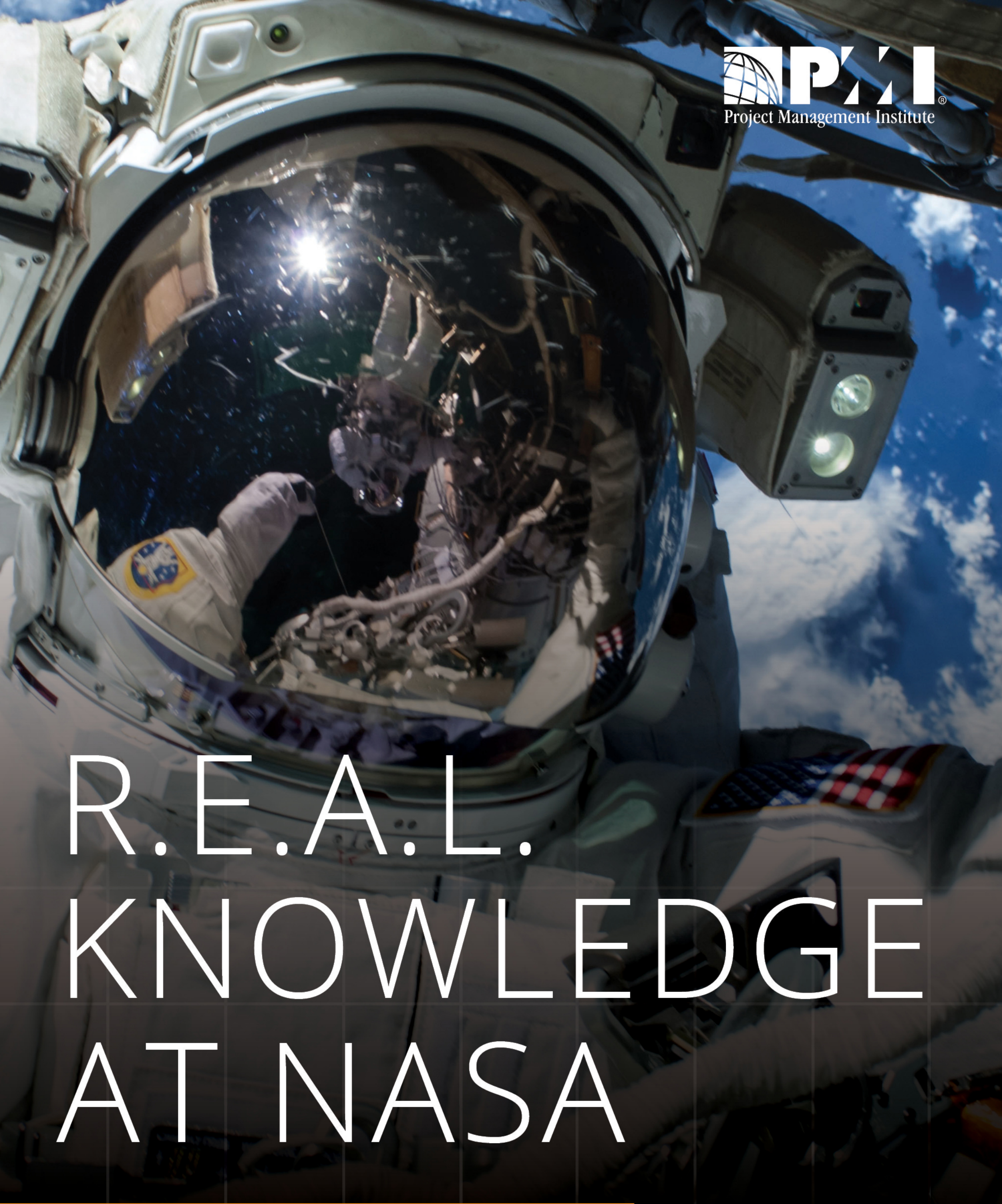

Project Management Institute

R.E.A.L. KNOWLEDGE AT NASA

A KNOWLEDGE SERVICES MODEL FOR THE MODERN PROJECT ENVIRONMENT

by Dr. Ed Hoffman and Dr. Jon Boyle

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PREFACE

REAL Knowledge at NASA presents a descriptive project practitioner–centered Knowledge Model derived from experience in developing Knowledge Services (KS) at the National Aeronautics and Space Administration (NASA).

It involves an organizational knowledge systems perspective that better negotiates rapid change and accelerated learning in data-rich complex project environments. It discusses the modern project environment and reiterates the historical context of knowledge and learning at NASA and covers the strategic imperatives that guide the design and development of a Knowledge Services (KS) Model (KSM) for individuals, teams, and organizations.

The operational components of knowledge capture and retention, sharing and application, and discovery and creation are specified as core processes with individual and organizational inputs of capabilities and expectations.

Considerations for the design of KS at NASA are discussed, including governance, federated approach, mapping, biases and heuristics, and practitioner capabilities. Examples are described based on the presented strategic imperatives and Knowledge Model, and the authors close with a summary and recommendations for future research. This model allows organizations to validate and add imperatives within their context to better design knowledge services for diverse challenges and opportunities.

THE PROJECT KNOWLEDGE ENVIRONMENT

How can organizations and practitioners best leverage project knowledge and knowledge services to get things done in the modern complex project environment?

Based on research, experiences, and conversations across public, private, government, industry, academia, and professional organizations, practitioners say it is increasingly difficult to bring ideas to fruition and projects to completion. This difficulty is reflected through several facets of recent research. One study found only fifty-six percent (56%) of strategic initiatives meet original goals and business intent in surveyed project organizations, and also reported that forty-eight percent (48%) of projects that are not highly aligned to organizational strategy succeed (Project Management Institute, 2014).

NASA collaborated with Aviation Week and industry leaders on the second annual Young Professionals Study and discovered that the top frustration of the under-thirty-five (35) workforce was bureaucracy and politics and that there is no time to innovate and create (Anselmo & Hedden, 2011).

Experience at NASA over thirty (30) years suggests that significant improvements can be gained through a focus on the capture and flow of project knowledge in terms of organizational, individual, and team project factors within an organizational systems perspective.

For NASA, knowledge involves the unique requirements, solutions, and expertise shared across individuals, teams, projects, programs, Mission Directorates, and Centers, often defined as codified knowledge (scientific knowledge, engineering and technical knowledge, and business processes) and know-how (techniques, processes, procedures and craftsmanship), presenting the classic dichotomy of explicit and tacit knowledge, where Polanyi (1966) first says of tacit knowledge, "we can know more than we can tell."

There are also other relevant types of knowledge that play a significant role, such as that in a social context. In one example, Neffinger and Kohut (2013) emphasized the importance of perceptions of strength and warmth in interpersonal and team environments and how an optimal balance of these characteristics informs social situations. A better understanding of the social context of project knowledge can serve as a basis for improved prioritization and a more pragmatic approach to problem solving. Organizational disregard for this type of knowledge can lead to project failures such as those described by in the NASA *Challenger* and *Columbia* Shuttle disasters (Hoffman & Boyle, 2013), where the technical root causes were investigated but the underlying causes were poor team communications and lack of organizational learning.

At the end of the day, NASA is a project organization. The driving motivation concerning knowledge is ultimately mission success. Complexity works against this focus on mission success, and it can take many forms:

» Confusing, vague, poorly defined priorities, strategies, lines of authority, governance, policies, roles and responsibilities and support, characterized by iterative reorganizations, constant budget changes, constant resource level adjustments, a proliferation of administrative burdens, and endless requirements.

» A proliferation of customers, stakeholders, and strategic partner interfaces at multiple levels of interest, involvement, and responsibility.

» Technical complexity and system integration issues within and across multiple disciplines and multiple systems.

» Increased data and information amount and availability for process input, throughput, and output.

» Multiple overlapping, conflicting, outdated processes and procedures that involve multiple points of contact distributed across multiple organizational levels and across multiple oversight and advisory entities, characterized by competing priorities, strategies, lines of authority, governance, policies, roles and responsibilities, and support requirements.

Complexity drives a rapid pace of change that impacts organizational social, technical, strategic, and administrative systems. Davenport and Prusak (1998) recognized this when they defined future success in terms of organizations that know how to do new things well and quickly. The shelf-lives of products and services are increasingly being shortened, requiring a management methodology that is flexible and adaptable across the operational and strategic contexts to accommodate change, yet rigorous enough to ensure that progress continues toward goals and objectives in the most efficient and effective way possible. Project management is a discipline often applied to achieve this flexibility and adaptability, thus handling the knowledge requirements for projects to better perform under these increased burdens makes sense. For NASA, a project knowledge systems perspective best addresses handling complexity within an environment of increasingly constrained resources.

As mentioned, one form of complexity is the amount of available data and information. According to the independent research organization SINTEF (Dragland, 2013), ninety (90) percent of the data in the world has been generated over the past two (2) years, an incredible statistic that reinforced a claim by former Google Chief Executive Officer Eric Schmidt at the 2010 Techonomy Conference (Kirkpatrick, 2010) that humans currently create as much information in two days as they did from the dawn of man through the year 2003. Regardless of competing perspectives from diverse organizations, it is an accelerating revolution of data, information, and knowledge that demands effectiveness and efficiency in the core processes of how it is captured and retained, shared and applied, and results in discovery and creation.

Change is accelerated by this expansion of data and information and requires organizations to better address strategy and decisions. Learning is alternately enabled and hindered by the rapid development and implementation of technological tools accompanying this relentless pace of change and churn. On one hand, it ensures data and information availability twenty-four hours a day, seven days a week. On the other hand, the capability to process the data and information into usable and actionable knowledge and wisdom and to focus organizations and practitioners on implementing solutions suffers. This wealth of data and information interferes with focusing, prioritizing, and moving confidently into the future, because planning often suffers when new data and information obscure the original intent. The inductive process of building a list of good ideas is worthless without the deductive prioritization of what is truly important in terms of context, urgency, and relevance, the magic that is delivered through good leadership.

This burden of change is ultimately placed squarely on the shoulders of what is termed the NASA technical workforce, practitioners possessing specialized skills that contribute to engineering efforts involving the disciplines of math, science, and technology. Over the years, their responsibility has shifted from a focus on the operational project objectives of scope, technical performance, quality, schedule, and cost to a more encompassing responsibility of functional activities, which includes business management, commercialization, new technology identification and development, strategy development, and often much more.

What is the nature of these barriers and complications originating from multiple sources on the path to achievement? Some are political, others related to competence at the organizational, team, and individual levels. Some concern leadership capability accompanied by poor communications up, down, or laterally in the organization. Perhaps there are incorrect, ill-defined expectations and a lack of strategic alignment in the project or across the larger organization. Others may reflect significant external market or business change. Regardless, they conspire in the dark corners of organizations to create a lack of focus and mission, a fragmenting of common purpose into special interests and personal agendas, and ultimately stasis, a potential death knell for modern organizations in a volatile competitive world.

A strategic knowledge systems perspective is essential to uncover and define project relationships and the risks inherent in project knowledge interfaces. This is critical since it provides insight into the nature of the realities that others live in. Unless this is analyzed and contingencies are planned for, the risk of failure increases. Fortunately the message is getting through to senior executives. In a Conference Board (Hackett, 2000) research report on Knowledge Management (KM), eighty percent (80%) of surveyed organizations had KM activities underway, sixty percent (60%) expected an enterprise-wide KM system to be in place within the next five (5) years, and twenty-five percent (25%) had a Chief Knowledge Officer or Chief Learning Officer in place. At the end of the day, capturing and effectively relating the journey to achieve outcomes is a story that each individual and team creates and shares.

For NASA, key knowledge imperatives and knowledge tools have been developed over the years to help project teams in their efforts. Relating this context helps in understanding where NASA is today and how these lessons can inform other project organizations.

Barriers and complications conspire in the dark corners of organizations to create a lack of focus and mission, a fragmenting of common purpose into special interests and personal agendas, and ultimately stasis, a potential death knell for modern organizations in a volatile competitive world.

CHAPTER ONE

HISTORICAL CONTEXT OF PROJECT KNOWLEDGE SERVICES AT NASA

In pursuit of what really works in project knowledge, how did NASA evolve to the point of appointing the first Chief Knowledge Officer (CKO) for the agency and establishing Center and Mission Directorate CKOs across the organization?

Many organizations face defining events that can drive organizational change and provide lessons for the future. For NASA, these defining events at a macro level are well known not only to employees but also to the general public. The changes that these events drove in the fabric of the organization are not as evident, especially through the lenses of knowledge and organizational learning.

As discussed in previous articles (Hoffman & Boyle, 2013) addressing the historical context, governance, and priorities of agency knowledge services, there are several events that have shaped the agency. One was the Challenger disaster in 1986 that killed seven (7) astronauts and forced the agency into brutal introspection. It resulted in the creation of a training program called the Program and Project Management Initiative (PPMI) that promoted project management capabilities in advance of agency needs. At a time where large, expensive, long duration programs and projects developed project practitioners through individual experience, coaching, and mentoring, this disaster forced a change toward systematized, codified, and vastly improved individual preparation.

Another defining event were the Mars Mission Failures in 1998–1999 (the *Climate Orbiter*, *Polar Lander*, and *Deep Space 2 Probes*) that occurred during the era of Faster, Better, Cheaper (FBC), a management paradigm adapting NASA to increasing mission demands in an environment of diminishing resources. **These mission failures and resulting investigations changed the agency's focus from individual to team capabilities and shifted emphasis to shared stories; the development of new policy guidance to prevent the operational mistakes that drove the failures; and a more disciplined approach to include better testing in science missions that did not involve crew safety issues.**

The *Columbia* disaster echoed the *Challenger* in 2003, where in this instance detaching foam damaged the wing on ascent of the vehicle and ultimately resulted in vehicle disintegration upon descent, killing seven (7) astronauts. The Columbia Accident Investigation Board (CAIB) discovered that NASA managers made assumptions that were technically indefensible, such as the assumption that the leading edge materials were tougher than the thermal tiles and could not be easily compromised. They also found that team processes, communications, and interpersonal dynamics were ineffective and NASA managers heard but did not listen to engineering and safety concerns (National Aeronautics and Space Administration, 2003). As a result, technical options were not fully explored and the vehicle and crew were lost.

This forced a re-learning of lessons from case studies, new multi-discipline knowledge-sharing forums, and major governance and policy changes such as: the creation of the NASA Engineering Safety Center (NESC) to support technical knowledge and capability; a change in NASA governance on the balance of power in technical missions; and an emphasis on defining technical authority in mission decisions. NASA also adopted mechanisms to improve communications and interpersonal dynamics that can defeat *Organizational Silence*, the tendency to say or do little despite the presence of significant organizational threats, and *Normalization of Deviance*, the organizational acceptance of risky situations and behavior due to increased frequency over time (Vaughan, 1996).

The ghosts of *Challenger* and *Columbia* still haunt the agency. In 2011, the NASA Aerospace Safety Advisory Panel (ASAP) reported that **the agency needed to create a more systematic approach capturing implicit and explicit knowledge and recommended the appointment of a formal agency-level Chief Knowledge Officer (CKO), supported by a set of appointed CKOs at each Center and Mission Directorate.**

ASAP was established in 1968 to iteratively evaluate NASA, through direct observation of operations and decision making, in terms of safety performance and providing advice to NASA senior leadership on how to improve that performance. In the aftermath of the *Columbia* accident, Congress required that the ASAP submit an annual report to the NASA Administrator and to Congress. The annual report examines agency compliance with the recommendations of the CAIB, as well as management and cultural factors related to safety.

Recently, the ASAP review team asked NASA project personnel, “What is being done to ensure these lessons are being formally and systematically captured and made accessible across the whole organization?” The responses indicated there was no system that effectively captured, shared, and allowed other projects to find these critical lessons. The issues of searchability, findability, and applicability continue to be great challenges. **Projects are committed to identifying and sharing critical knowledge and lessons within a team, but it is rare to find knowledge across a system of systems and across project boundaries. In an increasingly complex and interconnected world, this integration can spell the difference between success and failure.**

The Agency readily concurred with the CKO recommendation in 2011, focusing the agency’s knowledge strategy effort by appointing an agency CKO within the Office of the Chief Engineer (OCE) and designating CKO positions across Centers, Mission Directorates, and Functional offices.

The OCE evolved its functions toward serving as an enterprise-wide project management office (PMO), creating a structure responsible for developing and implementing the strategy, policy, standards, workforce development, advanced concepts, mission architecture, integration across program and mission boundaries, and program assessment for overall technical workforce development that supports project and program success at an enterprise level (PMI, 2012).

CHAPTER TWO

NASA KNOWLEDGE SERVICES GOVERNANCE

Any NASA knowledge management approach needs to be adaptable and flexible enough to accommodate the varied requirements and cultural characteristics of each Center, Mission Directorate, and Functional Office. A federated model was the best fit for the agency, **defining the NASA CKO as a facilitator and champion for agency knowledge services, not to serve as an overseer and direct manager.** It struck a balance between autonomy and responsibility, where Centers, Mission Directorates, and Functional Offices were free to determine the knowledge approach that best fits their particular needs, but were responsible for sharing knowledge that benefitted the overall agency. The governance document for NASA Knowledge, *NPD 7120 NASA Knowledge Policy for Programs and Projects* (National Aeronautics and Space Administration, 2013) was collaboratively rewritten because NASA had greatly expanded its knowledge activities over the past several years to include a wider array of services than simply capturing and retaining lessons learned.

The new policy ensured that NASA manages knowledge resources in a way that enables the agency to execute programs, projects, and missions with the highest likelihood of mission success, emphasizing a KS integrated strategic framework. It also defined the roles and responsibilities for CKOs at the Centers, Mission Directorates, and Functional Offices. The new policy addressed a set of KS priorities that clarified NASA objectives for project knowledge and emphasized the development and implementation of future knowledge initiatives, measures, and metrics (Figure 1):

- In terms of people, sustain and expand the use of the agency's intellectual capital across NASA's enterprises and generations through better networks, alliances, and communities of practice.
- In terms of people, increase collaboration across organizational barriers through promotion of a culture of openness.
- In terms of systems, support the technical workforce in executing NASA's missions efficiently and effectively through lessons learned, mishap reports, and promulgation of best practices.
- In terms of systems, create an integrated infrastructure of knowledge that identifies the value of information and aligns practitioner and organizational imperatives through accessible information and user-friendly services.

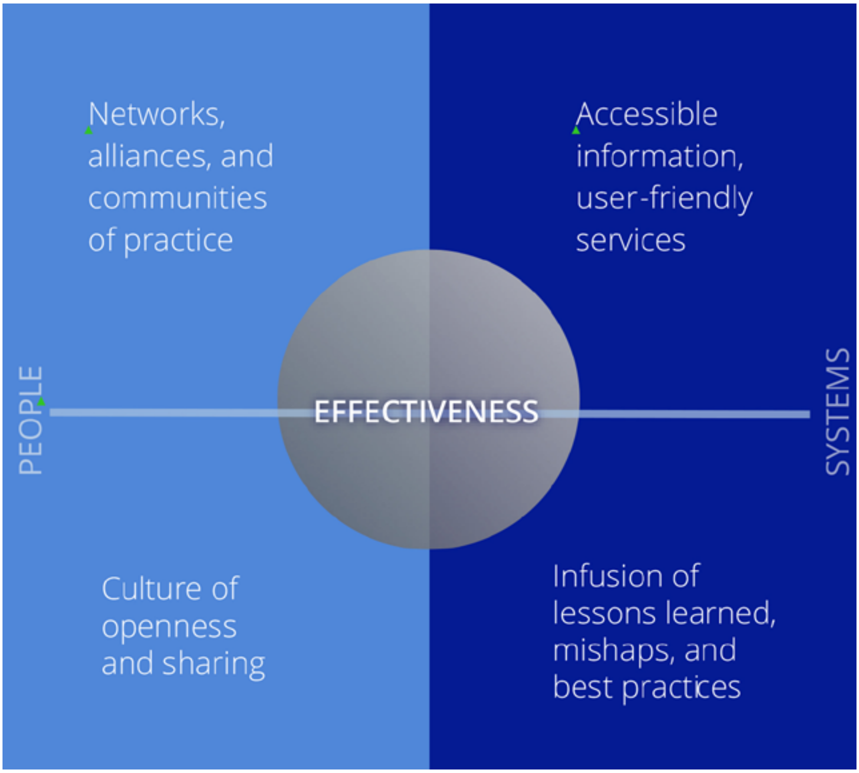

Figure 1: NASA Knowledge Services Strategic Framework

One of the most striking things that the agency's knowledge community discovered was the sheer depth and breadth of activity underway across the agency. Some of this activity was found through self-service, such as typing a query in a search box and getting answers that point in the right direction, involving one person at a time and that works best with *explicit knowledge* that does not require a lot of context or personal judgment. At the other extreme, *tacit knowledge* that was dependent on context and personal judgment was transmitted through social interaction at meetings and storytelling.

Given this range of knowledge activities, the NASA knowledge community identified an initial set of knowledge categories that addressed most of the activities taking place across NASA that could be populated on the first-ever Agency Knowledge Map (Figure 2):

» *Online Tools* — Include but are not limited to: portals; document repositories; collaboration and sharing sites; video libraries.

» *Search/Tag/Taxonomy Tools* — Dedicated search engine for knowledge (e.g., Google Search Appliance) and any initiatives related to meta-tagging or taxonomy.

» *Case Studies/Publications* — Original documents or multimedia case studies that capture project stories and associated lessons learned or best practices.

» *Lessons Learned/Knowledge Processes* — Any defined process that an organization uses to identify or capture knowledge, lessons learned, or best practices, including: Lessons Learned Information System vetting process; organization-specific lessons learned processes; benchmarking; cases; knowledge-sharing recognition programs; knowledge product validation processes; communications about expectations related to knowledge sharing.

» *Knowledge Networks* — Any defined knowledge network, such as: a community of practice; expert locator; mass collaboration activity; workspaces specifically designed to enable exchanges and collaboration.

» *Social Exchanges* — Any activities that bring people together in person to share knowledge (e.g., forums, workshops, Lunch and Learn/Pause and Learn, etc.). The reach of these activities can be multiplied through online tools such as videos and virtual dialogues.

The agency is now linking all identified products and series to the map and creating active links to the resources. The categories are not a perfect fit for every type of knowledge activity across diverse organizations and multiple disciplines, but the hurdle cleared was the awareness that the perfect is the enemy of the good. The knowledge community used these categories as an initial starting point that could be institutionalized, modified, and clarified during subsequent iterative reviews.

Figure 2: NASA Knowledge Map and Legend

The NASA knowledge community also recognized that there are valuable lessons to be learned from other domestic and international organizations in the federal government, industry, academia, and professional organizations. In extending the community beyond the core NASA footprint, the CKO Office is involved with several important communities of practice, two examples of which are: the Federal Knowledge Management (KM) Community that meets quarterly for sharing best practices and leveraging lessons learned; and the International Project Management Committee (IPMC) and Knowledge Management Technical Committee under the International Astronautical Federation (IAF).

CHAPTER THREE

STRATEGIC IMPERATIVES IN THE MODERN PROJECT KNOWLEDGE ENVIRONMENT

With the NASA historical context in mind, and reflecting on its journey to project excellence, what has emerged as driving strategic imperatives that inform the development of KS at NASA and, through analogy, other organizations?

At its core, NASA is a project organization fixated on mission success. There are twelve (12) mutually reinforcing strategic imperatives that have emerged from interviews, studies, and experience. These guide the design, implementation, and evaluation of Knowledge Services for NASA, and are discussed in no particular order of priority.

One critical strategic imperative is *Leadership*. It is ironic that one of the more fragmented disciplines provides valuable answers for the application of KS in organizations. Without effective leadership, KS and its results are at best serendipitous, at worst fail. The essence of leadership occurs with an insight that things should change, but also a profound realization that the reasons for change may be clear to leaders themselves but not necessarily to others. There exists an external stakeholder community as well as a core internal project team to lead, and both should be understood and managed. Additionally, good leaders align projects with organizational strategy, mission and goals, which is admittedly easier said than done in the modern environment of information overload and change. Successful implementation happens with a carefully articulated vision, leadership focus on that vision, and attention to detail on implementation.

It is a *Project World.* Varied organizations worldwide require a methodology allowing for rigor in managing temporary, unique initiatives toward the achievement of defined requirements and project goals and outcomes that are aligned to organizational strategy in an era of constrained resources. In this context, project management is uniquely positioned as an adaptable discipline that fits these requirements and can maximize the use of learning to promote efficiency and effectiveness. Again, the alignment of project goals to organizational strategy through good leadership is critical.

Knowledge is the essential element for the creation of successful physical and virtual products and services. It can be viewed as an organized set of content, skills, and capabilities gained through experience as well as through formal and informal learning that organizations and practitioners apply to make sense of new and existing data and information. It can also exist as previously analyzed and formatted lessons and stories that are already adaptable to new situations. The ascendance of leaders that can validate the realities to which projects are able to apply knowledge and base decisions on is key.

Talent Management addresses the specification, identification, nurturing, transfer, maintenance, and expansion of the competitive advantage of practitioner expertise and competence. It encompasses the broad definition of diversity that goes beyond the classic categories of color, race, religion, and national origin to domestic and international variables important to geographically dispersed multi-cultural teams, such as multi-generational, cross-discipline, and cross-experiential variables. This allows diverse groups to bring a diversity of experience, attitudes, knowledge, focus, and interests to the table, strengthening both inductive and deductive problem-solving approaches and nurturing innovation. Good leaders link talent management with executive sponsorship, organizational strategy, and the core work of the organization. They also achieve operational efficiencies by learning, working, and collaborating together at a distance independent of time and geography and leverage smart networks that provide content, access and connection to project data, information and knowledge. For NASA, talent management is represented as the variables of Abilities, Assignments, Attitudes, and Alliances (Figure 4).

Portfolio Management integrates projects with strategy and creates an organizing framework and focus that drives organizational purpose and activities. They provide a centralized function that promulgates a systems view of knowledge, where stove-piped disciplines and activities can transcend boundaries and discover and apply cross-disciplinary knowledge to increase competitive advantage and better achieve results. Organizational expectations can also be tested against reality at this level and adjusted and communicated accordingly to eliminate or mitigate errors and achieve better decisions.

Certification establishes objective, validated standards and functions to benchmark achievements in defined categories of practitioner performance and capability. It also provides organizations and practitioners a way to establish trust with superiors, peers, team members, customers and stakeholders, and provides a framework for adapting to change as well as a method to address emerging performance requirements. For practitioners, it provides a roadmap for individual development and serves to link organizational performance and individual capability (Duarte et al., 1995). Since people are essential in projects, certification allows for objective definitions of the four (4) Talent Management variables of Abilities, Assignments, Attitudes, and Alliances. An example of a discipline standard is *A Guide to the Project Management Body of Knowledge (PMBOK® Guide)* (Project Management Institute, 2013), which specifies the ten (10) Knowledge Areas that currently define the framework of the discipline.

Transparency is an important consideration as the network of organizational portfolio sponsors, project team members, customers, stakeholders, strategic partners, suppliers, and other interested parties tie into organizational strategy and project operations through information and communication technology tools. In this environment, nothing is hidden for long, and errors travel at the speed of light. Communications with each interface should be carefully defined across intensity and frequency dimensions, for example where external stakeholder communities may expect to be informed about progress at a higher level, but not as frequently or in-depth as internal leadership. Transparency that is formally built into the strategic business process encourages innovation, translating economies of scale and a breadth of experiential lessons into innovation and flexibility.

Frugal Innovation (*The Economist*, 2010) is a mindset that views constraints in an era of restricted and diminished resources as opportunities, leveraging sustainability and a focus on organizational core competencies to reduce complexity and increase the probability of better outcomes. Sustainability in particular has gained momentum as the cost to the planet and availability of resources increasingly impact business decisions. Organizational core competencies for a product or service involve what it must do in depth rather than what it can do in breadth, ensuring that organizational capacity in areas such as technological, social, political, economic, and learning dimensions are parts of the frugal innovation process. In a mutually reinforcing perspective, imperatives such as Transparency allow the broader team to share knowledge and experience to improve and innovate in terms of products and services, supporting the *Frugal Innovation* effort.

Accelerated Learning is the tactic of employing state-of-the-art digital technologies, traditional knowledge-sharing activities, modern learning strategies, social media processes and tools, and cross-discipline knowledge into the broadest possible view of learning for an organization. The operational knowledge process is closely linked to key internal and external knowledge sources and serves to clarify organizational expectations to optimize knowledge searchability, findability, and adaptability.

A *Problem-centric Approach* emphasizes a non-partisan, non-biased, non-judgmental, and pragmatic orientation toward problems and solutions, keeping the focus on achievement, improvement, and innovation. Organizational expectations are kept pragmatic and constructive when a problem-centric approach is encouraged and expected. At the end of the day, it is about problems, communications, power, and building a community of support focused on credible challenges. This orientation serves as the fuel for change while addressing competing agendas and administrative barriers, and directly addresses the issue of bias and heuristics that may introduce error in decisions.

Governance, Business Management, and Operations provide for pragmatic alignment, oversight, approvals, and implementation of project operations and establish rigor and processes. In an era of Frugal Innovation, management of the budget and clarity of funding requirements that support the overall effort must be visible and valued by leadership and the workforce. Nothing brings trouble faster than mismanagement of funds and a lack of focus on funding flow, so the oversight, tracking, and implementation of project activities need definition. Defined governance addresses the issue of siloed implementation and raises executive awareness as well as formalizes successful localized grassroots efforts.

Digital Technology makes it possible to examine new frontiers of potential knowledge and access multiple sources of data and information, but simultaneously causes organizations to be increasingly buried in data and information and have less time for focus and reflection. Technology is necessary but not sufficient for KS, but wonderful things can result from the application of technology, including open, social network-centric, non-proprietary, adaptable, and flexible frameworks that accelerate learning processes to deliver the right knowledge at the right time for particular needs while respecting context. The proper application of technology helps achieve learning results and better decisions at a lower cost.

CHAPTER FOUR

THE REAL (RAPID ENGAGEMENT THROUGH ACCELERATED LEARNING) MODEL

With the project environment, the strategic knowledge imperatives, and defining events serving as a framework, there was a critical need for a project KS Model that describes the interfaces, variables, and components. Alternatively, the last thing needed was a normative model prescribing the knowledge methods specific to siloed processes and tools as opposed to broader integrated approaches that are able to accommodate complex organizational strategies.

What analogy could another discipline provide in terms of a systems approach to better understanding the role of knowledge and learning in organizations? The entanglement principle of Quantum theory suggests that the measurement of the state of a Qubit (a unit of Quantum information) determines the potential states of the other Qubits it is linked to regardless of distance, but itself is only definitively defined when observed, prompting Einstein's famous description of "spooky action at a distance" (Bell, 1987). In extending the analogy, information can be understood when local knowledge is applied, but can be misunderstood if the information exists across levels of organization and time that lack context and drives interpretations colored by assumptions, biases, politics, personal agendas, and emotions. In this analogy, leaders applying an incorrect measure in defining the data and information could corrupt the original meaning and extract the wrong lessons, just as applying the wrong measure in physics would corrupt the hypothesis being tested. **Retaining and learning not only the lesson but also the context allows practitioners the potential to adapt lessons to diverse project environments.**

According to the Conference Board (Hackett, 2000), executives may not be familiar with or possess experience in the KM discipline, resulting in a lack of specific knowledge objectives and goals that can be integrated, measured, and managed, thus leading to the potential extraction of the wrong lessons. KS suggests a facilitative approach that not only addresses the topic of knowledge, but also emphasizes learning as an organization and ties the importance of knowledge as a resource across operational and strategic imperatives, reinstating the critical context of the information.

The NASA CKO Office developed the Rapid Engagement through Accelerated Learning (REAL) Knowledge Model (Figure 3) to promote the capabilities to more comprehensively and accurately define a problem; to encourage a pragmatic orientation that informs better decision making; and to help to address the issues of bias, ego, special interests, and personal agendas.

At the core of the REAL Knowledge Model is the operational KM cycle activities of capture, share, and discover, but with an effectiveness measure paired with the knowledge activity. For example: capturing knowledge is the action and retaining is the measure; sharing knowledge is the action and applying is the measure; and discovering is the action and creating outcomes is the measure. Surrounding the REAL Knowledge core activities are the Individual/Team Knowledge factors and the Organizational/Societal Expectations that mitigate the journey of the Challenge/Opportunity from inception through the knowledge cycle to successful project outcomes. Note that the process arrows are bi-directional in terms of influence and input, a guarantee of continuous change, learning, and adaptation.

In describing the REAL Knowledge Model, the following top-level generic flow serves to illustrate a potential progression of knowledge activity:

1. A *Challenge/Opportunity* is selected and prioritized (characterized by *Leadership, Knowledge, Project World, Portfolio*, and *Problem*-centric imperatives).
2. A learning project plan that compliments the project charter and project plan is initiated (characterized by K*nowledge, Accelerated Learning, Frugal Innovation* and *Governance, Business Management and Operations imperatives*).
3. The functional communities of practice are recruited with points of contact identified (characterized by *Leadership, Project World, Knowledge,* and *Talent Management* imperatives).
4. The core operational KM cycle is supported by specific KS learning strategies, methods, models, and technology tools to better define the opportunity; aggregate the data, information and knowledge; populate the alternatives for project decisions; provide appropriate online and traditional environments to spur and support innovation through discovery and creation; and support implementation through progressive and iterative knowledge support as the project proceeds through the lifecycle (characterized by *Knowledge, Technology, Frugal Innovation,* and *Accelerated Learning* imperatives).
5. Individual and Team Knowledge is leveraged, encouraged, supported, and enhanced through KS activities (characterized by *Knowledge, Talent Management, Accelerated Learning, Transparency, Frugal Innovation,* and *Certification* imperatives)
6. External environment expectations in terms of the organization and broader society are identified and operationalized into objective definitions of performance over time and space (characterized by *Leadership, Knowledge, Transparency, Frugal Innovation, Accelerated Learning, Digital Technology,* and *Governance, Business Management and Operations* imperatives).
7. Project outcomes are achieved in terms of improvement and innovation, and the activity proceeds through closeout to capture and retain lessons for upcoming projects (characterized by *Knowledge, Portfolio Management, Transparency, Accelerated Learning, Governance, Business Management and Operations,* and *Digital Technology.*

The REAL Knowledge Model component definitions are provided along with associated keywords and concepts to aid potential future research in taxonomies and ontologies related to the narrower model and to the broader knowledge and learning disciplines:

- **The *Challenge/Opportunity*** is a problem-centered issue in terms of a product or service that presents a potential for action toward defined outcomes. Possible keywords and concepts include: Vision and Possibilities; Requirements; and Organizational Capacity in Technological, Social, Political, Economic, and Learning.
- ***Individual and Team Knowledge*** are formal and informal individual and collective education, professional development, and lessons from direct and indirect experience applied to a *Challenge/Opportunity*. Possible keywords and concepts include: Assignments; Abilities; Formal Education; Professional Development; and Mentoring.
    - *Attitudes and Values* are the predispositions based on learning, experience, and the Challenge/Opportunity to evaluate the environment in particular ways. Possible keywords and concepts include: Personality and Inclination, Resilience, Open-mindedness, Curiosity and Skepticism, and Tempered Optimism. Note that these attitudes and values may also be collectively reflected in Organizational and Societal Expectations.
    - *Heuristics and Biases* are cognitive shortcuts and simplifications by individuals, teams, and organizations used to reduce complexity. Possible keywords and concepts include: Normalization of Deviance, Problem-solving and Decision Making, Fundamental Attribution Error, and Culture of Silence. These may be collectively reflected in Organizational and Societal Expectations.
    - *Abilities and Talent* are learned or natural patterns of action for both individuals and teams that possess potential to achieve goals. Possible keywords and concepts include: Critical Thinking and Creative Thinking; Problem Solving and Decision Making; Creating Alliances; and Leadership and Persuasion. These may be collectively reflected in Organizational and Societal Expectations.
    - *Project Knowledge* is the sum of the formal and informal individual and

team knowledge as previously discussed within the project context that is applied to existing and new data and information to a *Challenge/ Opportunity* to gain efficiency and effectiveness toward project outcomes. Possible keywords and concepts include: Success Stories and Failure Stories; Learning through Analogies; and Organizational Learning. These may be collectively reflected and applied through Organizational and Societal Expectations.

» ***Expectations*** are assumptions on probability of event occurrence for individuals, groups, organizations, and societies based on learning and experience. Possible keywords and concepts include: Adaptation to Change; Reputation; Executive Communications; and Past Performance.

  - *Organizational Culture* comprises common sets of values and assumptions that guide behavior in organizations that inform problem-solving and decision-making activity. Possible keywords and concepts include: Organizational Norms and Mores; Environmental Context; and Performance Management.

» ***Knowledge Capture and Retention*** is a core knowledge step involving the identification and storage of relevant content and skills. Possible keywords and concepts include: Alliances, Communities and Networks; Cases and Publications; Risk Records, Mishap Reports, Organizational Communications; and Stories.

» ***Knowledge Sharing and Application*** is a core knowledge step involving the representation, promulgation, and utilization of searchable and findable relevant content and skills. Possible keywords and concepts include: Digital Technology Tools; Informal Learning; and Best and Emerging Practices.

» ***Knowledge Discovery and Creation*** is a core knowledge step that covers original content and skills derived and developed from previous relevant content and skills that result in project outcomes. Possible keywords and concepts include: Searchability and Findability; Taxonomies; and Innovation.

» ***Project Outcomes*** are the achievement of original or improved products or services as defined by the project charter and validated by organizational expectations. Possible keywords and concepts include: Value; Improvement; Innovation; and Learning, Knowledge, and Growth.

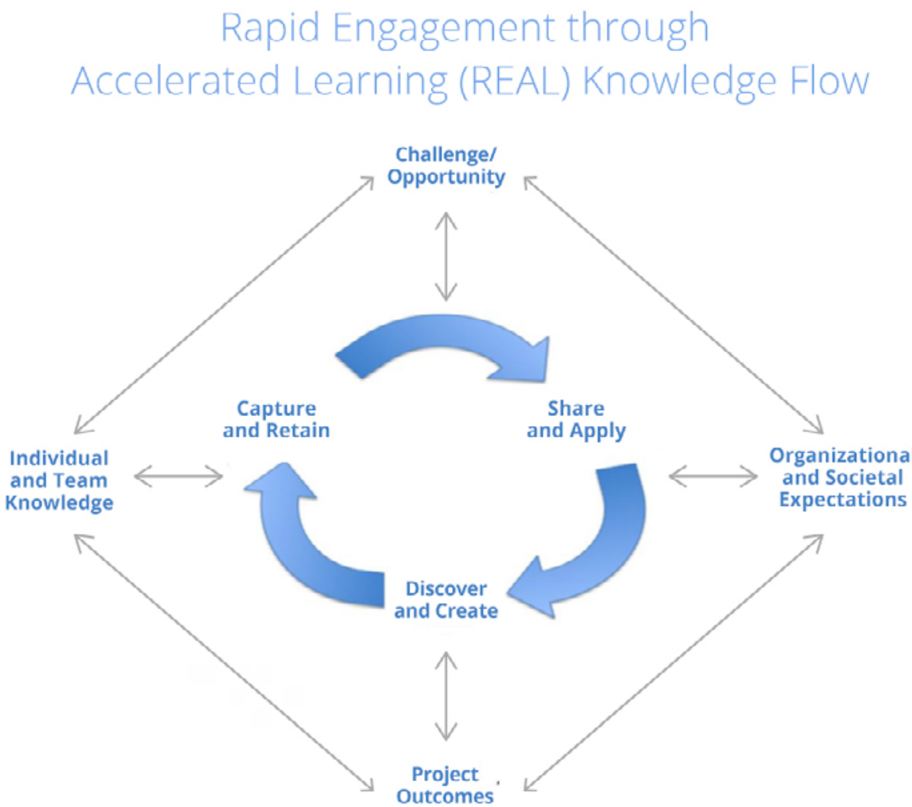

Figure 3: NASA REAL Knowledge Model

One of the components in the REAL Knowledge Model, *Organizational and Societal Expectations,* needs to be discussed due to its importance when addressing the topic of complexity. Human cognition is colored by inherent hard-wired preferences in thinking and in shortcuts that accompany decision-making processes, a product of choices and evolution. *Biases and heuristics* serve to reduce the amount of complexity, but also may introduce error. Additionally, these predispositions may differ across cultures. NASA represents a complex technical organization consisting of several divergent domestic and international cultures with different perceptions. Understanding these perceptions is important for the success of NASA's projects, especially since eighty percent (80%) of NASA programs and projects are international in nature.

Biases and heuristics **are not just cognitive distortions that affect decisions, but also social biases that affect individual and organizational behavior as well as learning and memory tendencies that affect perceptions and explanations of the world.** In our interview with Nobel Prize-winning scientist Daniel Kahneman on his recent *New York Times* bestseller *Thinking Fast and Slow* (2013), he clarified how humans address increasing levels of complexity in the project environment through *heuristics* that can introduce errors into decisions, a veritable catalog of fundamental predispositions that characterize human cognition.

System 1–type thinking is fast, instinctive, and emotional, whereas System 2–type thinking is slower, more deliberate, and more logical. Kahneman delineates cognitive biases associated with each type of thinking, starting with his own research on loss aversion, the unsettling tendency of people and organizations to continue funding a project that has already consumed a tremendous amount of resources but is likely to fail simply to avoid regret. From framing choices to substitution, the book highlights several decades of academic research to suggest that people place too much confidence in human judgment, resulting in different outcomes even given the same information input.

Biases and heuristics **should be viewed not exclusively in a negative context, but one where these distortions and shortcuts can also provide positive outcomes.** Many projects would not be started if executives waited until all the data and information were available to make a rational decision. *Biases and heuristics* serve to create an environment where possibilities and vision can drive an idea toward reality. Busenitz and Barney (1997) found that there is a fundamental difference in the way that entrepreneurs and managers in large organizations make decisions, and that biases and heuristics drive entrepreneurial decisions and are used to reduce complexity in the project environment, simplifying decision making and preventing data and information from overwhelming programs and projects, as well as serving to achieve buy-in and motivating practitioners. This often morphs into a tremendous disadvantage as projects mature from start-up activities to implementation and sustainability requirements. A brief set of examples from a rather extensive catalog are:

» Availability: Making judgments on the probability of events by how easy it is to think of examples and their consequences.

- Substitution: Substituting a simple question for a more difficult one.
- Optimism and loss aversion: Generating the illusion of control over events and fearing losses more than we value gains.
- Framing: Choosing the more attractive alternative if the context in which it is presented is more appealing.
- Sunk-Cost: Throwing additional money at failing projects that have already consumed large amounts of resources in order to avoid regret.
- Mental Filter: Focusing on one feature of something that influences all subsequent decisions.
- Fundamental Attribution Error: The tendency to overemphasize personality-based causes of behavior and underemphasize situational-based causes of behavior.
- Egocentric Bias: Recalling prior events in a favorable light to one's self rather than an accurate objective analysis.

Another important facet of the REAL Knowledge Model is in what NASA refers to as the four (4) **As:** ***Ability, Attitude, Assignments,*** **and** ***Alliances.*** These components of the Model are extracted from the Interpersonal and Team Knowledge, Attitudes and Values, Abilities and Talent, Knowledge Capture and Retention, and Knowledge Sharing and Application components. They are represented in Figure 4 across personal and interpersonal dimensions of effectiveness:

Figure 4: The 4A Word Cloud

CHAPTER FIVE

REAL KNOWLEDGE EXAMPLES AT NASA

The problems that NASA projects seek to solve are often novel in nature—"firsts" or "onlies" that increasingly demand the application of strategic imperatives such as frugal innovation, findable and searchable knowledge, and accelerated learning.

REAL Knowledge Services derived from the Model are designed to promote excellence in project management and engineering by building a community of practitioners who understand the knowledge flow framework of the organization and are reflective and geared toward sharing.

By facilitating and integrating agency-wide KS through interviews, forums, conferences, publications, research and digital offerings, the CKO Office helps ensure that critical lessons and knowledge remain searchable, findable and adaptable. The CKO knowledge network extends beyond NASA as well, to include expert practitioners from industry, academia, other government agencies, research and professional organizations, and international space agencies. This section covers three (3) examples of REAL Knowledge KS activities.

NASA CRITICAL KNOWLEDGE ACTIVITY

These are based on discussions with NASA senior leaders and are conducted by the NASA CKO Office to identify and understand high-priority lessons learned from the executive point of view that have significant impact on programmatic and engineering mission success for the overall agency. The intent is to identify an executive most-critical lessons list and ensure that list is appropriately captured in agency-level policies, standards, and learning and development programs.

The REAL Knowledge framework represents this as executive knowledge that creates organizational expectations for ongoing and future projects as well as informing all three of the central operational knowledge process elements and activities. Note that these lessons are heavily informed by previous program and project outcomes. This effort is driven primarily by the strategic knowledge imperatives of *Leadership, Knowledge, Portfolio Management, Transparency, Accelerated Learning, Problem-Centric Approach,* and *Technology*.

This activity was initiated across Centers, Mission Directorate, and Functional Office leadership in response to an Aerospace Safety Advisory Panel (ASAP) recommendation for a continuous, risk-informed, prioritized and formal effort in knowledge capture and lessons learned that will make them highly visible and easily accessible across NASA, supplemented by formal incorporation into appropriate policies and technical standards of those lessons that are most important to safety and mission success.

To achieve buy-in at the executive level, the process begins with interviews of senior leaders designed to promote a discussion that identifies critical mission knowledge and high-priority lessons learned. For NASA, it turned out that executives were very enthusiastic to share their views on these lessons but did not feel they had time or a process to ensure retention, sharing, and discovery of them for the technical workforce. Examples of sources for data, information, and knowledge for these lessons were identified as:

- Program and Project reviews
- NESC Technical Reports
- Mishap Findings
- Lessons-Learned Information System (LLIS) submissions

» ASAP recommendations

» Interviews

» Knowledge-sharing Forums

» Other technical findings as appropriate

This activity addresses a factor in the original question of managing projects in an increasingly complex project environment. Examples of complex environments abound: the management of the London Olympics; the development of new pharmaceuticals; the engineering of new airliners like the Boeing 787; and the development of new weapons systems such as the Joint Strike Fighter. The multi-disciplinary aspect of integrating the discipline technologies required for these systems is daunting, and requires project managers to juggle several balls in terms of which choices will result in the best outcomes for their projects. The more disciplines that are involved, the deeper and faster is the data and information stream.

Managing teams in this environment is another facet of complexity, as well as managing all of the other project interfaces in the broader environment so that the expectations of customers and stakeholders remain reasonable. Finally, since rarely does a plan remain immutable, changes of all magnitudes and bandwidths must be factored into the project equation. Critical Knowledge services at the front end of the process help to set and promulgate organizational expectations as well as identify and leverage existing and potential digital channels of distribution and engagement. It also functions to identify critical biases and heuristics at the executive level that can potentially be mitigated or translated into improved project measures and metrics.

As the Critical Knowledge activity progresses, the characteristics of appropriate agency lessons were defined in coordination with executives and the ASAP.

To qualify as Critical Knowledge within this framework, the lessons would need to fit the following criteria:

» **Possess broad applicability** across the agency that does not only refer to narrow information and knowledge essential only to a specified discipline community.

» **Represents the top five percen**t (5%) of updateable knowledge that is most important for programmatic and engineering missions to learn and implement.

- **Involve knowledge that keeps evolving** toward new applications and missions within a cost-constrained organizational environment.
- **Lends itself to a formal process** under current and future NASA knowledge services for formal incorporation into appropriate policies and technical standards as well as to technical workforce learning and development products and activities to prevent skills dissipating over time.

Once the interviews were completed and analyzed, the NASA CKO and Deputy CKO reported the results back to NASA executives and presented a proposal for the Knowledge Referee process (Table 2) that would determine lesson applicability, importance, evolution, and integration. This process is envisioned to occur bi-annually at NASA Headquarters and iteratively briefed to the NASA Deputy Administrator and the ASAP as well as Centers, Mission Directorates, and Functional Offices.

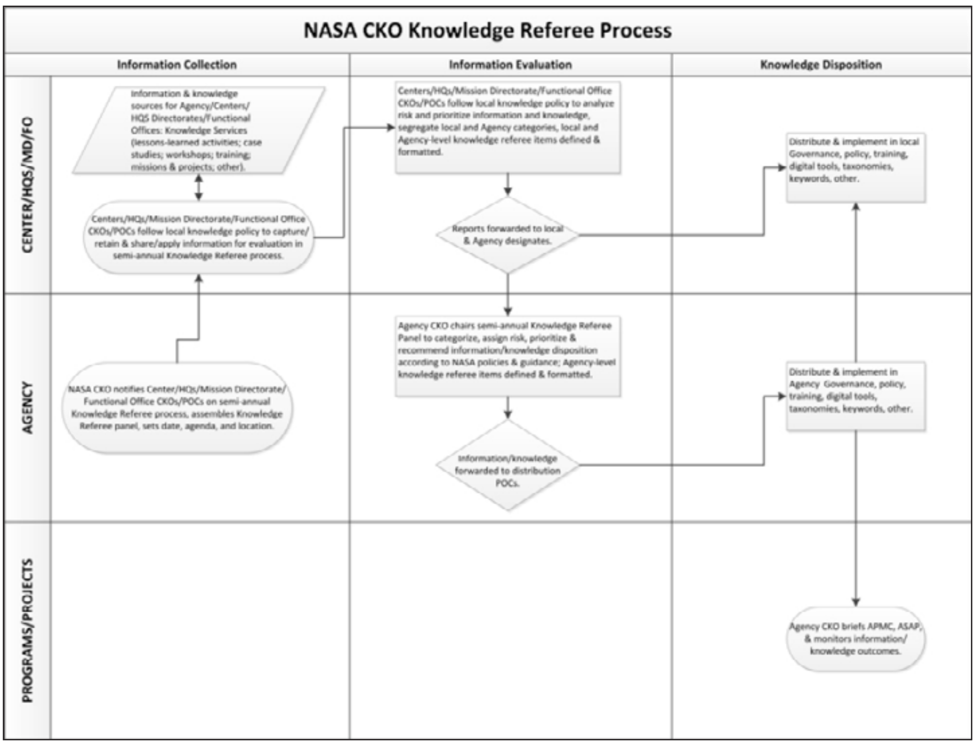

Figure 5: NASA Knowledge Referee Process

KNOWLEDGE FORUMS

Communication about the effective use of knowledge is central to all leadership and management challenges and is critical to the success of NASA's missions and the organization's long-term sustainability. The complexity of NASA's programs and projects demands an open, vigorous culture where communication is continuous, empowering individuals and teams at all levels to ask questions, share information, and raise concerns.

One form of KS that particularly lends itself to multiple requirements and formats is the Knowledge Forum. This format is particularly adaptable across organizational constituencies and is cooperatively designed to promote open communications through a number of channels about best practices, lessons learned, and new developments at NASA and throughout the world. These Forums range from small, engaging one-day events at Centers to agency-wide synchronous and asynchronous discussions with leading practitioners that are captured digitally and modularized through multiple distribution channels such as NASA TV.

The Forum service is driven primarily by the strategic knowledge imperatives of *Leadership, Knowledge, Talent Management, Portfolio Management, Transparency, Frugal Innovation, Problem-Centric Approach, Accelerated Learning,* and *Technology.*

Each customized Forum features leading experts and practitioners selected by the particular organizational entity and involves relevant knowledge-related challenges, relevant case studies, formal and informal discussions, and networking in order to accelerate learning and cultivate a vibrant knowledge network that can benefit NASA and its partners, customers, and stakeholders. Attendance is both virtual and physical, and leverages social media for concurrent and follow-on engagements.

Just months before the retirement of the Space Shuttle, a Forum entitled *Passing the Torch* provided an opportunity for master practitioners from the Space Shuttle and Constellation programs to reflect on some of the lessons-learned from the formulation, development, and operations of their programs and to look forward to and anticipate future space transportation systems requirements. As with most KS activities, it was a collaborative effort across the Academy and the Public Affairs Offices of Kennedy Space Center and NASA

Headquarters. The program included several panel discussions, including one dedicated to Young Professionals from various NASA centers and academia.

A final Forum example was the *Principal Investigator* (PI) *Team Forum*, an iterative collaborative effort between the NASA CKO and the Science Mission Directorate (SMD) that brought together teams from the Discovery mission Announcement of Opportunity (AO) process and the Mars 2016 Trace Gas Orbiter mission to gain a better understanding of the role of a Principal Investigator (PI) at NASA. Expert practitioners from past science missions shared stories, perspectives, lessons learned, and best practices with their colleagues. The proceedings from the forum were published in a multimedia wiki that keeps the knowledge updated and relevant. SMD currently views this activity as critical and it is a mandatory event for new NASA PIs.

PROJECT HOPE (HANDS-ON PROJECT EXPERIENCE)

An example of an agency-wide knowledge priority that focused on Talent Development as a priority was a cooperative workforce development program sponsored with the Science Mission Directorate (SMD) called Project HOPE (Hands-On Project Experience).

***Project HOPE* was driven primarily by the strategic knowledge imperatives of *Leadership*; *Project World*; *Knowledge*; *Talent Management*; *Frugal Innovation*; *Problem-Centric Approach*; *Accelerated Learning*; *Governance*, *Business Management*, *Operations*; and *Digital Technology*.**

This KS was designed to provide an opportunity for a team of early-entry NASA managers and engineers to propose, design, develop, build, and launch an actual suborbital flight project over the course of eighteen (18) months, enabling practitioners in the early stage of their careers to gain the knowledge and skills necessary to manage NASA's real future flight projects. All of the organization's governance, business management, and operations policies, procedures, standards, and sources of knowledge were applied to the project, yielding critical lessons within a real world context.

One example project was the joint Ames Research Center (ARC) and Langley Research Center (LaRC) ***Radiation Dosimetry Experiment*** **(RaD-X)** that was designed to obtain the first-ever, high-altitude dosimetric measurements of cosmic ray interaction in the upper atmosphere, while combining LaRC's unique capabilities in space weather applications, radiation effects on air transportation, and microsatellite development to create a low-risk, high-fidelity mission that addressed agency programmatic goals. Public and private entities currently use the NASA *Nowcast of Atmospheric Ionizing Radiation for Aviation Safety* (NAIRAS) model for informed decision making about radiation exposure safety for flight crews, the general public, and commercial space operations. RaD-X improves NAIRAS by obtaining data to perform verification and validation activities that enhance this capability. The project also strengthens microsatellite development at LaRC. The RaD-X microsatellite structure developed at LaRC flies on a scientific research balloon for 24 hours at approximately 36 km (~120,000 ft) and validates low-cost sensors for future missions and provides data to improve the health and safety of all future commercial and military aircrews that transit the poles.

The ***High Energy Replicated Optics to Explore the Sun*** (HEROES) project was a joint effort by Goddard Space Flight Center (GSFC) and Marshall Space Flight Center (MSFC). It involved a balloon-borne hard X-ray telescope observing solar flares with one hundred (100) times better sensitivity and fifty (50) times more dynamic range than the best solar observations to date. The instrument provided new views (improved angular resolution and sensitivity) of hard X-ray astrophysical targets. The HEROES team modified and flew the HEROES telescope to perform solar observations while taking advantage of nighttime for astrophysical observations. The project built on previous knowledge from past flight projects at MSFC and previous GSFC experience in developing instrumentation for solar observations and performing quality solar data analysis. It paved the way for future generations of both solar and astrophysics space-borne hard X-ray imager missions and the scientists and engineers to support them.

The ***Development and Evaluation of Satellite Validation Tools by Experimenters*** (DEVOTE) project was flown by LaRC. This project successfully achieved its science goals of enabling evaluation of next-generation satellite retrievals focusing on the ***ACE Decadal Survey Mission***; developing an in situ measurement platform that would be available for frequent and relatively low cost flights; developing advanced instruments; and comparing measurements to satellite and ground-based instruments. At the project's end, the DEVOTE team had successfully completed all planned modifications to the aircraft enabling both in situ and remote sensing platforms; flown 12 science flights for over 69 hours; and successfully completed all of its science and training objectives.

The ***Coastal and Ocean Airborne Science Testbed*** (COAST) project was flown by ARC over Monterey Bay, California. The team integrated and simultaneously flew three instruments in the testbed: a sun photometer, an imaging spectrometer, and radiometers. The instrument suite obtained data during the mission coincident with measurements from existing satellite sensors, measurements from a research vessel, and a small set of ground calibration sites.

A final example is the ***Terrain-Relative Navigation and Employee Development*** (TRaiNED) project by the Jet Propulsion Laboratory. In 2006, an initial development test was conducted onboard a sounding rocket flight that collected analog ground imagery during the descent portion of the rocket trajectory and positional data from launch to landing. This data were then used to further develop and test *Terrain-Relative Navigation* (TRN) computer algorithms. The TRaiNED project was the next step in the development of this new technology. As a second developmental test flight, the TRaiNED project advanced the first flight results by expanding the data set to include exo-atmospheric imagery in addition to descent imagery. Key members from the initial project acted as mentors for the TRaiNED team and assisted with the design, fabrication, and testing of the payload.

CHAPTER SIX

SUMMARY AND FUTURE RESEARCH

How can organizations and practitioners best leverage project knowledge and knowledge services to get things done in the modern complex project environment?

For NASA, KS was a steady progression of maturity influenced by the requirements of specific missions over time. The agency today is not the same one that went to the moon. Individual capability driven by internal experts fit the organization at the beginning, but that soon morphed into a team-based approach driven by diverse mission requirements as the purpose of the agency changed over the years.

The complexity of the project environment addressed by this paper forces KS to adjust to the new realities of knowledge findability, searchability, and adaptability, highlighting the need for accelerated learning within a systems perspective and revealing the synergy between the disciplines of Knowledge Management and Organizational Learning.

Recent stakeholder messages from 2002 through 2012 have indicated that NASA needs to take advantage of opportunities for greater coordination and collaboration across the organization (Aerospace Safety Advisory Panel, 2011

Annual Report). The agency formally recognized this need by designating the first NASA CKO to serve at the executive level for the agency.

The strategic imperatives that guide the development of NASA KS are a product of their times, addressing the realities and requirements for planning and action concerning leadership, complexity, limited resources, communication, knowledge, individual and organizational capability, and process. These imperatives can take different forms depending on specific organizational characteristics and needs at the strategic, operational, and tactical levels.

For NASA, the federated approach allowed an effective balance of autonomy and responsibility. With this approach, the knowledge community generated common definitions and purpose and developed reinforcing products and services that addressed both local and agency knowledge considerations, to include a new knowledge policy, an agency knowledge map, chairmanships of the Federal Knowledge Community and the and the development of the NASA REAL Knowledge Model. This model allowed the agency to formulate KS activities that addressed the strategic knowledge imperatives, achieve buy-in across diverse communities, and accelerate learning to reduce complexity and ensure risks based on knowledge were identified and mitigated or eliminated.

The REAL Knowledge Model was presented as a descriptive model of how knowledge flow and knowledge services work at NASA. Future research can advance the understanding of the components of this model to achieve normative assumptions, definitions, and standards that promote effective and efficient knowledge practices that reduce complexity and accelerate learning to achieve successful outcomes.

Accordingly, the following future research initiatives should advance understanding and yield practical benefits for project organizations:

1. What are the characteristics of challenges and opportunities that achieve organizational and individual commitment, align individual and organizational agendas, and promote effective project management?
2. How should organizations systematically address talent development in terms of Abilities, Attitudes, Assignments, and Alliances?
3. What are the metrics and measures that best capture effectiveness and efficiency in the knowledge processes and outcomes of capturing and retaining, sharing and applying, and discovering and creating?

4. Can biases and heuristics that drive organizational and societal expectations be identified and addressed to inform how organizations can make better decisions and design better measures for the Challenge/Opportunity, the core Knowledge Processes, and Project Outcomes?
5. What are the operational definitions and certification parameters of knowledge behaviors for project practitioners and how do they address talent development and capability requirements?
6. How can the characteristics that make data and information searchable and findable and result in adaptable knowledge in a systems approach to organizational knowledge and learning be operationalized to effective requirements and behaviors?
7. What is the nature of the relationship between knowledge services, accelerated learning, and reducing complexity?

CONCLUSION

There is much work and research needed for addressing how organizations and practitioners can best leverage project knowledge and knowledge services to get things done in the modern complex project environment. The potential mitigating and complicating variables that reduce the power of knowledge and learning are too numerous to list, but a descriptive model from a organizational systems perspective can serve as a framework to ensure that the breadth of relevant components are identified and operationalized, as well as serving as a map for future research toward informing a normative project knowledge model.

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