescing phase into an active community managed largely by practitioners themselves, it is expected to became a great asset to the Agency and to GN&C engineers.

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