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CREATING PORTFOLIO MANAGEMENT CONCEPTS FOR HIGHLY AGILE AND INNOVATIVE GOVERNMENT RESEARCH PROGRAMS USING DESIGN THINKING AND LEAN START UP METHODOLOGIES

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Abstract

Managing a research and development (R&D) portfolio presents numerous challenges, such as prioritizing research areas, remaining agile, strategic workforce planning, and measuring return on investment, impact, and innovation. One government R&D program is charged with producing a high degree of innovative, transformational breakthroughs in aviation technology. A practical, structured methodology for strategically prioritizing emerging aviation R&D in such an environment is lacking. The existing multi-criteria decision aid tools are primarily utilized at an enterprise level, take months to set up and collect data, require large teams of experts, are used on an infrequent basis, and are not conducive to a highly innovative, high-risk portfolio. Prior to audaciously creating a new portfolio prioritization process, the exact challenges with portfolio management for R&D projects were identified using the design thinking and lean start-up methods. A key part of this discovery process was interviewing stakeholders, as well as other managers of organizations charged with producing innovative portfolios. These interviews, as well as additional techniques, were used to develop a deeper understanding of the challenges and, subsequently, lay the foundation for development of an effective portfolio prioritization process. Four potential concepts that represent key findings emerged: carefully selected criteria for portfolio assessment and selection, targeted portfolio turnover rate, dynamic portfolio prioritization framework, and streamlined transition or commercialization of R&D. Acting on any one of the resulting portfolio management concepts will increase the transparency and confidence in portfolio decisions and, ideally, result in a greater degree of transformational breakthroughs in aviation technology.

Keywords

Project portfolio management, design thinking, project portfolio prioritization

Introduction

There are numerous challenges associated with managing a Research & Development (R&D) portfolio, such as prioritizing research areas, remaining agile, strategic workforce planning, and measuring return on investment, impact, and innovation. The National Aeronautics and Space Administration's (NASA) Aeronautics Research Mission Directorate (ARMD), a government R&D organization, owns the mission of developing technologies to meet the future needs of the aviation community for safe, efficient, flexible, and environmentally sustainable air transportation. One program, in particular, the Transformative Aeronautics Concepts (TAC) Program, is charged with producing a high degree of innovative, transformational breakthroughs in aviation technology. Strategic portfolio management is one key component in accomplishing those breakthroughs.

Currently, a practical, structured methodology for strategically prioritizing emerging aviation R&D in an environment where there are requirements to have an agile workforce and clearly measure return on investment and innovation is lacking. Specifically, there is no tool to aid project managers to effectively collect innovative ideas and prioritize them in their portfolio that can be efficiently utilized on an annual basis by a small team. The existing multi-

criteria decision aid tools are usually utilized at an enterprise level, take months to set up and collect data, require large teams of experts, are used on an in-frequent basis, and are not conducive to a highly innovative, high-risk portfolio.

Development of a practical prioritization process for use in the scenario described above is needed to result in a greater degree of successfully transferred technologies. One proposal is to develop a method and tool that practically applies an existing Project Portfolio Management theory (or amalgamation of theories) to improve the portfolio selection process for foundational, cross-cutting, low-Technology Readiness Level (TRL) (Mankins, 2004) research projects with high expectations of producing innovative aviation solutions.

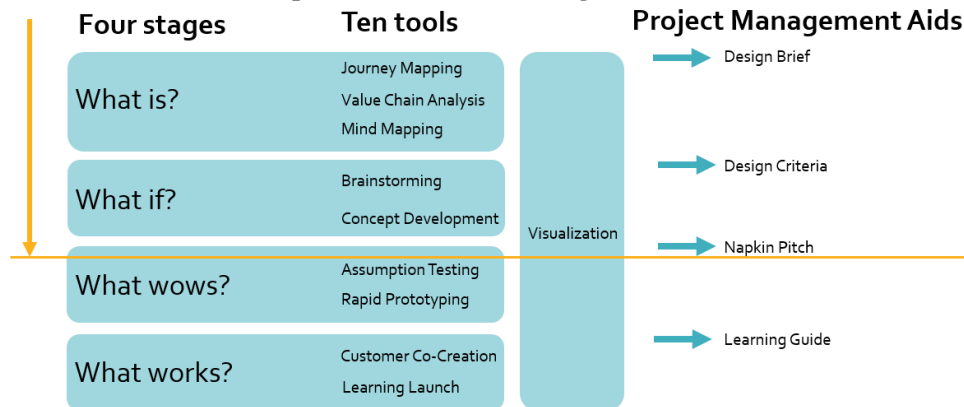
To achieve that goal, a deeper understanding of the needs and challenges of a portfolio prioritization process for the types of programs described above was needed. Any new method, tool, or process introduced into the program or project management structure will require monetary and human resources, as well as a learning curve. As such, any new process will need to have a strong value proposition in order to be adopted and regularly utilized by the program and project management team. Thus, the design thinking and lean start-up methods were utilized to perform a discovery process to hone in on specific challenges and build the value proposition for a new or tailored portfolio prioritization process. A vital part of this discovery process was interviewing key stakeholders, as well as other organizations, who use a portfolio prioritization process for their innovative portfolios. These interviews, as well as additional relevant design thinking techniques, were used to develop a deeper understanding of the problem statement that lays the foundation for further research and development on a new portfolio prioritization process for the TAC Program.

Design Thinking and Lean Start-Up Methodologies

Design thinking is a human-centered problem-solving process that utilizes a series of tools to arrive at a product that is designed for and with the customer or stakeholder (Liedtka & Ogilvie, 2011). Design thinking can be traced back to the 1940s with psychological studies of logical thinking and creativity (Wertheimer, 1945), 1950s with new creativity techniques inspired in part by the launch of Sputnik (Cross, 1993), and 1960s with the first publications on design thinking (Arnold, 1959; Archer, 1965). Since then, design thinking has gone through several decades of evolution with expanded applications and a more generalized theory, with much literature written on the topic.

The specific method used for this exercise comes from a training course at NASA offered by the Darden School of Business at the University of Virginia and the associated book by Liedtka and Ogilvie (2011). The design thinking method presented in the book is comprised of four stages: What is? (explores current reality); What if? (envisages new future); What wows? (makes choices); and What works? (enters marketplace). Each stage contains multiple tools and project management aids to guide the development of the product, as shown in Exhibit 1. The results of this exercise conclude at the beginning of the What if? stage with the creation of napkin pitches. The napkin pitches serve as concepts that could meet the needs of the stakeholders and should be further vetted and tested through techniques, such as assumption testing, prototyping, and learning launches. In this exercise, the napkin pitches represent potential areas for further research.

Exhibit 1. Design Thinking Stages, Tools, and Project Management Aids – adapted from Liedtka and Ogilvie (2011).



The lean startup methodology was developed by Eric Ries and refers to a process of continuous innovation, early testing, and iterating on a technology to achieve a better product market fit (Ries, 2011). The lean start-up methodology

is focused on three key elements: business (or mission) model canvas, customer development, and agile development. Instead of starting the development of a business (or mission) with a business plan, a business model is developed through a process called customer discovery. The problem is investigated before identifying a solution in order to search for a product-market fit. The main question answered in lean start-up is: “Can you build and deliver a product/service that satisfies the customer problem or need?” In this exercise, both the value proposition canvas and the customer discovery processes were utilized. The customer discovery process was combined with the journey mapping process from design thinking, as they are similar processes, and the benefit of both key concepts was desired.

Application of Design Thinking and Lean Start-Up

As described above, design thinking and lean start-up methodologies were utilized to identify key challenges and concepts for project portfolio management in a portfolio charged with innovation and technological breakthroughs. Each of the steps performed are summarized in this section.

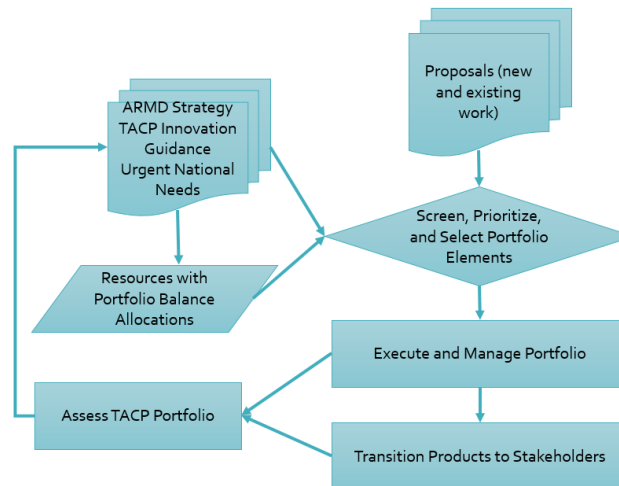
Design Brief

The first step in the design thinking process is to lay out a design brief – the first project management aid as shown in Exhibit 1. The goal of the design brief is to establish the scope and intent of the project, questions to be explored, and a target market (Liedtka & Ogilvie, 2011). In this case, the intent and scope of the project is to better understand the needs of the Program in terms of value proposition and portfolio management and to identify specific areas in the on-going portfolio management activities that are challenging or not ideal for the Program. Exploration questions include: 1) How does your organization bring value to its stakeholders? 2) What methods for portfolio management are currently being used? How is portfolio management done today? 3) What are the pros and cons of those methods? The target users in this case are the Program managers.

Visualization

Visualization is a tool that can be used in every stage of the design thinking process. It allows information to be represented as images – either literal pictures or a story that can be visualized in your mind. The goal is to reduce varying interpretation of text alone, especially in cross-disciplinary projects (Liedtka & Ogilvie, 2011). In this case, the project portfolio management process is being explored, so a flow chart is appropriate. A simplified version of the process, as it works today, is shown in Exhibit 2. New and existing work is screened, prioritized, and selected to be executed and managed as part of the program portfolio. Some elements are transitioned to stakeholders when ready. The portfolio is assessed on an annual basis. That assessment along with the annual strategy, innovation guidance, and urgent national needs are used to determine resource allocations and aid in selection of portfolio elements. The process is repeated on an annual basis. This visualization serves as a backdrop through the entire design thinking process.

Exhibit 2. Visualization of project portfolio management process.



Journey Mapping and Customer Discovery

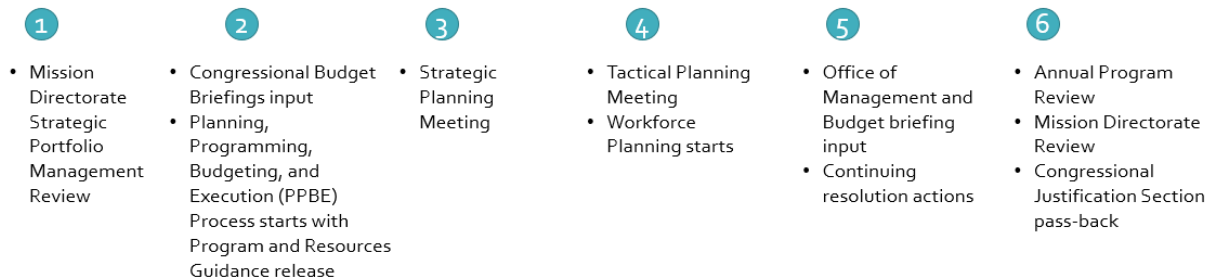
Customer discovery is a key component of the lean startup process and consists of an iterative process to understand the customers’ needs, situations, and pain points. Interviewing is a critical aspect of this process to discover and

learn, as well as validate assumptions about pain points. The focus is on learning, not selling your product (Austin, 2021).

Journey mapping, as described in Liedtka & Ogilvie (2011), is a design thinking tool that lays out a customer's experience as they interact with the product or service your company (or organization) offers. The map can focus on either the ideal or actual journey of your customer. The goal is to focus on the customer rather than the organization and produce an innovative product or service that adds value by easing your customers' frustrations and challenges. The journey mapping process consists of several steps as detailed below.

The customers for the journey mapping process are the Program managers. The simplified annual portfolio management journey through the annual portfolio management process is shown in Exhibit 3. The annual process is cyclical and can be seen to begin at various points throughout the year. As represented in the exhibit below, the process starts with an annual strategic portfolio management review, where key aspects of the budget are discussed and strategic decisions for future research are made. Then starts the Planning, Programming, Budgeting, and Execution (PPBE) cycle with the Congressional budget briefings and release of the Program and Resource Guidance from Headquarters. Programs and projects use that guidance to start their strategic, then tactical planning of work packages for the following years, working with the various NASA Centers and line managers to ensure proper workforce support and balanced resources. Later in the year, the Programs provide input for an Office of Management and Budget (OMB) briefing, and the operating budget is approved. In recent years, government agencies operate with a continuing resolution well into the fiscal year before the operating plan is approved, so actions associated with various budget scenarios are given. The yearly cycle ends with the annual Program and Mission Directorate reviews, as well as actions associated with OMB's decisions, or "pass-back." This journey represents a dynamic, iterative process that results in continual strategic thinking around portfolio content.

Exhibit 3. Program Portfolio Management Journey.



Perhaps the most impactful activity of the design thinking and lean startup processes was the interview component of the customer discovery and journey mapping tools. Through discussions with stakeholders in the portfolio management process, pain points and lessons learned can be gleaned – critically important information for identifying where the most value can be added in the Program's portfolio management process. The interviewing portion of journey mapping parallels the initial stages of customer discovery activity in lean startup methodology. This activity teases out the gains, pains, and jobs of customers, such that a problem/solution fit (or business model fit) can be designed. The purpose of customer discovery is to get out of the office and talking to customers or potential customers in a way that removes as much personal bias as possible.

Several customers, or program/project managers and executives, who were decision makers and portfolio managers in their organization were identified for interviews. Liedtka & Ogilvie (2011) suggest that 12 to 20 interviews be conducted representing a range of demographic attributes of interest. Other sources suggest about five interviews per user, persona, or demographic (Austin, 2021; Rosala, 2021; Nielsen, 2000; Nielson & Laundauer, 1993). In this case, ten managers were interviewed, including the primary stakeholders (i.e., TAC Program and project managers) and others inside and outside of NASA. This sampling size adequately represented the somewhat narrow persona characteristics needed for this activity and resulted in saturation of ideas and themes. The interviewees were selected using a combination of convenience, chain, and opportunistic sampling (Waltinger, 2019). Positions that were targeted include executive decision makers, program/project managers, and portfolio managers. The participants represent an array of government-funded R&D organizations and aerospace companies with varying portfolio management styles and investment strategies. Roles included project managers, program directors and executives, research center directors and executives, and transformation managers. Participants were 70% male and 30% female, and 80% were senior, late-career with 20% mid-career.

The interviews were conducted in a semi-structured format, in order to create a comfortable, organic, conversational-style interview experience. Each of the discussion prompts, shown in Exhibit 4, was covered in every interview, although not always in the same order. Using thematic analysis, several themes were uncovered from the interviews and are documented in Exhibit 5 (Boyatzis, 1998; Given, 2008).

Exhibit 4. Discussion Prompts.

How would you describe your research portfolio?	Do you feel you are getting the results you want from your portfolio?
How do you perform portfolio management in your organization?	Are you able to clearly describe your portfolio selection process in a satisfactory manner?
How do you decide what new priority areas or ideas make the cut line?	How do you ensure your portfolio contributes to your program's value proposition?
How do you decide when to end a research area or activity?	Who else should I talk to?
Do you use a formal portfolio management strategy?	

Exhibit 5. Interview Themes.

Most commented that a decision framework is important to justify funding decisions.	Most organizations fund different buckets or types of R&D.
Some organizations feature novel management techniques to instill a culture of fast-paced innovation.	Criteria for decisions tend to be subjective – introducing personal biases into the decisions.
Transitioning R&D to higher-TRL development programs or projects was noted to be difficult, although for differing reasons across organizations.	Teasing out old ideas that have been “rebranded” to fit new criteria and judging their current level of applicability and importance can be arduous.
One pain point was the delayed outcome of investments. It can take years (sometimes decades) of sustained investment before a technology is ready for commercialization or results in a transformational breakthrough, which can be vexing for managers who are trying to perfect their portfolio investment strategies and make key prioritization decisions.	Assessing new ideas with no track record and weighing them against ideas that have a known or more certain ending is difficult. One executive noted that sometimes proficiency must be demonstrated to a stakeholder in order for them to accept the risk of a new idea with no track record.
Timing is an important component of a portfolio management and investment strategy. When choosing what to invest in, need and opportunity should be matched.	The level of turnover or agility in a portfolio is difficult to target. How much is the right amount? Should we invest in people more than ideas?
Culture plays a large part in portfolio management decisions. A naturally risk-averse organization has a more difficult time prioritizing risky investments, even when the potential payoff is larger than less risky investments.	A rapid decision-making process is needed – especially in situations where funds are distributed or reduced during the fiscal year. Finding a balance between a formal and not-too-formal portfolio management process is necessary for most Programs or organizations.
Defining and measuring value in government R&D can be difficult – particularly when there is no clear return on investment to measure or estimate – resulting in difficulty prioritizing R&D activities qualitatively.	The struggle with weighing research from different disciplines against each other was also highlighted multiple times.

Value Proposition Canvas

Prior to moving to the next tool in the design thinking process (value chain analysis), a value proposition canvas was created based on the information from the journey mapping, or customer discovery, activity. A value proposition canvas aims to describe the interaction between customers and the product or service in detail. This is a concept from lean startup methodology, and feeds directly into the business model canvas (Coleman, 2022). An example of a template is shown in Exhibit 6.

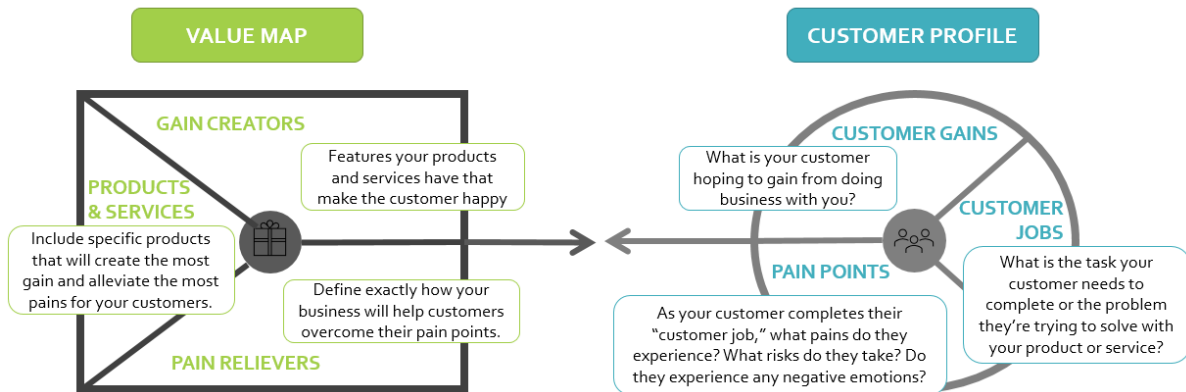
Starting with the customer profile portion of the value proposition canvas, a plethora of customers and associated customer jobs, gains, and pains were identified as they related to the Program's value proposition. These include stakeholders, such as industry (inclusive of entire aviation ecosystem), academia (professors, students), other government agencies, Department of Defense, education (K-12, Science, Technology, Engineering, and Math), NASA's ARMD, OMB, general public, Federal Aviation Administration, standards organizations (e.g., ASTM International, RTCA, SAE International, etc.), international organizations (e.g., North Atlantic Treaty Organization,

International Civil Aviation Organization, Joint Authorities for Rulemaking on Unmanned Systems), and NASA research centers. The Programs' portfolios affect each of these organizations either directly or indirectly. To maintain brevity, the results for each of the topic areas in the value proposition canvas, shown in Exhibit 6, are not displayed in this paper.

The value map aims to list the products and the ways that they can create the most gain and alleviate the most pain for the customers, or stakeholders. Products from the TAC Program include exploratory foundational research, revolutionary advances in aerospace, cutting-edge research, breakthroughs, fast-efficient design and analysis tools, innovative tools and technologies, sustained critical aeronautics core competencies, multi-disciplinary system-level results, valuable data, National Research Announcement funding, and more. Each of these products works to create gain and alleviate pain for the stakeholders.

The value map exercise creates a clearer understanding of what products or services are key components of the portfolio, the potential impacts of removing any one of those, and aids in identification of any gaps in the portfolio.

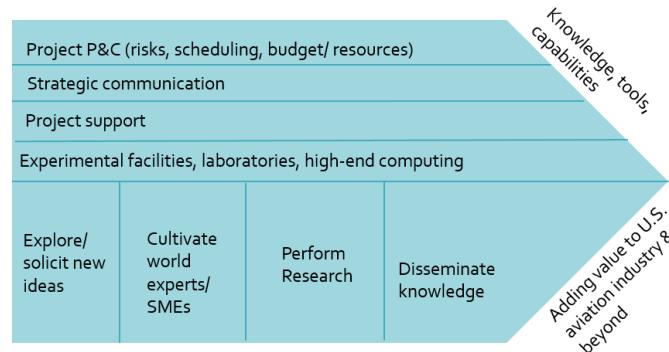
Exhibit 6. Value Proposition Canvas (Coleman, 2022).



Value Chain Analysis

The next tool in the 'What is?' stage is value chain analysis. The goal of this tool is to aid in avoiding a new product or service that may be valuable to your customers but not in profit for your business. In the context of this application, value chain analysis was used to avoid a portfolio management solution that may make a manager feel more confident in their decision but not result in a more impactful portfolio of R&D investments. This tool also helps identify which parts of a new business model or process are attractive and which parts of the existing business model or process are worth preserving. A template similar to the one in an article on the Business Insights blog of Harvard Business School's website (Stobierski, 2020) was used to complete a value chain analysis for the Program, as seen in Exhibit 7. Each of the primary and secondary activities are critically important to achieving the value of the Program.

Exhibit 7. Value Chain Analysis.



Design Criteria

The second project management aid is design criteria. The design criteria add further detail to the design brief for the 'What if?' stage of the design thinking process. The information presented in the design criteria represent valuable information and requirements for any potential solution and is used to evaluate concepts that will be developed in the following steps. The design criteria for this activity are shown in Exhibit 8.

Brainstorming

Brainstorming is another critical component of design thinking. It must not be completed too soon, however, before a thorough understanding of the problem is achieved. With this tool, new ideas for value creation can be conceived. There are many brainstorming methods available for use. The methods used for this exercise were: contra-logic (where the participants act as contrarians, challenging the dominant logic of the business or process); exploring the extremes (e.g., “What if the Program received funding based only on outcome?”); changing who does what (e.g., “How could we offload difficult task X to another party?”); exploring technology scenarios and trends (e.g., “How can we let customers configure and personalize our service?”); pretending to be someone else (e.g., “What if the Program was the Defense Advanced Research Projects Agency and could appoint term-limited program managers with complete launch authority and ability to move funds around more quickly?” (Defense Advanced Research Projects Agency, 2023)); and standing in the future and back-casting (e.g., “Other R&D organizations want to use our process to encourage innovation and impact in theirs. What attributes did our solution demonstrate to earn that opportunity?”) (Liedtka & Ogilvie, 2011).

The brainstorming process produced many new ideas and threads that could be pulled for concept development, the next step in the design thinking process. These are not shown here in order to preserve conciseness.

Exhibit 8. Design Criteria.

Design Goal	Create a portfolio management process that addresses one of the following pain points: <ul style="list-style-type: none"> Deciding which R&D proposals to fund based on a complex and somewhat dynamic set of criteria Deciding what parts of the portfolio to turn over and what to replace it with How to achieve acceptance of risky endeavors in a risk-averse organization
User Perceptions	<ul style="list-style-type: none"> Return on investment often takes a long time and is sometimes difficult to see happening in the moment Decision analysis methods are burdensome (i.e., slow, require funding or other resources, require expertise to use, etc.) Decision analysis tools are useful (Jones, 2009)
Physical Attributes	Custom software solution or subscription to existing software and an expert user of the software
Functional Attributes	<ul style="list-style-type: none"> Must be quick enough to run through portfolio prioritization at least once yearly Ideally, does not have steep learning curve Must be easily adjustable/agile
Constraints	<ul style="list-style-type: none"> Proof of concept must be possible within six months Any solution must be positioned in a way that it does not completely disrupt the Program

Concept Development and Napkin Pitches

The concept development tool assembles the best ideas from brainstorming into concepts that can be evaluated using the criteria established in the design criteria activity. In addition to using ideas from the brainstorming activity, themes from the journey mapping activity were also utilized to develop concepts. Four concepts were crafted from the brainstorming and transformed into napkin pitches. They represent key findings of the first five tools and three project management aids of the design thinking process. These concepts are designed to increase the value proposition of the project and increase transparency and confidence in portfolio decisions. The four concepts include the criteria used to select items in the portfolio, the targeted turnover rate, the framework to enable agility and innovation, and the streamlined transition of low-TRL R&D to customers. These are summarized below.

The first napkin pitch is focused on the criteria used to select which work to include in the R&D program portfolio. The needs, benefits, approach, and other potential service providers are shown in

Exhibit 9. The second napkin pitch is focused on the turnover rate that should be targeted in an R&D portfolio and is shown in

Exhibit 10. The third napkin pitch is focused on the framework needed to develop an agile, innovative program, as shown in

Exhibit 11. The final napkin pitch is focused streamlined transition of low-TRL R&D products to customers and is shown in

Exhibit 12.

Conclusions and Next Steps

Prioritizing research in a low-TRL R&D portfolio remains a difficult challenge for a multitude of reasons. The design thinking and lean startup processes allowed for a deeper exploration of those issues while removing some biases from personal experience. Four key concepts were developed for further investigation that could lead to a greater degree of transformational breakthroughs in aviation technology. These concepts focus on specific components of the project portfolio management process – the criteria used to select research activities, the appropriate target for turnover rate within the portfolio, the overall framework used to manage such an agile, innovative program, and streamlined transition practices for promising low-TRL research to customers.

The next steps include obtaining feedback from the immediate stakeholders (i.e., program and project managers) to identify which concept(s) is most appealing. Then assumptions will be identified and tested, where possible, and the prototyping and co-creation processes will occur. This effort will result in a meaningful addition to the body of knowledge for portfolio management for government R&D projects, as well as improve the value of an executing program and project at NASA.

Exhibit 9. Criteria Napkin Pitch.

<p>NEED Carefully selected criteria for portfolio assessment and selection Identified challenges with:</p> <ul style="list-style-type: none"> • Getting meaningful signs of progress for long-lead R&D • Assessing new, high-risk ideas against existing R&D activities with mostly known outcomes (lower risk) • Finding the "sweet spot" for investing in the right tech at the right time • Identifying and avoiding "rebranding" of an idea 	<p>APPROACH</p> <ul style="list-style-type: none"> • Research criteria in literature • Collect criteria used from other organizations • Thoroughly interview stakeholders to determine needs, goals, objectives of project • Develop and test a set of criteria for portfolio development and compare to decisions that were made without it (and associated outcomes)
<p>BENEFIT</p> <ul style="list-style-type: none"> • Project benefits from being able to clearly show portfolio management process and connect value proposition to criteria using select portfolio elements • ARMD gains a sense of confidence that the right work is being done • Receivers of project products should receive more products that they need at the right time 	<p>OTHER SERVICE PROVIDERS</p> <ul style="list-style-type: none"> • Consulting firms • Academia

Exhibit 10. Turnover Napkin Pitch.

<p>NEED Targeted portfolio turnover rate Identified challenges with targeting the right amount of portfolio turnover for maximum impact</p>	<p>APPROACH</p> <ul style="list-style-type: none"> • Research turnover rate in literature • Collect information about turnover rates from other organizations • Thoroughly interview stakeholders to determine needs, goals, objectives of project • Vary turnover rates (i.e., 10%, 20%, 30% (over a period of three years and assess outcomes
<p>BENEFIT</p> <ul style="list-style-type: none"> • Project benefits by maximizing impact of investment • ARMD gains a sense of confidence that the right work is being done and that the portfolio is appropriately agile • Receivers of project products should receive more products that they need at the right time 	<p>OTHER SERVICE PROVIDERS</p> <ul style="list-style-type: none"> • Consulting firms • Academia

Exhibit 11. Framework Napkin Pitch.

NEED Focus on the framework Identified challenges with developing a rapid, agile framework for managing the R&D portfolio; specifically for a framework that varies across different types of R&D within the project and across different phases of planning and execution during the year	APPROACH <ul style="list-style-type: none"> • Research portfolio management frameworks in literature • Collect information about portfolio management frameworks from other organizations • Thoroughly interview stakeholders to determine needs, goals, objectives of project • Develop a framework that works for the project and assess outcomes against previous performance
BENEFIT <ul style="list-style-type: none"> • Project products should receive benefits by maximizing impact of investment • ARMD gains a sense of confidence that the right work is being done and that the portfolio is appropriately agile • Receivers of project more products that they need at the right time 	OTHER SERVICE PROVIDERS <ul style="list-style-type: none"> • Consulting firms • Academia

Exhibit 12. Transition Napkin Pitch

NEED Streamlined transition of low-TRL R&D <ul style="list-style-type: none"> • Increasing the rate of transition of promising low-TRL R&D to customers • Establishing communication frameworks to enable streamlined transition • Implementing working agreements with other ARMD Mission Programs to enable a smoother, more painless transition of technology 	APPROACH <ul style="list-style-type: none"> • Research R&D transition frameworks in literature • Collect information about turnover rates from other organizations • Thoroughly interview stakeholders to determine needs, goals, objectives of project • Develop a framework that works for the project and assess outcomes against previous performance
BENEFIT <ul style="list-style-type: none"> • Project benefits by maximizing impact of investment • Project benefits from being able to clearly show portfolio management process • ARMD gains a sense of confidence that the right work is being done and that the portfolio is appropriately agile • Receivers of project products should receive more products that they need at the right time 	OTHER SERVICE PROVIDERS <ul style="list-style-type: none"> • Consulting firms • Academia

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