Personalization and Codification at NASA:

A Case of an Evolving Knowledge Management Strategy

By

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Declaration

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Summary

Ikujiro Nonaka proposed the distinction between tacit and explicit knowledge in his classic paper "The knowledge-creating company". Nonaka's archetypes proved foundational for the field of knowledge management, dominating subsequent theoretical discourse and strongly influencing knowledge management strategy in the years that followed. The influence of Nonaka's tacit-versus-explicit distinction on knowledge management strategy can be seen most clearly in a paper published by Hansen, Nohria and Tierney entitled "What is your strategy for Managing Knowledge?" in the Harvard Business Review. Building on Nonaka's tacit-versus-explicit distinction, Hansen et al. contend that an organization's knowledge management strategy must either focus on codification or on personalization, highlighting how each of these strategies exhibits distinct organizational characteristics and warning that attempting to straddle both strategies risks organizational failure.

While Nonaka's tacit-explicit paradigm remains influential as a foundational concept in knowledge management, Hansen et al.'s extension of this concept has subsequently been criticized and disproved by several authors. This thesis takes a fresh look at Hansen et al.'s theory in the context of the National Aeronautics and Space Administration (NASA) to determine whether NASA conforms to Hansen et al.'s theory and whether this conformity/non-conformity has any effect on NASA's effectiveness as a knowledge organization as predicted by Hansen et al. However, while authors to-date have focused on whether an organization conforms to one of Hansen et al.'s extreme archetypes, none have looked at the evolution of an organization's knowledge management practices over time through the lens of Hansen et al. NASA is a knowledge-intensive organization with a long and publicly-available record that not only documents its of knowledge management practices but also its successes and failures as well as the considerations that shaped its knowledge management strategy.

This analysis uses the organizational characteristics identified by Hansen et al. to evaluate NASA's current competitive strategy, knowledge-economics model, knowledge management strategy, I.T. strategy and human resources strategy. The analysis also shows how NASA's previous knowledge management strategies focused alternately on personalization and then on codification, and how NASA experienced and responded to the respective limitations of each strategy. The results of the analysis show that NASA cannot be classified as either pursuing an archetypical codification or personalization strategy, and that despite straddling both strategies the organization is showing a strong positive performance.

Opsomming

Ikujiro Nonaka het in sy klassieke artikel "The Knowledge Creating Company" 'n onderskeid tussen stilswyende en eksplisiete kennis getref wat in die veld van kennisbestuur 'n fundamentele onderskeid geword het en die teoretiese diskoers oorheers het. Die onderskeid het onder meer die kennisbestuurstrategie in die daaropvolgende jare sterk beïnvloed. Hierdie invloed is duidelik waarneembaar in 'n belangrike artikel deur Hansen, Nohria en Tierney, getiteld "Wat is jou strategie vir die bestuur van kennis?" in die Harvard Business Review. Die artikel beweer dat 'n organisasie se kennisbestuurstrategie óf moet fokus op kodifikasie of op personalisasie, en beklemtoon hoe elk van hierdie strategieë met afsonderlike organisatoriese eienskappe gepaardgaan en waarsku dat 'n poging om beide strategieë te volg waarskynlik onsuksesvol sal wees.

Terwyl Nonaka se idees steeds 'n invloedryke grondbeginsel van kennisbestuur is, het verskeie latere outeurs Hansen et al. se toepassing van hierdie idees op kennisbestuurstrategie gekritiseer. Hierdie tesis oorweeg Hansen et al se teorie in die konteks van die "National Aeronautics and Space Administration" (NASA) om te bepaal of die organisasie se kennisbestuurstrategie Hansen et al. se teorie gestand doen en of enige effek op NASA se doeltreffendheid as 'n kennisorganisasie soos voorspel deur Hansen et al. naspeurbaar is. Hoewel skrywers tot op datum gefokus het op die vraag of 'n organisasie aan een van Hansen et al. se uiterste argetipes voldoen of nie, het niemand tot dusver na die evolusie van 'n organisasie se kennisbestuurstrategie en praktyke gekyk deur die lens van Hansen et al. se teorie nie. NASA is 'n kennisintensiewe organisasie met 'n lang en publiek toeganklike dokumentasie van die kennisbestuurspraktyke wat gevolg is, sowel as oor suksesse en mislukkings, en die oorwegings wat bepalend vir hulle kennisbestuurstrategie was.

Hierdie analise gebruik die organisatoriese eienskappe wat deur Hansen et al. geïdentifiseer is om NASA se huidige strategie, kennis-ekonomiese model, kennisbestuurstrategie, informasie tegnologie strategie en menslike hulpbronne strategie te evalueer. Die analise toon hoe NASA se vorige kennisbestuurstrategieë afwisselend gefokus het op personalisering en kodifikasie, en hoe NASA die onderskeie beperkings van elke strategie ervaar het en daarop gereageer het. Die resultate van die analise toon dat NASA nie geklassifiseer kan word

as 'n organisasie met 'n tipiese kodifikasie- of personaliseringsstrategie nie, en dat die organisasie, ten spyte van Hansen et al. se argument, 'n sterk positiewe prestasie getoon het.

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1. Introduction

1.1 Background

In 1991 Ikujiro Nonaka proposed the distinction between tacit and explicit knowledge in his classic paper "The knowledge-creating company" (Nonaka, 1991). Tacit knowledge is characterized as being highly personalized therefore difficult to formalize, and typically perceived to be knowledge that resides in a person's head. Explicit knowledge is more formal and systematized, and is most often equated with knowledge codified on paper. Nonaka's archetypes proved foundational for the field of knowledge management, dominating subsequent theoretical discourse and by extension strongly influencing knowledge management strategy in the years that followed.

The influence of Nonaka's tacit-versus-explicit distinction on knowledge management strategy can be seen most clearly in a paper published in the Harvard Business Review in 1999 entitled "What is your strategy for Managing Knowledge?" by Hansen, Nohria and Tierney. Building on Nonaka's tacit-versus-explicit distinction, Hansen et al. (1999) contended that an organization's knowledge management strategy must either focus on codification (based on explicit knowledge) or on personalization (based on tacit knowledge). Hansen et al. highlighted how each of these strategies exhibits distinct organizational characteristics and warned that attempting to straddle both strategies would lead to the risk of organizational failure. Hansen's et al.'s (1999) theory is also interesting because the authors make bold assertions that are fundamentally connected with their own perception of how knowledge should be defined and the way in which it should be managed. Chief among these is Hansen's et al.'s perceived co-dependency between innovation and personalization, and the idea that codification and personalization practices should be treated as substitutes than as complements when it comes to managing knowledge.

While Nonaka's tacit-explicit paradigm remains influential as a foundational concept in knowledge management, Hansen et al.'s (1999) extension of this concept into the codification-versus-personalization paradigm has been criticized and disproved by several authors. Hansen et al. can arguably be considered at risk of being discounted as being outdated and irrelevant, as the thinking around knowledge management strategy has 'moved on since then'. However, Hansen et al.'s theory nevertheless retains value as it extends

Nonaka's foundational concepts into their strategic equivalents. It seems that Hansen et al.'s resulting archetypes are rarely mirrored in actual organizations, but remain useful in denoting the two extreme types between which a knowledge management strategy can locate and characterize itself.

This thesis will investigate current knowledge management practices at the National Aeronautics and Space Administration (NASA) in order to find out whether NASA's organizational structure and its knowledge management practices align it with Hansen et al.'s (1999) archetypical codification-based or personalization-based organizations. NASA was actively engaged in efforts to better manage its knowledge in 1990s, and can be considered to be an early-adopter at a time when knowledge management practices advocating the codification of knowledge were current. This study will not only look at NASA's knowledge manage practices, but also how and why it got there.

Whether NASA aligns or not with one of these archetypes will help to determine whether having a knowledge management strategy that is predominantly characterized by codification or personalization is necessary for organizational success, or whether attempting to straddle both strategies will result in organizational failure. This will support a second aspect of the analysis, which is to show how NASA's knowledge management strategy has evolved over time, since the advent of Nonaka's tacit/explicit distinction to the present day. This will show how in the early days knowledge management at NASA focused on personalization and then in the mid-1990's altered its focus to codification before finally a mixed strategy as NASA experienced and responded to the limitations inherent in each strategy over the years.

This is important because authors to-date in their criticisms of Hansen et al. (1999) have focused on whether an organization conforms to one of Hansen et al.'s extreme archetypes at a point in time. No authors have taken an organization and used Hansen et al. to look at the evolution of its knowledge management practices over time. However, because NASA is an innovative and knowledge intensive organization with a readily available record of knowledge management practices going back at least as far as the early 1980s it is possible to apply Hansen et al. (1999) to NASA in this way.

In order to use NASA as a test case for Hansen et al.'s (1999) theory this study needs to determine the conceptual boundaries of Hansen et al.'s theory, identify the key elements of

Hansen et al.'s (1999) theory, and then review knowledge management activities at NASA in terms of each of these elements to determine the extent to which knowledge management activities at NASA conform with Hansen et al.'s theory. This will be done in the next section.

1.2 Hansen et al.'s (1999) theory

In 1999 a paper by Hansen, Nohria and Tierney entitled "What is your strategy for Managing Knowledge?" appeared in the Harvard Business Review. The paper was attempting to show that when it comes to managing its knowledge, an organization must decide between taking an approach that is either predominantly about codification or an approach that is predominantly about personalization. Hansen et al.'s theory highlighted how each strategy is characterized by specific organizational characteristics, and concluded with the caveat that attempting to straddle both strategies is likely to undermine organizational success. This section provides a brief overview of Hansen et al.'s (1999) paper, highlighting it main points with respect to codification versus personalization.

1.2.1 *Hansen et al.'s (1999) paper in brief*

Hansen et al. (1999) begin by explaining that the growth in intellectual assets in organizations across the world has resulted in the increased need for knowledge management practices and I.T. capabilities to support these knowledge management practices.

The two main strategies identified by Hansen et al. (1999) are (i) the strategy of codification of knowledge, and (ii) the strategy of personalization knowledge. They explain the nature of each of these strategies, and then go into further detail concerning the economic model, knowledge management strategy, information technology requirements, and human resources implications of each strategy.

Hansen et al. (1999) substantiate the discussion with examples of how these two different strategies are used across different management and strategic consultancies, noting that because these organizations involve knowledge intensive practices they tend to be leaders in knowledge management and in using I.T. to support knowledge management. The authors go on to show how these principles are also applied by organizations in the healthcare sector, and in the industrial sector.

The paper then goes on to discuss how the characteristics of the company will influence the choice of strategy and identifies some key questions that can help to clarify how choice of knowledge management strategy can support competitive strategy. Hansen et al. (1999) also discuss additional concerns such as whether different knowledge management strategies can be applied to different business units within the same organization, and how to adapt to the commoditization of knowledge over time.

A summary of the above points with respect to the codification and personalization strategies will follow here, as well as regarding the role of company characteristics, the key questions, and the additional concerns. The real-world examples used by Hansen et al. (1999) to illustrate the discussion will not be included, as the intention is to summarize the theoretically relevant points of Hansen et al.'s paper rather than to replicate its whole contents.

1.2.2 *The codification strategy*

Hansen et al. (1999) do not commit to a stated definition of codification, but rather explain it throughout the paper by reference to examples:

> *"Knowledge is carefully codified and stored in databases, where it can be accessed and used easily by anyone in the company. We call this the codification strategy." (Hansen et al., 1999: 107).*

> *"Knowledge is codified using a "people-to-documents" approach: it is extracted from the person who developed it, made independent of that person, and reused for various purposes." (Hansen et al., 1999: 108).*

Based on the examples given by Hansen et al. (1999), it can be concluded that codification is a process whereby knowledge is made independent of the originator by being converted into a knowledge asset that can be used by other persons to achieve an outcome requiring specialist knowledge that they do not themselves possess.

Note that in this case a knowledge asset could be taken to mean a paper document, electronic document, process or procedure, or electronic system. Codification means that knowledge is not tied to the originator. When incorporated into the competitive strategy of an organization, this means that that knowledge assets are developed once, and then transferred into a document repository or system that allows it to be reused many times over to implement high-quality, reliable, fast solutions in other projects that have similar requirements.

In terms of economics, one of the main benefits of codification is that costs to produce knowledge are incurred once, and this knowledge can then be reused across multiple projects. Knowledge reuse reduces the turnaround time on projects, thereby increasing efficiency and reducing costs. The standardized approach tends to also be less intensive in terms of communications, as staff are implementing a solution rather than developing one. It also means that staff can be deployed in larger teams with a high ratio of less skilled/experienced staff. The resulting economies of scale allow for more projects to be undertaken at a lower cost and in a shorter time, resulting in higher revenues and a higher company growth rate.

The knowledge management strategy that underpins this is a people-to-documents approach. This means extracting expertise from specialists and storing it in knowledge objects for reuse. These knowledge objects can be designed at the outset, or they can be adapted by taking deliverables from a previous project and making them re-usable for other projects. A knowledge object may be a document but could also take the form of an algorithm in a system. These knowledge objects can subsequently be used by junior consultants to implement complex projects.

The codification approach tends to require a bigger investment in information technology, as more complex systems are needed to store and disseminate the reusable knowledge, and to provide systematic support (for example, to prompt call center users to ask the right questions and provide them with the correct responses). This generally means investing in databases, search engines and/or customer records management systems.

From the human resources perspective, pursuing a codification strategy requires investment in the people and technology to facilitate administration and implementation of knowledge assets. These would not be experts in that field of knowledge, but could be administrative staff such as content managers to curate and maintain the knowledge assets, and staff to implement the knowledge assets (typically junior consultants). Since products are intended to be standardized, staff could be trained in groups or using online training, rather than direct person-to-person mentoring. Graduate-level staff tend to be more affordable, allowing for a higher ratio of lower-level consultants to highly skilled/experienced consultants. A basic amount of high-level staff will persist because there will still be the need for some person-to-person knowledge transfer to ensure that codified knowledge is appropriately applied. The incentive structures in the company would need to be set up to reward contributions to the knowledge base, and the proper use of the systems.

1.2.3 *The personalization strategy*

Hansen et al. (1999) similarly do not provide a consolidated definition of 'personalization', but rather explain it through examples:

> *"[personalization initiatives] focus on dialogue between individuals, not knowledge objects in a database. Knowledge that has not been codified—and probably couldn't be—is transferred in brainstorming sessions and one-on-one conversations. Consultants collectively arrive at deeper insights by going back and forth on problems they need to solve." (Hansen et al., 1999: 107)*

> *"… knowledge is closely tied to the person who developed it and is shared mainly through direct person-to-person contacts. The chief purpose of computers at such companies is to help people communicate knowledge, not to store it. We call this the personalization strategy." (Hansen et al., 1999: 107)*

Based on these descriptions, personalization can be defined as a process that seeks to facilitate the transfer of knowledge and/or the generation of insights through increased interaction between individuals, groups or communities, either directly or indirectly through a system.

An organization seeking to leverage personalization of knowledge in its competitive strategy will be aiming to provide innovative, analytically-rigorous advice on strategic problems by channeling the expertise of highly skilled/qualified individuals.

In terms of economic strategy, value comes from innovation and customized solutions for unique, high-level strategic issues that although resulting in higher costs also commands a significantly higher price tag with higher profit margins than under a codification strategy. Teams are smaller in size, with a higher ratio of experts as they rely on the individual expertise of highly qualified and experienced consultants. Due to the high cost of developing the necessary expertise, such organizations tend to exhibit slower growth.

The knowledge management strategy revolves around person-to-person transmission of knowledge. This necessitates drawing on networks of other experts to share tacit knowledge that is generally too context specific to be effectively codified. This can help to tap into experience from across many projects and specializations, as well as geographically diverse experience.

Information technology plays a more limited role under a personalization strategy. Its main focus is on systems that help foster networks of people. This frequently includes telecommunications, videoconferencing, and directories of experts (also referred to as 'people finders'). While a document repository is generally still required, this serves a more basic objective of holding background information and technical details to support the project, rather than being the source of the solution. Such an organization also typically incurs higher travel, costs as physical meetings are emphasized in addition to telecommunications.

The human resources element under a personalization strategy also differs compared to that of a codification strategy. Under a personalization strategy, the organization relies on its ability to recruit and retain highly qualified staff. For management consultancies this typically means M.B.A. holders with a tolerance for ambiguity and a high capacity for problem solving. Standardized training is replaced by mentoring programs and an emphasis on the accumulation of experience. Collaboration and knowledge-transfer between experts is also essential, meaning that staff need to be encouraged to collaborate and co-operate (for example by returning phone calls promptly), or for example by transferring staff between offices to facilitate the establishment of social networks.

1.2.4 *The dangers of attempting to straddle both strategies*

Hansen et al. (1999) devote a section to warning of the potential dangers of straddling both strategies. Attempting to straddle both codification and personalization strategies can lead to confusion as staff are under pressure to behave as both implementers of a standardized solution (codification) and strategic innovators trying to develop a customized solution (personalization), or they come into conflict with other staff as they try to enact different strategies for the same solution.

Attempting to codify and reuse material can also result in disappointment on the client side when the solution is not specialized enough to addresses the client's particular problem. Codification may have failed to capture enough of the rich tacit knowledge embodied in the source, creating knowledge objects that are not versatile enough and became counterproductive. When the knowledge objects lack detail, the burden of providing that additional tacit knowledge can end up falling on staff that do not have the capacity to handle the load as the situation starts to revert to seeking a personalized solution.

In cases such as the one described above, where an organization recognizes that the generic nature of its solutions is inadequate and tries to compensate by undertaking expensive innovation and personalization of products, the organization can undermine its primary strategy of low-cost service provision through reuse of knowledge objects. This can result in escalating costs and expanding timelines for the client, and reduced margins for the provider.

1.2.5 *Company characteristics and choice of strategy*

As mentioned above, Hansen et al. (1999) give examples of management and strategic consultancies, as well as of organizations in the healthcare sector and the industrial manufacturing sector, describing how the organization's strategy influences its choice of knowledge management strategy and its decision as to whether to pursue a codification or a personalization strategy.

The paper discusses how Andersen Consulting, Ernst and Young, Access Health, and Dell Computers use codification to drive their low-cost, high-growth company strategy. By contrast, organizations like Bain, Boston Consulting Group, McKinsey, Memorial Sloan-Kettering Cancer Centre, and Hewlett-Packard use personalization to support their company strategy of providing highly-customized services and innovative products. Hansen et al. also discuss the case of CSC Index, an organization that attempted to straddle both codification and personalization strategies and ended up undermining its own competitive strategy.

1.2.6 *Three questions to clarify choice of strategy*

Since an organization's competitive strategy should drive the choice of knowledge management strategy, an organization must be clear on what its competitive strategy is. Hansen et al. (1999) provide three questions that can help an organization to clarify how its choice of knowledge management strategy can support competitive strategy.

Question 1: Does the organization offer standardized products or customized products? For standardized products, codification is best. For a customized product, personalization is recommended.

Question 2: Does the organization have a mature product or an innovative product? Mature products make a codified approach possible, while innovative products are better handled using a personalization strategy.

Question 3: Do staff rely on explicit knowledge or tacit knowledge to solve problems? If staff rely on explicit knowledge, codification works better. If staff rely on tacit knowledge, personalization is better. As tacit knowledge exchange requires a lot of nuance and detail, trying to convert inherently tacit knowledge into explicit knowledge is likely to fail.

1.2.7 *Two additional concerns*

The paper notes that there are two additional concerns that need to be taken into account when selecting a knowledge management strategy. These are (i) whether you can apply different knowledge management strategies to different business units, and (ii) how to respond to the commoditization of knowledge over time.

In answer to the first question, Hansen et al. note that codification and personalization strategies can co-exist in an organization, but there must be an emphasis on one while the other strategy plays a supporting role. An exception could be made when business units operate in relative isolation, under which circumstances each business unit could operate under its own competitive- and knowledge-management strategy, and staff would not come into conflict with one another to undermine the benefits.

With respect to the commoditization of knowledge, some knowledge-intensive products/services can become standardized (commoditized) over time and thereby become cheaper and more plentiful. This means that where a certain product/service used to require a skilled expert to do the work, the problem is now well-understood and sufficiently advanced methodologies/systems/processes have been developed that a standardized solution can be implemented by a less qualified person. This can reduce the competitive strategy of companies pursuing a personalization strategy and relying on the need for expensive experts in that field.

In a situation where the knowledge in a certain field has become commoditized, an organization that relies on innovation (personalization) should move out of that area and into new fields that require expert advice. Organizations specializing in implementation (codification) should invest expertise in commoditized knowledge as it matures, acquiring it and moving it to reuse and scalability. The fundamental message here is that organizations should keep their knowledge management strategy unchanged and focus on finding markets where it can be put to better use.

1.2.8 *Conclusion of Hansen et al.'s paper*

As a final caveat, Hansen et al. (1999) note that knowledge management needs to be integrated with the organization's competitive strategy, not just farmed out to the I.T. or human resources department.

Selecting the appropriate knowledge management strategy will benefit both the organization and the customer. However, in the absence of such a choice the customer may get an inappropriate solution and staff become confused about priorities. Ultimately, strong leadership is needed to select the appropriate knowledge management strategy and implement it correctly.

1.3 Methodology

Hansen et al.'s (1999) theory can be summarised as containing three assertions:

(i) An organization can focus primarily on codification or personalization. Even if not explicitly stated, the choice will be evident in the knowledge management practices as well as the competitive strategy, information technology setup, and human resources implications.

(ii) Depending on what approach is primary, the other approach can play a supporting role.

(iii) The two approaches cannot be given equal emphasis without compromising the effectiveness of the organization.

These assertions can be seen as a set of conditions (1 and 2) and a prediction (3) and provide a simple framework for testing if Hansen et al.'s theory holds for knowledge management at NASA. On a basic level, it can be expected that either:

Outcome 1: NASA is consistent with Hansen et al.'s (1999) knowledge management conditions and as predicted by Hansen et al.'s theory is succeeding as an organization, or

Outcome 2: NASA is not consistent with Hansen et al.'s (1999) and as predicted by Hansen et al.'s theory is failing as an organization.

Outcomes 1 and 2 are consistent with Hansen et al.'s (1999) theory. However, there are other alternatives that would call the validity of Hansen et al.'s theory into question, specifically:

Outcome 3: NASA is consistent with Hansen et al.'s (1999) knowledge management conditions but contrary to predictions by Hansen et al.'s theory is failing as an organization. Note that if this is the case it should be considered that this failure could be due to a factor unrelated to knowledge management practices.

Outcome 4: NASA is not consistent with Hansen et al.'s (1999) knowledge management conditions but contrary to predictions by Hansen et al.'s theory is succeeding as an organization.

These outcomes can be represented in the following table:

Table 1 Potential outcomes of the analysis

	NASA succeeding?	NASA failing?
Scenario A: NASA follows Hansen's KM rules	Outcome 1: Hansen's predictions are consistent	Outcome 3: Hansen's prediction did not hold
Scenario B: NASA does NOT follow Hansen's KM rules	Outcome 4: Hansen's predictions did not hold	Outcome 2: Hansen's predictions are consistent

To populate the above analysis, three questions need to be resolved:

1.3.1 *Is NASA focusing primarily on either a codification or a personalization strategy?*

This could be resolved through reviewing materials available on NASA's knowledge management portal, reading transcripts of interviews with NASA CKO's and papers written by them, and NASA's Knowledge Map.

This will be undertaken in chapter 3 (Case Analysis), which has four subsections to consider what sort of knowledge management model NASA is pursuing by considering what its competitive and knowledge-economics strategy, its knowledge management strategy, its human resources approach, and its I.T. strategy tell us about its approach to knowledge management. The characteristics raised by Hansen et al. (1999) in relation to codification and personalization can be summarised in the table below:

Table 2 Organizational characteristics under codification and personalization strategies

	CODIFICATION	PERSONALISATION
Competitive strategy	High quality and reliable products/services provision with fast turnaround and low costs, resulting in rapid growth of market share.	Customized, innovative products/services delivered by channeling individual expertise. This means slower turnaround and higher cost, but steady growth and a high quality/success ranking.
Economic model	Reuse economics means invest once in a knowledge asset, reuse many times; large teams with high ratio of juniors to seniors; Focus is on generating large overall revenues.	Expert economics means highly-customized solutions to unique problems; small teams with a low ratio of juniors to seniors; high fees focused on maintaining high profit margins.
Knowledge management strategy	People-to-documents emphasizes electronic systems that codify, store, disseminate and allow reuse of knowledge.	People-to-people emphasizes dialogue between people, to develop networks so that tacit knowledge can be shared directly.
I.T. strategy	Invest heavily in I.T. to connect people with re-usable codified knowledge.	Invest moderately in I.T. and use it to facilitate conversations and the exchange of tacit knowledge.
Human resources strategy	Recruit young, less experienced staff to act as implementors of reusable knowledge assets. Training is standardized for groups or through online training. People incentivized to contribute to document databases.	Recruit highly-qualified/experienced staff to apply their analytical and creative skills to unique problems. Staff are developed through mentoring and accumulation of experience. Staff are rewarded for sharing knowledge with others.

By looking at how NASA conforms to these parameters it will be possible to tell is focusing primarily on a codification or a personalization strategy.

1.3.2 *Is there evidence of a dominant approach or is there evidence of straddling?*

It is not enough to show that a particular strategy (e.g., personalization) is being followed. It must also be clarified whether the alternative strategy is in a supporting role (i.e., following the 80-20 rule), whether the alternative is absent altogether, or whether there is evidence of straddling. Straddling could be taken to be where the supporting strategy represents more than 20% in the strategic mix.

This will be considered in chapter 4 (Discussion), which will summarize the findings under chapter 3 (Case Analysis) on the following table (Table 3 Organizational scorecard showing example values) to determine whether NASA is primarily following one strategy or another, or a mixture of the two.

Recall that Hansen et al.'s (1999) theory is concerned with how an organization with a specific knowledge management strategy will tend to have specific organizational characteristics that support that strategy. For example, companies with a codification strategy will tend to exhibit compatible human resources and I.T. strategies, as described above. For this reason, the table below shows how an organization can be evaluated on separate organizational characteristics to determine whether all parts of the organization are consistently working in support of a codification or personalization strategy, or whether the organization has mixed characteristics that could potentially work at cross-purposes to one another.

Once the organization's characteristics have been evaluated against Hansen et al.'s (1999) archetypes, the average will reflect something close to a 50-50% split for a balanced strategy or an 80-20% split for a strategy that is biased in favor of one approach (as envisaged by Hansen et al., 1999).

Table 3 Organizational scorecard showing example values

	Codification	Personalization
Competitive strategy & knowledge-economics	*80%*	*20%*
Knowledge management strategy	*50%*	*50%*
Human resources strategy		
I.T. strategy		
Overall		

Populating the table above will produce a summary of the results of this study with respect to how NASA conforms to Hansen et al.'s (1999) two main categories of knowledge management practices.

1.3.3 *Effectiveness: Is NASA succeeding or failing as an organization?*

Hansen et al. (1999) do not provide much guidance on what qualifies an organization as successful. For example, an organization can be exhibiting success in the short term but fail in the long term; the failure could be due to extraneous factors such as economic downturn, a poor policy environment or political interference (especially likely for government agencies).

This will be considered in chapter 4 (Discussion), which will review reports that show what proportion of NASA's projects are on-track, how well NASA is meeting its performance objectives and also how satisfied NASA staff are with their workplace. The idea is that if NASA is failing as an organization due to staff conflict over knowledge management practices, it should reflect in these metrics.

1.3.4 *Conclusion on methodology*

Resolving these three questions will provide enough evidence to place NASA in one of the quadrants on Table 1 (Potential outcomes of the analysis) and make an informed evaluation of whether knowledge management activities at NASA are consistent with Hansen et al.'s (1999) theory, or whether they present challenges to this theory.

1.4 NASA – a good test case for Hansen et al.'s theory

This section will give some background on NASA and explain why NASA is a favorable choice for testing the theory of codification versus personalization presented by Hansen et al. (1999).

1.4.1 *A bit of background on NASA and its centers*

The National Aeronautics and Space Administration (NASA) is an independent agency of the United States government responsible for the civilian space program, as well as aeronautics and aerospace research. Its predecessor was the National Advisory Committee for Aeronautics (NACA, founded in 1915), which was essentially transformed into NASA in 1958 ('National Advisory Committee for Aeronautics', 2018). It has an estimated 17,381 employees across ten field centers, and in 2017 commanded an annual budget of US$19.5 billion ('NASA', 2018).

NASA's vision, mission and strategic goals are spelled out on NASA's website ('NASA Strategic Plan 2018', 2018). They are as follows:

NASA's Vision: "To discover and expand knowledge for the benefit of humanity"

NASA's Mission:

> *"Lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the Solar System and bring new knowledge and opportunities back to Earth. Support the growth of the Nation's economy in space and aeronautics, increase understanding of the Universe and our place in it, work with industry to improve America's aerospace technologies, and advance American leadership." ('NASA Strategic Plan 2018', 2018: 6)*

NASA's four strategic goals:

(i) Discover: Expand human knowledge through new scientific discoveries
(ii) Explore: Extend continuous human presence deeper into space and to the moon for sustainable long-term utilization
(iii) Develop: Address national challenges and catalyze economic growth [through the promotion of new technologies]

(iv) Enable: Optimize capabilities and operations [referring to proper management of human capital, operations, and infrastructure, as well as promoting productive partnerships]

From the Vision, Mission and Strategic goals it is clear that NASA positions itself as a leader in innovation across a wide range of applications and challenging fields.

NASA is not characterized by a single, central location. Its operations are spread across multiple field centers in the United States, each specializing in a different aspect of the sciences and technologies that support NASA's missions and projects in pursuit of the four strategic goals. The NASA Education Implementation Plan (2015 - 2017) (2015: 22) provides a useful summary description of the ten NASA field centers, showing the extent of the work they do:

(i) Ames Research Center (ARC): Ames specializes in research geared towards creating new knowledge and new technologies that span the spectrum of NASA interests.

(ii) Armstrong Flight Research Center (AFRC): As the lead for flight research, Armstrong continues to innovate in aeronautics and space technology.

(iii) Glenn Research Center (GRC): Glenn Research Center develops and transfers critical technologies and systems for safe and reliable aeronautics, aerospace, and space applications.

(iv) Goddard Space Flight Center (GSFC): The mission of the Goddard Space Flight Center is to expand knowledge on the Earth and its environment, the solar system, and the universe through observations from space.

(v) Jet Propulsion Laboratory (JPL): The Jet Propulsion Laboratory, managed by the California Institute of Technology, is NASA's lead center for robotic exploration of the solar system.

(vi) Johnson Space Center (JSC): From the early Gemini, Apollo, Skylab and Shuttle Projects to today's International Space Station program, Johnson Space Center continues to lead NASA's effort in Human Space Exploration.

(vii) Kennedy Space Center (KSC): Kennedy Space Center leads the world in preparing and launching missions around the Earth and beyond.

(viii) Langley Research Center (LRC): Langley continues to forge new frontiers in aviation and space research for aerospace, atmospheric sciences, and technology commercialization.

(ix) Marshall Space Flight Center (MSFC): Marshall Space Flight Center is world leader in the access to space and use of space for research and development to benefit humanity.

(x) Stennis Space Center (SSC): Stennis is responsible for NASA's rocket propulsion testing and for partnering with industry to develop and implement remote sensing technology.

In addition to the field centers, NASA also has mission directorates (Aeronautics Research Mission Directorate, Science Mission Directorate, Human Exploration and Operations Mission Directorate, and Space Technology Mission Directorate), a mission support directorate (covering things like procurement, infrastructure, shared services etc.), and long-term projects that complement and support the work done at the field centers (NASA Organization Chart, 2015).

NASA is recognized as the creator and user of some of the United States' highest technology[1]. However, a sequence of disasters in the late 1990's and the early 2000's resulted in investigations by government and regulatory bodies that highlighted concerns about knowledge management practices at NASA:

(i) A series of Mars mission failures (Climate Orbiter, Polar Lander and Deep Space 2) resulted in an investigation by the Government Accountability Office (GAO) in 2002. The GAO subsequently expressed its concerns about its findings in a report entitled "NASA: Better Mechanisms Needed for Sharing Lessons Learned".

(ii) Soon after in 2003, the Space Shuttle Columbia Disaster occurred. Among its findings, the Columbia Accident Investigation Board (CAIB) Report stated that NASA "has not demonstrated the characteristics of a learning organization" (Columbia Accident Investigation Report: Volume 1, 2003:12).

[1] Gregory Whitesides, Executive Director of the National Space Society, cited in Sternstein (2006: 40-41).

(iii) In 2011 the NASA Aerospace Safety Advisory Panel (ASAP) recommended that the agency undertake a more systematic approach to capturing implicit and explicit knowledge, and furthermore that NASA appoint an agency level chief knowledge officer (NASA Aerospace Safety Advisory Panel - Annual Report 2011: 2012).

The recommendations from these reports drew attention to the way in which knowledge management was being practiced at NASA, highlighting weaknesses and prompting the agency to take action. Each subsequent incident and the ensuing Reports resulted in a review of practices, fundamental changes in how NASA approached knowledge management, and more resources being devoted to the discipline.

As a result, NASA has seen a steady evolution in how it practices knowledge management in order to reach the point it is at today. With chief knowledge officers coordinating across field centers and departments, it is possible to analyze NASA's approach to knowledge management and determine how accurate Hansen et al.'s (1999) predictions are when it comes to evaluating the practices of what is arguably one of the most pre-eminent knowledge-based organizations in the world.

1.4.2 *Why is NASA a good choice for testing Hansen et al.'s theory?*

Since the disasters mentioned above, NASA has had time to refine its approach to knowledge management. Given that it is a federally-funded civilian program, a lot of comprehensive documentation about its knowledge management practices are publicly available.

There is the potential caveat to this that, as described above, NASA is not a single organization but is actually comprised of many different organizations working together. While this is true, it will also be shown in the discussion on NASA's knowledge management journey (section 3.2.1) that NASA follows a federated approach to knowledge management whereby knowledge management activities across all its centers is directed by one chief knowledge officer at the center. This means that although there is a degree of autonomy at each center, there is still a consistent thread that runs through the culture of knowledge management at NASA.

This makes NASA a good case study, as it provides the knowledge management community with insight into how this knowledge-intensive organization has defined its critical knowledge activities and selected a knowledge management strategy to match. NASA is a good candidate for testing Hansen et al.'s (1999) framework for a number of reasons:

NASA is a knowledge-intensive organization

Hansen et al.'s (1999) framework is specifically concerned with knowledge-intensive organizations and seeks to show how an organization's choice of knowledge management strategy can have a direct impact on that organization's efficacy.

It would be difficult to contend that there is such a thing an organization that does not leverage on knowledge to some degree, and Hansen et al. (1999) do not stipulate that there are organizations to which their framework will not apply. However, it stands to reason that Hansen et al.'s framework is best illustrated in a knowledge-intensive organization where the effects (or lack thereof) will be most clearly observable.

For example, in an organization that depends heavily on a specific commodity it may be difficult to determine whether the organization's efficacy is being affected by volatility in commodity prices, exchange rates, labor costs or other factors, or whether it is attributable to matching the knowledge management strategy to appropriate economic, I.T. and human resources strategies.

NASA provides a good test case because it is focused on leveraging knowledge to address highly-specialized problems. NASA does not have any direct competitors and is federally funded. This means that it is unlikely to experience volatility due to a substitute in the market and is also insulated to a large extent from the market forces that other firms need to consider. Therefore, NASA is relatively pure example of a knowledge-intensive firm that removes many of the extraneous factors that could complicate the analysis of an organization operating in normal market conditions.

Operational information available to the public

Evaluating Hansen et al.'s (1999) framework in terms of a real organization requires a lot of information about that organization to be available. This is challenging, as privately owned or commercial companies have an interest in protecting their intellectual property in order to maintain their competitiveness in the market. Similarly, many government agencies are engaged in work that they consider sensitive, such as military or defense.

NASA is not subject to these same considerations. Due to NASA being a federally funded civilian program, a lot of information about its activities and the research it generates is open to the public and available on its web portal. NASA also has – amongst its multiple objectives - the explicitly stated goals (‘Office of STEM Engagement: Overview’, no date) of:

- Strengthening NASA and the Nation's future workforce
- Attracting and retaining students in science, technology, engineering and mathematics, or STEM, disciplines
- Engaging Americans in NASA's mission

The attainment of these goals is facilitated by NASA making its information available to the public. This open access is enhanced by a directive issued by the White House Office of Science and Technology Policy (OSTP) in 2013 that set a goal of making direct results of federally funded science freely accessible to the public to the greatest extent possible (‘OSTP Memo Sets Goal of Public Access’, 2013). The directive does make exceptions with respect to sensitive materials such as patents and material governed by personal privacy, proprietary, or security laws (‘All Scientific Research Funded by NASA Is Available For Free’, 2018).

This means that Information about NASA is more freely available than for most other knowledge intensive organizations, facilitating the analysis of NASA’s activities in a way that would not be possible for most organizations.

Clearly identifiable knowledge management initiatives

As referenced above (1.4.1 A bit of background on NASA and its centers), subsequent to the Mars mission failures and the Columbia disaster, NASA was given a mandate to implement better mechanisms for sharing lessons-learned, improve its capacity to learn as an organization, and undertake a more systematic approach to capturing knowledge.

This means that NASA has appointed an agency chief-knowledge officer (CKO) as well as knowledge management leaders (such as CKOs and knowledge-services leads or KSLs) at all of its centers and departments. Numerous knowledge-management initiatives have been detailed in NASAs knowledge management map and the NASA online portal.

It is an acknowledged problem that many organizations do not have an explicitly defined knowledge management capacity, sometimes relegating this to either I.T. or human resources functions where it is undertaken by personnel who have no experience of knowledge management. as Hansen et al. (1999) point out, 'companies that isolate knowledge management in functional departments like HR and IT risk losing its benefits' (1999: 115). Therefore, in testing Hansen et al.'s framework, it is preferable to use an organization where knowledge-management professionals are working to explicitly manage knowledge. This is expected to provide a more robust analysis than assuming that initiatives undertaken in other departments are proxies for knowledge management.

Publicly available performance metrics

A fundamental aspect of Hansen et al.'s (1999) framework is that an organization cannot straddle both the codification and the personalization knowledge strategies without potentially compromising its own effectiveness and undermining its own competitive advantage.

This means that in order to evaluate the efficacy of Hansen et al.'s (1999) framework, it is not only necessary to identify the nature of an organization's knowledge strategy, but also whether the organization is functioning effectively. If an organization is straddling both strategies, then according to Hansen et al. this can lead to confusion among its knowledge workers and compromise the efficacy of the organization. On the other hand, if an organization is able to straddle both strategies and still function effectively, this would be inconsistent with Hansen et al.'s predictions and could indicate a weakness in Hansen et al.'s framework.

NASA makes a good test case because the agency's activities are extensively reviewed in line with the requirements of the Government Performance and Results Act (GPRA) Modernization Act of 2010 (FY 2019 Volume of Integrated Performance, undated: i). The results are published in NASA's annual Volume of Integrated Performance, which shows ratings in terms of both performance goals and annual performance indicators for each project. Independent rankings of NASA's employee satisfaction are also available online ('Best Places to Work in the Federal Government', 2017); this is a relevant metric, as a workplace where knowledge workers are confused or frustrated is likely to rank poorly or show a declining trend in workplace satisfaction.

These reviews provide a good indication of whether NASA is succeeding or failing as an organization. When combined with what analysis shows about NASA's knowledge management strategy, this will give an indication of whether Hansen et al.'s (1999) predictions are robust or not.

1.4.3 *Conclusion on NASA as a test case for Hansen et al.*

For the reasons outlined above, NASA is expected to provide a good test case for Hansen et al.'s (1999) framework. It is an organization engaged in knowledge intensive work, there is a lot of publicly available information available about the organization, it has clearly defined knowledge managers and knowledge management practices, and there are readily available performance metrics against which the success of the organization can be evaluated. This is the type of organization and information needed to test the application of Hansen et al.'s framework to determine whether the theory is accurate.

1.5 Chapter outline

Chapter 1 has introduced the topic, a summary of Hansen et al.'s (1999) paper, outlined the methodology that will be followed in this thesis, and explained why NASA is a good test case for Hansen et al.'s theory. The thesis will now proceed in the following manner:

Chapter 2 (Theory) will discuss the theory in greater detail, looking at the literature to see how Hansen et al. (1999) can be contextualized in the broader field of knowledge management, how Hansen et al.'s theory has fared when reviewed by other authors, and whether authors involved in Hansen et al.'s original paper have any subsequent work that provides additional insights.

Chapter 3 (Case Analysis) will look at NASA's organizational characteristics to examine how NASA's activities measure up against the organizational characteristics from Hansen et al.'s (1999) theory that were identified in chapter 1. Accordingly, this chapter has been broken up into sub-sections to enable each organizational characteristic to be dealt with more clearly on its own.

Chapter 4 (Discussion) will evaluate the results of chapter 3 (Case Analysis) to see if NASA's knowledge management strategy is based predominantly on codification or personalization, or whether NASA shows evidence of attempting to straddle both. Based on NASA's mix of activities in this regard, Hansen et al. (1999) makes predictions about how NASA should be performing as an organization. It will also analyze NASA's performance to determine whether the findings support Hansen et al.'s (1999) predictions. This will give an indication as to the robustness of the predictions made by Hansen et al.'s theory.

Chapter 5 (Conclusion) considers the extent to which NASA's has supported or disagreed with Hansen et al.'s (1999) theory. Where disagreement is found, there is an attempt to identify the differences in perspectives that led to the disagreement. The overall findings of the study are discussed, potential weaknesses are reflected on, and further avenues for research are proposed.

This is followed by a list of the References used in this study. Note that this is a list of references used, not a Bibliography of sources consulted. It also does not contain details of papers cited by authors referenced in the text, as these have not been consulted directly. However, where another source has been cited by a reference, efforts to include details of this source are included as a footnote in the text.

2. Theory: Knowledge Management Strategy

Since the publication of Hansen et al.'s (1999) theory there have been publications that have discussed, applied and/or critiqued the theory, including further work by one of the authors involved in the original [1999] publication.

This chapter will summarize some of these publications in order to:

(i) explain the conceptual perspective that Hansen et al. (1999) appear to be taking on the nature of knowledge,

(ii) consider some of the critiques raised about Hansen et al.'s theory, and

(iii) see if subsequent work involving one of the original authors of the Hansen et al. (1999) paper provides further insights into the theory.

The first is useful because by understanding what Hansen et al. (1999) perceive knowledge to be, it helps to clarify their assumptions about how they assume it should be handled and potentially also identify potential strengths, weaknesses and contradictions associated with that view.

The second is useful because this study may have the following outcomes:

- This study may find that NASA conforms to Hansen et al.'s (1999) theory, potentially disagreeing with points raised by these critical authors and opening an avenue for further investigation.
- This study may show that NASA does not conform to some specific aspect of Hansen et al.'s (1999) theory, and these studies may corroborate the finding by showing that this has previously been identified by other authors as a weak point in Hansen et al.'s theory, thereby adding weight to their arguments.
- On the other hand, this study may show that NASA does not support Hansen et al.'s (1999) theory due to an aspect of the theory that has never before been criticized by other authors, again opening an avenue for further investigation.

The third point (work involving one of the original authors) is useful because it provides an author of the original paper the opportunity to potentially clarify points in the previous paper that met with contention, or even revise parts of the theory. On the other hand, it may also show that years down the line one of the original authors still stands by their original claims.

2.1 What perspective do Hansen et al. take on the nature of knowledge?

Hansen et al. (1999) see personalization as a scenario under which essential knowledge can be held in the heads of highly qualified consultants. This suggests that Hansen et al. views knowledge in a manner consistent with the epistemology of possession. Under the epistemology of possession, knowledge is:

"… seen as a personal property of the individual knower who is able to confer meaning on data and information by drawing from his or her own subjective experiences, perceptions and previous understandings." (Newell et al., 2009: 3).

In the field of knowledge management, the epistemology of possession is closely tied to the Structural perspective of knowledge (Newell et al., 2009: 7), and these both take an 'entitative' view of knowledge (Newell et al., 2009: 12). That is to say, this perspective views knowledge as an object or resource that can be possessed, accumulated, and transferred. This has as its basis the idea that knowledge can exist independently of context, which has attracted criticism from subsequent theorists that consider this closer to being 'information' than knowledge.

The Structural perspective is also criticized on the grounds that it sees organizations as "a collection of interdependent parts (e.g., machines and people) that work in harmony towards a common, agreed-upon goal (e.g., organizational survival and profit)." (Newell et al. 2009: 13). This is also apparent in the quote above that refers to knowledge as "a personal property of the *individual* knower" [my emphasis] (Newell et al., 2009: 3), and is reflected in Hansen et al.'s (1999) theory when they cite some management consultancies as utilizing a competitive strategy based on "channeling *individual* expertise" [my emphasis] (Hansen et al., 1999: 109).

Hansen et al.'s (1999) example of codification is focused on organizational staff acting primarily as 'implementors' of codified 'knowledge'. That Hansen et al. are comfortable with the concept that what has been codified into documentation or systems can be referred to as "knowledge" again shows that Hansen et al. see knowledge along the lines of an epistemology of possession.

Furthermore, Hansen et al.'s (1999) version of codification includes a scenario whereby Access Health uses a call-center with a "clinical decision architecture" system to help a nurse to make recommendations to callers/patients. This is basically the application of a ruleset.

This general approach is described and criticized by the CKO of NASA's Goddard Space Flight Center, Dr Edward Rogers (2011: 18), when he cites Shukla and Srinivasan (2002)[2] as stating "the purpose of first-generation KM programs is to improve operational efficiency of the employees by enhancing access to rule sets", and in the same paper links this to a statement [cited] by McElroy (1999)[3] that "conventional knowledge management practice, then, boils down to little more than getting the right knowledge to the right people at the right time. Think single-loop learning". Rogers (2011:18) is showing that this approach is old-fashioned and outdated when it comes to knowledge management practices.

The epistemology of possession and the structural perspective of knowledge has come to be seen as outdated compared to more recent theories that see knowledge as a practice or a process (rather than a thing) that is undertaken as a more social and organizational activity (rather than an individual/expert activity) (Newell et al. 2009: 14).

Newell et al. (2009: 134) note:

"*The Hansen study focused on consulting firms, and, […], it is possible to question whether their [Hansen et al.'s] analysis emphasizes the role of individual experts at the expense of the role of groups and communities in creating and sharing knowledge. It may be relevant for consultancy firms employing talented individuals, but it is doubtful whether it applies to all organizations*."

Therefore, it can be seen that Hansen et al.'s (1999) theory has been built on the foundation of a structuralist perspective and incorporates the limitations inherent to that perspective. The fundamental blind spot in Hansen et al.'s theory appears to be that between personalizing knowledge in individuals and codifying knowledge in I.T. systems, Hansen et al. (1999) have missed the role played by the organization. The organization makes knowledge work into a group activity (social), and provides, enabling contexts that bring together different groups, and shared purpose that helps to define priorities, and processes to help negotiate the meaning of knowledge in question (Newell et al. (2009: 14).

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[2] Rogers (2011) cites this article but does not include its citation in his references.

[3] McElroy, M.W. (1999). Double-Loop Knowledge Management, MacroInnovation Inc. Available from www.macroinnovation.com

Since the organization does not come into Hansen's et al.'s (1999) theory, and Hansen et al. view knowledge a resource that needs to be held somewhere, Hansen et al. are forced to allocate the knowledge either to the individual (through personalization) or to a repository (through codification).

2.2 Papers that raise critiques of Hansen et al. (1999)

Hansen et al.'s (1999) theory has resulted in papers that focus quite specifically on weaknesses in their theory. What follows here are five papers that criticise various aspects of Hansen et al.'s theory.

2.2.1 *Liu, Chai, and Nebus (2013)*

A paper by Liu, Chai, and Nebus (2013) states that "In recent years many studies have revealed that organizations should adopt a mixed strategy.". Liu et al. (2013) cite papers by Scheepers et al. (2004), Greiner, Bohmann, and Krcmar (2007), Kumar and Ganesh (2011), as well as an article by Koenig (2001). Liu et al. (2013) join these authors in proposing the desirability of a mixed strategy. The purpose of Liu et al.'s paper is to develop a systematic framework whereby an organization can analyze its knowledge reuse processes and balance its mix of codification and personalization based on their knowledge management costs/benefits.

Liu et al. (2013) take a more complicated perspective than Hansen et al. (1999) when it comes to talking about what constitutes knowledge, specifically referring to the category of reusable knowledge. They are not referring to the codification of documents and simple if-then rules. Liu et al. (2013) describe how re-usable knowledge is characterized by levels of complexity and significance. Complexity refers to a high time and effort input required from both producers and users of re-usable knowledge, while significance refers to knowledge with a high value (such as engineering solutions process innovations, and engineering know-how). They point to the distinction between problem-driven reuse, that focuses on solving an immediate problem, and knowledge-driven reuse, that is concerned with continuous improvement. Liu et al.'s (2013) study focuses on knowledge-driven reuse.

Liu et al.'s (2013) conclusion is that "Balancing codification and personalization strategies is crucial for improving knowledge reuse within an organization" (Liu et al., 2013: 769). Liu et al. hold that by taking into account the number of reusable knowledge items, reuse patterns, and interest alignment between employees and the company, an organization can select the right mix of codification and personalization strategies (Liu et al., 2013: 770). This is in direct opposition to Hansen et al. (1999), who clearly states that organizations must not straddle both strategies or they will risk failure (1999: 112).

2.2.2 Greiner, Bohmann and Krcmar (2007)

Greiner et al. (2007) were cited by Liu et al. (2013) as one of the papers supporting the feasibility of a mixed knowledge management strategy. Greiner et al. (2007) were concerned with studying the influence of organizational environment on the selection of knowledge management strategy. They achieved this by undertaking case studies of 11 companies, wherein they categorized the knowledge management initiatives across six criteria and evaluated how these fitted with the business strategy of the organizational unit.

While Greiner et al. (2007) agreed with Hansen et al. (1999) when they concluded that "the knowledge management objectives and strategy need to concur with the company's/business unit's objectives and strategy" (2007: 13), they also noted that:

> *"[the analysis] also showed that some companies deploy both approaches – codification and personalization – within the same KM initiative. This supports propositions that codification and personalization are not two extremes but rather dimensions that can be combined (Gammelgaard and Ritter, 2005)" (Greiner et al., 2007: 11).*

This was followed by the further observation that:

> *"The case studies did not clearly indicate a higher level of success for the companies that used both approaches. But it can be assumed that a sole reliance on one strategy may be too one-sided, e.g. a sole concentration on codification and reuse of knowledge may not be enough to face the dynamic and turbulence of the markets (Afuah, 1998). On the other side, bringing people together does not necessarily lead to innovation if the knowledge is not exploited." (Greiner et al., 2007: 11).*

Therefore, while Greiner et al. (2007) do not find that a mixed strategy clearly results in either failure or success of an organization, they do end up siding with the critics of Hansen et al. (1999) expressing their belief that codification and personalization strategies can be combined in an organization and that a single strategy may be too one-sided (Greiner et al., 2007: 11).

2.2.3 *Koenig (2001)*

Koenig's (2001) article appeared in KM World Magazine. It is brief, and by far the most vocal critic of Hansen et al.'s (1999) propositions with the statement "While the advice to match one's strategy with the context is admirable, the "Do not straddle" advice is overly simplistic; indeed, it is dangerously misleading."

Koenig (2001) focuses his criticism on the 80-20 strategy split advocated by Hansen et al. (1999: 112) and advocates greater variability in the split. Koenig (2001) goes on to qualify this by claiming to have undertaken quantifiable and rigorous research into pharmaceutical companies that shows:

> *"[…] that the most salient difference between the less successful vs. the more successful pharmaceutical companies is that the less successful firms have a knowledge environment with an 80-20 emphasis (on codification), while the more successful companies, have an equal emphasis on codification and on personalization. They have deliberately adopted the 50/50 straddle that Hansen, Nohria and Tierney advise us to avoid." Koenig (2001).*

Koenig (2001) concludes by supporting the notion that knowledge management strategy should align with business strategy, but appears closely allied to Liu et al. (2013) in concluding that straddling is not a recipe for disaster as predicted by Hansen et al. (1999), and that the correct balance of codification and personalization could lie anywhere between the 80-20 mix advocated by Hansen et al. (1999).

2.2.4 *Kumar and Ganesh* (2011)

Kumar and Ganesh (2011) are investigating the knowledge management strategies followed by product development (PD) units in Indian manufacturing firms. They surveyed 284 employees across 19 different PD units to determine whether the strategy being followed was codification or personalization, and conducted a number of statistical tests and analyses on the information they gathered. They found that although personalization was the preferred strategy, codification was not clearly in a supporting role. That is to say, they concluded that Hansen et al.'s (1999) 80-20 rule was not being observed. Despite this, they did not observe any significant negative influences as a result.

Kumar and Ganesh (2011) refer to Hansen et al.'s (1999) approach as the 'biased approach' (i.e., biased in favor of one strategy), and where neither strategy dominates they refer to it as a 'balanced approach' (2011: 19). Kumar and Ganesh (2011) cited a paper by Haesli and Boxall (2005)[4] that supported Hansen et al.'s (1999) biased approach, but also cited research by Jasimuddin, Klein, and Connell (2005), Mukherji (2005), and Scheepers, Venkitachalam, and Gibbs (2004)[5] that supported the balanced approach.

Kumar and Ganesh's (2011) findings do not provide support for Hansen et al.'s (1999) warning against having a balanced strategy:

> *"[…] in other words, units with a stronger leaning towards personalization did not necessarily do better than those with a more balanced strategy, as might have been expected from the propositions of Hansen et al. (1999) that firms which adopt an 80-20 mix of the two strategies will perform better than those that have a near equal mix. In sum, no clear pattern relating with strategy balance with performance was observable." (Kumar and Ganesh, 2011 :130).*

Despite the indeterminate nature of the findings above, Kumar and Ganesh (2011) go on to note that:

> *"[…] if a firm's overall strategic agenda is such that it needs both the benefits derived both from the reuse of explicit knowledge, as well as the generation and dissemination of employees' tacit knowledge in good measure, then balancing the two strategies may be the right thing to do." Kumar and Ganesh (2011: 130)*

As such, Kumar and Ganesh (2011) are in agreement with the authors discussed so far in this section that Hansen et al.'s (1999) warning against a balanced approach to codification/

[4] Haesli, A. and Boxall, P. (2005). 'When knowledge management meets HR strategy: an exploration of personalization-retention and codification-recruitment configurations'. International Journal of Human Resource Management, Vol. 16 No. 11, pp. 1955-75.

[5] Scheepers et al. (2004) is discussed in more detail below, the full citation is contained in the References at the end of this document.

personalization is unfounded and that a balanced approach may, in fact, present a desirable alternative.

2.2.5 *Scheepers, Venkitachalam and Gibbs (2004)*

Scheepers et al. (2004) assessed Hansen et al.'s (1999) argument about the 80-20 strategy mix across four case-study organizations, and came to a more nuanced conclusion than the other authors covered so far in this section.

Scheepers et al. (2004) state that they found some support for Hansen et al. (1999) but also felt that Hansen et al.'s model needed some refinement, as it could lead to an organization locking itself into one strategy. This was illustrated in one of the case organizations they investigated:

> *"[…] the ineffective knowledge use in this case could be attributed to the lack of attention to personalization in support of their (dominant) codification approach. At the same time, the case highlights the difficulty that organizations can face in implementing the 80/20 knowledge strategy mix advocated by HNT [Hansen, Nohria and Tierney]." (Scheepers et al., 2004 :216)*

They concluded that Hansen et al.'s (1999) model was useful for determining an organizations initial strategic direction (codification or personalization), but that organizations needed the flexibility to evolve their strategy mix over time. Specifically, they state:

> *"[…] HNT's advice may be useful during the early stages of strategy development (e.g. to prioritize initiatives), but becomes less applicable over time. In fact, we see a risk in slavishly following HNT's 80/20 rule; the organization could fixate on the dominant choice and 'lock' itself in strategically." (Scheepers et al., 2004: 217).*

Scheepers et al. are clear that they "do not suggest a 'wholesale' rejection of the HNT model" (2004:217), and state that it is valuable in helping an organization determine its initial knowledge management strategy.

It is unclear in this case whether Hansen et al.'s (1999) theory is supported by Scheepers et al. (2004), or whether Scheepers et al. is seeking support from Hansen et al. The rejection of any exceptions was fundamental to the theoretical value of Hansen et al.'s model. Scheepers et al.'s (2004) refinements are of great value, but essentially disregard Hansen et al.'s landmark statement of "do not straddle" (Hansen et al., 1999:112). Therefore, the position taken by this thesis is that Scheepers et al. (2004) has taken issue with the same aspect of Hansen et al.'s theory as the other authors in this section - that is to say, Scheepers et al. do not support the "no straddling" rule and the mandated 80-20 mix.

2.3 Conclusion on papers raising critiques of Hansen et al.

From the papers reviewed above it can be seen that while Hansen et al.'s (1999) theory may be seen as a pioneering piece of work (Liu et al., 2013: 757), there are subsequent analyses that disagree with its claims and underlying assumptions about knowledge management.

While there is consensus among the dissenting authors discussed above that Hansen et al.'s (1999) statement that knowledge management strategy needs to align with business strategy is correct, the most contentious issue is Hansen et al.'s prediction that codification and personalization can only coexist in a roughly 80-20 split, without risking organizational failure. The authors above disagree and argue that this is not supported by empirical evidence. It has been observed that, contrary to Hansen et al.'s predictions, straddling both codification and personalization will not automatically lead to failure, and that strategies could feasibly co-exist in ratios other than the 80-20 split. Even Scheepers et al.'s (2004) attempts to support Hansen et al.'s theory through refinements theory require that the prohibition on straddling and the mandated 80-20 mix ultimately be abandoned.

These studies undermine Hansen et al.'s (1999) implicit assumption about the nature of codification and personalization, that these two approaches exist in opposition to one another. By showing that they can coexist the authors above show that they may in fact be complementary, which is a fundamentally different way of looking at these two components parts of the knowledge management paradigm.

2.4 Subsequent work by members of Hansen et al.'s authors

A subsequent paper by Hansen and Nørbjerg (2005) presents a case study of some of the difficulties encountered by software development companies trying to decide on codification versus personalization strategies. This is a useful paper because it shows Hansen et al.'s (1999) theory being applied by one of the original team members, which provides an opportunity to clarify potentially contentious points from the original paper. It is also six years after the original paper, by which stage the criticisms of Koenig (2001) and Scheepers et al. (2004) have also been published, and are therefore available for rebuttal.

While Hansen et al. (1999) did not provide a definition of "knowledge management" in their paper. However, this subsequent paper by Hansen and Nørbjerg (2005) cite Quinitas et al. (1997) to provide a definition of knowledge management as:

> *"[…] the task of developing and maintaining organizational processes or practices to create, acquire, capture, share and use knowledge wherever it resides to enhance learning and performance in organizations including the creation of environments in which learning and knowledge exchange can take place."*

Recognizing organizational processes or practices as things that can capture knowledge is something new, not previously acknowledged under Hansen et al. (1999). Organizational learning features prominently in this definition, and Hansen and Nørbjerg (2005) follow this with a discussion of individual learning and organizational learning. This leads one to expect that the views of Hansen and Nørbjerg (2005) will differ from those of Hansen et al. (1999), in that Hansen's (2005) view has been updated to recognize the role of the organization and move on from Hansen et al.'s (1999) structural perspective.

However, Hansen and Nørbjerg (2005) go on to base their paper on the unaltered concepts of codification and personalization that were established in Hansen et al. (1999). In the subsequent discussion of the codification and personalization concepts, Hansen and Nørbjerg (2005) are clear that under a personalization strategy: "The organizational memory is based on its *individuals* [my emphasis], and information technology is used primarily as a means to locate knowledgeable people and enable direct communication."

Hansen and Nørbjerg's (2005) statement that organizational memory is based on the memory of individuals is a contradiction in terms. Hansen and Nørbjerg (2005) abandon their reference to processes, procedures and shared practices as potential holders of organizational knowledge, retreating back to the structuralist perspective that maintains the emphasis on the individual as the holder of knowledge. This is because under the epistemology of possession that underlies the structural perspective:

"… knowledge is seen as a possession of the human mind, and treated as a mental (or cognitive) capacity, or resource, that can be developed, applied and used to improve effectiveness in the workplace." (Newell et al. 2009: 3).

Hansen and Nørbjerg (2005) are unable to concede that knowledge held for the purposes of innovation can reside anywhere by in a human mind. By focusing on the individual, Hansen and Nørbjerg (2005) disregard the idea of the 'collective mind' of the organization. The obvious drawback of this is that if your organization grows, you will need a lot of individuals to hold all the knowledge, leading Hansen and Nørbjerg (2005) and go on, in the same paragraph, to note that:

"The main drawback of this [personalization] strategy is that it is not very effective in situations where specialized solutions are not needed and also it does not scale as well as the codification strategy – e.g., certain people in the organization easily become bottlenecks." (2005: 3).

This shows that Hansen and Nørbjerg (2005) maintain Hansen et al.'s (1999) view that personalization is the appropriate strategy for innovation, and that due to the emphasis on the individual being the store of knowledge this will present difficulties in a large organization (which promises to problems for reconciling this theory with an organization like NASA that is both large and innovative).

By the end of the paper, Hansen and Nørbjerg's (2005) state that neither strategy was able to satisfy all the members of the software development companies that were investigated, and that while the framework was able to guide organizations to a limited extent in choosing their knowledge management strategy, they conclude:

"The framework is too simple to be able to comprehend the complexity of a modern (software) organization since the knowledge management strategy needed might be different depending on the organizational level in the organization. This said the framework might be provide a good rule-of-thumb in explaining what the necessary means on a specific organization level might be, and to point management in the right direction."

This conclusion by Hansen and Nørbjerg (2005) seems to start to recognize the contention raised by the other authors above, that a more balanced strategy is needed. However, by the end of the paper it can be seen that Hansen and Nørbjerg (2005) have not done much to alter Hansen et al.'s (1999) theory beyond an attempt at incorporating organizational learning into the theory, that in the end proved incompatible with their structural perspective.

Like Hansen et al. (1999), Hansen and Nørbjerg (2005) maintain that personalization is the strategy required for innovation. Hansen and Nørbjerg (2005: 3) also state that personalization will not scale as well as codification. Therefore, it can be expected when it comes to a large organization that innovates on a daily basis, some fundamental disagreements with Hansen et al.'s (1999) theory will inevitably arise.

2.5 Conclusion on gaining some perspective on Hansen et al.

This chapter reviewed available publications in order to determine what conceptual perspective Hansen et al. (1999) is taking on knowledge, consider what other authors had to say about Hansen et al.'s theory, and determine if work by one of the original authors of the Hansen et al. paper provides further insights into the theory.

It was found that Hansen et al. (1999) are taking a conceptual view of knowledge consistent with the epistemology of possession and the Structural perspective. This view sees knowledge as being closer to information than subsequent views do, in that it can be possessed, accumulated and transferred. As a result, it can be held as codified knowledge in rule-sets and as personalized knowledge in the heads of experts. The organization, communities of practice and knowledge held in organizational processes/practices does are not acknowledged in this perspective, and the organization is merely seen as the sum of its parts.

That Hansen et al. (1999) takes this view means that insofar as innovation is concerned, it cannot come from codified knowledge (rule-sets) and they are ignoring the role of the organization. Hansen et al.'s view is that innovation has to be the product of an individual human mind. This presents problems for acknowledging communities of practice, or the role of knowledge embedded in organizational processes and procedures, and means that if the innovative organization wants to grow, it needs more individual experts.

Reviewing other authors showed that they all agreed with Hansen et al. (1999) that knowledge management practices need to align with an organization's competitive strategy, but they all criticized Hansen et al.'s assertion that codification and personalization strategies could not be practiced in a more balanced mix than an 80-20 split.

A subsequent paper by Hansen and Nørbjerg (2005) applied Hansen et al.'s original theory, with the modification that it attempted to account for organizational learning. However, in trying to maintain a structural perspective Hansen and Nørbjerg inaccurately attributed organizational learning to individual learning, which failed to advance Hansen et al.'s (1999) theory. Hansen and Nørbjerg (2005) were forced to concede that Hansen et al.'s (1999) framework is too simple and that different strategies may be needed for different parts of an organization.

This chapter shows that the major weakness that is emerging on Hansen et al.'s (1999) theory is the statement that codification and personalization cannot coexist in an organization as equals and must be practiced in an 80-20 split. This weakness appears to come from Hansen et al.'s perception of codification and personalization as being opposites that exist in tension with one another, rather than as complementary tools, and Hansen et al.'s continued adherence to an outdated epistemology of possession/structural perspective that places too much emphasis on individual expertise at the expense of recognizing the role of the organization.

3. Case Analysis: Knowedge Management Strategy at NASA

As discussed under methodology, this section will review NASA's activities as an organization through four sections, in line with the key characteristics of organizations identified by Hansen et al. (1999). These sections are (i) competitive strategy and knowledge economics, (ii) knowledge management strategy, (iii) approach to human resources management, and (iv) investment in I.T.

Each section will identify NASA as either approximating the characteristics of an organization that according to Hansen et al. (1999) should rely on codification, an organization that relies on personalization, or potentially approximating both categories. This section will provide the material for chapter 4 (Discussion), wherein it will be decided if NASA fits mainly into one strategy or the other, or if it is attempting to straddle both strategies.

3.1 Competitive strategy and economic model

As discussed in section 1.3 (Methodology), determining whether NASA's competitive strategy is geared towards codification or personalization consists of showing whether the organization aims to provide high quality and reliable products/services provision with fast turnaround and low costs (codification), or customized, innovative products/services delivered by channeling individual expertise, resulting in slower turnaround and higher cost, but steady growth and a high quality/success ranking (personalization).

Determining NASA's knowledge-economics model consists of distinguishing whether NASA engages in reuse economics (codification) or expert economics (personalization). In this context, reuse economics means investing once in a knowledge asset and reusing many times and large teams with high ratio of juniors to seniors. (It is of interest to note here that Hansen et al. (1999) do not acknowledge the need to keep investing in a knowledge asset to keep it up-to-date; this is an activity that would need to be undertaken by staff that were highly-qualified in that field, as it could not just be done by graduate-level implementors). Expert economics means highly-customized solutions to unique problems and small teams with a low ratio of juniors to seniors.

Since NASA is a federally-funded government agency, revenues and market share are not applicable measures here. However, the remaining factors in the descriptions above can be resolved to the following scorecard:

Table 4 Competitive and knowledge-economics strategy scorecard

Codification	Personalization
High quality and reliable products/services provision with fast turnaround and low costs.	Customized, innovative products/services delivered by channeling individual expertise.
Reuse: investing once in a knowledge asset and reusing many times.	Expert economics: highly-customized solutions to unique problems.
Large teams with high ratio of juniors to seniors.	Small teams with a low ratio of juniors to seniors.

3.1.1 *Competitive strategy*

As noted in section 1.4 (NASA – a good test case for Hansen et al.'s theory), NASA's Vision, Mission and Strategic objectives (which will not be repeated here) include statements like "expand human knowledge through new scientific discoveries" and "extend continuous human presence deeper into space and to the moon". This clearly points to a focus on customized, innovative products/services that is characteristic of personalization.

The competitive strategy under codification hinges on "fast turnaround and low costs". The only time that NASA ever came close to trying this was in the 1990's during the Faster-Better-Cheaper initiative, where:

> *"the goal was to drastically reduce project costs while speeding development times. Development was indeed faster, and missions were indeed cheaper—but the approach was flawed, as the doomed 1999 missions suggest." (MacCormack, 2004).*

The failure of two Mars missions within 3 months of each other resulted in criticism for the Faster-Better-Cheaper initiative that have ultimately seen management practices (and knowledge management practices) move on from this paradigm. Given the size and duration of NASA projects, "fast turnaround and low costs" is simply not an accurate description for an organization that consumed 0.47% (USD 19,509 MN) of the federal budget of the United States of America in 2017 ('Budget of NASA', 2018).

Therefore, it seems that NASA's competitive strategy puts it in the category of what Hansen et al. (1999) would consider appropriate for organizations practicing a personalization knowledge management strategy. However, therein lies the problem, as Hansen et al.'s conditions rely on this innovative and customized product being delivered by "channeling individual expertise". As will be shown below, does not sound like a feasible description of NASA's projects where teams run into the hundreds of members as projects of enormous scale conscript so many departments to their cause. The following quote would serve well in the next two sections covering knowledge reuse and teams at NASA, but it is presented here to illustrate how NASA has an emphasis on teams over Hansen et al.'s channeling of individual expertise.

> *"Because each project team has a different assignment and a different mission, people tended to think, 'We never do the same thing twice. Lessons don't apply since the mission is always unique.' But what we do over and over is put together a team to accomplish a mission. So that suggested what the knowledge management focus should be." (Rogers, 2013: 22).*

Therefore, although NASA is not pursuing Faster-Better-Cheaper the classification of NASA as having a competitive strategy based on Hansen et al.'s (1999) definition of personalization would depend solely on its characteristic of innovation and not its characteristic of channeling individual expertise, and so is questionable at best.

3.1.2 *Knowledge-economics at NASA*

Again, ignoring statements about revenue effects, this question focuses on the extent to which NASA potentially reuses knowledge, whether NASA relies on highly customized solutions delivered by experts, and also whether it uses large teams full of juniors or small teams full of experts.

Reuse of knowledge at NASA

In chapter 2 (Theory) a paper by Kumar and Ganesh (2011) disagreed with Hansen et al. (1999) and noted that a balanced to knowledge management strategies may be desirable. During their paper they also cited a paper by Iyer, Jayanti, Lou, Kalyanaraman and Ramani (2005) wherein it is "[…] estimated that more than 75 percent of engineering design activity comprises of reuse of previous design knowledge to address new design problems." Therefore, it would seem that as far as engineering is concerned there is scope for significant knowledge reuse and given that NASA relies heavily on engineering of all types, this should be borne in mind.

This point is explicitly made by the CKO of JPL, David Oberhettinger - noted by Prusak and Schwartz's (2016) to be a key contributor to the overall KM strategy for NASA - when he states in JPL's Knowledge Management Strategy: "'Knowledge husbandry' can save JPL time and money if it enables key knowledge to be reused on future projects" (Oberhettinger, 2014: 5). He reiterates this point in an online post entitled "Why Manage Knowledge?" on the JPL website:

> *"The JPL KM program will seek opportunities for JPL to reuse costly knowledge that is not presently captured for reuse. Knowledge that can be shown to be of high value to future projects and at risk for loss will be targeted for capture and sharing." (Oberhettinger, Undated).*

Knowledge reuse is clearly a priority for JPL, as Oberhettinger raises it again in an interview in 2013 when he states:

> *"If the project budget does not provide adequate resources for archiving project-specific knowledge for easy retrieval, then it may impact our ability to reuse technology developed at great expense. […] It creates a situation where JPL doesn't know what JPL knows! For example, it was unfortunate that JPL design of the throttled engine needed for the Descent Stage on Mars Science Laboratory necessitated making inquiries to Viking project staff who had long since retired." (CKO News Staff, 2013).*

Edward Rogers (the CKO at Goddard Space Flight Center) and Mike Ryschkewitsch (NASA's Chief Engineer) produced a NASA internal discussion document in 2008 entitled "Knowledge Reapplication: Enhancing Organization Learning at NASA" wherein they take a close look at this exact issue. Note that in this context reapplication is synonymous with reuse.

Rogers and Ryschkewitsch (2008) describe how the knowledge reapplication model used by NASA relies on personal experience, personal networks, and common knowledge (typically kept in a repository).

Rogers and Ryschkewitsch (2008) note how personal experience can be enhanced through job rotations or participating on diverse projects and missions. Personal networks are also enhanced in this way, as well as through workshops, communities of practice, and other similar events. Common knowledge is often kept in repositories like libraries and databases, as well as in the standardized training.

They further note how the three systems are interrelated. For example: (i) someone who does not know something (personal experience) may know someone who does (personal network), or be able to look it up in the repository (common knowledge), or (ii) the repository (common knowledge) may point you to a person (with personal experience) who you didn't know (now added to your personal network). Therefore, these systems function most effectively when they are used to enable each other, and the authors state that staff "[…] should enhance their ability to learn from all three paths in an integrated fashion." (Rogers and Ryschkewitsch, 2008: 5).

Rogers and Ryschkewitsch (2008) also highlight that it is when unrealistic expectations are placed on one system as the primary learning vehicle that disappointment follows. For example, (i) expecting too much technical detail from a personal contact may lead to disappoint unless your contact can point you to a document in the repository, or (ii) documents from the repository may lack context without a personal contact to fill in the background information for you.

This is important because in pointing out how no single system should be the primary system it shows Rogers and Ryschkewitsch (2008) taking a polar opposite view to Hansen et al. (1999) who make the firm statement "do not straddle" (1999: 112) and advocate focusing on a primary system.

Furthermore, Rogers and Ryschkewitsch (2008) take the position that learning and knowledge reuse is predominantly an interpersonal activity. This is reflected in the following statement:

> *"The NASA learning model is useful because it points to where intervention can help. Specifically, there are six intervention points that can enhance organization learning at NASA: 1) effective job rotation, 2) personal reflection[6], 3) knowledge sharing forums, 4) common core communities, 5) case-based training and 6) lessons learned. Each of these can be thought of as an organizational practice that individually may not seem*

[6] This point is about staff members taking time during projects to identify and consolidate possible lessons.

tremendously effective but when combined add up to a powerful learning energy for the organization." Rogers and Ryschkewitsch (2008: 6)

From the above six activities, the first four rely mainly on interpersonal transfer, while the last two (training and lessons-learned) have the potential for systematic/I.T. applications. This shows that knowledge managers at NASA are fully aware of the value of personalization and incorporate it into their strategies. This is reinforced elsewhere in the same document where Rogers and Ryschkewitsch (2008) state:

"The key to managing knowledge is not necessarily to extract it from its origins but to facilitate its use both at the source and within communities across the organization. […] Centralizing knowledge repositories for IT efficiencies may decrease knowledge utilization rates by reducing relevance, access and context all of which help knowledge flow to new challenges." Rogers and Ryschkewitsch (2008: 7)

This shows that NASA is also aware of the weaknesses implicit in trying to extract 'knowledge' from the workforce and codify it in a system. Instead, they take the position that knowledge reuse can be enhanced through personalization. This is incompatible with Hansen et al. (1999), who sees knowledge reuse as fundamental to codification and not to personalization. As such, the perspective put forward by Rogers and Ryschkewitsch (2008) don't fit under either the codification or personalization approaches.

Therefore, overall it can be seen that NASA has positive statements about knowledge reuse from many reputable sources, and it is also evident that at NASA knowledge reuse is seen as an activity rooted in both personalization (personal knowledge and networks) and codification (common knowledge). Therefore, with respect to knowledge reuse versus expert economics, NASA appears to have foot in both codification and personalization camps.

Team composition

The next question is how NASA designs its teams. Does it use large teams of junior "implementors" or small teams of experts? Again, in the context of NASA the answer does not readily identify with one or the other.

Hansen et al. (1999: 109) discuss how under a codification strategy relying on reuse economics one should use large teams with a high ratio of less experienced "implementors" relative to experienced staff; under a personalization strategy that relies on expert economics, one should use a small team comprised mainly of experts. Essentially, this can be boiled down to "large team – few experts" or "small team – many experts".

In an article entitled "Good Team Design" by NASA's Chief Knowledge Officer, Edward Hoffman, published in NASA's APPEL Magazine, he discusses some of the elements that he perceives as important in teams. His perspective on team composition is relevant here insofar as it disagrees with Hansen et al.'s perception of ideal team composition under codification versus personalization strategies.

Hoffman (2009: 1) describes how "Sitting in on the Shuttle Flight Readiness Review, I saw many of the factors that go into good team design in action" and describes how:

> *"The Shuttle Flight Readiness Review goes against the literature that advises minimizing the number of people on a team. There are more than one hundred people in the room, all of whom contribute at different points. The size of the team reflects the range of technical expertise needed and the interdependence of the systems they understand." (Hoffman, 2009: 1).*

It may be argued that such a large assembly of participants will still require a leader that takes an overarching view of the process, however, Hoffman (2009) notes that "[…] there are several leaders of the review process […]" and that "[…] sheer number of experts present provide[s] the diversity of ideas essential to the complex, interdependent issues involved […]".

These observations show that the CKO of NASA does not share Hoffman et al.'s perceptions concerning ideal team composition. In terms of team composition, using this example and the high praise reserved for it by the NASA CKO, it is not possible to fit NASA's "large team – many experts" under Hansen et al.'s (1999) categories of "large team – few experts" or "small team – many experts". Therefore, as for reuse economics or expert economics, NASA is unable to fit into the categories provided by Hansen et al.'s (1999) theory but rather presents a hybrid of each.

3.1.3 *Conclusion of competitive strategy and knowledge economics at NASA*

It is clear from this section that in terms of competitive strategy and knowledge economics, NASA contradicts Hansen et al.'s (1999) descriptions of codification and personalization by delivering innovation through its project teams (rather than through individual experts), reusing knowledge through a combination of codification and personalization, and by having large teams comprised of experts. While there are clearly significant elements of codification and personalization present, it is not possible to identify a dominant strategy and so in this respect NASA must be said to be following a balanced strategy, or as Hansen et al. would term it, straddling.

3.2 Knowledge management strategy

This section will look at NASA's knowledge management strategy from a number of different perspectives and constitutes a major part of the analysis. It is divided into four sections that will examine:

1. NASA's knowledge management journey – This is a review of the events since the mid-1980's that have helped to shape NASA's approach to knowledge management. By showing what NASA has tried and subsequently abandoned, it is possible to see the contrasts between what went before and what is new about the current approach.
2. The agency-level knowledge management strategy – This shows the perspective on knowledge management taken by the chief knowledge officer at the central agency level, which will influence how knowledge management is practiced at the various centers and departments.
3. Knowledge management at the centers – The NASA centers and departments are allowed a lot of autonomy in their respective approaches to knowledge management. Therefore, it is necessary to investigate the extent to which the agency-level knowledge management strategy reflected at the centers.
4. NASA's knowledge map – NASA's main knowledge management tool is its knowledge map. This part of the analysis will investigate what the knowledge map can show about knowledge management practices at NASA and how they conform to Hansen et al.'s theory.

3.2.1 *NASA's knowledge management journey*

To understand NASA's perspective on knowledge management at the agency level, it is necessary to briefly review the sequence of events and factors that helped to shape, and in some cases explicitly directed, NASA's knowledge management strategy. The value of this is that when reviewing sources, it is important to be able to identify the era from which they originate, as they may have subsequently been replaced by different thinking.

Hoffman and Boyle (2013) authored a useful paper entitled "Tapping Agency Culture to Advance Knowledge Services at NASA" that provides a brief overview of the key milestones in the evolution of NASA's knowledge management activities. This paper is extensively referenced in this section, augmented with Regulatory Reports and additional sources to provide a more detailed discussion of how NASA's approach to knowledge management has experienced significant changes over time.

A tradition of mentoring

Hoffman and Boyle (2013: 23-24) describe how NASA's model for staff are development during had traditionally relied on mentoring its staff through large scale, long duration projects. The scale and timeframe of these projects made it logical to develop its staff through a "natural progression of learning in a more deliberate and hierarchical context." They state that:

> *"NASA leadership implicitly understood that the training curriculum represented perhaps 10 percent of the preparation necessary to produce a successful generation of project professionals. The bulk of preparation resided in two critical sources—the sheer amount of time and duration to gain professional experience in the real world of projects, and the unstated but essential reliance on a previous generation of project talent who would naturally serve as mentors, coaches, and experts." Hoffman and Boyle (2013: 24)*

This is clearly a case of what Hansen et al. (1999) would consider knowledge transfer through personalization. However, when the Space Shuttle Challenger exploded on liftoff in 1986, it forced NASA to concede that it was not infallible, and compelled it to rethink its approach to project management, culminating in the Faster-Better-Cheaper initiative.

The era of Faster-Better-Cheaper (FBC)

Subsequent to the Challenger disaster NASA adopted the Faster-Better-Cheaper (FBC) initiative. FBC at NASA was summarised in the United States General Accounting Office (GAO) Report as follows:

> *"In 1992 NASA adopted the FBC philosophy as a way of managing programs and projects. An important element of this approach was a reduction in NASA headquarters management and moving more program responsibility to NASA's centers. This philosophy also increased the demand for program and project managers at a time when NASA was experiencing a significant reduction in staff due to retirements, downsizing, and departures to industry. Prior to FBC, there were fewer missions, and program and project managers accumulated significant first-hand experience before managing a program. Under FBC, with a threefold increase in projects and fewer staff, this was not always the case. Relatively unseasoned managers who were challenged to be more efficient and innovative and to take greater risks in designing and implementing missions led many projects." (GAO Report, 2002: 8).*

Part of the reorganization that took place under FBC was the inception of the Program and Project Management Initiative (PPMI). This was characterized by 'competency-driven project management' that manifested in formal career development paths linking project competencies to learning and education directed at an Agency level. Over subsequent years the PPMI ultimately evolved into NASA Academy of Program, Project and Engineering Leadership (NASA APPEL) (Hoffman and Boyle, 2013: 24). The end result was that "Challenger led to individual preparation becoming systematized, codified, and improved" (Hoffman and Boyle, 2014: 52).

The Lessons Learned Information System (LLIS) was also established at this time, in 1995. The LLIS is the official agency repository for Lessons Learned. Lessons learned are written up and submitted from across NASA, where they are screened for relevance and to ensure that they do not contain sensitive or proprietary information. A final review is undertaken by the Office of Safety and Mission Assurance, after which the Lesson is entered into the database and available for referencing by other project managers and staff.

The NASA Procedures and Guidelines for Program and Project Management Processes and Requirements (NPG 7120.5A) requires that program and project managers review and apply significant lessons learned from the past throughout the program or project life cycle (GAO Report, 2002: 19). However, this was not always the case. A 2001 survey that found only a quarter of managers at NASA were actively contributing to the LLIS system, with a similar number of managers "unaware the system even existed" (MacCormack, 2004).

However, in 1999 two Mars missions failed in close succession. The Mars Climate Orbiter burned up entering the Martian atmosphere because the navigation software incorrectly used English instead of metric units, thereby computing the incorrect trajectory. Three months later the Mars Polar Lander was lost during a landing attempt – subsequent investigations suspect due to premature shutdown of the Lander's descent engines (GAO, 2002: 9).

General Accounting Office Report (2002)

The Mars mission failures prompted investigation by GAO, and in January 2002, the GAO produced a report entitled "NASA – Better Mechanisms Needed for Sharing Lessons Learned".

The GAO attributed the failures to the Faster-Better-Cheaper initiative and raised concerns that lessons learned from past mishaps and programs were not being applied effectively toward future mission success (GAO, 2002: 10). In the reports the GAO stated that:

> *"The limitations in NASA's ability to share lessons learned point toward two underlying problems: cultural resistance to sharing knowledge and the lack of an effective strategic framework and management attention for overcoming such resistance." (GAO, 2002: 36).*

NASA's Strategic Plan for Knowledge Management (2002)

In response to the GAO Report, the "NASA Knowledge Management Team" (a collection of NASA managers that preceded the appointment of the agency-level chief knowledge officer) produced the Strategic Plan for Knowledge Management in April 2002 (see references). However, it appears that this plan failed to have the desired effect. In a document entitled "Building the Goddard Learning Organization" (2011) by Goddard Space Flight Center CKO Dr Edward Rogers, he describes how:

"Unfortunately, that document [the 2002 NASA Strategic Plan for Knowledge Management] fell short of achieving effective change and remains in a draft form. In contrast, this Goddard Plan is designed to overcome the previous focus on IT as a KM driver and an over-emphasis on capturing knowledge from workers for the organization as opposed to facilitating knowledge sharing among workers." (Rogers, 2011: 5).

The last statement is significant as it points to the NASA's KM emphasis in the early 2000's had been on capturing and codifying knowledge rather than encouraging sharing between workers. However, Rogers (2011) notes that an increased appreciation of the role of knowledge sharing (a personalization approach) followed in the next few years. However, for this to happen there had to be a catalyst.

Columbia Accident Investigation Report (CAIB) 2003

NASA was busy reviewing its approach to knowledge management and renewing its emphasis on knowledge capture when in 2003 disaster struck again when the Space Shuttle Columbia disintegrated on re-entry.

The CAIB Report (2003) identified a number of factors, ranging from technical causes to organizational causes. Suffice to say that the problem stemmed from the fact that when damage to the space shuttle was observed, the decision to continue with the mission was not based on robust engineering data and safety practices, but rather on a consensus based on "well it hasn't caused a problem before" (technically termed a 'normalization of deviance') that was able to persist through a series of poor communications.

In terms of what the CAIB Report had to say about practices relating to knowledge management, it was specific in pointing out the LLIS system and the known issues with its underutilization in the statement:

"The Lessons Learned Information System database is a much simpler system to use, and it can assist with hazard identification and risk assessment. However, personnel familiar with the Lessons Learned Information System indicate that design engineers and mission assurance personnel use it only on an ad hoc basis, thereby limiting its utility. The Board is not the first to note such deficiencies. Numerous reports, including most recently a General Accounting Office 2001 report, highlighted fundamental

weaknesses in the collection and sharing of lessons learned by program and project managers." (CAIB Report, 2003:189).

In the end, the Columbia Accident Investigation Board (CAIB) concluded, among many other shortcomings, that NASA "[…] has not demonstrated the characteristics of a learning organization." (CAIB Report, 2003:12). Hoffman and Boyle (2013) explain how this resulted in renewed efforts from knowledge services at the agency, which took the form of printed media, a variety of forums served by communities of practice both within and outside the agency, and a concerted effort to capturing and sharing knowledge through lessons-learned (Hoffman & Boyle, 2013: 24).

This shows how NASA did not move away from the paradigm of 'capturing knowledge', but sought to complement it with a greater emphasis on sharing. However, the desire to increase sharing faced other challenges, as it occurred:

"[…] at a time when experience and talent is at a premium to achieve mission success, NASA's workforce is increasingly young and inexperienced, and many of the most experienced project managers are preparing to retire. This speed of change has catapulted NASA and other organizations to respond to new challenges through rapid technological innovation, increased interdependence on alliances and partnering, and innovative approaches to capture and channel knowledge." Hoffman & Boyle (2013: 25)

Therefore, faced with the urgent need to increase sharing in an organization that was large, geographically spread, and facing the imminent retirement of much of its knowledge, it was necessary to leverage technology as well as social means. This shows the start of recognizing that a more balanced strategy is needed.

NASA Aerospace Safety Advisory Panel (ASAP) 2011

In 2011 the Aerospace Safety Advisory Panel (ASAP) submitted its Annual Report to the U.S. Congress in which reports on what it has observed at NASA with respect to operations, decision-making processes, safety culture and other strategic topics.

While the ASAP Report (NASA Aerospace Safety Advisory Panel, 2012) specifically complimented the staff at Johnson Space Center and Goddard Space Flight Center for their good work in cataloging and managing NASA critical knowledge, it went on to note that:

> *"These examples, while excellent and laudable, do not constitute an approach that ensures the identification and capture of critical NASA implicit and explicit knowledge Agency-wide in a manner that would allow any NASA employee (or, under some circumstances, NASA partners and contractors) a single process or tool to locate and then access all of the information resources." (NASA Aerospace Safety Advisory Panel, 2012: 12).*

The ASAP Report then made a specific recommendation that was a defining moment for knowledge management at NASA:

> *"The ASAP has recommended that NASA establish a single focal point—a "Chief Knowledge Officer"— within the Agency to develop the policy and requirements necessary to integrate knowledge capture across programs, projects, and Centers. Additionally, the ASAP has recommended that NASA consider establishing Chief Knowledge Officer positions at all NASA Centers and in all Mission Directorates to ensure standardization of programs and lessons learned as we move forward." (ASAP Report, 2011: 12)*

NASA responded to this by appointing Dr Edward Hoffman as its first agency-level CKO in 2012. Hoffman and Boyle (2013: 26) describe how the Chief Knowledge Officer (CKO) was to act as a facilitator and champion for agency knowledge services, supported by designated CKOs at each center and mission directorate. This federated approach enabled knowledge management efforts to adapt to the requirements and cultural characteristics of each center and mission directorate.

Hoffman's influence introduced some changes to the emphasis of knowledge management as it was practiced at NASA. With reference to the existing draft Strategic Plan for Knowledge Management (2002), Hoffman and Boyle (2013) note:

> *"At the beginning of redefining the strategy and framework, NASA's existing knowledge policy was limited to a singular focus on lessons learned and the proprietary*

Lessons Learned Information System (LLIS) database, despite the fact that the organization had greatly expanded its knowledge activities over the past several years to include a wider array of services. This clearly established the need for a new knowledge policy that reflected the breadth of independent knowledge services now in use across the agency. This federated approach resulted in a natural progression to identify, characterize, and define agency knowledge services into a knowledge map […]. The map helps all practitioners to achieve mission success. It is updated quarterly and briefed to senior NASA leadership." Hoffman & Boyle (2013: 26).

Hoffman and Boyle's (2013) paper concludes with a section entitled 'The Future of Knowledge Services' where they state that:

"*Knowledge services imply an active exchange of wisdom and lessons through access to both people and technology. Often there can be a contest between technology and people approaches, but an optimal balance of both is necessary." Hoffman and Boyle (2013: 26)*

This final quote shows that NASA's chief knowledge officer is well aware of the tension that can exist between the I.T. driven aspects of knowledge management (typically characteristic of codification) and the personalization aspects, but believes that these two aspects can work synergistically. This is a strong indication that NASA's knowledge management leaders are in favour of a balanced approach.

Conclusion on NASA's knowledge management journey

This section provided some context as to how NASA has evolved it knowledge management activities in response to the events and challenges that have arisen starting the Challenger Disaster in the mid-1980's, and culminating with the appointment of NASA's first agency-level CKO, Dr Edward Hoffman in 2012.

The sources referenced above show that in 2013 there is already evidence that Hoffman is a proponent of an approach to knowledge management that "balances both people and technology" rather than focusing on just one strategy as Hansen et al. (1999) recommend. This promises to put NASA's approach to knowledge management at odds with Hansen et al.'s theory of how knowledge management should be undertaken.

The next section of this chapter will look at Dr Hoffman's approach directing knowledge management at a central level, followed by a section containing a sample of interviews from NASA centers, departments and projects to show how knowledge management is being handled at a local level.

3.2.2 *NASA's central strategy*

In order to get a better idea of NASA's approach to knowledge management at a central level, reference is made to three documents that provide insight into NASA's central knowledge management strategy. While an effort has been made to preserve some context and background information, the particular focus on highlighting where they make explicit reference to elements that can be construed as representative of codification and personalization.

Working Knowledge at NASA (2013)

In his presentation entitled 'Working Knowledge at NASA', NASA CKO Doctor Edward Hoffman notes that because of the complex nature of knowledge at NASA, the agency has opted for a federated model for coordination and collaboration of knowledge interests. He substantiates this choice by referring to how many CKOs outside of NASA have tried to "manage" all the knowledge in their organizations and failed. This is also referred to in the paper entitled "Tapping Agency Culture" by Hoffman & Boyle (2013: 26). Under the federated model, the NASA CKO functions as facilitator and champion for knowledge while knowledge managers at the individual NASA centers are given space to implement the systems that best suit their context (Hoffman, 2013).

This structure follows on the recommendations by the Aerospace Safety Advisory Panel (ASAP), wherein it was recommended that "[…] NASA establish a single focal point (a Chief Knowledge Officer [CKO]) within the agency to develop the policy and requirements necessary to integrate knowledge capture across programs, projects, and centers." (Hoffman, 2012: 1).

Hoffman highlights that when it comes to finding knowledge, it is "imperative to have a network" (2013: 23). Hoffman says that this is because knowledge is social. Hoffman notes that NASA's existing knowledge policy NPR 7120.6 is limited in its singular focus on lessons learned and the lessons-learned information system (LLIS), and that because NASA has greatly expanded its knowledge activities (as illustrated on the industry's Knowledge Map), a new knowledge policy is needed that reflects the breadth of knowledge approaches in-use across NASA (Hoffman, 2013).

The significance of this paper is that Hoffman refers to knowledge capture but also to knowledge networks (with emphasis on the social aspect of these networks). These are elements of codification and personalization, respectively, and show that NASA is taking a more balanced view of knowledge management practices.

K2020 at ARC: One NASA Strategy in a Federated Model (2016)

In this document, Prusak and Schwartz (2016) are commenting on NASA's Knowledge 2020 event, convened by NASA's CKO Dr Edward Hoffman. The event centered on the challenge of creating an agency-wide Knowledge Strategy among a network built on a federated model. Regarding the knowledge management approach taken by NASA, Prusak and Schwartz's (2016) noted that:

> *"The NASA KM program has many features but can be briefly summarized as knowledge acquisition and sharing, focused on knowledge application and undergirded by knowledge leadership and management commitment." (Prusak and Schwartz, 2016: 5).*

Prusak and Schwartz (2016) did not go into detail on NASA's overall KM strategy, but did note that "A very important component of NASA's strategic emphasis is the identification and utilization of critical knowledge" (Prusak and Schwartz, 2016: 5).

This referred to a project undertaken to identify and prioritize critical knowledge, as described by the IKNS Capstone Project undertaken by Columbia University and NASA (Bell et al., 2015). Prusak and Schwartz (2016) noted how NASA had found that many KM projects failed because they were indiscriminate in the knowledge they captured, and operated on the principle of "more is better". The IKNS Capstone Project's objective was to recommend a method for identifying, prioritizing, capturing and transferring critical knowledge. Critical knowledge was defined as "broadly applicable lessons learned that enable mission success, stimulate critical thinking and help raise questions that need to be addressed at various phases in the project life-cycle" (IKNS 2015: 4). This means that among other things, knowledge referees would be looking for (i) lessons with broad applicability, (ii) that involved the top 5% of updateable knowledge, (iii) can keep evolving towards new applications and missions, and (iv) that lends itself to being incorporated into processes, policies, standards and training to prevent it being lost.

The IKNS Critical Knowledge Project can be seen as a project aimed at codifying critical agency knowledge. Its focus was mainly on codification, and while it advocated the distribution of critical knowledge through policies/procedures/standards and training, there was a lack of personalization elements.

Prusak and Schwartz (2016) did note how Patrick Johnson, CKO of the Human Exploration and Operations (HEO) Mission Directorate, presented on plans made by his team that clearly involved the identification and capture of critical knowledge, with an explicit theme devoted to enabling and encouraging "good usage by talks, publications, online tools, and internal publicity" (Prusak and Schwartz, 2016: 7). This shows elements of codification and personalization existing side-by-side in the same Directorate, and shows that NASA is serious about capturing and codifying important knowledge, as opposed to just pursuing networks (personalization). Again, this is indicative of a more balanced approach to knowledge management.

"Five Questions for Ed Hoffman" (2013)

This interview undertaken by the APPEL News staff with NASA CKO Dr Hoffman shows that Hoffman perceives NASA to have a balance of strategies aimed at 'capturing' and 'sharing':

> *"If you look at our NASA knowledge map you can see we've got some excellent work going on in terms of capturing case studies, capturing NASA stories. The map also shows great work in the area of sharing our lessons, pause and learn activities, and learning from reviews. We have face-to-face activities with people coming together to share and to learn. I think we are good at having experts who share, and we have strong communities of expertise in many different disciplines—we are often leaders in that."*

The initiatives aimed at 'capturing' can be seen to relate to codification, while the initiatives aimed at 'sharing' show instances of 'personalization'. This is an indication that NASA's KM strategy sees the importance of both. Hoffman places a lot of emphasis on sharing:

"[…] the sharing component, to really make sure that we have an organization and projects and programs that work off the principle of sharing your expertise, sharing your wisdom, sharing your knowledge." (Hoffman, 2013:1).

Hoffman also discusses the importance of access to knowledge and wisdom, and shows how he sees it as containing a lot of elements of personalization as well as codification:

"the importance of access—access to knowledge and wisdom. We have created an environment where people need to have access to the people to talk to, to training and learning, to building their communities of practice, and also to having alliances and networks. There is also access through technology such as social media and being able to go into the computer and to find what or who you are looking for." (Hoffman, 2013:1)

In contrast to the paper on critical knowledge, in this paper the focus is on personalization.

Conclusion on NASA's central strategy

From the papers presented above it can be seen that while NASA has a strong focus on identifying and capturing critical knowledge, there is also an emphasis on the social elements such as networks, sharing and people having access to other people. Neither strategy is clearly promoted above the other, and it can be concluded based on this that at a central level NASA is promoting a knowledge management strategy that attempts to balance codification and personalization efforts. This means that at a central level, NASA's appears to be going against Hoffman et al.'s (1999) admonition and is straddling both practices.

3.2.3 *Knowledge management at NASA centers, departments and projects*

While NASA may at a central level espouse knowledge practices that show a balance between codification and personalization, the federated approach taken by NASA with respect to this issue leaves the different centers, departments and projects a lot of latitude to exercise their own brands of knowledge management.

This section is intended to determine whether knowledge management practices at these organizations reflect the same balance between personalization and codification. It is not possible to review all 25 organizations represented on the NASA knowledge management map within the space constraints of this dissertation. Therefore, this will be done by reviewing transcripts from interviews with knowledge managers across a mix of nine centers, departments and projects, with a particular focus on detecting whether their perspective favors a balance between codification and personalization, or is biased in favor of emphasizing one approach as per Hansen et al.'s (1999) recommendation.

Ames Research Center (ARC)

Mendoza holds that it is of critical importance to capture and organize lessons learned because "many things that we do are not new, but a lot of the new things we do are based on what we did before." ('NASA Ames' Donald Mendoza': 2017). This points to knowledge reuse being a significant factor for ARC, and this is a characteristic of codification.

Mendoza also states that with respect to the application of lessons learned at ARC, "for the most part the majority of what happens is very, very organic. What I mean by that is it's all people-based." This now balances the perspective with some personalization. He points out how:

> *"It's a very difficult thing to basically refer someone to a giant database and say, 'Here, go and queue the database for lessons on propulsion systems,' or 'Here's a spreadsheet that has all the lessons from Mission A. See if any of them are applicable to Mission B.'"*

Mendoza shows how personalization needs to be complemented with codification when he says "We try to engage the human element as much as possible, but that's not always possible because oftentimes the human is no longer at the agency, so then we turn to the machinery of the process." To formalize this knowledge so that it's not people dependent, it needs to be captures in the Lessons Learned Database. Mendoza is responsible for establishing the policies and procedures that ARC uses to capture and disseminate lessons learned, and has authored over 400 lessons learned. Mendoza also refers to how lessons are captured at JPL and embedded in the centers policies and procedures:

> *"At JPL they have a program whereby once a lesson gets processed through their machinery, there's a group of humans who then assess the knowledge or the output of the machinery and decide how to fold that into their business as usual. […] When they get a lesson, they will assess it for which document needs to be enhanced or revised or changed based on that lesson. So rather than having the end user have to*

go to some specific database to look for a lesson on some part, they're just doing their work. The knowledge is already embedded in the instructions that they're using."

This is an important observation for how learning can be embedded in the organization practices, making it into a 'learning organization' that transfers knowledge by integrating it into policies and procedures to drive reuse, rather than relying on dissemination and adoption on an individual basis.

In the interview Mendoza can be seen to take a view of knowledge management at ARC that is balanced between personalization and codification, and has highlighted the importance of knowledge reuse for the agency.

Armstrong Flight Research Center (AFRC)

An interview with AFRC's CKO Bradford Neal ('NASA Armstrong Flight Research Center's Bradford Neal', 2017) is posted on the NASA APPEL website. During the interview, in answer to the question "How does your organization share knowledge?", Neal's response is:

"A lot of the knowledge transfer at Armstrong takes place through human interaction. We try to promote the interaction of less experienced folks with more senior folks through work assignments and our internal review processes. We also hold occasional lunchtime seminars and colloquia to cover topics that we feel are of interest to the broader community."

This is distinctly about personalization. Neal's interview also discusses how AFRC collects and maintains flight data and project records, collects and disseminates lessons learned, encourages its staff to write technical reports, and encourages presentations at technical conferences and symposia. Neal highlights the challenge of "allowing people the opportunity to slow down long enough to think about what knowledge they have collected, and then how they are going to capture and present that in ways that are easily communicated". This shows more emphasis on codification. Neal also discusses importance of understanding the reasons underlying processes and procedures at the center, so that staff understand the lessons embedded in those organizational practices and can update or replace these organizational processes without risking the loss of the organizational learning that went into their creation.

This first part of Neal's interview shows that AFRC has a strong emphasis on activities synonymous with personalization. However, there is also evidence of a variety of activities aimed at codification and how organizational knowledge are bound up in the centers policies and procedures. The end result is that knowledge management at AFRC can be judged to involve a combination of both personalization and codification initiatives.

Marshall Space Flight Center (MSFC)

In an interview with MSFC CKO Paul McConnaughey ('NASA Marshall's Paul McConnaughey', 2017), he discusses how knowledge management at MSFC involves knowledge capture, case studies and the collection and distilling of lessons learned, as well as their focus on communities of practice and communities of interest.

McConnaughey makes an interesting statement that "in order to check ourselves, we went through all the lessons learned from shuttle and Constellation, and measured ourselves in respect to what we were or were not doing to follow lessons learned from those two programs. Those were the nearest ones. One was very successful and they chose to flow it into policy."

This echoes the observation by Mendoza at Ames Research Center, when he described how JPL embeds lessons learned into the centers' policies and procedures to make a 'learning organization', and Neal from Armstrong Flight Research Center who insisted that the reasons underlying organizational practices needs to be understood so that key lessons can be preserved. Therefore, MSFC shows a commitment to codification as well as elements of personalization from the cultivation of communities of practice.

Johnson Space Center (JSC)

An interview undertaken by NASA's knowledge management staff with JSC's CKO Jim Rostohar ('NASA Johnson's Jim Rostohar', 2017) in 2017 shows that he can be taken to be supportive of personalization when he states that "A healthy knowledge sharing environment really contributes to and enhances our quality management efforts". Rostohar goes on to state:

> *"I come from a communication background, so I feel communication is extremely important to knowledge sharing. The extent that we can effectively communicate the value of knowledge management is directly proportionate to our success."*

However, Rostohar also discusses initiatives that are firmly rooted in codification, for example JSC support the Engineering Academy by developing case studies and classroom materials using information from their databases. Under successful knowledge efforts, he notes improvements in search functionality, strengthening of case studies, and improvements in their Lessons Learned Program, which all revolve around documentation. Rostohar also shares a success story about an engineering team that needed to access research done under the Apollo program, without which they would need to develop and certify new contingency measures that "would take two to three years and add an additional cost of several million dollars." However, when the engineers tried using JSC's newly implemented IHS Goldfire analytical search tool they were able to find the relevant information that they had not been able to find using the standard JSC search tool. This enabled the project to move forward without incurring the additional cost and time delays.

The interview with JSC's CKO show that JSC understands the value of personalization but also has prominent codification initiatives. The anecdote also shows that JSC still relies on knowledge developed decades earlier, pointing to significant reliance on knowledge reuse. Therefore, JSC can be seen to have a mixed strategy.

NASA Engineering and Safety Center (NESC)

An interview with the CKO at NESC, Dan Yuchnovicz ('NASA Engineering and Safety Center's Dan Yuchnovicz', 2016), focuses on the identification and capture of key knowledge and lessons across projects. Yuchnovicz tells how the NESC "was established in July 2003 in response to the Space Shuttle Columbia accident and provides independent assessment of technical issues for NASA programs and projects".

The NESC typically has between 80 and 100 assessments open at a time. The assessments contribute to the capture lessons learned (for submission to the lessons-learned information system) and the compilation of technical bulletins (one-page summaries of engineering knowledge, best practices and references to further information). Other main outputs include NESC Engineering Reports, and NESC Technical Updates. NESC then surveyed trends across

1,900 recommendations and over 100 lessons learned from over 600 Assessment Reports to determine how these were being used by the agency.

The NESC Academy offers videos, online training and webinars that get senior technical experts to share critical competencies. At the time of the interview, the NESC Academy had surpassed 50,000 lifetime views, 20,000 of which took place in the year of the interview.

Yuchnovicz also referenced the reuse of knowledge at NASA with an anecdote of how the NESC brought several Apollo era engineers out of retirement to assist with the Constellation Program, and in the process recovered many Apollo engineering reports thought to be gone.

The interview with Yuchnovicz shows a strong emphasis on codification at NESC, reinforces by what is clearly a significant investment in online training facilities. In terms of Hansen et al. (1999), this would check all the boxes of people-to-documents, reuse economics, invest heavily in I.T. to connect people with reusable codified knowledge and use it to train your staff at a distance. Nonetheless, the reference to Apollo era engineers, and reliance on senior technical experts to lead assessment teams and develop training shows that NESC depends to large extent on individual expertise even though it is on a scale that tends to surpass the reliance on any single individual. Considering the evidence, NESC seems to tend towards a codification-based strategy.

NASA's Scientific and Technical Information Program Office (STI)

Karen Fallon is the Knowledge Services Lead at STI. In an interview from 2017 ('STI's Karen Fallon', 2017) published on the NASA APPEL website, she describes how STIs collection of research is:

> *"a highly esteemed repository of scientific and technical research information. We have a technical team that preserves it, but also ensures that it is maintained at the highest degree of preservation in order to make the oldest documents from the early 1900s as searchable as submissions from yesterday."*

Further on in the interview, Fallon alludes to the sheer volume of records they curate and make available on both public and restricted-access platforms:

> *"On our public site (NTRS) we average about 400,000 downloads per month. It's important to caveat this number. These are searchers who have not just googled*

something. They have come to search NASA STI for defined pieces of information. We also average 20,000 to 30,000 requests per month for specific, restricted information which is sourced from the registered user site (NTRS-R). The combined repositories have over 4.5 million entries from the early 1900s during the Wright Brothers up until today."

Fallon goes on to note how in terms of I.T. "we try to ensure that we have the latest and greatest technology and practices as far as maintaining, preserving and disseminating our information." The interview with Fallon shows that STI is focuses almost exclusively on codification, giving little thought to personalization. Given the nature of STI's mission this is not surprising, and there is acknowledgement from Fallon that she sees STI as being involved in information management rather than knowledge management when she states:

"Another challenge we face is how best to exist as an entity, transacting and cooperating as an agency information management resource — but also pursuing the sweet spot where the information management and knowledge management activities intersect within NASA. Our goal is to complement knowledge management efforts in addition to other large federal repositories, so we collaborate in a complementary way."

STI would not exist as a separate program if knowledge reuse did not represent significant value for NASA. STIs focus on codification also highlights how agency centers and departments have different objectives, and this in turn will affect the balance of codification and personalization practiced by that center or department in the context of the greater NASA picture. Therefore, like NESC, STI seems to be practicing a strategy based on codification.

Stennis Space Center (SSC)

The interview with SSC's CKO John Stealey ('SSC's John Stealey', 2012) starts with Stealey stating that one of their biggest challenges is accessing historical technical data, specifically the assumptions and calculations supporting engineering designs. Stealy also discusses how SSC has sometimes needed to access past employees to re-learn the knowledge underlying current systems.

Stealey feels that a major misunderstanding around knowledge is that it can be captured, maintaining that "True knowledge can't be stored outside a practitioner's mind. The only way to completely capture and maintain it is to use it." Stealey refers approvingly of knowledge capture projects, case study development and the incorporating knowledge capture into project design and processes at other centers but does not give examples of explicit knowledge capture at SSC.

The interview with Stealy is brief, and while it clearly points to SSC's fundamental reliance on knowledge reuse, it does not seem solely wedded to either codification or personalization practices beyond expressing the conviction that knowledge is stored in people and in practices. This presents something of a dichotomy, as according to Hansen et al. (1999) reuse is a characteristic of codification, while storing knowledge in practitioners (although not to say the practices of organizations) is characteristic of personalization. SSC would need to be classified as a mixed strategy.

NASA Engineering Network (NEN)

The NEN is a collaborative system designed to enable knowledge sharing among geographically dispersed practitioners. It is an online system that incorporates communities of practice, federated search functionality that 30 different engineering repositories across NASA, the lessons-learned system, expert locators, and other resources for NASA engineers.

Daria Topousis is the Project Manager and Knowledge Services Lead at NASA's Engineering Network Project. In an interview from 2017 ('NEN's Daria Topousis', 2017), she discusses how although the network is comprised of both repositories and communities, the communities have become fundamental to supporting knowledge sharing through NEN. She explains this in the following statement:

> *"Communities of practice are really critical to NEN and to knowledge sharing and knowledge growth in the engineering discipline. In the early days of NEN the communities were just another element that was equal to search and lessons learned. As we've developed the communities, we have found that they have become the heart of NEN and the knowledge sharing that happens between people."*

She substantiates this by explaining how community members will access information from the repositories, but also post questions about it on the network and initiate discussions with peers. This carries the same message as the NASA internal discussion document on "Knowledge Reapplication at NASA" (Rogers and Ryschkewitsch, 2008) discussed earlier, wherein it was explained that "personal experience", "personal networks" (both examples of personalization) and "common knowledge" (i.e., codified knowledge stored in repositories) are complementary rather than being substitutes. Gaps in one area can be bridged by leveraging one of the others, for example calling a friend to ask for help accessing technical information you don't have access to. The idea that codification and personalization can exist as complementary activities in the same activity is at odds with Hansen et al.'s (1999) theory, which requires a dominant-subordinate paradigm along the lines of an 80-20 split.

With respect to Hansen et al. (1999), Topousis raises in her interview how NEN's knowledge management practices include personalization and codification initiatives, and how personalization is an important complement enabling the use of codified knowledge, suggesting that codification and personalization are not necessarily contradictory to one another.

Jet Propulsion Lab (JPL)

David Oberhettinger, the CKO at JPL, has made significant contributions to knowledge management strategy at an agency level as well as at JPL, and Oberhettinger's contributions are referenced in other parts of this thesis.

In an interview in 2013 ('JPL's David Oberhettinger', 2013) Oberhettinger referred to the importance of repositories and advanced search technology, as well as to Lunch-and-Learn sessions and Pause-and-Learn sessions for supporting JPL's projects. Repositories and search technology are typically tools to support codification, while Lunch-and-Learn Pause-and-Learn sessions are typical personalization activities designed to bring staff together to share knowledge.

That Oberhettinger gave equal emphasis to both codification and personalization in the brief interview, without clear emphasis on one or the other, shows that JPL probably takes a balanced view of knowledge management. That is to say, JPL does not emphasize one approach and subordinate the other.

Conclusion from KM at NASA centers, departments and projects

The interviews above re-emphasized that NASA relies on knowledge reuse to a large extent (this was also seen in the previous sections that referred to knowledge economics) and that sometimes the knowledge that NASA relies on is held in the heads of experts, resulting in them having to seek out retired experts to recover 'lost' knowledge. The CKOs at the NASA centers generally recognized this to be a problem that needed to be addressed by improving the capturing and sharing of knowledge across the organization.

Where NASA has captured knowledge it is not just codified in documents, but also stored in organizational practices (e.g., processes and procedures) so that the application of this knowledge becomes part of the work routine. While the CKOs interviewed above recognize the need to improve codification to prevent knowledge loss, and generally have various initiatives aimed at capturing this knowledge, most CKOs were explicit in noting that an overreliance on codification alone will not work. Exceptions could be found in departments/projects specifically geared towards codification, like NEN and STI where the focus was on record-keeping. However, it could be argued that this resulted from a mandate focused almost exclusively on maintaining a repository. Nonetheless, most CKOs have expressed a need to balance codification with personalization. Indeed, many of the interviews showed that codification and personalization needed to co-exist to enable one another.

This meant that knowledge management practices across NASA centers, departments and projects could generally be seen to be in-line with the knowledge management strategy expressed by Hoffman at the central level. It also means that NASA can be seen to be pursuing both codification and personalization strategies, or straddling as it would be termed by Hansen et al. (1999).

3.2.4 *What does NASA's Knowledge Map look like?*

NASA's Academy of Program/Project and Engineering Leadership (APPEL) manages the NASA knowledge portal that brings together all of NASA's knowledge resources. A central feature of the portal is the "NASA Knowledge Map". This map does not describe the actual stocks of knowledge at NASA, but rather lists all the knowledge services and initiatives across the different centers and categorizes them by type (NASA Knowledge Map, undated). As such, because it maps knowledge management activities it may be more accurately thought of as a "knowledge management map", but to avoid confusion this thesis will refer to it by NASA's designation of the NASA Knoweldge Map.

In this section the focus is evaluating the information available in NASA's KM Map to answer 3 questions:

(i) How does NASA categorize its knowledge management initiatives?
NASA CKOs have classified their initiatives in a consistent way across these 6 categories. An examination of the categories to see what they contain and how they correspond to Hansen et al.'s (1999) two categories of people-to-documents or people-to-people will give an insight into how NASA's knowledge management activities correspond to Hansen et al.'s theory.

(ii) How are initiatives distributed across these categories?
There are 414 initiatives across the 6 categories. Does the distribution of these initiatives across the categories give us more insight into whether NASA is leaning towards people-to-documents or people-to-people overall?

(iii) What is the balance of initiatives (by category) across the centers?
There are 25 centers represented on the knowledge map. Do all the centers exhibit the same mix of categories and initiatives? Are certain types of center similar? What does the mix of people-to-documents or people-to-people initiatives reveal about the knowledge management strategy? Are there other characteristics that could help to explain the variance between centers?

The answers to the 3 questions above will give an indication whether knowledge management efforts are tending towards people-to-documents or people-to-people, or perhaps both at the same time. This can then be compared to the insights gained from the interviews with NASA CKOs and the information that they have published about knowledge management at NASA to see if it provides a consistent picture with respect to their knowledge management strategy.

How does NASA categorize its knowledge management initiatives?

The six categories used by NASA (Hoffman, 2013) are:

- KM online tools - Any online knowledge tools, including but not limited to: portals, document repositories, collaboration and sharing sites, video libraries. Examples of initiatives found under the online tools category shows information systems, SharePoint for collaboration, Best Practices repositories, lessons-learned information systems, document management systems, data storage and archiving, digital libraries and repositories, E-libraries, websites, wikis, and online portals. It also contained a photo repository, a problem reporting and corrective action system, a safety, health & environmental portal, a shuttle knowledge console, an online mentor matching portal, and a video library.

- Search/tag/taxonomy tools - Dedicated search engine for knowledge (e.g., Google Search Appliance); any initiatives related to meta-tagging or taxonomy. Examples of specific initiatives found in this category show mainly search engines, application development to support search engines, data mining and analytics tools, taxonomies and tagging for information systems and lessons-learned systems, and a cross-referencing service.
- Case studies/Publications - Original documents or multimedia case studies that capture project stories and associated lessons learned or best practices (e.g., GSFC case studies; APPEL case studies and ASK Magazine stories; NASA Safety Center case studies, etc.).Collating the initiatives under this showed predominantly case studies as well as reports, strategy papers, public papers, historical records, oral history transcripts, newsletters, articles and presentations.
- 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, knowledge sharing recognition programs, etc.). In terms of actual initiatives, this category included mainly lessons-learned processes (including processes for capturing lessons, “distilling teams”, advisory committees, review committees, submission, and storage repositories), benchmarking activities, document management procedures (storage and archival), as well as continuous improvement processes (e.g., Six Sigma), training program content, and some pause-and-learn activities (arguably another brand of lessons-learned).
- Knowledge networks - Any defined knowledge network, such as a community of practice, expert locator, or mass collaboration activity. The initiatives in this category showed a lot of communities of practice, working groups, expert locators, online chat groups, and a wiki.

- Face-to-face - Any activities that bring people together in person to share knowledge and enhance relationships, trust, and open exchanges. Impact can be multiplied through online sharing. The initiatives listed under this category were mostly concerned with events, workshops, colloquia, courses, facilitated sessions, knowledge forums, lunch-and-learn sessions, knowledge map conversations, master's forums, seminars, panel discussions, presentations, pause-and-learn workshops, storytelling events, virtual research labs and mentoring programs.

These categories offer a useful insight into how knowledge managers at NASA perceive knowledge management in terms of people-to-documents and people-to-people. The main question is whether these can provide a useful metric for how knowledge management efforts at NASA conform to Hansen et al.'s (1999) theory of 'codification' versus 'personalization' strategies.

The 'people-to-documents' approach is basically synonymous with codification, while the 'people-to-people' approach is synonymous with personalization. Therefore, going forward in this chapter, the terms codification and personalization will be used. Considering the first four categories, they all seem to fall under the definition of 'codification':

1. KM online tools – These are repositories built around holding codified knowledge and making it available to other users. Note NASA has not included 'expert locators' here, but instead classified these under 'knowledge networks'. Therefore, these systems are exclusively concerned with storing codified knowledge.
2. Search/tag/taxonomy tools – Tools to classify codified knowledge and make it easier for users to find the knowledge stored in repositories and systems, these are an integral part of codification efforts.
3. Case studies/Publications – These are the most fundamental form of codified knowledge, that has been made independent from its originator and converted into a document (electronic or physical).
4. Lessons learned/Knowledge processes – These are processes to facilitate the capture and conversion of knowledge, and therefore fall under the codification effort.

The last two categories correspond to 'personalization':

5. Knowledge networks – This describes ongoing group interactions (such as working groups, communities of practice) and tools used to facilitate these groups (such as expert locators and wikis). Therefore, as this category focuses on interaction rather than codifying knowledge, it is considered to correspond to personalization under Hansen et al.'s (1999) framework.
6. Face-to-face – This category describes in-person events and once-off events, although it does not rule out the use of online resources. Being primarily about communication and interaction between persons rather than codification, it is considered to fit Hansen et al.'s (1999) concept of personalization.

None of the categories shares characteristics that can be found under both codification and personalization strategies, and so none are considered to present a 'mixed' classification.

That there are four categories of codification versus two categories of personalization is a useful distinction, but this alone does not reveal the extent of activity under each category and therefore whether activities are weighted more in favor of one type of activity than the other. Therefore, the next step is to consider how initiatives are distributed across the categories.

How are initiatives distributed across these categories?

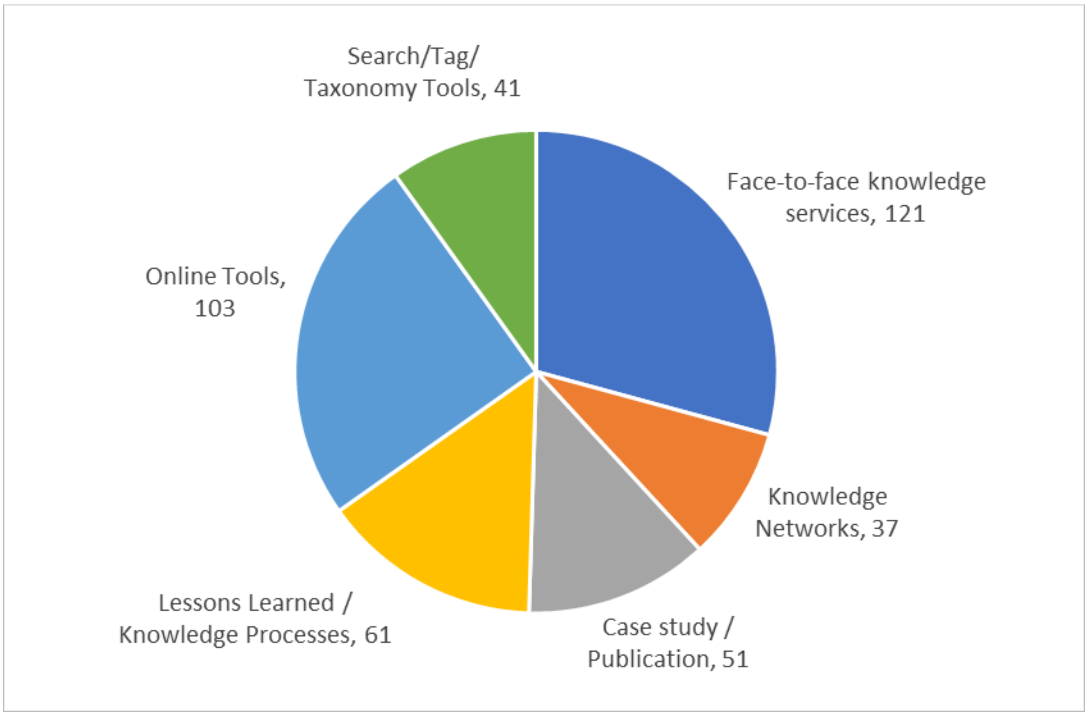
The distribution of initiatives across the categories may provide some insight into whether NASA is leaning towards codification or personalization in terms of its knowledge management. Extracting individual initiatives from the NASA Knowledge Map generates a list of 414 separate initiatives in 6 categories across 25 centers, represented in figure 1 below:

Table 5 Initiatives by category across NASA centers

	PERSONALISATION		CODIFICATION			
Center or organization	**Face-to-face knowledge services**	**Knowledge Networks**	**Case study / Publication**	**Lessons Learned / Knowledge Processes**	**Online Tools**	**Search/Tag/ Taxonomy Tools**
Academy of Program/Project and Engineering Leadership	9	0	9	0	0	0
Aeronautics Research Mission Directorate	1	3	2	2	1	0
Ames Research Center	2	1	0	4	4	0
Armstrong Flight Research Center	2	0	1	1	2	1
Cost Analysis Division	1	1	1	0	3	2
Glenn Research Center	4	1	1	3	2	0
Goddard Space Flight Center	12	2	6	5	3	4
History Office	1	3	2	4	5	2
Human Exploration and Operations Mission Directorate	5	1	0	5	5	2
Independent Verification and Validation	9	3	1	4	5	4
Jet Propulsion Laboratory	17	3	3	3	7	4
Johnson Space Center	8	1	5	2	3	3
Kennedy Space Center	2	0	0	3	7	2
Langley Research Center	5	2	0	3	8	3
Marshall Space Flight Center	3	3	3	4	8	0
NASA Engineering and Safety Center	9	2	3	3	9	1
NASA Engineering Network	4	1	0	4	2	2
NASA Safety Center	8	4	5	4	6	2
Office of Human Capital Management	1	2	0	2	4	0
Office of Procurement	6	0	0	0	3	0
Office of the Chief Health and Medical Officer	0	0	1	0	0	1
Science Mission Directorate	7	0	0	1	9	2
Scientific and Technical Information	1	2	1	2	3	4
Space Technology Mission Directorate	1	1	6	0	3	2
Stennis Space Center	3	1	1	2	1	0
TOTAL	**121**	**37**	**51**	**61**	**103**	**41**

Using NASA's classification, a more visual representation of the initiatives across the agency can be provided in Figure 1 below. From this it can be seen that no single category of initiative commands an unduly large or small share of the initiatives.

Figure 1 NASA knowledge services and initiatives



This is important because it shows that the category definitions have been consistently applied across the initiatives and centers/departments. Had each center/department been responsible for devising their own categories and classifying their initiatives accordingly, there would have been a proliferation of categories and less consistency in how initiatives were classified between them.

From this it can be seen that the largest category of knowledge initiative is 'face-to-face' knowledge services with 121 initiatives (29% of the initiatives). This is followed closely by 'online tools' with 103 initiatives (25%). Lessons learned / knowledge processes are 61 initiatives (15%), case studies / publications have 51 initiatives (12%), search/tag/taxonomy tools have 41 initiatives (10%), and knowledge networks (the smallest group) account for 37 (9%) of initiatives listed on the knowledge map.

Following on the discussion in the preceding section ("How does NASA categorize its knowledge management initiatives"), totaling the number of initiatives under each category can give a better idea of the prevalence of initiatives under each category. This has been carried out in the table below (Table 6 NASA knowledge initiatives by type).

Table 6 NASA knowledge initiatives by type

Categories of knowledge initiative	Type of initiative	Count	%	
Online tools	*codification*	103	25%	62%
Search/tag/ taxonomy tools	*codification*	41	10%	
Case study / Publication	*codification*	51	12%	
Lessons learned / Knowledge processes	*codification*	61	15%	
Knowledge networks	*personalization*	37	9%	38%
Face-to-face knowledge services	*personalization*	121	29%	
Total		**414**	**100%**	

Recall that in the previous section ("How does NASA categorize its knowledge management initiatives?") it was determined that the first four categories (online tools, search tools, case studies/publications, and lessons learned/knowledge processes) could be assumed to qualify as codification initiatives based on Hansen et al.'s (1999) framework. Similarly, it was determined that the last two categories (knowledge networks, face-to-face services) could be classified as personalization initiatives. No categories were identified as having a 'mix' of codification and personalization initiatives.

If the four codification categories are totaled up (as in Table 6 above), codification accounts for 62% of initiatives listed on the NASA Knowledge Map. Conversely, the two categories identified as personalization account for 38% of the initiatives listed on the NASA Knowledge Map. From this it can be seen that by a simple count, there are more codification initiatives than there are personalization initiatives at NASA, and suggests that NASA is favoring a codification, or "people-to-documents" approach, but not to the extent where it is the dominant strategy by an 80-20 margin. From this perspective, it looks like NASA is exercising a balanced strategy with a slight emphasis on codification.

What is the balance of initiatives (by category) across the centers?

Thus far the analysis has examined knowledge management initiatives at NASA from a consolidated perspective (i.e., for NASA as a whole). While this approach is interesting in terms of identifying a potential overall trend, it may not be an accurate indication of what is happening at each of the NASA centers on an individual basis.

The centers may exhibit different tendencies in terms of codification or personalization. Groups of centers may show similar traits. Centers may mix codification and personalization to differing degrees, and based on available information there may be other characteristics that influence whether a center emphasizes one strategy over another. Therefore, this section will look at the balance of codification and personalization initiatives at each of the centers to see if it reflects the overall pattern at NASA, and if the centers do behave differently, then in what way.

To undertake this analysis, the number of codification and personalization initiatives at each center was totaled, respectively. The number of 'knowledge networks' initiatives and 'face-to-face services' initiatives were added together to determine the total number of personalization initiatives per center. The number of 'online tools' initiatives, 'search tools' initiatives, 'case studies/publications' initiatives and 'lessons learned/knowledge processes' initiatives were added together to determine the number of 'codification initiatives per center. The results are shown in Table 7 below, where they are ranked from most personalization initiatives to least personalization initiatives.

A third column shows the total number of initiatives (personalization initiatives and the codification initiatives added together).

Table 7 Personalization versus codification initiatives at NASA centers

Type of initiative	Codification	Personalisation	Total
Jet Propulsion Laboratory	17	20	37
Goddard Space Flight Center	18	14	32
NASA Safety Center	17	12	29
Independent Verification and Validation	14	12	26
NASA Engineering and Safety Center	16	11	27
Johnson Space Center	13	9	22
Academy of Program/Project and Engineering Leadership	9	9	18
Langley Research Center	14	7	21
Science Mission Directorate	12	7	19
Marshall Space Flight Center	15	6	21
Human Exploration and Operations Mission Directorate	12	6	18
Office of Procurement	3	6	9
NASA Engineering Network	8	5	13
Glenn Research Center	6	5	11
History Office	13	4	17
Aeronautics Research Mission Directorate	5	4	9
Stennis Space Center	4	4	8
Scientific and Technical Information	10	3	13
Ames Research Center	8	3	11
Office of Human Capital Management	6	3	9
Kennedy Space Center	12	2	14
Space Technology Mission Directorate	11	2	13
Cost Analysis Division	6	2	8
Armstrong Flight Research Center	5	2	7
Office of the Chief Health and Medical Officer	2	0	2
TOTAL	**256**	**158**	**414**

From Table 7 above, it can be seen that the 25 NASA centers show a wide variation in the number of initiatives documented on the agency's KM map, from as few as 2 at the Office of the Chief Health and Medical Officer, up to as many as 37 at the Jet Propulsion Lab (JPL).

The reason for this variance in number of knowledge management initiatives is not clear, and a thorough investigation of the possible causes for this could constitute a whole other study. The reasons could be historical, or due to the prevailing culture at the center. However, initial expectations are this its correlate with the nature of the work undertaken by the center and/or the size of the center. For example, it may be expected that centers involved in more process-driven activities (like procurement and cost-analysis) would face less need for scientific innovation than a field center, and therefore have fewer knowledge management initiatives. Similarly, smaller centers can be expected to have fewer knowledge management initiatives than larger centers. However, it needs to be investigated to determine if this is actually the case.

Based on the brief description of agency centers given in section 1.4, it is clear that the table is not reflecting work in descending order of complexity or expertise. These organizations are all engaged in equally challenging aspects of the aerospace industry.

To progress the analysis, the information from Table 7 has been augmented to produce Table 8 below. This shows field centers in bold, and to also indicates number of employees (where this information is available). Employment figures were obtained from the NASA FY 2017 Agency Report (2017: 10), with the exception of JPL and the Independent Verification and Validation facility. These were obtained from the Caltech website ('Caltech at a Glance', 2018) and Wikipedia ('Independent Verification and Validation Facility', 2018), respectively. Note that these numbers show employees only, and do not take into account contractors that may contribute significant additional headcount at the facility.

Table 8 Personalization and codification against organization type and employee count

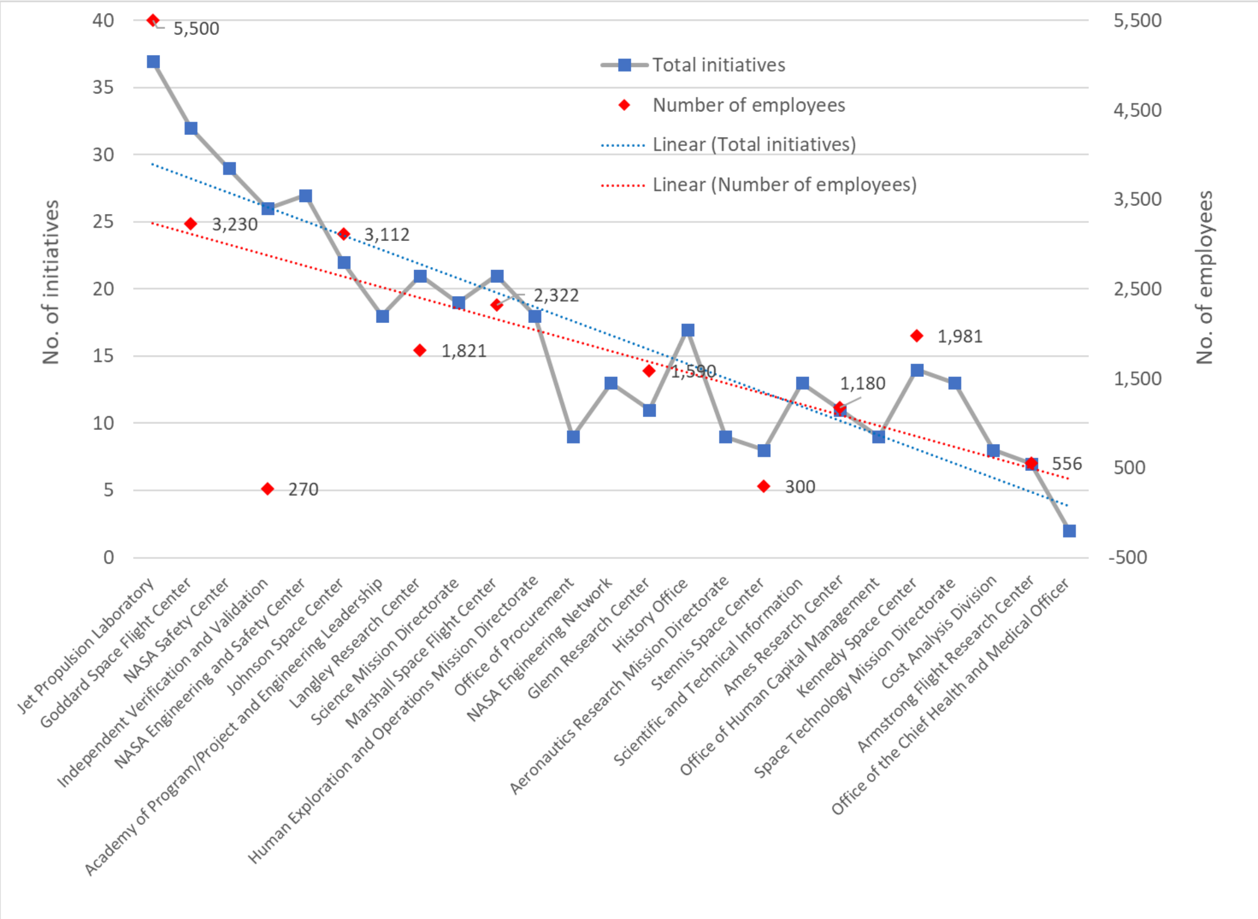
Type of initiative	Employees	Codification	Personalisation	Total
Jet Propulsion Laboratory	5500	17	20	37
Goddard Space Flight Center	3230	18	14	32
NASA Safety Center		17	12	29
Independent Verification and Validation	270	14	12	26
NASA Engineering and Safety Center		16	11	27
Johnson Space Center	3112	13	9	22
Academy of Program/Project and Engineering Leadership		9	9	18
Langley Research Center	1821	14	7	21
Science Mission Directorate		12	7	19
Marshall Space Flight Center	2322	15	6	21
Human Exploration and Operations Mission Directorate		12	6	18
Office of Procurement		3	6	9
NASA Engineering Network		8	5	13
Glenn Research Center	1590	6	5	11
History Office		13	4	17
Aeronautics Research Mission Directorate		5	4	9
Stennis Space Center	300	4	4	8
Scientific and Technical Information		10	3	13
Ames Research Center	1180	8	3	11
Office of Human Capital Management		6	3	9
Kennedy Space Center	1981	12	2	14
Space Technology Mission Directorate		11	2	13
Cost Analysis Division		6	2	8
Armstrong Flight Research Center	556	5	2	7
Office of the Chief Health and Medical Officer		2	0	2
TOTAL		**256**	**158**	**414**

Looking at the field centers indicated in **bold** in the table above, it can be seen that the number of initiatives corresponding to field centers and other departments/projects ranges widely.

The case can be made by looking at a few examples. In terms of field centers, the Goddard Space Flight center has 32 initiatives, while at the other end of the scale Armstrong Flight Research Center has only 7 initiatives listed. Similarly, for other departments, the Independent Verification and Validation facility has 26 initiatives listed, while the Office of the Chief Health and Medical Officer has only 2 listed. Finally, comparing departments and projects to field centers, it can be seen that the Office of Procurement has more knowledge management initiatives than the Stennis Space Center (8) or the Armstrong Flight Research Center (7). Therefore, it does not seem that the nature of the work undertaken by the center is a reliable indicator of whether it will have many or few initiatives.

Employee numbers, on the other hand, show a more positive correlation. Higher employee numbers tend to correlate with more knowledge management initiatives in general. The reasons for this remain ambiguous: it could be that more staff mean that there is more knowledge work being undertaken, or it could mean that in bigger populations knowledge is not shared as easily and so extra effort is needed to disseminate it. Again, this could be the topic of further study in itself. The information from Table 8 (Personalization and codification against organization type and employee count) is illustrated as a graph in Figure 2 below, with trendlines added.

Figure 2 Total number of initiatives and employee numbers



In Figure 2, the number of centers has been organized from highest number of initiatives to lowest number of initiatives (left to right) using a line chart. Employee numbers were not available for all the centers and facilities, so these have been added using a scatterplot corresponding to the secondary axis.

Trendlines where added for both datasets. The trendlines show that a high number of employees corresponds to a high number of initiatives. This may be explained on that basis that a large organization is less able to rely on informal means of knowledge codification and transfer, as may be found in a small organization. Therefore, it makes sense that a large organization is more likely to implement formal initiatives to ensure that knowledge is captured and transmitted effectively.

Ratio of codification to personalization

The analysis so far has shown the variance in knowledge management initiatives across NASA centers and offered some explanations for this variance. However, it has not yet addressed the mix of codification to personalization initiatives that could serve as an indicator whether NASA is pursuing an overall codification or personalization strategy, or attempting to straddle both.

To investigate this an additional indicator showing the ratio of codification to personalization initiatives has been added in Table 9 below. A number greater than 1 indicates that the center has more codification initiatives than personalization initiatives. A number less than 1 indicates that the center has more personalization initiatives than codification initiatives.

For example, Jet Propulsion Lab has 17 codification initiatives divided by 20 personalization initiatives, which gives a ratio of 0.9 indicating that there are more personalization initiatives than codification initiatives. For Goddard Space Flight Center, 18 codification initiatives divided by 14 personalization initiatives gives a ratio of 1.3, indicating that there are fewer personalization initiatives than codification initiatives.

Table 9 The ratio of codification to personalization initiatives

Type of initiative	Codification	Personalisation	Total	Ratio (C:P)
Jet Propulsion Laboratory	17	20	37	0.9
Goddard Space Flight Center	18	14	32	1.3
NASA Safety Center	17	12	29	1.4
Independent Verification and Validation	14	12	26	1.2
NASA Engineering and Safety Center	16	11	27	1.5
Johnson Space Center	13	9	22	1.4
Academy of Program/Project and Engineering Leadership	9	9	18	1.0
Langley Research Center	14	7	21	2.0
Science Mission Directorate	12	7	19	1.7
Marshall Space Flight Center	15	6	21	2.5
Human Exploration and Operations Mission Directorate	12	6	18	2.0
Office of Procurement	3	6	9	0.5
NASA Engineering Network	8	5	13	1.6
Glenn Research Center	6	5	11	1.2
History Office	13	4	17	3.3
Aeronautics Research Mission Directorate	5	4	9	1.3
Stennis Space Center	4	4	8	1.0
Scientific and Technical Information	10	3	13	3.3
Ames Research Center	8	3	11	2.7
Office of Human Capital Management	6	3	9	2.0
Kennedy Space Center	12	2	14	6.0
Space Technology Mission Directorate	11	2	13	5.5
Cost Analysis Division	6	2	8	3.0
Armstrong Flight Research Center	5	2	7	2.5
Office of the Chief Health and Medical Officer	2	0	2	undef.
TOTAL	**256**	**158**	**414**	

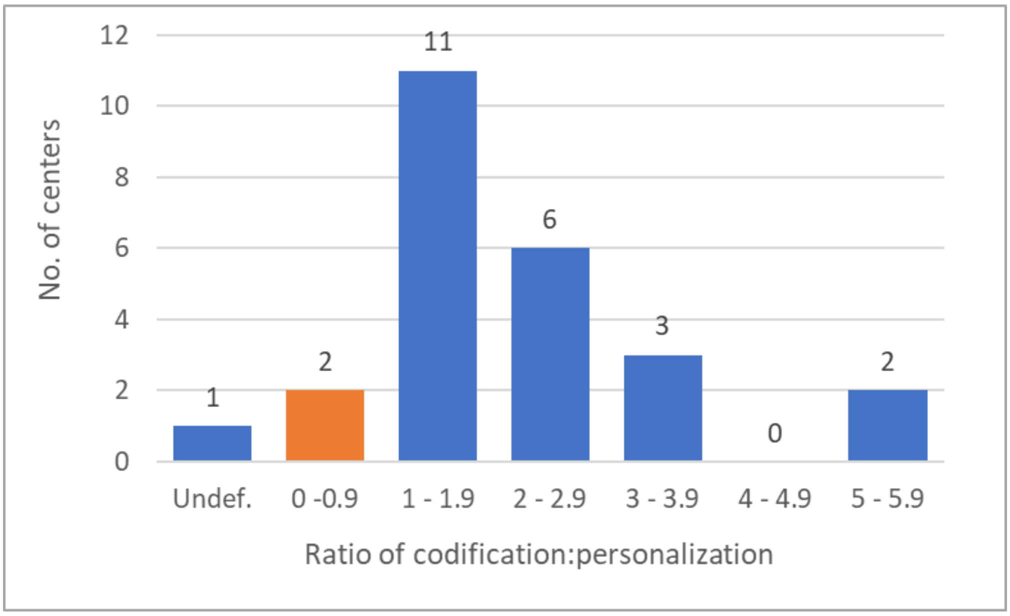
Across the 25 centers/departments, 21 have more codification initiatives than personalization initiatives, 2 have an equal balance, and only 2 have more personalization initiatives than codification initiatives. Unfortunately, no information is available that gives an indication of the relative sizes of these initiatives. This would add a useful dimension of 'weighting' that could balance out the differences in frequency of initiatives.

The information from the table above is summarised in the histogram below (Figure 3). Note that the Office of the Chief Health and Medical Officer has an 'undefined' ratio, as 2 codification initiatives divided by 0 personalization initiatives does not yield a meaningful result.

It is interesting to note that JPL has significantly more personalization initiatives than any of the other 24 centers/departments. With 20 personalization initiatives, JPL has 43% more personalization initiatives than the center with the next highest count, which is Goddard Space Flight Center at 14 personalization initiatives. JPL also ranks in the top-three for codification initiatives. It may be worth noting that JPL is the only 'privately run' NASA field center ('Caltech Receives Five-Year JPL Contract from NASA', 2012). The California Institute of Technology, often referred to as Caltech, has been involved in JPL since its inception and note that JPL has never been operated by any other institution. That Caltech is an academic institution rather than a government agency may result in JPL being managed differently from other NASA centers, and may be a factor in the greater emphasis on personalization initiatives.

In Figure 3 below the codification: personalization ratios shown in Table 9 The ratio of codification to personalization initiatives are presented as a histogram showing the number of departments that have a positive codification: personalization ratio (more codification initiatives than personalization initiatives).

Figure 3 Number of centers/departments by codification: personalization ratio

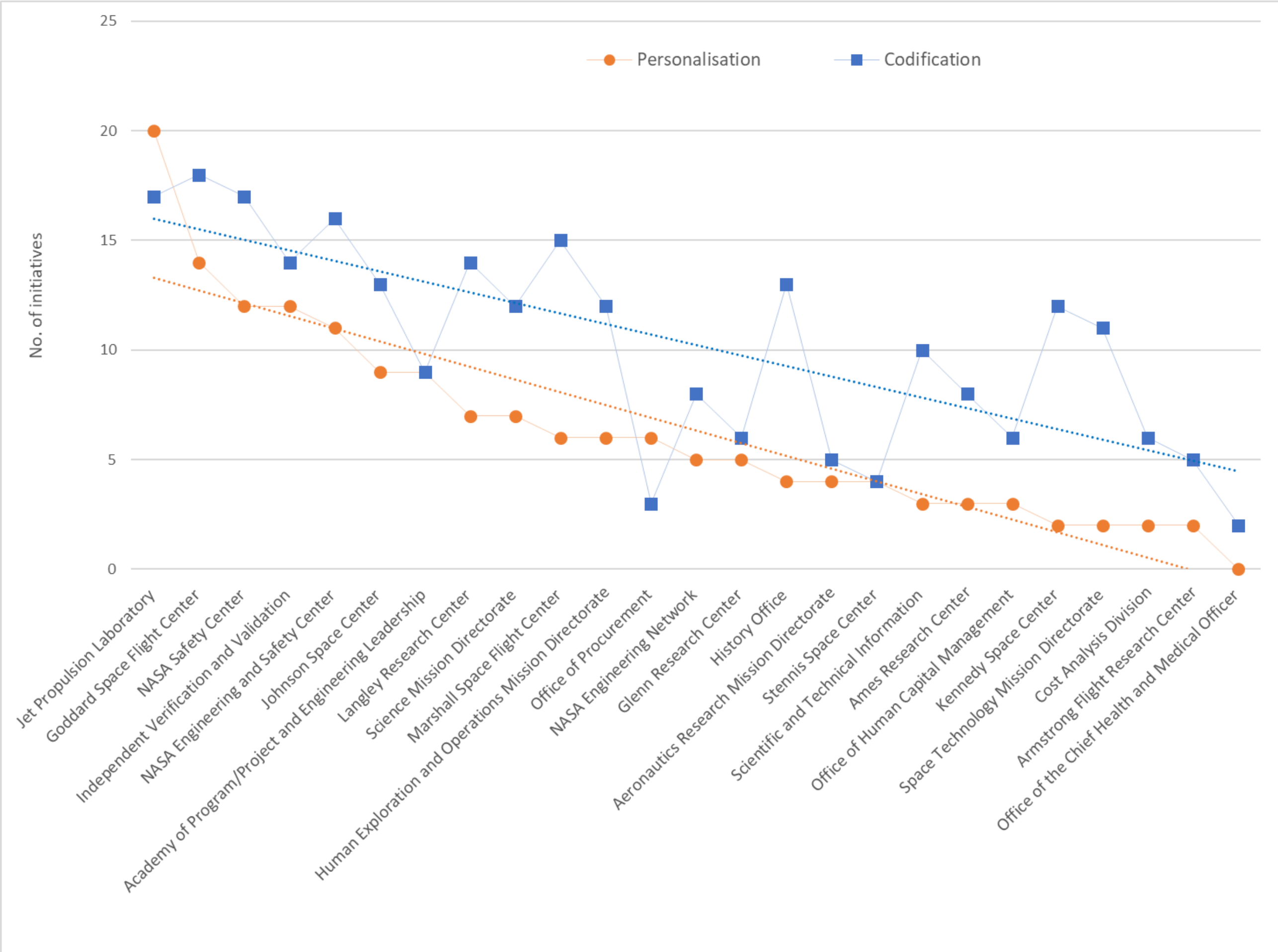


In Figure 3 it can be seen that 22 of the 25 centers either have as many or more codification initiatives as personalization initiatives (23 if the Office of the Chief Health and Medical Officer is included in this count for having 2 codification initiatives and no personalization initiatives). 11 (i.e., 6 + 3 + 2) centers/departments have at least twice as many codification initiatives as personalization initiatives. Two centers have more than 5 times more codification initiatives than personalization initiatives.

This indicates a high prevalence of codification initiatives within centers/departments and across NASA as a whole and may suggest that codification is the dominant strategy over personalization. However, if Figure 2 (Total number of initiatives and employee numbers) is revised to show codification and personalization initiatives (rather than just total number of initiatives) it may moderate this conclusion.

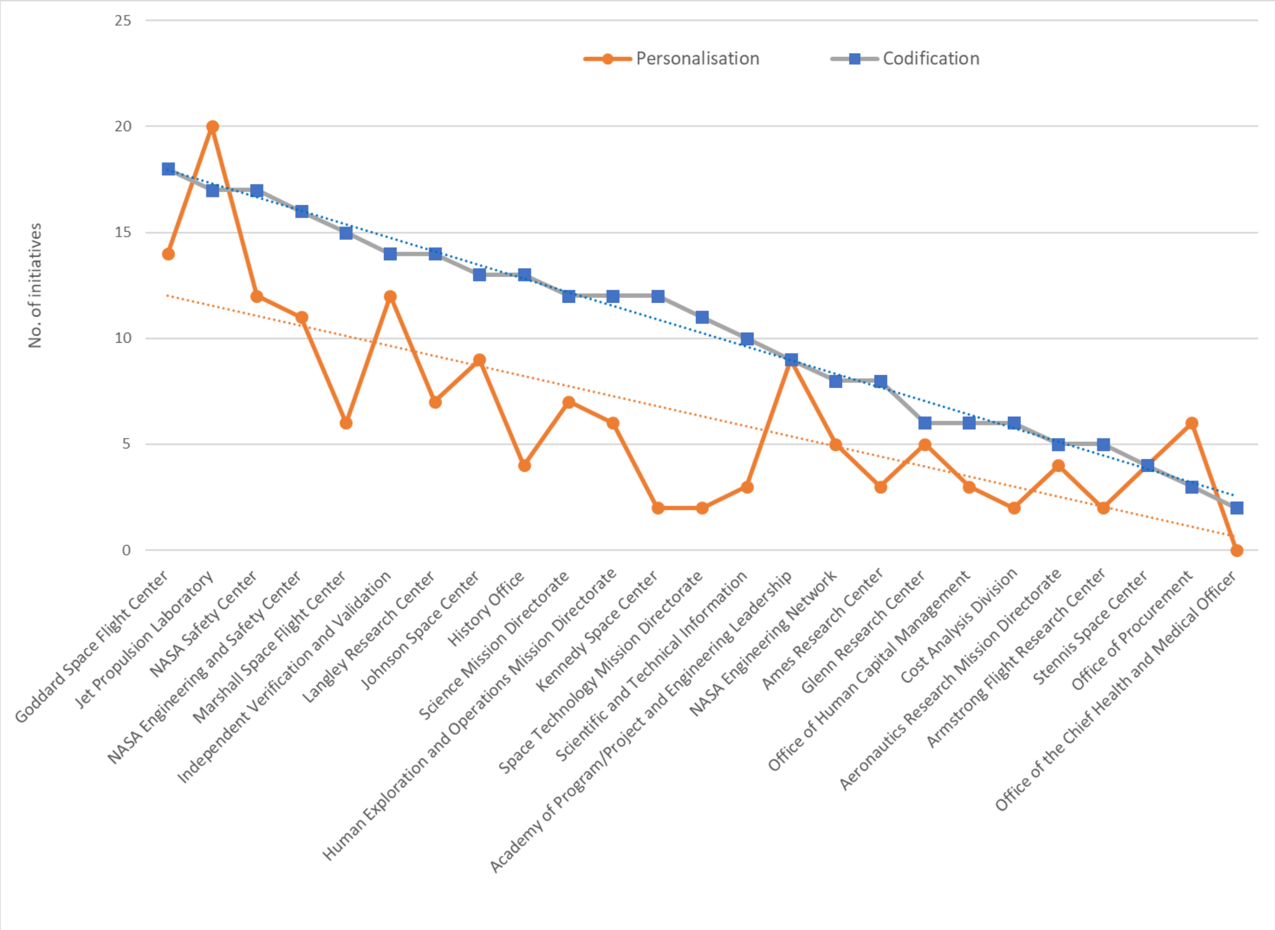
This has been done in Figure 4 below, which centers ranked by number personalization initiatives (highest to lowest) and also shows the number of codification initiatives. The addition of trendlines for each of these graphs shows that organizations that have a high number of codification initiatives also have a high number of personalization initiatives, and vice versa. That is to say, organizations tend to have many of both or few of both compared to other organizations.

Figure 4 Trends in personalization and codification initiatives, ranked by personalization



The situation can be seen to be the same when centers are ranked by frequency of codification initiative first, as shown in Figure 5 below:

Figure 5 Trends in personalization and codification initiatives, ranked by codification



This could also be seen as supporting the conclusion that where a center has a high number of knowledge management initiatives it generally manifests as a mix of both types of initiatives, but with the emphasis tending to be on codification initiatives across almost all the NASA centers.

Therefore, although it can be concluded that NASA's knowledge management approach emphasizes codification, or people-to-document systems, the number of personalization initiatives in the mix is still quite high. This supports the conclusion that NASA's Knowledge Map shows a balanced approach to codification and personalization.

The main question then is whether the personalization initiatives here are playing a supporting role to the codification initiatives, or whether NASA is engaged in an attempt to straddle both knowledge management approaches.

Conclusion on NASA's knowledge map

NASA has categories that clearly correspond to person-to-documents and person-to-person knowledge management initiatives. NASA CKOs have classified their knowledge management initiatives into these categories, and the categories show that that there are more person-to-documents initiatives than person-to-person initiatives. However, this does not provide information as to the extent of activities in each category and it is necessary to look at the number of individual initiatives under each category.

The individual initiatives from each of these categories also show a leaning towards codification initiatives over personalization initiatives. Within the individual centers the story is slightly more nuanced. The number of initiatives by center ranges widely. It does not seem to depend on the nature of the work undertaken at the center, but centers with more employees tend to have more of both types of initiatives. Once again, the number of codification initiatives outweighs the number of personalization initiatives at almost all centers, which is not in line with Hansen et al.'s (1999) expectations regarding how personalization is needed for innovation.

However, there are also prominent elements of person-to-person (personalization) initiatives. Because personalization strategies, although being fewer in number, still present a significant proportion of activities on the map (38% in Table 6), the evidence presented does not support the notion that the personalization initiatives are in a supporting role to the codification initiatives. As such, the analysis of the knowledge map supports the conclusion that NASA is practicing a balanced knowledge management strategy, or straddling.

3.2.5 *Overall conclusion on NASA knowledge management strategy*

NASA's knowledge management journey shows how since the mid-1980's NASA went from emphasizing a personalization approach to emphasizing codification in the 1990's until the advent of its federated model where the emphasis is on a balance between people and technology. NASA's central strategy clearly exhibits elements aimed at identifying and capturing critical knowledge as well as focusing on ensuring sharing of knowledge and access to knowledge. Therefore, knowledge management strategy at the agency level can clearly be seen to be straddling both codification and personalization.

To determine if the individual centers, departments and projects are following this lead, transcripts of interviews with CKOs across the NASA centers and departments were reviewed, as well as an analysis of the NASA knowledge map. Both of these showed evidence that a balanced strategy is being pursued, although in the case of the Knowledge Map the emphasis seemed to be more on the codification side. However, the mix was not so uneven so as to approximate an 80-20 mix. While there was plenty of evidence of codification, it was not found that it was being promoted as the dominant strategy, and there was no evidence to suggest that personalization was being allocated a supporting role. As such, NASA can be said to have a balanced knowledge management strategy, or what Hansen et al. (1999) would refer to as 'straddling'.

3.3 Human resources strategy

This section will focus on determining whether there are any metrics available from NASA's human resources department that suggest NASA is taking a human resources approach that is compatible with codification or personalization under Hansen et al.'s (1999) framework.

Hansen et al. (1999) note that depending on their choice of competitive strategy, a company will pursue a compatible human resources strategy. An organization pursuing a codification strategy will recruit less experienced staff to implement solutions based on knowledge reuse, are more likely to train their staff in a standardized way (for example in groups or through online computer-based learning) and incentivize staff to contribute to databases and repositories (Hansen et al., 1999: 109).

Organizations that pursue a personalization strategy are more likely to recruit highly-qualified, experienced staff in order to apply their analytical and creative skills to unique problems. Staff are developed through mentoring and the accumulation of experience (not standardized training), and staff are incentivized to share knowledge directly with other staff (Hansen et al., 1999: 109).

Four indicators will be considered in order to investigate whether NASA conforms to one or the other approach. Investigating these to see if the characteristics described by Hansen et al. (1999) are present, it will be possible to determine if codification or personalization is being followed.

1. Staff occupations – What categories of work do the staff at NASA do, what sort of qualifications are staff members in each category expected to hold, and what is the distribution of staff across these categories. This will give an indication whether NASA can

rely on developing fresh graduates, or whether NASA is likely to employ staff that are already experienced and qualified.

2. Employee turnover - If NASA is relying on using less experienced graduates to implement solutions then it is likely it would show an elevated employee turnover rate amongst its science and engineering staff. Conversely, maintaining a complement of qualified and experienced staff would show a reduced employee turnover among its scientists and engineers.
3. Length of service / staff age - Similarly, length of service and staff age parameters should show a higher proportion of young staff with lower length of service for a codification strategy, and a higher proportion of older staff with longer service lengths for a personalization strategy.
4. Staff training - Staff training under a codification scenario should show more instances of online training platforms and standardized group training. Under a personalization scenario there is likely to be more evidence of mentor programs.

Unfortunately, it has been difficult to find information relating to incentivizing staff to document or share knowledge. Nonetheless, the four indicators above should provide sufficient evidence to draw a conclusion about NASA's human resources approach and how it reconciles with its knowledge management approach.

3.3.1 *Staff occupations at NASA*

Information on the NASA workforce by is available through the NASA Workforce Information Cubes database (Workforce Information Cubes for NASA, undated). Data extracted from this is show in Table 10 below.

Table 10 NASA staff by occupation at September 2018

NASA staff by occupation at Sept 2018	**Employees**	**% of total**
Scientific and engineering	11,164	65%
Professional administration	5,071	29%
Clerical	256	1%
Technician	765	4%
Wage	-	0%
Total	**17,256**	100%

NASA occupations in each category can be described as follows (NASA Occupations, undated):

Engineering and Scientific - Occupations in this category require knowledge in a specialized field such as science, math, engineering. These positions generally require a bachelor's degree or higher degree with major study in a specialized field. This group covers positions such as aerospace engineering, biology, computer engineering, computer science, general engineering, and meteorology.

Professional and administration - Occupations in this category require knowledge of principles, concepts, and practices associated with organizations, administration or management. Some positions relating to accounting and law may require specialized education, most of these positions do not (except for contracting positions) as they generally involve the type of skills (analytical, research, writing, judgment) typically gained through a college level education, or through progressively responsible experience. This group covers positions such as administrative specialist, budget analyst, contract specialist, information technology specialist, and public affairs specialist.

Clerical and administrative Support - Occupations in this category provide general office or program support duties such as preparing, receiving, reviewing, and verifying documents; processing transactions; maintaining office records; or locating and compiling data or information from files. This group covers positions such as accounting technician, clerk-typist, management assistant, office automation clerk, procurement clerk, and secretary.

Technical support - Occupations in this category support professional or administrative work. Duties require practical knowledge of techniques and equipment, gained through experience and/or specific training less than that represented by college graduation. This group covers positions such as electronics technician, engineering technician, meteorological technician.

From Table 10 above it can be seen that scientific and engineering is the largest category of staff at NASA, and from the specialized nature of the qualifications required for this category it would seem that NASA needs to recruit staff with a relatively high level of qualification for this role. However, as will be seen later in this chapter, NASA has good facilities for developing staff technical capabilities in-house, and so it is difficult to conclude with confidence whether NASA strategy is to recruit highly-qualified and experienced staff, or recruit graduates and develop them further in-house. As a result, the determination of NASA’s human resources approach (codification or personalization) will need to rely on further analysis below.

3.3.2 *Employee turnover at NASA*

Hansen et al. (1999) explain how an organization using the codification strategy will recruit younger, less experienced staff to act as implementers of the organization’s knowledge management assets, which are codified into repositories. This helps to keep costs low to support rapid growth and large revenues, but graduates working for such an organization will have limited opportunities to grow their experience and advance their career or earnings.

Consequently, it is expected that after gaining some early work experience at such an organization, the young employee will move on to a company offering greater development and career opportunities. This will also enable the organization to replace their staff with a fresh crop of low-cost, high-energy graduate students. The net result is that organizations pursuing a codification strategy can be expected to exhibit higher staff turnovers.

Hansen et al. (1999) contrasts this with organizations that follow a personalization strategy that relies on recruiting highly qualified staff with accumulated skills and experience, and on developing them further. These staff are likely to be trained through one-on-one mentoring.

This approach is likely to be characterized by lower staff turnover as existing staff accumulate knowledge and experience that is seen as an asset to the company. They are given the freedom to apply their expertise and paid at a high enough level to keep them from leaving the organization.

Hansen et al. (1999) gave Ernst and Young as an example of a management consultancy that embraces the codification strategy. Therefore, it is expected that Ernst and Young should show a high level of staff turnover relative to other companies in the management consultancy space. Staff turnover statistics are published in the 2016 Annual Report for Ernst and Young Switzerland (one of the only Annual Reports available online), and are shown in Table 11 below.

Table 11 Employee turnover rate for Ernst & Young (Switzerland)

Financial year	Turnover	Total employees	Turnover %
2014	441	2240	19.69%
2015	508	2425	20.95%
2016	527	2627	20.06%

Table 11 shows that over 2014, 2015 and 2016 Ernst and Young Switzerland had an annual staff turnover ranging from 19.69 – 20.95%. This seems high, but in order to calibrate expectations, it needs to be determined whether these rates are higher or lower than other organizations.

Hansen et al. (1999) cite Andersen Consulting as another example of a codification-based company, and examples of personalization-based companies as McKinsey and Company and Bain and Company. The difficulty with using these as comparators is that Anderson Consulting no longer exists, and McKinsey and Bain are both private firms and therefore do not provide publicly-available Annual Reports.

An outdated article from Fortune Magazine of April 1987 (‘A consulting firm too hot to handle?’, 1987) refers to Bain and Company having an 8% staff turnover rate, noting that this is substantially below the industry average of 20% and seems consistent with Hansen et al.’s (1999) theory. Furthermore, these statistics may be relevant given that Hansen et al. (1999) wrote their paper in 1999 – not as long after 1987 as today’s date - and it seems that Ernst and Young still subscribe to the high industry average cited in this article.

It may be that 8% is considered to be a relatively low staff turnover rate and 20% a relatively high staff turnover rate in the management consulting sector. However, this still needs to be put in perspective if comparisons are to be made with NASA, which is in a different sector altogether.

To calibrate expectations in this regard, it is useful to consider turnover rates across other sectors in the American economy. The Compensation Force website provides employee turnover rates by industry for the year 2015 (‘2015 Turnover Rates by Industry’, undated). These are from data collected by Compdata Surveys and Consulting (based in Kansas, United States). These are presented in Table 12 below.

The table has two columns: ‘voluntary’ and ‘total’. Voluntary turnover counts instances where staff have left a company to pursue other opportunities, whereas ‘total’ includes dismissals, redundancies and the like. In this analysis we are interested in voluntary staff turnover.

Table 12 Employee turnover across major sectors in the United States in 2015

Turnover in 2015	Voluntary	Total
All industries	11.6%	16.7%
Banking and Finance	14.2%	19.1%
Healthcare	14.2%	18.9%
Hospitality	17.8%	25.9%
Insurance	8.8%	12.2%
Manufacturing and distribution	9.1%	14.8%
Not-for-profit	11.6%	15.7%
Services	9.0%	14.9%
Utilities	6.1%	9.0%

From these figures it can be seen that the overall range of voluntary staff turnover is between a low of 6.1% in utilities and 17.8% in hospitality. Banking and finance (which seem most analogous to management consultancy) seem to be located at the higher end of the scale at 14.2%.

The figures cited in Fortune Magazine and Ernst and Young's annual report may be citing overall turnover. Nonetheless, from the table above it can be seen that 8% can be considered at the low end of the scale, and 20% would rank high as an 'industry average' even in total turnover terms.

Therefore, from this it can be seen that:

(i) a staff turnover of 8% can be considered low by the standards of any sector and 20% can be considered high, and

(ii) associating a low staff turnover with organizations practicing personalization and a high staff turnover with organizations practicing codification appears to be consistent with Hansen et al.'s (1999) theory.

It follows from this that if staff turnover at NASA is analyzed and found to be low (i.e., below 8%) this could be taken as an indication that NASA has human resources practices consistent with a personalization strategy. Conversely, if staff turnover is found to be high, it is an indication that NASA may have human resources practices consistent with a codification strategy.

While "turnover" is the broad indicator here, the direct factors that contribute to it are things such as job satisfaction, remuneration (and benefits) structure, relative scarcity of skills, advancement and achievement in areas such as academia, and managerial practices (such as pressure to advance or leave the company). Information on remuneration at NASA was not available for study, and it is not easy to conjecture: levels could be low due to being a federal-funded agency, or high due to the specialized nature of the work and the high-profile of many of the projects. However, it is likely that the knowledge workers at NASA have a high degree of intrinsic motivation as they get to work on 'interesting projects' that also open avebues for significant academic recognition.

Using data from the NASA Workforce Information Cubes website (Workforce Information Cubes for NASA, undated), staff turnover for science and engineering staff was calculated and the results presented in Table 13 below.

Table 13 Annual turnover in science & engineering staff at NASA

Financial year	Staff losses	Average employment	Turnover
2012	512	11,535	4%
2013	490	11,413	4%
2014	433	11,339	4%
2015	578	11,167	5%
2016	496	11,053	4%
2017	505	11,105	5%

Staff turnover is calculated as total staff losses in a period divided by average staff number for that period, multiplied by 100 to arrive at a percentage value ('How to calculate staff turnover?', undated). From the table above it can be seen that among NASA's science and engineering staff, staff turnover for the past 5 years has ranged between 4-5%.

This is lower than the turnover average for any sector (voluntary or otherwise), and this suggests that NASA retains and develops its staff rather than maintaining high-levels of recent graduates and junior staffers. According to Hansen et al. (1999) the low staff turnover would suggest human resources practices that are consistent with a personalization approach.

3.3.3 *Length of service of staff at NASA*

Data was also drawn from the NASA Workforce Information Cubes website[7] to show the number of years of service for science and engineering staff at NASA. This is shown in Table 14 below:

Table 14 Years of NASA service for science & engineering staff at FY2017

Years of NASA Service	No. of S&E staff	% of total	
Under 5 years	1,375	12%	
5 to 9	1,929	17%	56%
10 to 14	1,504	14%	
15 to 19	1,335	12%	
20 to 24	489	4%	
25 to 29	2,605	24%	
30 to 34	1,252	11%	44%
35 to 39	410	4%	
40 or more	144	1%	
Total	**11,043**	**100%**	

This data shows that only 12% of science and engineering staff have been employed at NASA for under 5 years, 70% of staff have been employed at NASA for over 10 years, and 44% of staff have been employed at NASA for 20 years or more.

The years of service in the tables are an indicator that science and engineering staff are able to develop within the organization. This is consistent with an organization pursuing a personalization strategy that develops its staff as knowledge assets. A company pursuing a codification strategy is more likely to see staff having to circulate between organizations within the sector to gain experience and advance their careers. According to Hansen et al.'s (1999) theory these numbers are more likely to be consistent with a personalization strategy.

3.3.4 *Staff training at NASA*

Under a personalization strategy there is expected to be a greater reliance of mentoring and interpersonal transfer of knowledge, while under a codification strategy there is expected to be a greater emphasis and standardized and group training, typically provided by online training systems. As an example of standardization, Hansen et al. (1999) cite the example of

[7] Available from: https://wicn.nssc.nasa.gov; Date accessed: 07 September 2018.

Ernst and Young's Center for Professional Education, where recruits are sent to undertake standardized training (1999: 10).

NASA appears to have a strong mentoring framework in place, as well as strong standardized training systems. These are discussed in more detail below.

Evidence of mentoring

NASA shows a strong emphasis on mentoring as a method of knowledge transfer. Mentoring at NASA is organized by the Office of Human Capital Management (OHCM), which also has a number of career development and leadership programs under the same banner (NASA Mentoring Program Framework, 2007: 2). The NASA Mentoring Program Framework lays out a list of mentoring programs across the 10 NASA field centers, as well as at NASA headquarters, the NASA Shared Services Center, and individual agency programs (NASA Mentoring Program Framework, 2007: 6). It discusses the provision of formal as well as informal mentoring, with formal mentoring taking a structured approach that incorporates metrics to ensure improved performance and the maintenance of program integrity (NASA Mentoring Program Framework, 2007: 4). It identified mentoring as filling the following purposes (NASA Mentoring Program Framework, 2007: 1):

- An open-environment for information sharing
- To provide opportunities for open interaction between employees from different levels and disciplines
- Relationship building to facilitate the sharing of organizational knowledge
- A vehicle for transferring formal to information organizational knowledge
- Enhanced communication and collaboration across all levels
- Improved individual motivation, performance and innovation, and
- Transfer of technical knowledge, when applicable.

The age of the Mentoring Program Framework (2007) and the fact that an updated framework could not be located on the NASA portal raised the possibility that this program was no longer active. However, links were found the Modern Mentoring Program at NASA Headquarters (NASA Headquarters Modern Mentoring Program, undated), and other more recent references to mentoring activities at NASA could be found. These included:

A current article by on the NASA APPEL portal (posted in 2012) on "getting the most from your mentor"(McDermott, 2012), A 2016 video in the APPEL portal by Dan Rasky (Senior Scientist at NASA) on the Mentor & Apprentice Work Model ('Dan Rasky: Mentor & Apprentice Work Model', 2016), and A 2017 article by Doctor Lester Wright about the Mentoring Matters program at Goddard Space Flight Center (Wright, 2017). Wright serves as program manager for the mentoring program for the Talent Cultivation Office at NASA Goddard Space Flight Center.

Evidence of online training systems

In an article posted on the APPEL web portal by NASA CKO Dr Ed Hoffman entitled "Technology-enabled learning" (Hoffman, 2009), he highlights that technology-enabled learning is not a universal panacea, stating that:

> *"I possess a healthy skepticism when it comes to using technology to achieve better learning outcomes. This is not an unfounded bias. I have seen millions of dollars spent on technology that promises gains in workforce competence and capability but fails to deliver." (Hoffman, 2009: 1)*

However, Hoffman (2009) follows this by explaining how the appropriate use of technology coupled with sound learning-design principles can deliver benefits, and points to how online training enables content to be updated to keep pace with the accelerating rate of knowledge expiration.

Hoffman (2009) goes on to discuss how NASA's Academy for Program/Project and Engineering Leadership (APPEL) uses technologies for learning, referring to examples of online publications, decision-making tools, blogs, wikis, social and professional networking sites to facilitate communities of practice, virtual environments, and online video sharing.

NASA's Academy of Program/Project & Engineering Leadership, or APPEL, is a knowledge-dedicated resource for NASA that is responsible for developing and administering a curriculum and tools that advance the skills and careers of the NASA workforce, as well as support knowledge management and sharing activities ('About APPEL Knowledge Services', undated).

The most recently available Annual Report at time of writing is APPEL's Annual Report for the 2016 financial year (APPEL Annual Report, 2016). In the report, APPEL director Roger Forsgren states that APPEL trained 3,300 participants in over 146 courses in the financial year (APPEL Annual Report, 2016: 4).

These are not generic professional development courses from third-party service providers, such as health and safety awareness or Excel competency courses. Of the 146 courses, over 60 of them are specifically designed and developed by APPEL to meet the needs of NASA's technical workforce (APPEL Annual Report, 2016: 9). The APPEL course catalogue shows that 22 courses are available as on-demand online courses (APPEL Course Catalog: On-demand Learning, undated).

In 2017, NASA announced that APPEL had been recognized as the top project management academy in the world for three years running by Human Systems International (HIS), a subsidiary of the Project Management Institute ('From the APPEL Director', 2017).

The HSI audit evaluates 14 benchmarks, including curriculum content, internal business administration, knowledge management, and internal and external collaborations, and APPEL earned the highest scores ever recorded since HSI began assessing project management training over 20 years ago. The audit includes more than sixty project management academies from companies and organizations such as Rolls Royce, BAE Systems, Airbus, Shell Oil, Siemens, and Mercedes-Benz ('APPEL Named Best Academy in the World by Human Systems International', 2015).

This shows that the HSI audit is a robust measure of project management training capability, and that NASA is a leader in providing standardized training that consistently meets high standards. This sounds comparable to Hansen et al.'s (1999) example of the Ernst & Young's Center for Professional Education, that was cited as being typical of the human resources approach to human resources management under a codification strategy (Hansen et al., 1999: 10).

3.3.5 *Conclusion on NASA's human resources strategy*

In attempting to determine whether NASA's approach to human resources management conforms to Hansen et al.'s (1999) theory regarding codification versus personalization this analysis has looked at four factors, specifically:

Staff occupation as an indicator of whether NASA is recruiting graduates and developing them in-house (codification), or whether NASA prefers to recruit highly qualified and experienced staff (personalization). The analysis showed that NASA has a high proportion of scientists and engineers with diverse and specialized technical skills. This suggests that NASA relies on recruiting staff that are already highly qualified, but was not conclusive.

Employee turnover for NASA was significantly below the average for any other sector. According to Hansen et al.'s (1999) framework this is consistent with human resource practices under a personalization strategy, whereby staff are retained and developed into high-value knowledge assets rather than treated as implementing agents of externalized knowledge assets.

Length of service / staff age showed that NASA is characterized by staff with long service records, with 70% of staff having stayed at NASA for over 10 years. This is also consistent with human resource practices under a personalization strategy.

Staff training at NASA showed a strong emphasis on mentoring, which according to Hansen et al. (1999) is consistent with human resources practices under personalization. However, NASA also has world-class facilities offering standardized training and online learning facilities, which according to Hansen et al. is consistent with codification.

The net result is that according to the theory put forward by Hansen et al. (1999), NASA exhibits human resources management practices that are associated with personalization, but has also invested significant resources in setting up standardized training and online-learning facilities. According the Hansen et al.'s theory, the latter are consistent with human resources management practices that are associated with codification. Therefore, the analysis is forced to conclude that NASA is straddling both codification and personalization practices when it comes to human resources practices.

3.4 I.T. strategy

Hansen et al. (1999) hold that organizations that emphasize codification will tend to invest heavily in I.T. primarily as a means of connecting people with re-usable, codified knowledge, while organizations that emphasize the personalization of knowledge will tend to invest moderately in I.T. and use it as a means of facilitating dialogue and the exchange of tacit knowledge (Hansen et al., 1999: 109).

In order to determine whether NASA's I.T. practices are tending towards codification or personalization, the analysis in this section will need to show whether (i) the extent of NASA's investment in I.T. is moderate and/or heavy, and/or (ii) whether the purpose of NASA's I.T. is to connect people with re-usable codified knowledge or facilitate conversations between people.

Unfortunately, in the case of point (i) the extent of NASA's investment in I.T., 'moderate' and 'heavy' are subjective terms and so it is unclear how Hansen intend this to be evaluated. The most reasonable interpretation seems to be that the organization incurs lower/higher I.T. costs relative to similar organizations in the same sector. However, as there are no organizations that would provide a comparable benchmark to NASA given its size and the nature of its work. Therefore, this analysis will rely on point (ii), that is to identify whether the purpose of NASA's I.T. is to facilitate the reuse of codified knowledge or facilitate conversations between people. Given that much of the information necessary to support this analysis has been developed in previous sections, this will be a relatively short section by comparison.

Note that this analysis is concerned with how I.T. is employed store and move knowledge around the organization, and is distinct from the I.T. employed in specific project objectives. That is to say, this analysis is confined to evaluating the manner in which I.T. is used to support the organization and the workforce, and not the I.T. built into a Mars rover.

3.4.1 *Connecting staff with re-usable codified knowledge*

In section 3.2.4 (What does NASA's Knowledge Map look like?) there was a relatively detailed discussion of NASA's Knowledge Map (NASA Knowledge Map, undated), and it can be seen that there are two categories of initiatives on the knowledge map that are concerned with I.T. systems, namely (i) knowledge management online tools, and (ii) search/tag/taxonomy tools. The two categories with their descriptions (Hoffman, 2013) and contents are again given here:

- KM online tools - Any online knowledge tools, including but not limited to: portals, document repositories, collaboration and sharing sites, video libraries.

  Examples of initiatives found under the online tools category shows information systems, SharePoint for collaboration, Best Practices repositories, lessons-learned information systems, document management systems, data storage and archiving, digital libraries and repositories, E-libraries, websites, wikis, and online portals. It also contains isolated cases across the centers of: a photo repository, a problem reporting and corrective action system, a safety, health & environmental portal, a shuttle knowledge console, an online mentor matching portal, and a video library.

- Search/tag/taxonomy tools - Dedicated search engine for knowledge (e.g., Google Search Appliance); any initiatives related to meta-tagging or taxonomy. Examples of specific initiatives found in this category show mainly search engines, application development to support search engines, data mining and analytics tools, taxonomies and tagging for information systems and lessons-learned systems, and a cross-referencing service.

From the category descriptions and nature of the initiatives contained therein, it is clear that NASA relies heavily on I.T. systems to store codified knowledge and make it searchable and available for staff to reuse. These systems are also likely to contain a lot of knowledge embedded in their design, put there in-line with best practices and learnings developed during earlier missions. These two categories accounted for 35% of the initiatives listed on the NASA Knowledge Map (refer to Table 6, page 71).

Similarly, this is the case with the online training facilities described in section 3.3.4 (Staff training at NASA). In that section it was shown that NASA has 22 on-demand online courses available to staff though its APPEL portal (APPEL Course Catalog: On-demand Learning, undated).

This shows that NASA has clearly expended significant effort and resources into I.T. systems designed to hold codified knowledge and make it available to NASA staff for reuse.

3.4.2 *Facilitate conversations and exchange of tacit knowledge*

Despite the prevalence of systems to store codified knowledge, it was shown in section 3.2 (NASA's knowledge management strategy) that NASA also has many initiatives that are aimed at facilitating dialogue and tacit knowledge exchange among staff. To a large extent these manifest as events and communities of practice, which are not I.T. driven and therefore do not qualify in this analysis.

However, the Knowledge Map (NASA Knowledge Map, undated), also shows personalization initiatives that rely on I.T., such as Marshall Space Flight Center's groups on ExplorNet, that functions as an expert-finder and discussion board, and its IdeaLab portal, where ideas, challenges and concepts can be posted. Langley Research Center also has an online Phonebook tool that functions as an expert-locator.

The interview with Daria Topousis from the NASA Engineering Network (Under section 3.2.3 Knowledge management at NASA centers, departments and projects, page 62) also showed how NEN's online tools are relied on to support extensive communities of practice. The 50 communities of practice supported by NEN reflect as a single entry on the Knowledge Map, under "knowledge networking" activities. This means that, apart from potentially being underweighted in the analysis, they are also classed as a personalization activity rather than the work of an I.T. system, even though the I.T. plays an integral role in their delivery.

Therefore, although the ratio of "I.T. tools to facilitate conversations" versus "I.T. tools to store knowledge" seems low this could be because repositories are explicitly recognized on the Knowledge Map and therefore are more prominent, while tools that facilitate conversations, (such as email, staff directories and video-conferencing tools) are simply seem as part of the furniture and therefore not listed as "knowledge sharing initiatives".

3.4.3 *Conclusion on NASA's I.T. strategy*

The analysis above shows how NASA appears to have invested significantly in I.T. tools to store codified knowledge, and they feature prominently on the organizations Knowledge Map. Where NASA's Knowledge Map lists initiatives to promote the personal exchange of knowledge, it can be difficult to identify which of these are enabled through I.T. systems. However, although the investment in I.T. to facilitate conversations may not be easy to identify on the Knowledge Map, there is evidence from previous sections (such as the NEN interview) that these systems to support personalization of knowledge are pervasive throughout NASA.

Therefore, while it is concluded that NASA appears to have an I.T. strategy geared towards supporting codification, there is known to be significant personalization of knowledge happening on the back of existing office infrastructure. Under Hansen et al.'s (1999) theory, the fact that NASA devotes significant resources to its information systems would suggest that it is embracing a codification strategy, but there is also evidence (such as the NEN interview) that show that there is extensive support for personalization through NASA's I.T. systems. As such, NASA can be judged to be straddling both codification and personalization, but perhaps with an emphasis on codification.

4. Discussion: Dominant versus Hybrid Strategies

4.1 Dominant strategy and straddling

Recall that a fundamental pronouncement of Hansen et al.'s (1999) paper was:

> *"[…] companies that use knowledge effectively pursue one strategy predominantly and use the second strategy to support the first. We think of this as an 80-20 split: 80% of their knowledge sharing follows one strategy, 20% the other" (Hansen et al. 1999:112).*

Therefore, this section will consolidate the results of each of the sections in chapter 3 (Case Analysis) to determine if they add up to show an organization that is biased in favor of codification or personalization, or whether NASA is straddling both approaches using a more balanced knowledge management strategy.

Recall that the tool that was to be used for this purpose was introduced in section 1.3 (Methodology). This tool took the form of a table that will be used by reviewing the conclusions of sections 3.1 to 3.4 in chapter 3 (Case Analysis) and assigning a percentage weighting between characteristics of 'codification' and 'personalization'. For example, a balance between both strategies could yield 50% in each column, while a biased approach would show an 80-20% split, respectively. This will show whether – on balance – one type of strategy is being favored or whether the emphasis is spread across both perspectives.

At the commencement of this exercise it is important to note that allocating percentages to each organizational characteristic carries a high degree of subjectivity. This applies not only to the weighting within each category/organizational characteristic, but also to the weighting between each category/organizational characteristic. For example, does the human resources approach taken by the organization have as much impact as the competitive strategy? Intuitively it does not seem that it should, but it is difficult to propose an alternative. Therefore, it must be acknowledged that the percentages allocated here probably constitute the main subjective assumption in this analysis, and should be the first aspect of this analysis subjected to scrutiny when performing a sensitivity analysis.

The following paragraphs provide a brief description of the findings under each aspect of the Case Analysis (undertaken in the previous chapter), and the percentage weighting that has been accorded to each organizational characteristic depends on how closely it is considered to conform to Hansen et al.'s description of a codification or personalization organization.

The evaluation of competitive strategy sought to show whether NASA was aiming to provide high quality and reliable products/services provision with fast turnaround and low costs indicative of codification, or customized, innovative products/services delivered by channeling individual expertise indicative of personalization. While NASA's knowledge management journey showed how NASA went through the era of 'Faster-Better-Cheaper' and capturing knowledge in the LLIS in the 1990s, it did subsequently evolve its approach from around 2010. It did not abandon efforts by codification, but instead augmented them with an increased focus on collaboration and inter-personal sharing across the organization. This moved NASA's competitive strategy away from from being exclusively about codification and increased the personalization component. However, emphasis on embedding knowledge in organizational practices and procedures, the focus on project teams and the sheet scale of collaboration across NASA also precluded NASA from being solely invested in a personalization strategy. Therefore, on competitive strategy, while NASA may have at one stage have fitted well with a personalization strategy before attempting to shift its focus to codification during the era of FBC, it has moved on to a balanced approach and currently does not fit exclusively with either of Hansen et al.'s archetypes.

In terms of knowledge economics, the fundamental questions are about the extent of knowledge re-use and team composition. A high degree of knowledge re-use and teams with lots of junior staff relative to senior staff is characteristic of a codification strategy, while highly customized solutions from a small team with a high ratio of senior staff is indicative of a personalization strategy. NASA CKO's explicitly state that knowledge re-use or reapplication is very important to NASA and they view codification and interpersonal transfer of knowledge as complements rather than substitutes. NASA has put in place world-class standardized and online training facilities, and also rely heavily on embedding knowledge in practices and procedures rather than relying on databases and individual experience. When considered in conjunction with the large project teams involved at NASA, it is again not possible to identify NASA as being invested primarily in either a codification or a personalization strategy with their knowledge economics. For the reasons outlined above, competitive strategy and knowledge economics are accorded a 50-50 weighting between codification and personalization in the summary table.

Evaluating NASA's knowledge management strategy needed to determine whether NASA was focusing on a people-to-documents approach (codification) or a people-to-people approach (personalization). NASA's knowledge management journey showed how it had gone from relying on personalization (characterized by mentoring) in the 1980s, to an increased emphasis on codification in the 1990s, before taking a balanced approach from about 2010. The appointment of its first agency-level CKO saw a dual emphasis on knowledge capture as well as knowledge networks, again straddling both strategies. Knowledge management at each of the respective centers showed some variation in emphasis, but an overall acknowledgement of the need to address the need for codification as well as interpersonal sharing, and also the important point that much organizational knowledge can be stored in shared practices and procedures, such that it is neither codified or personalized, but rather embedded in the organization. Knoweldge stored in organizational practices and procedures does not fit with either category under Hansen et al. (1999) but remains an important part of NASA's knowledge management practices. A review of the knowledge management initiatives recorded on the Agency's Knowledge Map showed an emphasis on people-to-documents initiatives, such that the knowledge management practices were accorded a 70-30 weighting in favor of codification. The weighting was kept short of 80-20 as there were a number of significant people-to-people initiatives such that it could not be said that one approach was primary approach and the other subordinate or in a supporting role.

The human resources strategy was evaluated using several variables, specifically mix of occupations, employee turnover, length of service and staff training. A personalization scenario was likely to see the recruitment of highly qualified individuals who remained with NASA for longer and were accorded personalized mentoring. A codification approach would likely exhibit higher recruitment of graduates and interns, higher staff turnover and shorter length of service, and standardized staff training delivered to groups or through online platforms. It was difficult to detect whether NASA was recruiting and developing graduates or hiring fully-fledged experts, but the high ratio of "S&E" (scientific and engineering) staff suggested personalization. Similarly, the low employee turnover and high average length of service pointed to strong staff retention and development, also indicative of an organization investing in personalization of knowledge. However, when it came of staff training, NASA had moved away from relying on mentoring as it did in the 1980s to more standardized training and online training facilities. Hansen et al. (1999) would see this as characteristic of a codification organization, but this may be because Hansen et al. had in the 1990s not envisaged the scale of NASA and the currently available level of technological advancement whereby online training can deliver an almost interpersonal experience. For this reason, the human resources approach is given a 70-30 weighting in favor of personalization.

Evaluating the I.T. strategy in terms of Hansen et al.'s theory requires the distinction to made whether there is (i) a heavy investment in I.T. to connect staff with reusable content, or (ii) a moderate investment to facilitate interpersonal transfer of knowledge. This section was relatively short and drew on the results of the NASA Knowledge Map analysis to show that significant investment was being undertaken in connecting staff to reusable knowledge. In terms of NASA's knowledge management journey, if the emphasis on using I.T. for codification was not there since the advent of NASA then it is likely to have arisen with the LLIS in the 1990s and continued since then. However, as I.T. systems have become more versatile since the 1990s it is expected that Hansen et al.'s definitions are becoming more difficult to interpret. For example, it was shown that in areas of NASA seemingly concerned only with codification (such as the NASA Engineering Network), the I.T. systems incorporate significant features to facilitate the personalization of knowledge through discussion boards and online communities of practice. Therefore, the weighting accorded to I.T. systems will lean only marginally in favor of codification at 60-40. The results of the populated table can be seen in Table 15 below:

Table 15 Knowledge management strategic balance at NASA

	Codification	Personalization
Competitive strategy & knowledge-economics	50%	50%
Knowledge management strategy	70%	30%
Human resources strategy	30%	70%
I.T. strategy	60%	40%
Overall result	53%	48%

It is interesting to note from the results in the table above that while the organization may have knowledge management practices (in the second row) predominantly geared towards codification, other aspects of the organization (in this case human resources practices) may be more supportive of personalization practices.

The end result is that while NASA may favor one strategy more in some organizational aspects than in others, NASA on average adopts a balanced strategy. Under the individual organizational aspects there was no imbalance strong enough to show that one strategy is dominant and the other subordinate, or of one strategy being designated to a supporting role.

It is important to re-emphasize what was noted under the evaluation of knowledge management strategy: that NASA's practice of embedding knowledge in practices and procedures does not fit with Hansen et al.'s theory under either codification or personalization, and as such is an important part of NASA's strategy that cannot be reconciled under Hansen et al.'s archetypes.

The overall result, when taken as a simple average, shows a 53:48 split that is marginally in favor of codification. The conclusion that can be drawn from this is that when NASA's competitive strategy, knowledge economics, knowledge management strategy, approach to human resources, and I.T. strategy are analyzed in line with the organizational characteristics laid out in Hansen et al.'s (1999) theory, NASA is found to be following a balanced approach to knowledge management. NASA does not appear to be significantly biased in favor of one strategy over the other, certainly not to the extent recommended by Hansen et al.'s 80-20 rule. That is to say, NASA is straddling both codification and personalization strategies.

The investigation into NASA's knowledge management journey (section 3.2.1) since the 1980s provides another interesting aspect to this analysis, as the weightings in this table would certainly have fluctuated with the changes in practices between the 1980s and the present day. While there is insufficient data (i.e., on the prevalence of I.T. systems and human resources parameters) from those days, it is highly likely that the weighting would have been far more pronounced on the personalization side in the 1980s before adjusting to take on more codification characteristics in the 1990s with FBC, before achieving the present day's middle-of-the-road strategy weighting.

Lastly, in terms of the percentage weightings, while it has already been stressed that the allocation of these percentages are liable to subjective judgement, the mathematics implicit in the table above offers some insight into how the table above would need to change to show an alternative conclusion (i.e., that NASA is an organization invested primarily in codification or personalization). To be judged as being in one category or the other, the overall result would need to show 80% or more in that one category. To achieve this, either the majority of categories would need to be judged as being greater than 80% to the extent that they compensate for those categories that are below 80% (thereby bringing the whole average up above 80%), or the categories greater than 80% would need to be weighted as contributing significantly more to the average than the other lesser categories. When viewed in these terms, it can be seen that the shift in percentages and underlying weightings would need to be significant to push to NASA into one category exclusively (e.g., over the 80% threshold), and the material presented in this analysis is unlikely to support such a conclusion.

4.2 Success as an organization

Now that it has been determined that NASA is straddling both codification and personalization strategies, the final part of analyzing Hansen et al.'s (1999) theory is to determine how NASA is performing as an organization.

Recall that in their paper, Hansen et al. (1999) warn that: "Executives who try to excel at both [codification and personalization] strategies risk failing at both. Management consulting firms have run into serious trouble when they failed to with one approach" (1999: 112).

Hansen et al. (1999) predict that the failure will be due to the organization undermining its own efficacy in terms of providing either a standardized solution versus a customized one, as well as the polarizing of staff into groups favoring one strategy or the other.

The veracity of Hansen et al.'s (1999) predictions can be tested by reviewing data on organizational performance and on employee satisfaction. In an organization that straddles both strategies and results in poor organizational performance, it is reasonable to expect that this will manifest in dissatisfaction from staff. Alternatively, if it is found that the organization is performing well and the staff show a high level of satisfaction, then an explanation could be that the organization has a predominant focus on a single knowledge strategy and Hansen et al.'s prediction is robust. However, if it is found that the organization does not have a dominant knowledge management strategy and is still succeeding with satisfied staff, then the prediction from Hansen et al.'s theory will be shown to be potentially inaccurate.

4.2.1 *NASA's performance in terms of strategic objectives*

To evaluate NASA's performance as an organization requires a brief discussion of its strategic goals and objectives, and how they are measured. NASA's strategic themes, goals and objectives are summarised in the table below:

Table 16 NASA strategic themes, goals and objectives

Theme	Strategic Goal	Strategic Objective
Discover	Expand human knowledge through new scientific discoveries	1.1 Understand the Sun, Earth, Solar System, and Universe. 1.2 Understand responses of physical and biological systems to spaceflight.
Explore	Extend human presence deeper into space and to the Moon for sustainable long-term exploration and utilization	2.1 Lay the foundation for America to maintain a constant human presence in low Earth orbit enabled by a commercial market. 2.2 Conduct human exploration in deep space, including to the surface of the Moon.
Develop	Address national challenges and catalyze economic growth	3.1 Develop and transfer revolutionary technologies to enable exploration capabilities for NASA and the nation. 3.2 Transform aviation through revolutionary technology research, development and transfer. 3.3 Inspire and engage the public in aeronautics, space and science.
Enable	Optimize capabilities and operations	4.1 Engage in partnership strategies. 4.2 Enable space access and services. 4.3 Assure safety and mission success. 4.4 Manage human capital. 4.5 Ensure enterprise protection. 4.6 Sustain infrastructure capabilities and operations.

(FY 2019 Volume of Integrated Performance, undated: 21)

Strategic goals are broken down into strategic objectives. Strategic goals may have a number of underlying programs and/or projects, are further devolved into performance goals and annual performance indicators. Performance goals describe the multiyear performance of a program or project. Annual performance indicators only show a single year of a program or project. This means that a project's performance can be evaluated for that year as well as over the project lifetime.

Table 17 Example: strategic goal devolved to specific annual performance indicator

Strategic goal	Expand human knowledge through new scientific discoveries
Strategic objective	1.1 Understand the Sun, Earth, Solar System, and Universe.
Performance goal (PG)	Send a satellite into orbit by 2025 [years into future]
Annual performance indicator (API)	Complete specification of satellite processing module [this year].

NASA utilizes a system of color rankings to rate its performance goals and its annual performance indicators. The colors follow a stop-light sequence of red/yellow/green as explained below:

Table 18 NASA performance color rankings

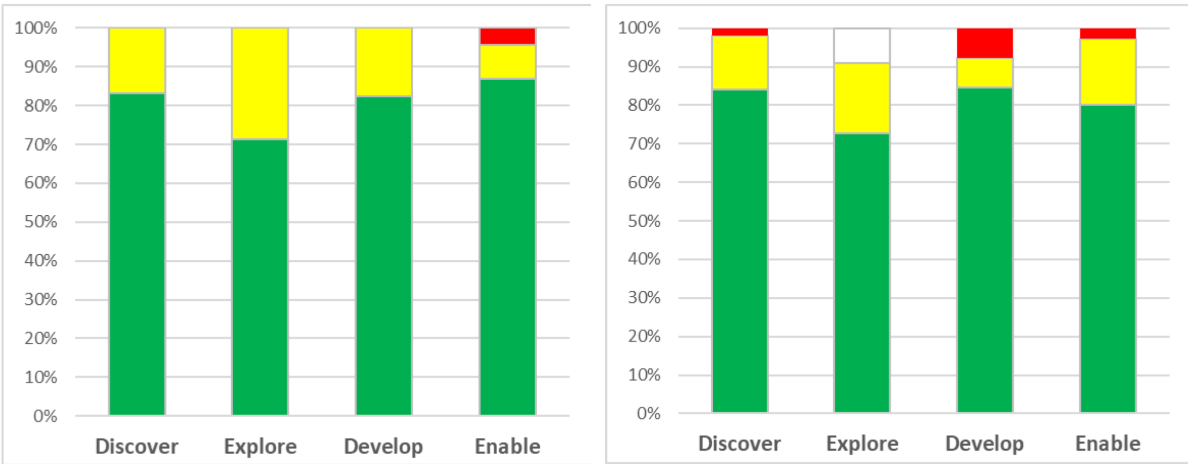
Green	On track or complete – NASA completed or expects to
Yellow	Slightly below target and/or behind schedule – NASA completed or expects to complete this performance measure but is slightly below the target and/or moderately behind schedule.
Red	Significantly below target and/or behind schedule – NASA did not or does not expect to complete this performance measure within the estimated timeframe. The program is substantially below the target and/or significantly behind schedule.
White	A performance measure cannot be assessed against its success criteria and NASA senior management cancel or postpone the measure. NASA is no longer pursuing activities related to the performance of this measure or the program did not have activities during that fiscal year.

(FY 2019 Volume of Integrated Performance, undated: 21)

Figure 6 below ranks the achievement of the multi-year performance goals and the annual performance indicators for each of the strategic goals (Discover, Explore, Develop, Enable). This shows that across all the strategic goals the ratings are predominantly 'green', showing that everything is on-track. The majority of projects outside of the 'green' category are ranked 'yellow' – slightly below target or behind schedule, and by no means indicates failure.

Figure 6 Multi-year and annual performance indicators for FY 2017

6.1 Performance Goals (multi-year) 6.2 Annual Performance Indicators



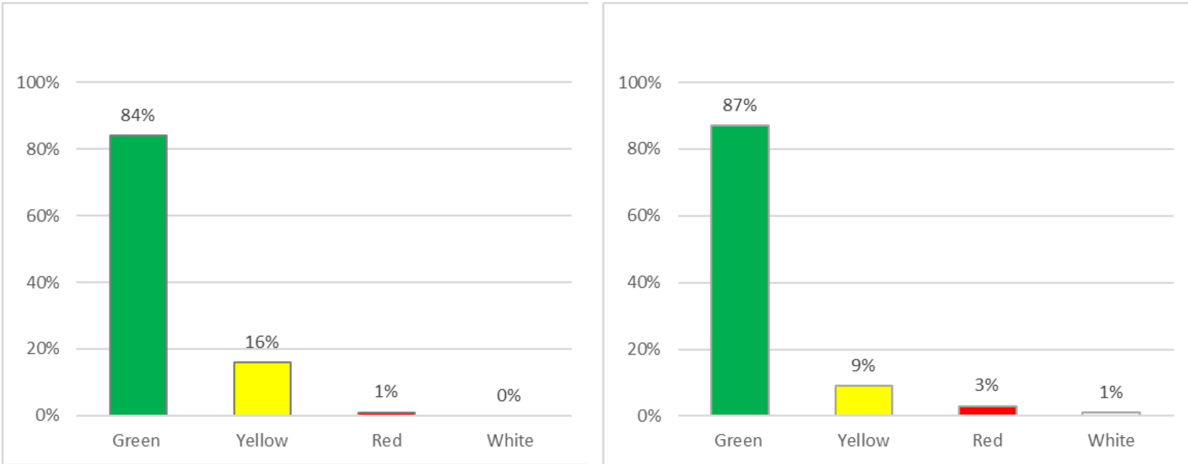
(FY 2019 Volume of Integrated Performance, undated: 21)

The two graphs above can be further aggregated to show the overall progress of the Agency (Figure 7 below). This shows the overall number of projects in each of the categories of green, yellow, red and white.

Figure 7 Overall Performance Goals and Annual Performance Indicators for FY 2017

7.1 Performance Goals

7.2 Annual Performance Indicators



(FY 2019 Volume of Integrated Performance, undated: 21)

From Figure 7.1 above, it can be seen that for overall performance goals reflecting the health of the project over its multi-year lifetime, 84% of are in the green (on-track or complete), 16% are yellow (slightly below target and/or behind schedule), and 1% are red (significantly below target and/or behind schedule).

From Figure 7.2 above, it can be seen that for annual performance indicators, 87% of are in the green (on-track or complete), 9% are yellow (slightly below target and/or behind schedule), 3% are red (significantly below target and/or behind schedule), 1% are white (performance measure cannot be assessed at this time).

From these figures it is apparent that the majority of projects and programs at NASA are under control and progressing according to plan. Hansen et al.'s (1999) framework predicts that if NASA was straddling two knowledge strategies it is likely to encounter problems and undermine its own efficiency and effectiveness. However, if this were the case, it is unlikely that annual performance indicators or performance goals would be at 87% and 84% green, respectively. These indicators suggest that NASA is an effective and successful organization.

4.2.2 *Employee satisfaction*

Hansen et al.'s (1999) theory discusses how mixing knowledge strategies can polarize staff into those who want to pursue a standardized approach versus those who want to develop novel solutions to problems (Hansen et al., 1999: 114). Hansen et al. go on to point out how this can lead to problems as "employees will be confused about priorities" (Hansen et al., 1999: 116).

Under Hansen et al.'s (1999) theory, it would then follow that under circumstances where an organization is unsuccessfully attempting to straddle two different knowledge strategies, there is likely to be a negative impact on employee satisfaction.

Levels of employee dissatisfaction, confusion or frustration that would negatively impact on organization performance are likely to be detectable in workplace satisfaction surveys. By reviewing the results of an independent employee workplace satisfaction survey for NASA, it should be possible to see if there is any evidence of these levels of confusion.

The 'Partnership for Public Service' is a non-profit, nonpartisan organization that has been undertaking workplace surveys since 2003 using a statistical model developed in collaboration with the CFI Group that is also employed in the CFI Group's American Customer Satisfaction Index.

The Partnership for Public Service produces the 'Best Places to Work' survey that is published on bestplacestowork.org, and the rankings for 2017 have been calculated based on the views of more than 498,000 civil servants from 410 federal organizations on a wide range of workplace topics ('Best Places to Work in the Federal Government', 2017).

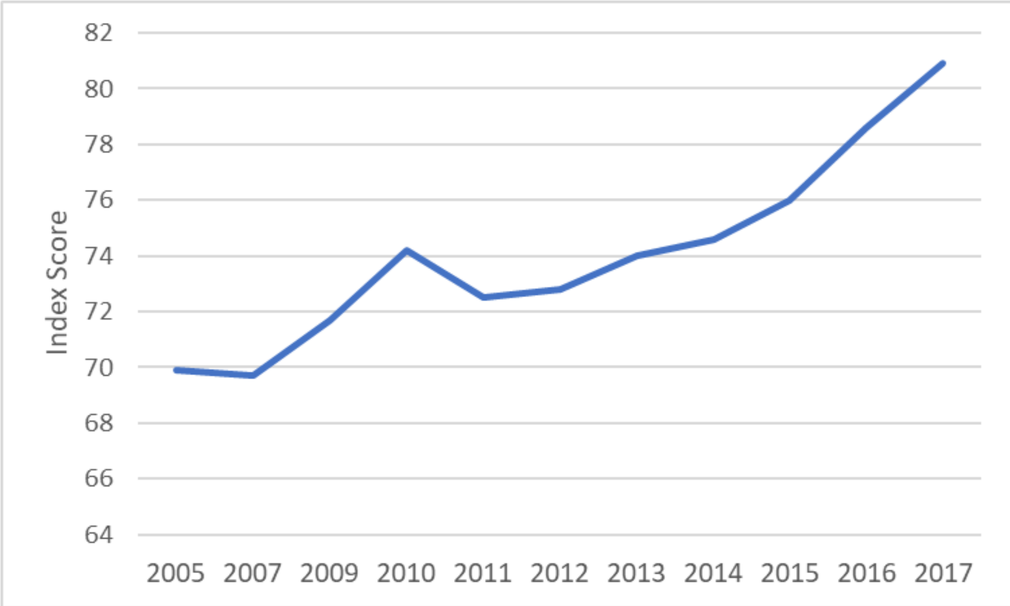
In the survey results, NASA ranks in first place among 18 large government agencies. In 2017 it achieved an index score of 80.9, 2.3 points up from 2016. This is reportedly the sixth consecutive year that NASA has been ranked the best workplace among large federal agencies ('NASA's employee satisfaction continues to soar', 2017).

NASA has shown an upward trend in employee satisfaction for the past 7 years (since 2011), and an overall upward trajectory since 2007 ('Best Places to Work in the Federal Government', 2017).

Table 19 NASA Workplace Satisfaction Index Score (2005 - 2017)

YEAR	2005	2007	2009	2010	2011	2012	2013	2014	2015	2016	2017
SATISFACTION	69.9	69.7	71.7	74.2	72.5	72.8	74	74.6	76	78.6	80.9

Figure 8 NASA Workplace Satisfaction Index Score (2005 - 2017)



The decline observed in the chart above during 2011 may have been due to the retirement of NASA's three space shuttles. A former NASA astronaut was quoted in a new article during this period saying that this had led to uncertainty and low morale in the organization ('With 'Coolest Job Ever' Ending, Astronauts Seek Next Frontier', 2011). The shuttles Discovery, Endeavour and Atlantis were retired in March, June and July of 2011, respectively, and marked the end of the 30-year space shuttle program ('Space Shuttle Retirement', 2018). The explanation that staff satisfaction was negatively affected by this event seems consistent, rather than suggesting that it was due to employee confusion stemming from inefficient knowledge practices or organizational failure stemming from poor knowledge practices.

The survey results show a high level of workplace satisfaction among staff at NASA, and where there was a decline in workplace satisfaction it appears to be due to extraneous factors. Being able to apply both codification and personalization equally and still exhibit high levels of workplace satisfaction is not consistent with Hansen et al.'s (1999) theory.

4.2.3 *Conclusion on success of NASA as a knowledge-based organization*

The information presented above on NASA's performance show that the organization is meeting both its annual performance objectives and its long-term project objectives. With 87% and 84% of short- and long-term project objectives rated as 'on-track or completed', respectively, this can be taken to show an organization that is functioning effectively in a knowledge-intensive sector.

The information on staff satisfaction show that staff are more satisfied working at NASA than at any other large federal organization. Satisfaction has increased steadily over the years, and where there is evidence of past dissatisfaction, this can be linked to other extraneous events. It seems unlikely that employees at NASA could exhibit such a high level of workplace satisfaction and yet also be confused about knowledge practices to the extent that the organization is at risk of overall failure.

Chapter 4 (Discussion) has shown that that the evidence all points to NASA as straddling both codification and personalization strategies. Hansen et al.'s (1999) theory would therefore predict that the organization would be encountering difficulties as a result, but the analysis in this chapter shows high levels of operational performance and employee satisfaction. This suggests that Hansen et al.'s theory is not robust when it comes to predicting the relationship between knowledge management strategy and organizational performance.

5. Conclusion

Section 1.3 (methodology) described how Hansen et al.'s (1999) theory could be tested against NASA's knowledge management strategy to determine its robustness and proposed that there were four potential outcomes to the analysis. These were shown in Table 1 in section 1.3 and have been repeated here as Table 20 below.

The analysis conducted in this study showed that the knowledge management activities undertaken at NASA do not conform to the characteristics of an organization emphasizing a codification or personalization strategy, as recommended by Hansen et al.'s (1999). The analysis also shows that, contrary to predictions by Hansen et al., this has not been detrimental for NASA's performance as an organization. This would place it at "Outcome 4" on the table below:

Table 20 Outcome of the analysis

	NASA succeeding?	**NASA failing?**
Scenario A: **NASA follows Hansen's KM rules**	Outcome 1: Hansen's predictions are consistent	Outcome 3: Hansen's predictions did not hold
Scenario B: **NASA does NOT follow Hansen's KM rules**	Outcome 4: Hansen's predictions did not hold	Outcome 2: Hansen's predictions are consistent

As such, when it comes to testing Hansen et al.'s (1999) theory using NASA's knowledge management strategy, Hansen et al.'s theory was overall not found to be robust.

Reviews of papers by other authors agree that while Hansen et al.'s (1999) recommendation that the organization's knowledge management strategy needs to match its competitive strategy, there is consensus that Hansen et al.'s prescription to emphasize one strategy over another in an 80-20 mix is flawed, and that there may be benefits to be had from a more balanced approach. This is supported by the results of this analysis, where NASA is following a balanced approach in terms of knowledge management strategy and has not found this to be detrimental to the performance of the organization.

The weaknesses in Hansen et al.'s (1999) theory may arise from the fact that, conceptually speaking, Hansen et al. seems to be an adherent to the epistemology of possession [of knowledge]. This is a relatively outdated concept of knowledge that takes a material view of knowledge, perceiving that it can be possessed, accumulated and transferred. This view neglects the role of the organization and how knowledge can be the result of shared practices and processes. This meant that were NASA CKOs pointed to knowledge being held in organizational processes and procedures, this could not be classified according to Hansen et al.'s archetypes.

As a result, Hansen et al. (1999) is subject to a number of limitations, specifically:

(i) Hansen et al. (1999) perceive knowledge is either recorded in rule-sets under codification or kept in the head of the individual expert as per personalization. Hansen et al. disregard the role of the organization and of processes and practices as ways in which knowledge can be accumulated in an organization.

(ii) Hansen et al. (1999) perceive codification and personalization to exist in tension with one another, rather than as complements.

(iii) Innovation cannot take place without an expert to deliver it, and an innovative organization cannot grow unless it accumulates more individual experts. Consequently, Hansen et al.'s (1999) theory implies difficulties for an innovative company that wants to scale up.

This puts NASA at odds with Hansen et al. (1999) with respect to the limitations described above, as NASA believe that:

(i) Knowledge can be held in experts and in codified in databases, but also in teams and in the organization (through its policies and procedures).

(ii) Codification and personalization are needed as complements, to bridge gaps in personal knowledge, personal networks or codified knowledge.

(iii) Therefore, innovation is an incremental process that relies on referencing all three sources, and is not subject to the limitations of the individual.

However, this study also shows that NASA has not always operated under its current knowledge management methodology. Instead it has gone through an evolution in terms of its knowledge management activities. Using the characteristics described by Hansen et al.'s

(1999) archetypes, it is possible to see that in the past NASA was consistent with Hansen et al.'s recommendations to emphasize one knowledge management approach over the other. NASA had an emphasis on personalization in the 1980s that changed to and emphasis on codification in the 1990s, and finally settled on a balanced approach from around 2012 onwards.

This study has shown that Hansen et al.'s (1999) theory is a useful extension of Nonaka's (1991) categories of tacit and explicit knowledge, and to illustrate how organizational characteristics can support the link between knowledge management strategy and competitive strategy. While there is the acknowledged shortcoming in Hansen et al.'s theory that it should not necessarily be taken as a prescription to manage knowledge in an organization using only one approach, this study has shown that there may be merit in considering a balanced approach, and that a balanced approach can in fact help to overcome knowledge gaps in an organization.

Hansen et al.'s (1999) archetypical codification- and personalization-based organizations may be extreme examples seldom practiced in reality, but they provides useful summaries of the sort of organizational characteristics that would characterize approaches from each end of the codification and personalization spectrum. Therefore, although knowledge management strategy has moved beyond Hansen et al.'s theory, it is the characteristics of Hansen et al.'s archetypes that enable us to pinpoint how NASA has evolved its knowledge management strategy to encompass the best of both codification and personalization strategies to address the challenges of tacit and explicit knowledge.

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