JPL Strategic Plan for Knowledge Management

"To make good use of what JPL knows"

David Oberhettinger, (Acting) Chief Knowledge Officer (CKO)

Office of the Chief Engineer

NASA/Caltech Jet Propulsion Laboratory

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Need Statement

In March 2013, the NASA civil service workforce approaching retirement—those 50 years of age or older— outnumbered NASA employees under age 35 by more than three to one (50% vs. 15%).[1] (For NASA personnel in the Science & Engineering occupational categories, the age disparity is even greater.) Twenty years ago, the over-50 and under-35 percentages were equal. Twenty percent of the NASA workforce is expected to retire during FY13 through FY18. This attrition of the most experienced personnel presents a serious knowledge retention challenge for NASA. For JPL, replacing this intellectual capital is particularly difficult because nowhere outside JPL and its contractors does there exist an equivalent hub of expertise in deep space system development and operation from which to draw experienced staff. Other JPL knowledge may be lost, not due to personnel turnover, but due to project turnover when no concerted effort is make to retain and share knowledge critical to the success of future projects. Knowledge is often treated as if it was acquired at no cost, and as if corporate survival does not depend on it.

The NASA Office of the Chief Engineer has announced a knowledge management (KM) initiative in which the NASA Centers are required to plan and implement KM programs. *Knowledge management* is an established discipline, featuring both practitioners and academics, that focuses on knowledge as a strategic asset that must be managed to ensure that it is retained and shared within the organization. Knowledge transfer is a commonplace practice that is only one element of KM: the KM discipline provides a disciplined approach to consciously evaluating and managing the process of organizational learning. NASA has directed each NASA Center to appoint a KM point-of-contact with the HQ program. NASA is presently drafting an Agency-wide KM policy, and KM program requirements will follow. Hence, JPL needs to plan to conform with the NASA initiative, and perhaps to excel in a manner that preserves and leverages JPL intellectual capital.

This plan proposes a strategy to manage and maximize JPL's intangible assets for the benefit of the Lab, its flight projects, and our NASA stakeholder. The JPL KM plan is aligned with JPL's and NASA's overall strategy and objectives. Specific JPL knowledge retention/sharing problems that this plan addresses includes:

- Attrition of key personnel, and of their knowledge.
- Poor accessibility to critical knowledge, including technical data acquired by projects.
- Repetition of technical errors (i.e., lessons that JPL failed to learn).
- Inability to repeat successes (e.g., design of the MSL throttled engine required making inquiries to Viking project staff who had long since retired).
- Ineffective training and retraining.
- Project and institutional work that must be repeated because no one was held responsible for preserving the results.

These problems are not intractable, but rather are attributable to an inadequate priority placed on the management of intangible assets within the JPL culture. An example of a practice where personal knowledge is shared quite effectively is the publication of technical papers; enterprise-wide knowledge over decades is captured and easily accessed by JPL in its Problem Reporting System. Because JPL's primary business is engineering design and development, management of

[1] See Appendix A

knowledge within engineering and related fields (e.g., procurement, project costing) should be given precedence.

> *"At NASA, a relatively small number of people devote their time explicitly to knowledge work—in APPEL, for instance, through knowledge programs at the Jet Propulsion Laboratory and Goddard, and in recent Exploration Systems Mission Directorate efforts to link knowledge sharing to risk management. As in many organizations, though, there is more knowledge work to be done than there are people to do it, and the Agency may need to do more to preserve and share its project knowledge."*[2]

Objective

JPL will establish a process (Figure 1) for preserving and leveraging intellectual capital for future missions. An Office of the Chief Knowledge Officer (OCKO) will manage a program to identify, capture, and distribute key JPL knowledge/ know-how/expertise/intellectual capital for leverage, reuse, and transfer across the Lab and NASA. The KM program will:

- Attain JPL-wide understanding of our KM challenges and potential benefits, and employee buy-in for investing labor and other resources in managing critical knowledge.
- Provide a clear plan that defines the JPL KM needs and the steps necessary to meet objectives.
- Coordinate with the Agency-wide KM initiative led by the NASA Chief Knowledge Officer (CKO).
- Obtain the support of JPL senior management, including resources needed for KM program implementation.
- Baseline KM best practices, improve them, and communicate them across the Lab.
- Furnish metrics or key performance indicators against which progress can be measured.

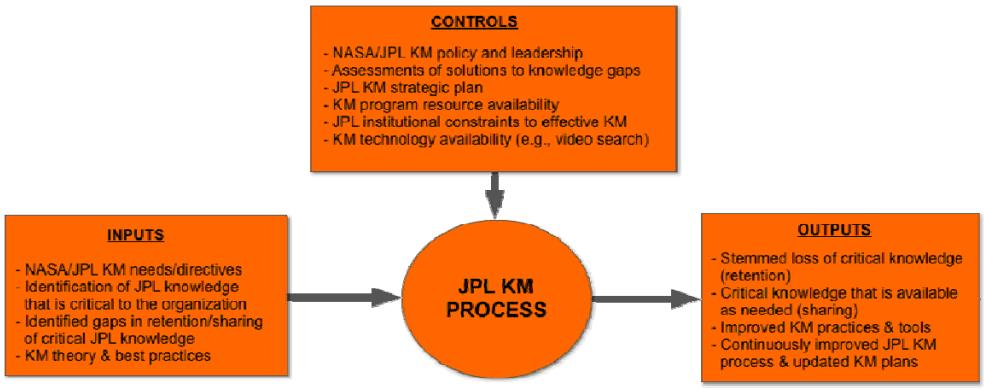


Figure 1. The JPL knowledge management process

[2] Laurence Prusak and Don Cohen, "NASA and the Future of Knowledge," ASK Magazine, Vol. 32, Fall 2008, p. 47.

Vision

JPL will "*make good use of what JPL knows*."

Responsibilities

Responsibility for implementing the KM program will reside within the JPL engineering organization to ensure that the program is engineering knowledge-driven, rather than focused on the development of tools. Overall responsibility for implementing the KM program will be placed on a JPL CKO within the JPL Office of the Chief Engineer. Primary responsibility for retaining and sharing critical knowledge within their purview will be retained by individuals and managers within the project and line organizations.

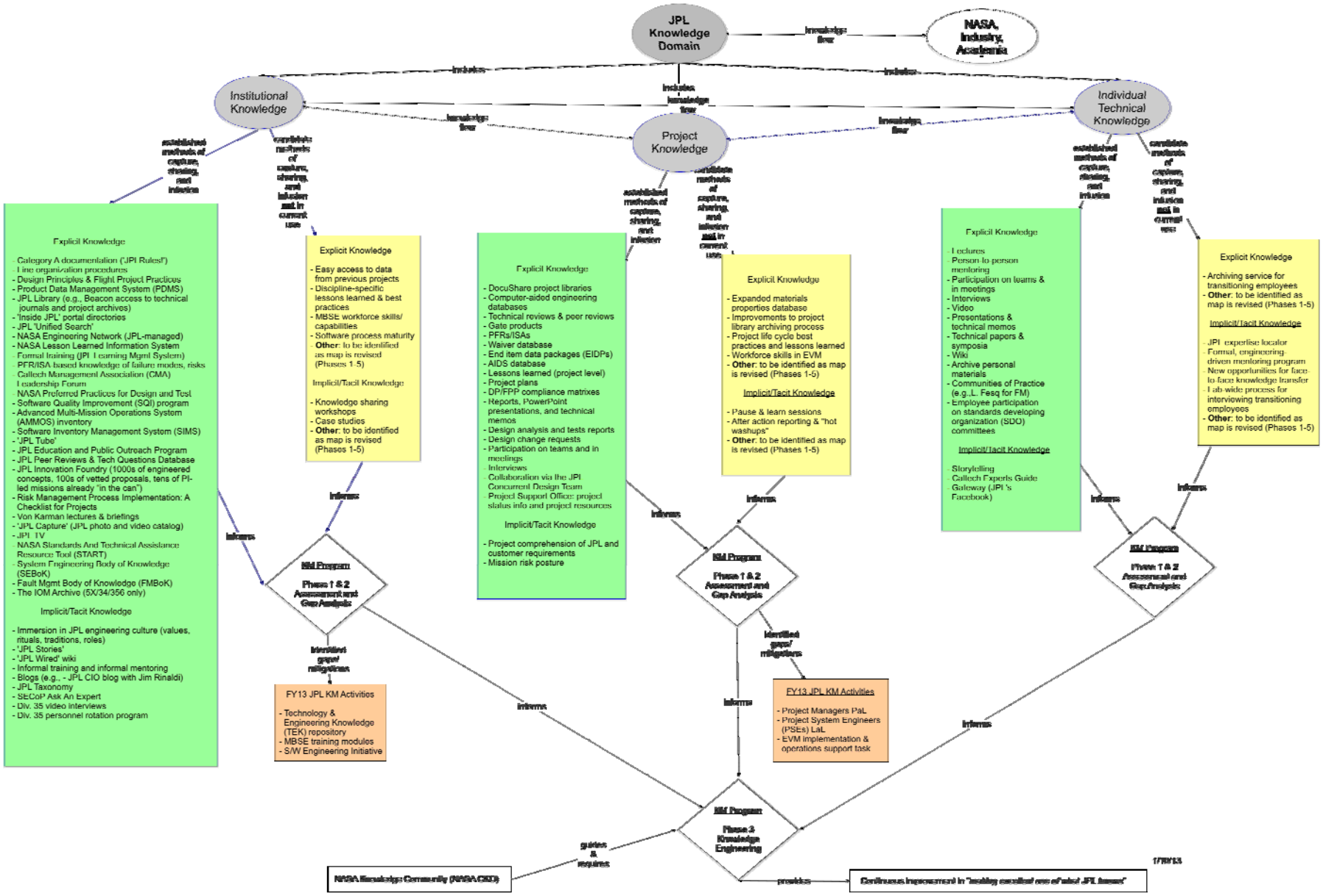
KM Program Plan

A KM program will be planned and implemented to address critical issues of JPL competence and organizational survival stemming from environmental change (e.g., turnover of projects and key personnel, NASA budget reductions). The program will seek to make the most of the knowledge that is available to JPL, generating understanding and incrementing awareness. Specifically, JPL will identify and prioritize JPL-critical knowledge, identify gaps in retention and sharing, implement remedial measures and practices, coordinate with the NASA KM program, and establish a process for continuous improvement. The JPL KM program will be implemented in five phases:

1. **Find out what we know.** Identify what knowledge is critical to JPL engineering excellence, competence retention, and to meeting JPL and NASA objectives such as mission "affordability" that may effect JPL organizational survival. This activity will include a *knowledge mapping* task that will depict repositories of knowledge within JPL knowledge domains, and relationships between them. (Figure 2 is a preliminary draft knowledge map, based on information that has not yet been vetted, that is provided for illustration.) Initial input on knowledge located within the line and project organizations that is critical for retention and sharing will be obtained from the JPL Engineering Board (JEB). Participation by other knowledge practitioners, such as the JPL librarians and website curators, will also be solicited. Determine whether NPR 7120.5 (and the JPL Design Principles) could serve as a JPL KM standard by informing the scope of knowledge defined as critical to JPL's mission.

2. **Evaluate JPL KM processes and identify knowledge retention/transfer gaps.** Assess how effectively JPL is managing the critical knowledge identified in Phase 1, and identify KM process gaps. To what extent does "*JPL not know what JPL knows*?" Do JPL organizational learning processes exploit JPL intellectual capital adequately to meet the knowledge needs of JPL and NASA? A comprehensive overview is needed to identify missing elements in the significant, but piecemeal, knowledge codification and collaboration efforts already underway at JPL and shown in Figure 2. For example, to what extent has JPL factored the need for knowledge retention into JPL workforce planning?

JPL Knowledge Map



Outline current JPL KM practice, and how improvements can benefit the organization. Baseline industry practices, and determine which might be compatible with the JPL engineering culture and what would constitute KM best practice for JPL specifically. Identify which metrics or key performance indicators (e.g., how many people attend a knowledge forum) would be effective measures of KM progress. Amend the knowledge map to depict how both explicit and tacit knowledge flows within the JPL project organization and line organization, and identify where the flow is restricted. (Explicit knowledge can be transferred by documentation and training, but the implicit or "tacit" knowledge used in decision making can be transferred only imperfectly by interviews, mentoring, and storytelling.) The completed knowledge map may be usable to effect a knowledge audit that provides objective evidence of JPL KM strengths, weaknesses, and risks. Assess how effectively JPL is managing the critical knowledge identified in Phase 1 above. Identify knowledge assets and KM process gaps.

3. **Seek to "make better use of what we know."** Design and implement a *knowledge engineering* program, which may include processes, technology, organizational structures, and specific action items, to improve the retention and sharing of JPL intellectual capital. Identify related resources, deliverables, schedules, and responsibilities needed to close the knowledge retention/sharing gaps identified in Phase 2. Highlight key dependencies such as personnel availability, KM program/budget approval, and risks. Outline steps required within the JPL leadership/planning process to advance the KM agenda and initiate action. Determine whether the organizational and engineering culture can best benefit from KM efforts to (1) capture specific critical knowledge, versus (2) facilitate *social capital*. (That is, the KM program will likely attain a balance between "connecting people with information" and "connecting people with informed people.")

   In the first year of the JPL KM program, assure long term JPL senior management support for KM by focusing on core tasks that will bring limited but assured, high visibility benefits. Investment in tasks that will return benefits over a longer term will be given less priority in the first year. Depending on the identified KM process gaps from Phase 2, FY13 tasks may include one or more of the following[3]:

<u>Example Tasks</u>

- **Lessons Learned.** JPL has a mature lessons learned process that served as the model for the Agency-wide process established in 2005 by NPR 7120.6, The NASA Lessons Learned Process. JPL has a Lessons Learned Committee that has met weekly since 1985 to identify and document lesson learned, and JPL recently implemented an effective close-loop infusion method to ensure that the lessons get used. The KM program plans to support continuation of this successful process.

- **Project libraries.** Some of the engineering analysis and test data acquired by flight projects over the course of the project life cycle can be reused by subsequent projects to save on development costs or to mitigate risk. After launch, however, JPL flight

[3] These example tasks are furnished to illustrate specifically how Phase 3 knowledge engineering may be applied to preserving and exploiting JPL intellectual capital, and are not intended to prejudge the results of the Phase 1 and 2 investigations.

projects place a low priority on maintaining the project library, and JPL personnel report difficulty accessing technical data on completed projects. The JPL record retention policy (DocID 64333) is aimed primarily at preserving records to demonstrate fulfillment of requirements, rather than to facilitate understanding or reuse. The NASA policy on records retention is for NASA projects to preserve project data for three years following end-of-project, but there is no requirement that the data be accessible. Even if all archived project reports and technical data were easily accessible, it is not clear that projects adequately capture important engineering decisions and their rationale. What is the minimum set of documents that a project should retain for the benefit of follow-on projects? Who on the project should be made responsible for retaining critical knowledge—a project knowledge manager? This task would address JPL policies on project retention of project knowledge. Demonstrating some progress toward fixing this problem may cement support for future knowledge engineering initiatives because this problem is widely acknowledged by the JPL workforce. If Phase 1 can identify what types of documents in project libraries are of great interest to other projects, then some of these could be stored in a centralized engineering repository (with appropriate safeguards).

- **Maintain knowledge repositories.** Not all knowledge generated by JPL is contained in project libraries; valuable information may be lost if it is not archived. For example:

    - Material test reports, which assess the suitability of materials for JPL applications, have been found to be stored on engineers' bookshelves. If not archived and make accessible, these tests may need to be repeated for future missions.

    - Searches of JPL archives find a number of mishap investigation board (MIB) reports on JPL mission failures, but they find no central repository that includes all such MIB reports.

    - Source evaluation teams (SETs) convened to review subcontractor proposals include members with technical backgrounds but no experience in the procurement-related disciplines. The tacit knowledge gained by previous SETs on SET "dos" and "don'ts" is not captured in lessons learned that can be communicated to these inexperienced team members.

The NASA Johnson Space Center (JSC) CKO actively solicits JSC staff to independently donate critical knowledge in any format for digitization and archiving. At JPL, the principal responsibility for archiving historical data lies with the JPL Library. Based on the information obtained in Phases 1 and 3, the CKO will assess whether JPL-critical knowledge is being:

1. Accurately identified and archived.
2. Captured/transferred in the best way available.
3. Maintained it in a manner that does not affect the viability/usability of the knowledge.
4. Made retrievable by the JPL workforce.

5. Made easy to find and share.

- **Pause & Learn.** A pilot *Pause & Learn* (PaL) program will be initiated in which JPL project managers meet bi-monthly to discuss project management problems that they each have encountered. The candidate venue for this exercise is the monthly meeting of project managers chaired by the Associate Director for Flight Projects and Mission Success. Each PaL session would feature a project manager sharing a recent project problem or opportunity with the other project managers—what problem was encountered on the project, what solutions worked, and what the project manager would have done differently. The ground rules for these informal presentations would include “not for further distribution” and “no PowerPoint slides permitted.” Based on the results of the pilot program, the PaL could be extended to Project System Engineers (PSEs) and Mission Assurance Managers (MAMs). The PaL implemented by GSFC has proven popular with GSFC project managers.

  In March 2013, a monthly *Lunch & Learn* session was initiated in which Project System Engineers (PSEs) are invited to a meal for a discussion of a major cross-project issue. For example, the topics for the first two sessions were "How to Implement Class D Missions" (10 attendees) and “What Constitutes an As-Designed Baseline and Associated Gate Products” (18 attendees).

- **Knowledge-sharing workshops**. Workshops are an effective way to share technical and management information and to connect people (i.e., facilitate social capital). “Common Threads” workshops were held at JPL in 1996 and 1997 in which JPL technical leaders shared insights with ~100 JPL employees on technical problems that persist from project-to-project and from decade-to-decade. The Ross/Nieberding *Space Systems Development Lessons Learned* two-day course has been taught at many NASA Centers. NASA APPEL has expressed interest in sponsoring a JPL workshop that incorporates these elements, and the CKO will pursue workshop opportunities in cooperation with JPL Professional Development. The KM program will also influence the JPL professional development curriculum and improve real-time sharing among projects.

- **Tool development.** Although this KM program does not center on information technology, or the development of tools and databases, there are information technologies that support knowledge engineering. The JPL OCIO has been very open to the adoption of new applications like social networking and video sharing to enhance communication within project teams. Technologies like semantic search offer great promise for making knowledge more accessible. The KM program will seek to influence the development and acquisition of such tools, and it will collaborate with other NASA Centers that are pursuing advanced capabilities.

- **Retiree outbriefing.** Retirees, others personnel leaving the Lab, and employees transitioning to new jobs may be willing or eager to share insights within their area of expertise that they feel to be key to mission success. NASA Johnson Space Center archives important documents provided by employees and solicits video interviews from retirees. The KM program will consider effective means to capture the explicit and tacit knowledge of key personnel upon retirement or transition.

- **Mentoring.** Formal classroom training has limited effectiveness in conveying knowledge within the more specialized technical disciplines; the worldwide scarcity of expertise specific to deep space systems limits knowledge acquisition through hiring, leaving mentoring as a vital JPL recourse. Mentoring is particularly effective in transferring implicit knowledge, and JPL has a mentoring program. However, the formal JPL mentoring program is largely a Human Resources, rather than an Engineering, function. Informal mentoring is performed within groups in the JPL line organization. The KM program will baseline mentoring programs in the aerospace industry, and assess opportunities for JPL improvement. Initial consideration may be given to having divisional chief engineers conduct their version of Bill Leyman's "*How to be a Chief Mechanical Engineer*" class.

- **Technical discipline-specific lessons learned and best practices.** Although JPL sections maintain documents that assure that design, development, and operations activities meet requirements, guidance references are also very valuable in preserving discipline-specific technical knowledge and lessons learned. Formal JPL lessons learned approved by the JPL Lessons Learned Committee (LLC) are published in the NASA Lesson Learned Information System (LLIS). But the lesson learned topics selected and validated by the LLC are suited to general Lab-wide or NASA-wide use and are not intended to inform decision making within a narrow technical discipline. In the past, however, JPL sections supporting engineering and related disciplines like Propulsion Engineering and Thermal Engineering have sought to create repositories of discipline-specific lessons learned and best practices. Although such repositories are best owned and maintained by the line organization that oversees the specific technical discipline, they have tended to languish because they were not consistently given priority. The CKO will support the creation and maintenance of several pilot repositories of engineering discipline-specific lessons learned or best practices.

- **Knowledge capture and transfer (KCT).** KCT is a lifecycle KM approach in which projects actively and collaboratively capture knowledge related to activities over the project lifecycle (e.g., ATLO) for the purpose of providing project process improvement and guidance for ongoing and future activities—both within the JPL project and for the benefit of future projects. This knowledge includes lessons learned, best practices, things that worked, and things that can be improved. The intent is to establish and embed these practices within work processes in a tailored, non-invasive way that supports continual improvement and provides resources for the future. The KCT process includes both face-to-face elements and web-based (digital) resources, such as Process 2.0, Critical Process Mapping, Knowledge-Based Risks, Knowledge Sharing Forums, and Knowledge Cafes that are conducted by project teams. KCT has been implemented effectively by the NASA Human Exploration and Operations Mission Directorate (HEOMD), but this project-focused approach may be better suited to the longer duration (e.g., Cassini class) projects than to smaller JPL project teams.

- **Enlist the JPL knowledge community in KM.** Managing JPL intellectual capital and facilitating organizational learning is the responsibility of the entire JPL workforce—not just the CKO. To enlist the JPL workforce in KM, a quarterly JPL

KM newsletter will be published to inform the Lab of KM objectives and activities. An example of the format and content is the Risk & Knowledge Management Quarterly Update e-mailed by NASA HEOMD. An Office of the CKO webpage will also be prepared and maintained to acquaint the JPL workforce with JPL KM concepts, objectives, plans, and products.

KM program implementation will seek a balance between "quick-wins" and building a sustainable, long-term KM capability. By focusing on some quick wins that can be implemented in a short time frame, our employees, Lab management, and our NASA stakeholder will see some visible, immediate benefits, and they will be more likely to support efforts that have a longer-term payoff. Where feasible prior to launching major initiatives, the CKO will utilize pilot projects that will allow the KM program to test a knowledge engineering approach and make errors before any Lab-wide rollout. The program will focus on efforts with benefits that will penetrate to the knowledge users and generate grass roots support for KM.

4. **Coordinate with HQ KM program.** NASA is presently preparing an Agency-wide KM strategic plan, and a NASA Procedural Requirement (NPR) will likely be issued that will replace NPR 7120.6 and impose KM requirements on NASA Centers. The CKO will coordinate with the NASA KM program, assure that the JPL KM program is consistent with NASA requirements, and report to the NASA CKO on the status of the JPL KM program. The JPL CKO will also keep abreast of KM activities at the NASA Centers; this may aid JPL in identifying KM success factors, such as:

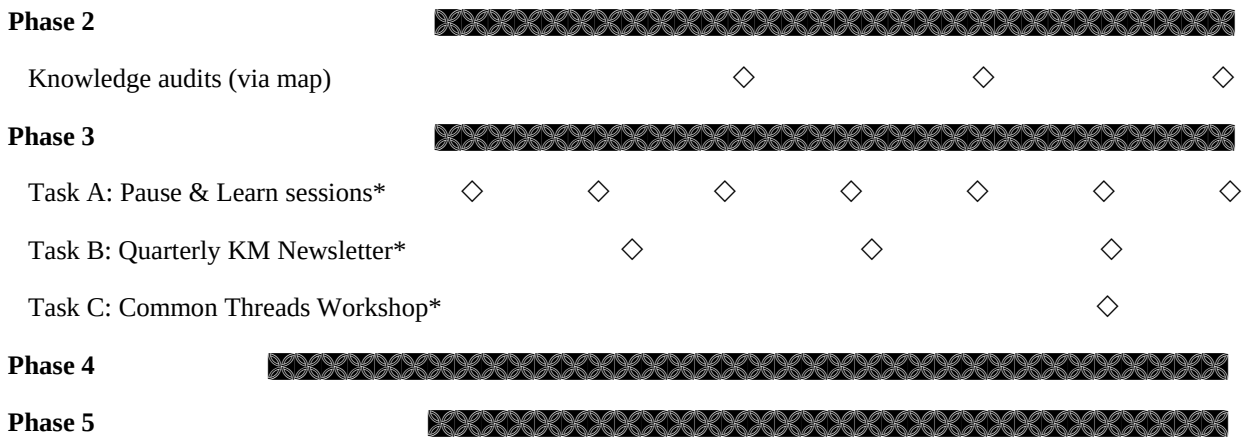
   - What KM measures have proven effective at NASA Centers and in industry.
   - Are there useful KM metrics that would serve as indicators of performance?

5. **Continuous Improvement Process.** The CKO will implement a KM continuous improvement program. Establishing a process of continuous improvement will mean re-evaluating the JPL KM process and continuing to identify knowledge gaps and implementing corrective measures. New technologies will emerge that enhance knowledge capture and sharing. The KM program will seek to influence these, as well as JPL organization changes that may facilitate knowledge processes. Ultimately, the goal is to affect a JPL culture change by cultivating a greater desire by individuals and organizations to husband intangible assets. The CKO will track progress in achieving a mature JPL KM process, in filling organizational learning gaps, and in mitigating the risk of "*not making good use of what we know*" at JPL.

Schedule

The FY13 schedule for the above activities, pending availability of funding, is:

FY13	Q1	Q2	Q3	Q4
Phase 1				
Knowledge Map rev	◇	◇	◇	◇
JEB assessment	◇			



*The actual selection of the Phase 3 task or tasks will be influenced by the results of Phases 1 and 2.

If funding for the above activities is not available for FY13, then the JPL FY13 KM program will focus on one or more “easy-wins” such as implementing Pause and Learn sessions for JPL project managers.

Appendix A

NASA Workforce Trends

The aging of the workforce and the potential loss of their tacit knowledge is a significant problem for NASA. Today's NASA workforce approaching retirement (Figure 3)—those 50 years of age or older— outnumbers NASA employees under age 35 by more than three to one (50% vs. 15%). The disparity is even greater for the subset of Science & Engineering (S&E) personnel occupational categories (50% vs. 14%). Twenty years ago (Figure 4), the over-50 and under-35 numbers were equal, with only a slight disparity for S&E personnel (36% over 50 vs. 33% under 35).

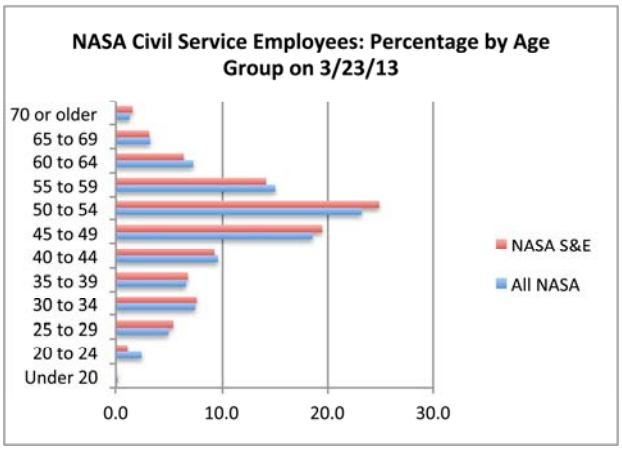


Figure 3. Today's NASA workforce distribution (bell curve) peaks for employees in their late 40s and in their 50s.[4]

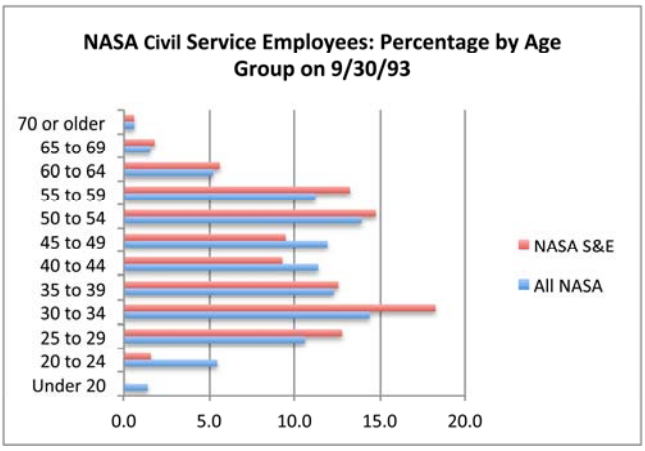


Figure 4. The NASA workforce distibution of twenty years ago was essentially level for the various age groups.[4]

Of the 17,900 current NASA employees, 20 percent are expected to retire during FY13 to FY18 (Figure 5). Fully 63 percent of the total FY13–18 attrition is expected to be due to retirement.

[4] COGNOS WICN tool (3/23/13 data), Workforce Strategy Division, NASA Office of Human Capital Management, http://wicn.nssc.nasa.gov/wicn_cubes.html Note: The NASA workforce data do not include JPL employees.

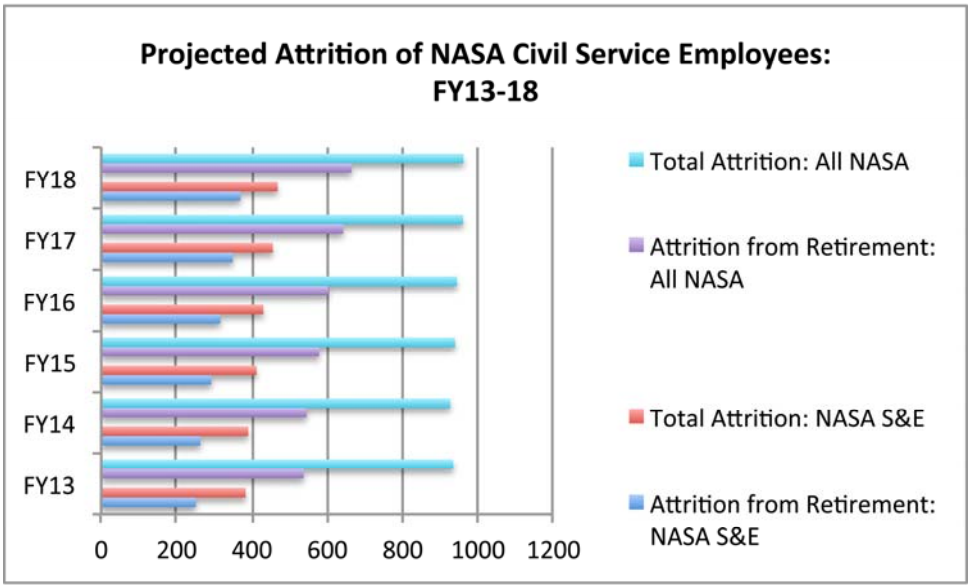


Figure 5. Projected annual attrition of the existing NASA workforce, and for the subset of Science & Engineering personnel[4]