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E. Natasha Stavros

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Wicked Problems Need WKID Innovation

Innovation as a Process to Develop a Disruptive Technology Product

This article describes WKID Innovation, a framework to tackle wicked problems and a process for strategic, systematic change management.

E. Natasha Stavros

OVERVIEW: Wicked problems result from complex systems and often have no single solution. WKID Innovation, a framework to tackle wicked problems, is modeled after the National Aeronautic Space Administration's (NASA) science system engineering. NASA is a leader creating disruptive technologies that alter the way that people, companies, and industries operate. Since 1958, NASA has pioneered innovation to advance human knowledge, engineering the first human landing on the moon, successfully landing rovers on Mars, and leaving our solar system, literally going where no man has gone before. While driving innovation in new frontiers, NASA collects accurate, reliable Earth observations that change how we live. WKID Innovation is a framework to scale NASA processes for innovation, specifically by using the knowledge hierarchy to bridge design thinking and complex systems science to system engineer and manage disruptive innovation.

KEYWORDS: Innovation, NASA, Information technology, Process, Wicked problem

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Companies seek to create entirely new markets through disruptive innovation that can change user and consumer behavior. Innovation and disruption have become buzzwords in recent history. Changing people's behavior and their associated organizational systems is not a well-constrained problem; it is a "wicked" problem. Wicked problems involve multiple organizations and often involve disagreement about the causes and best solutions (Australian Public Service Commission 2018). Such problems are resistant to resolution (Rittel and Webber 1973), have no single solution, and therefore require a systematic approach.

In the modern era, innovation tends to leverage massive quantities of data collected from a multitude of sources. With so much data out there, how can we strategically invest to change people's behavior while mitigating risks? Arguably, NASA is one of the first technology-based disruptive innovators in the world, pioneering innovation that has changed society since 1958. For example, NASA engineered the first human landing on the moon despite only having 30 minutes of man hours in space at the time of US President John F. Kennedy's challenge in 1961 (Hero 2019). This was an engineering and management feat on par with other Man-Made World Wonders, that NASA had "better knowledge of how to plan, coordinate, and monitor the multitudinous and varied activities of the organizations required to accomplish great social undertakings" (Wolfe 1968, p. 753). Today, NASA continues to lead innovation to new frontiers in our galaxy and beyond, while collecting accurate, reliable Earth observations and developing technologies that change the day-to-day way we live our lives. NASA does this using "strategic agility" that involves "a multitude of champions scattered around the organization who push forward initiatives that slowly create change" (Heracleous, Terrier, and Gonzalez 2018). As such, wicked problems—cultural or social problems that are difficult to solve—are exactly the kind of problems that NASA works to solve.

In this article, I describe the process NASA uses to innovate; outline a framework to generalize and scale NASA processes for innovation to new, non-aerospace domains; present a case study; and conclude with thoughts for future applications. I

Natasha E. Stavros is the Director of the University of Colorado Boulder Earth Lab Analytics Hub through the Cooperative Institute for Research in Environmental Sciences (CIRES). She specializes in data science, image processing, and information technologies with specific focus in complex systems, including fire ecology, biodiversity, and urban ecology. She worked for seven years at the NASA Jet Propulsion Laboratory, California Institute of Technology as a program manager, project manager, and system engineer on projects ranging in scale from tens of thousands of dollars to over a billion US dollars. She owns WKID Solutions, a company that provides educational resources and coaching services for inventors on topics unrelated to Earth System Science. natasha.stavros@colorodo.edu

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present a convergent framework that incorporates best practices across theory of change, design thinking, complex systems science, data science including artificial intelligence, technology transfer, and system engineering and management.

NASA Process for Innovation

How does it really become NASA's (2021) vision to "reach for new heights and reveal the unknown so that what we do and learn will benefit all humankind"? At present, NASA relies on the Decadal Surveys, which the US National Academies produces about every 10 years. For these surveys, the National Academies solicit community input on the current state of understanding with respect to each of the four science areas: earth science, planetary science, heliophysics, and astrophysics. They then synthesize these inputs to outline goals and objectives for each of the domains to advance humanity's understanding in the next decade. NASA uses this Decadal Survey to determine which missions to develop. For each mission, NASA creates a detailed plan for how the mission will advance systematic understanding and how it will successfully deliver on time and on schedule.

This plan comes from mapping the needs outlined in the Decadal Survey to mission requirements by following the scientific method and using something called a Science Traceability Matrix (Table 1). A mission will select a single Decadal Survey goal for "revealing the unknown," and then create discrete objectives for meeting that goal. There can be many objectives for a single goal; for each objective a row is added to the matrix. Each objective is generally met by testing a hypothesis. Each hypothesis can be broken down into what kinds of physical parameters are needed to test that hypothesis. Data are the common string tracing science to mission requirements, and specifically the level of processing needed to interpret the data. NASA broadly defines the "level" of data based on the amount of processing required to get to that level of information. In this sense, the Science Traceability Matrix follows the knowledge hierarchy (Figure 1).

The traceability from wisdom to data is important to NASA realizing its vision. Specifically, NASA maps science goals to science objectives and the key physical parameters needed to address those objectives, thereby informing the instruments and spacecraft build specifications for collecting data. What makes NASA's process unique is that there are few references to wisdom in college textbooks (Rowley 2007). In fact, a study conducted in 2007 found wisdom mentioned in only three textbooks; one defined wisdom as accumulated knowledge that enables application to new situations or problems (Jessup and Valcich 2008). As such, wisdom is applied understanding (Aven 2013) or informed action. For example, people have a very deep understanding of gravity on Earth, so it is possible to apply the concept of gravity in space or on Mars to inform how to land a Rover safely on the surface even under vastly different atmospheric conditions (Steltzner and Patrick 2016). This is wisdom, and it can help inform or change our actions. Defining wisdom in this way enables use of the knowledge hierarchy as a framework to scale NASA processes for designing and developing "disruptive" missions to new technologies.

WKID Innovation: A Framework for Designing Disruptive Technologies to Solve Wicked Problems

Others have documented the organizational mechanisms for facilitating NASA innovation success (Heracleous, Terrier, and Gonzalez 2018), including a recent move to embrace open innovation (Davis, Richard, and Keeton 2015), and how NASA documents technology readiness for operations using Technology Readiness Levels (TRL) (Millar and Larkin 2021). WKID (pronounced "wicked") Innovation documents the processes for designing NASA Innovation in the context of innovation literature—for example, TRL 1 as basic principles for transitioning research to applications and TRL 2 as the application concept formulated—and provides a methodological framework to implement NASA processes for innovation on specific projects of variable size and application. WKID Innovation uses best practices from theory of change, design thinking, system engineering, and project management, the

TABLE 1. NASA Science Traceability Matrix*

Science Goals	Science Objectives	Physical Parameter Observation	Observable Measurement Requirement	Instrument Functional Requirements	Mission Functional Requirements
Direct Quote from NASA Decadal Survey or Science Plan	*Determine if* hypotheses from	*Properties* predicted to differ due to hypotheses	*Signals to observe properties* predicted to differ due to hypotheses	*Signal* characteristics: spectral, spatial, temporal, etc.	Observation Location, Observation Time, Observation Direction, and Change
	Level 4 Data Product	**Level 2 & 3 Data Product**	**Level 1 Data Product**	**Level 0 Data Product**	

Note*: The NASA Science Traceability Matrix is used to define instrument and mission requirements to advance humanity's scientific understanding of life's existence on Earth, our solar system, and beyond. Table 1 is adapted from Weiss, Smythe, and Lu (2005).

scientific method, and the knowledge hierarchy to mitigate risks while creating disruptive technology.

WKID Innovation transcends any one discipline and covers a breadth of topics, thus the success of WKID Innovation relies on system engineering. The vee-model describes how to system engineer a project (Fosberg and Mooz 1991). By mapping the desired change in actions to the knowledge hierarchy in the context of project management, we can system engineer a change in actions (Figure 2). The foundational premise is that human actions are determined by what we know to be true based on observations of our experience in the world. Specifically, informed action (**W**isdom) is determined by values and the patterns of what we **K**now to be true within a given context based on the patterns of **I**nformation that we observe from evidence or the **D**ata available.

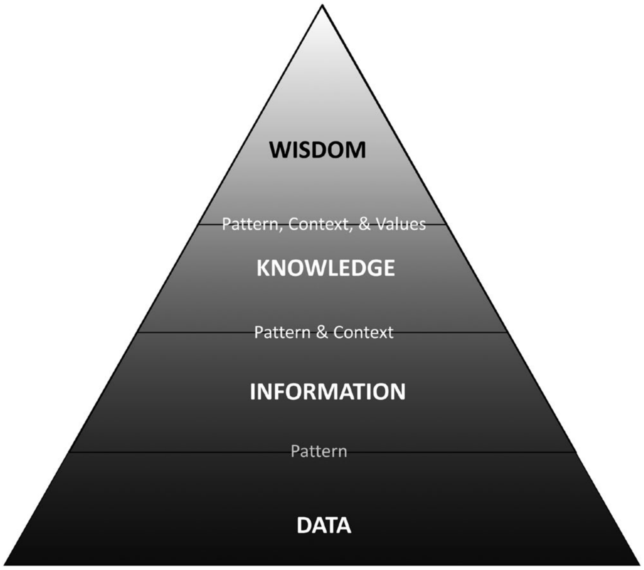

FIGURE 1. Knowledge Hierarchy representation (adapted from Ackoff [1989])

The first step in applying WKID Innovation is to map the concept of operations, or informed actions (wisdom), of the current state to identify the opportunity for improvement that would change actions. Mapping the concept of operations can be really challenging, but, if you want to change the current business environment with the adoption of a product (National Research Council 2004), you must understand the current business environment as it relates to policy, economic, sociocultural factors, and technology/tools (PEST) (Aguilar 1967). Thus, to identify a product for changing the current system comprising people, processes, hardware, software, and their interactions (National Aeronautics Space Agency 2016), we must understand the informed actions by people and the processes and the policies that govern them, the economics of trade, the cultural influences, and the technical capabilities (Daniher and Cureton 1992).

Key to executing a change in the system is not only mapping the concept of operations, but also communicating and documenting a shared vision and implementation among the many players. To do this, we must examine the behaviors of the people in the system we want to change, which informs what we want to know that people cannot or do not articulate. To define a shared vision for the opportunity of improvement based on the informed actions of people in the system, I have adapted the NASA Science Traceability Matrix into a Change Traceability Matrix. Expanding the Theory of Change (Weiss and Connell 1995), the Change Traceability Matrix maps long-term goals of change to preconditions based on the knowledge hierarchy and the premise that people's actions are informed by what they know and the information that is available to them. Specifically, it maps the

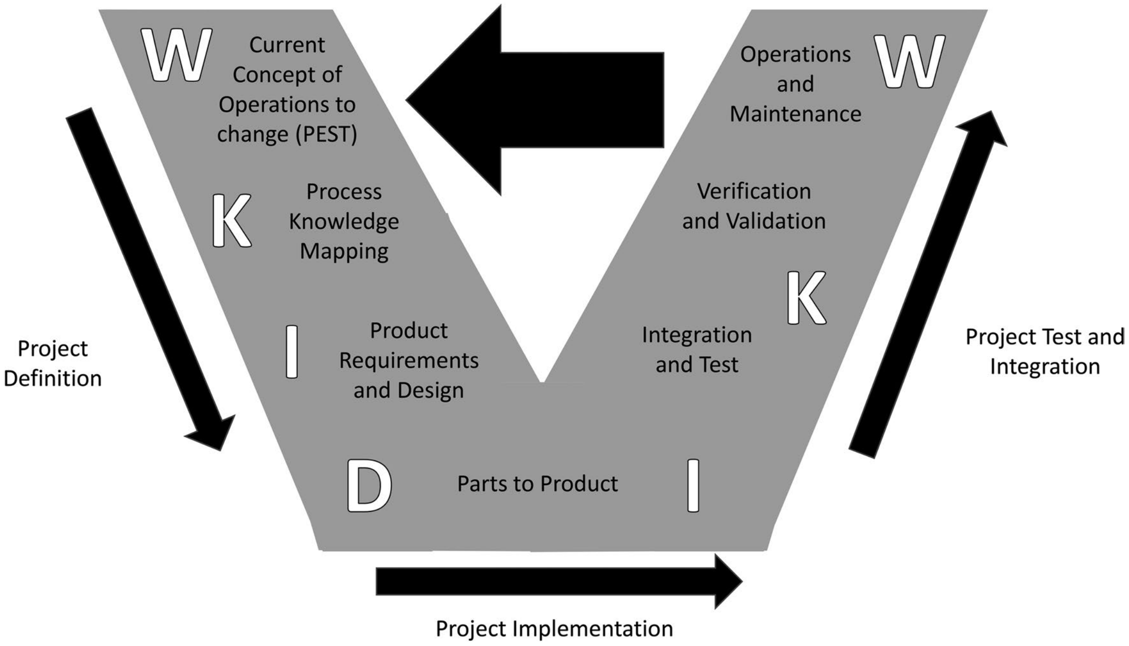

FIGURE 2. The WKID Innovation framework

driving policy and economics that govern people and define their interactions and documents the decision context for the actions intended for change. From this, we use process knowledge mapping (Wexler 2001) to translate people's behaviors into the knowledge and information on which they rely as well as any available data. Then we define our opportunity for product improvement and the metrics for evaluating that improvement.

WKID Innovation creates clear traceability for the value-add to the existing system that our opportunity would provide. Value-add is commonly referred to in the context of demonstrating the return on investment. Often people confuse "return on investment" with the "value of information" (VoI) (Wilson 2015); however, it is worth noting that while VoI is one metric of return on investment, it is not the only one (Brouseselle, Benmarhnia, and Benhadj 2016).

Once we understand what the product needs to do based on what constitutes value-add to the existing system, we can define the requirements by extending the Change Traceability Matrix into a Product Traceability Matrix (Table 3). The purpose of the Product Traceability Matrix is the opportunity for improvement as defined from the Change Traceability Matrix. From this goal, we can define discrete objectives. A big goal, like changing a system, has many objectives. For each objective, a row is added to the Product Traceability Matrix and the product and conditions under which the product adds value are defined: what it needs to do functionally and the limitations or constraints on the design of the product. If the product does not have certain functionalities, then the benefits of using it will not be realized, and it will not be adopted. In this way, the metrics for return on investment constitute a "performance floor" that stakeholders must have to make it worth the effort to adopt the product (Nash 2020).

Following the product life cycle, after we have a well-constrained problem space and product definition, we can actually build it, and verify and validate its known value using our defined metrics for return on investment. After demonstrating the value-add of our system, we can refine our concept of operations, thereby changing how we operate and affect wisdom.

Case Study: The Geospatial Imaging Spectroscopy Processing Environment on the Cloud (ImgSPEC)

An example of applying WKID Innovation to developing a prototype NASA data system of the future is the Geospatial Imaging Spectroscopy Environment on the Cloud (ImgSPEC). At present, NASA uses science data systems to process raw signals from instrument measurements into physical parameters called Level 2 data products. In this paradigm, there are barriers associated with prototyping algorithms that process data from raw instrument measurements to information used to test hypotheses and advance scientific understanding. During a personal communication, Andrew Bingham, the JPL Instrument and Science Data Systems section manager, said, "In the era of big data, algorithm developers require a full-scale data system to test and validate their algorithms. Such a system requires significant resources to implement and sustain, which can be a major barrier to small projects."

TABLE 2. Change Traceability Matrix*

Policy, Economics, and Sociocultural factors that govern people and the Technology (processes) that drive their interactions			Process Knowledge Mapping		
Decision Context	**Decision**	**Decision Approach**	**Reliant Information**	**Reliant Data**	**Opportunity for Improvement**
—Why is there a decision to be made? —What is the impact of that decision? —What are the driving motivations (policy mandate, money, etc.)?	—What is the decision that needs to be made? —Who makes that decision and to whom are they accountable?	—What is the current technology/tools used to inform the key decision?	—What information is needed to make a decision and requirements on latency, accuracy, etc.?	—What data are needed to create that info? —Does the data science exist to convert it to information?	—What are the current limitations? —What improvements could be made?

Note*: The Change Traceability Matrix helps to map the concept of operations of the current policy, economics, sociocultural status, and technologies, while illuminating the opportunity for improvement and the metrics for evaluating return on investment. Table 2 is a modified version of the "Application Traceability Matrix" commonly used by NASA. It has been refined by the many groups working with the NASA Earth Science Division Applied Science Program, including the Jet Propulsion Laboratory Applied Science System Engineer Group.

TABLE 3. Product Traceability Matrix*

Goal	Objectives	Product Requirements	Functional and Design Requirements
Opportunity for Improvement	—What technology/tool has been funded?	—What are the conditions under which the technology/tools or information adds value?	—What does the product need to do functionally to add value? —How does the system need to be designed?

Note*: The Product Traceability Matrix maps the opportunity for improvement to product requirements.

Upgrading and changing how NASA currently implements data systems is, however, a wicked problem. It requires buy-in by many organizational levels: the domain expert scientists typically consulting on algorithm development and use of data; the lead NASA center designing the data system using in-house capabilities; the mission flight project that treats the data system as a subsystem and organizes component contributions from different companies/organizations; and NASA headquarters, which allocates funding and organizes across flight projects using millions of dollars of legacy investments to sustain business operations. With all of these stakeholders, no one solution exists (Rittel and Webber 1973) for how best to develop the data system of the future that would change how NASA processes data to reduce barriers to use and transform how we live in the world today—for example, respond to natural hazards, set crop prices, inform shipping and navigation, etc.

Thus, to define what a data system of the future looks like, I worked with stakeholders at all levels within JPL and at NASA to fill in the Change Traceability Matrix (Table 4), making sure that their needs were captured and considered in the design—that is, the "Decision Context."

Why is there a decision to be made? The most recent Earth Science Decadal Survey released in 2017 (National Academies of Sciences, Engineering, and Medicine 2018) recommended five designated (that is, missions with earmarked funds by NASA) Earth observing systems to change the current understanding of the Earth system and provide societal benefit. Building these observing systems will enable a new era of big data from Earth observations and an opportunity to determine if the current mode of operations is the most effective. One of the recommended Earth observing systems is called Surface Biology and Geology (SBG), which should provide open data access of global imaging spectroscopy data at regular repeat intervals. Imaging spectroscopy provides unique, value-added information (Cawse-Nicholson et al. 2021) benefitting society (Culver et al. 2020) by mapping the chemical fingerprints of the atmosphere and Earth's surface. Imaging spectroscopy is also backwards compatible with the existing Landsat constellation (Seidel et al. 2018), which has proven invaluable over the past 30 years to governments, industry, science, and non-profits alike (Wu et al. 2019).

Upgrading and changing how NASA currently implements data systems is, however, a wicked problem.

What is the impact of that decision? Numerous barriers exist to realizing the full value of imaging spectroscopy data that would not be addressed by the current mode of operation. Specifically, imaging spectroscopy data has high dimensionality (Thompson et al. 2017), which results in large data volumes and processing needs with associated costs that could limit use. Moreover, imaging spectroscopy data requires specialized expertise in processing that may not be available to the breadth of users for which it could serve. SBG users span four major disciplines: biosphere (aquatic and terrestrial), hydrosphere, atmosphere, and mineralogy. These users range from inexperienced managers, policy makers, and the general public, who simply want synthesized information for situational awareness as events happen on Earth—for example, mass tree mortality because of droughts—to the experienced remote sensing algorithm developers and data scientists. In either case, users often want data synthesized to actionable information. This information often requires integrating the data with other datasets.

What are the driving motivations? NASA is committed to open data under US Executive guidance Circular A-130 "Managing Information as a Strategic Resource." This policy outlines open access and transparency in publicly owned data (Office of Management and Budget 2016). The current paradigm for providing these data is under the province of a single mission collecting data.

Who makes that decision and to whom are they accountable? Continuing to fill in the Change Traceability Matrix, the key decision is how to design the data system of the future that maximizes the utility of these data for as many people as possible. At present, each mission creates its own data system as a subsystem of the larger mission.

What is the current technology/tools used to inform the key decision? In the Change Traceability Matrix, the present decision approach is that NASA missions deliver global, publicly available data by producing quality Level 0 raw data to

TABLE 4. ImgSPEC example of the Change Traceability Matrix*

Decision Context	Decision	Decision Approach/ Current Technology	Reliant Information	Reliant Data	Opportunity for Improvement
New Surface Biology and Geology Mission with old and new user communities and big barriers to entry	Maximize data utility by reducing barriers to entry	Mission subsystem of a production environment for processing Level 0 to Level 2 data products	Generalized user workflows developed by algorithm developers with science domain expertise	Mission Data and Ancillary Data	Enable scientists to spend less time processing and more time analyzing data

Note*: ImgSPEC example of the Change Traceability Matrix* define the problem space with clear traceability to the opportunity for improvement.

Level 2 data products, which relies on legacy methods for designing mission-specific data systems as production environments using generalized user workflows.

What information is needed to make the decision? A team of algorithm development experts with domain expertise in relevant science will work with the mission team to assess trades and downstream impacts of mission design considerations for scientific exploration.

What data are needed to create that information? By design, the algorithm developers use mission-generated and ancillary data.

Continuing the Change Traceability Matrix, the opportunity for improvement lies in addressing the current limitations of this approach.

What are the current limitations? What improvements could be made? The current paradigm limits the science and number of applications that can be addressed because any single mission has limited funds and therefore selects a subset of information for which to process the data based on what it deems valuable for its predefined priorities. Anyone who wants to use the data for purposes beyond the scope originally envisioned by the mission must then collect all the mission data in conjunction with other needed data into their own environment; develop tools for processing data in bulk; and then process it to value-added information for scientific advancement or decision-making. This process is extremely cumbersome and results in slow turnaround from data creation to value-add as well as duplicative efforts with many repeating preprocessing steps as others' work is not findable, accessible, interoperable, and reproducible (Wilkinson et al. 2016). Thus, the opportunity for improvement is designing a data system that facilitates accelerated scientific advancement (Knowledge) and changed actions (Wisdom) by enabling open-source software (National Research Council 2018) to streamline and collaborate on tools for processing data, thereby reducing the amount of time spent processing data and increasing the time spent analyzing the data to provide value-add.

Now that we have identified the goal to change the way that we do science, we need to define a discrete path forward. We can break this goal down by moving the opportunity for improvement from our Change Traceability Matrix into the first column of our Product Traceability Matrix. In so doing, we define a product. Rapid prototyping is important to the success of technology transfer and mitigating risk (National Research Council 2004). In this case, our prototype data system is called ImgSPEC and is designed to support a subset of users in terrestrial ecology, with the intent to be scalable to the population of potential users. Thus, the objective is as follows: ImgSPEC should expand the use of existing imaging spectroscopy data by developing an on-demand science data system for distributing standard and custom Level 2+ data products for the terrestrial ecology discipline.

Rapid prototyping is important to the success of technology transfer and mitigating risk.

Following the methods of Stavros et al. (2020) for defining the functional requirements, we conducted a series of interviews across the range of representative users with varying experience levels to collect user stories (Wautelet et al. 2014). These user stories included the processing steps and pain-points associated with working with imaging spectroscopy data, which were mapped to desired functionalities of ImgSPEC and prioritized by frequency of need (Stavros et al. 2020). This resulted in three ImgSPEC use cases:

1. A need for a standard product that is universally applicable in accordance with the traditional NASA paradigm;
2. User-adjusted parameterizations of a standard algorithm that enables customization to local conditions; and
3. Model development using imaging spectroscopy and other data for generating information of value that others may want.

We also used these interviews to inform which metrics we should be tracking to determine return on investment. For example, users would be more inclined to use our system if it reduced download times; provided easy provenance for reproducibility; and enabled a scalable work environment from small to big jobs. As such, the metrics to determine return on investment of ImgSPEC include reduced download times, reproducibility of other users' code, and ease of algorithm deployment at scale.

Using the Product Traceability matrix, I mapped our objective for a prototype data system to product requirements that meet the needs of the three use cases for providing value-add to the existing system:

1. When imaging spectroscopy data are available, ImgSPEC shall enable users to process a standard product, custom parameterization, or develop/implement their own algorithms over a desired area and time.
2. ImgSPEC shall include a documentation approach (metadata) to maintain provenance of on demand user workflows and enable reproducibility.
3. ImgSPEC shall be open source and archive ImgSPEC software to make it publicly available.

Next, I mapped user workflows to product components in a ImgSPEC Concept of Operations diagram to define system functional and design requirements (Figure 3).

We then applied a hybrid waterfall-Agile management approach to build core components for creating a minimum viable product, while still enabling flexibility for testing different methods of implementation between milestones. After each internal test, we conducted a "user acceptance test" to verify progress and implementation approaches, a crucial step for risk reduction to keep the product in scope and avoid straying from its value-add, which enables continued support from our early adopters and champions who are promoting

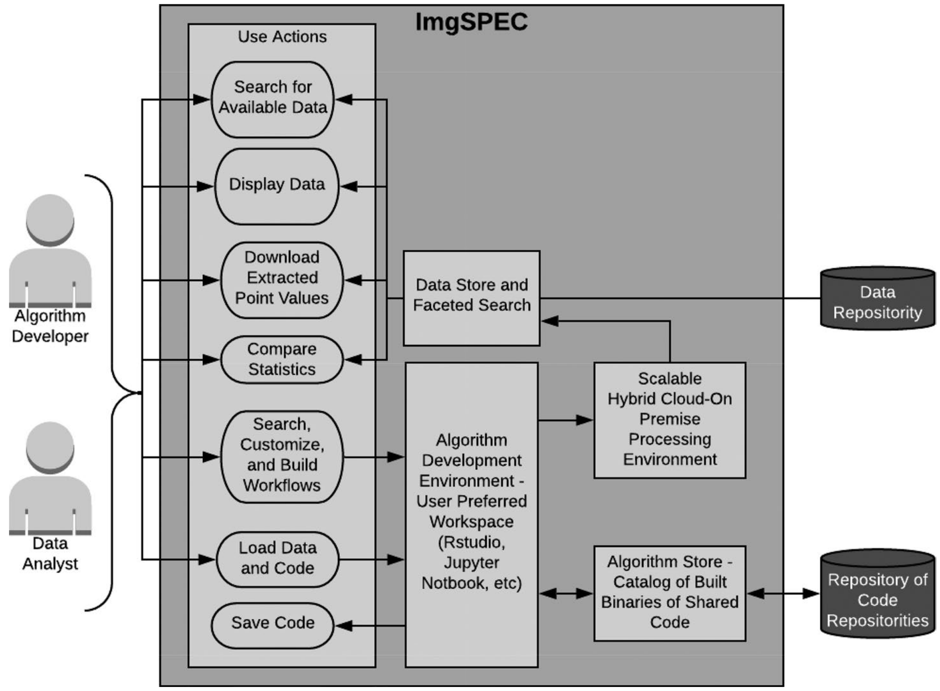

FIGURE 3. Simplified version of the ImgSPEC Concept of Operations

its development and future use. These iterative and continued engagements enable testing the value-add of our prototype, benchmarking costs, and exploring potential risks. For example, through these system tests we have learned of implementation challenges related to information security and firewalls that resulted in changed implementation strategies. These challenges illuminate the "wicked" nature of the problem. Although project design and definition involved stakeholders at all levels of the system being affected, there was a missing stakeholder: information security.

While the prototype ImgSPEC successfully demonstrates reduced barriers to entry for using imaging spectroscopy data, it is clear that additional functionalities are needed. Specifically, ImgSPEC demonstrates a scalable, user-friendly work environment that can process ~300x more data files in the same amount of time as a single computer. This value has garnered support of early adopters and champions. ImgSPEC is growing its functionality through follow-on efforts to continue to test its viability for transition (National Research Council 2004) into a full mission system, including considerations for funding models and information security. While it would be nice to fund all new functionalities (Goal), realistically, we will have to prioritize developments (Objectives) and define another round of product, functional, and design requirements. As the project grows in success, it will get pulled in more directions, thus illuminating the importance of a well-defined Change Traceability Matrix that anchors growth in the direction of the change we wanted to see (Opportunity for Improvement/Goal) and sets an appropriate scope.

This iterative nature in growing functionality by testing a minimum viable product derived by the end goal (Weiss and Connell 1995) highlights the importance of a hybrid waterfall-Agile management structure. It also demonstrates how WKID Innovation is iterative and how wicked problems are defined through the process of finding solutions (Rittel and Webber 1973).

Discussion

WKID Innovation scales NASA processes for innovation to new, non-aerospace domains. It is unique in that it starts by purposefully designing a product from the beginning to affect change by focusing on "wisdom" and relying on the knowledge hierarchy to inform strategic investments based on systematic understanding. In this way it parallels Design for Six Sigma (DFSS) (Anthony and Coronado 2002) that aims to define, measure, analyze, design, and verify products through an iterative process to converge on an optimal solution. Many of the statistical techniques and tools in DFSS could be used in WKID Innovation. WKID Innovation focuses on how to systematically collect information and define a complex system with the explicit goal of changing the current system that has many stakeholders across organizations.

WKID Innovation's emphasis on wisdom parallels the mindset of Design Thinking characterized by strong orientation to stakeholders' unhidden and hidden needs, prototyping, and divergent and subsequent convergent thinking (Brenner, Uebernickel, and Abrell 2016). A PEST analysis (Aguilar 1967) and the Change Traceability Matrix help illuminate hidden and unhidden functional needs of a product or products by the many stakeholders. These functional needs can then trickle into product definition(s) through the Product Traceability Matrix. In this way, WKID Innovation specifically addresses key limitations often inhibiting adoption of technologies, identified by the National Research

Council as, "the lack of information given to vendors about the relevant functional and technological needs. . . [rather than] strict adherence to detailed but incomplete specifications" (2004, p. 5).

WKID Innovation maps the knowledge hierarchy to the project life cycle and is intended to facilitate prototype deployment and evolution. Its iterative process can be used at any phase of a project's life cycle and at any level of product development—that is, prototyping through full-scale deployment. This iterative process enables consistent and constant validation of the value-add of the product being developed within the context of verifying the knowledge gain (National Research Council 2004) and subsequent change in actions. This leverages the "fail fast and often" philosophy that enables development and testing of a minimum viable product quickly with growing functionality that can be tested along the way to reduce the risks to investment long-term.

Specifically considering divergent and subsequent convergent thinking, WKID Innovation facilitates coordinated, collaborative solutions to wicked problems. As such, WKID Innovation cannot be done in a vacuum. It provides a framework to help document motivations and the functional needs across divergent views rather than dictate a single solution up front. In populating content into the traceability matrices, people can iterate ideas of divergent solutions into a convergent set of criteria by which to collaboratively define innovative solutions that require negotiation, a collaboration, not compromise (Voss and Raz 2016). Collaboration is a foundational pillar for NASA innovation success as it organizes people, companies, and countries around varying cultures and priorities (Heracleous, Terrier, and Gonzalez 2018).

Efficient trade space exploration (Nash 2020) is crucial to the effort of converging from divergent ideas. Regardless of how efficiently stakeholders can converge on a solution, a lot of pre-work is involved in understanding a complex system and getting buy-in from the diverse range of stakeholders involved in the wicked problem (Rittel and Webber 1973); this pre-work inherently takes time and iteration. For ImgSPEC, we have spent seven years mapping the key players' policies and financial models to inform a succinct problem definition and prototype solution that has resulted in stakeholder buy-in to develop and build the prototype. At each stage, stakeholders are involved from defining the concept of operations through build testing and verification. While this process takes time, the advantage is that by defining the problem space collaboratively, participants feel heard and are more likely to "own" the result, proliferating its use and instituting the change the product aims to accomplish.

Those applying WKID Innovation must periodically reassess whether the opportunity for improvement in the Change Traceability Matrix remains valid for the current state and whether the defined product is still the most effective. ImgSPEC is only possible because of the advancements of many component technologies being developed over the last decade. The Change Traceability Matrix must be re-evaluated periodically to determine how the landscape is changing so that innovation can adapt to the new environment.

Conclusion

WKID Innovation codifies NASA processes for innovation into a framework that can be scaled and applied beyond aerospace. WKID Innovation is a process for strategic, systematic change management. It is product-agnostic, whereby a product could just as easily be a bureaucratic or political process (new method) as an information technology (product). The novelty of WKID Innovation is that change starts from a deep examination of the behavior of people and a clear mapping of the decision context around their informed actions to drive requirements for systematic change. WKID Innovation is a framework to facilitate systematic change in how we live today.

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