NASA SYSTEMS ENGINEERING BEHAVIOR STUDY

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1.0 Executive Summary

In March 2008, the Office of the Chief Engineer (OCE) held a meeting with top NASA Systems Engineers (SEs) for the purpose of developing shared understanding and agreement regarding the practice of systems engineering across the Agency. As a critical core competency, the effective development of SEs is vital to the future of NASA's success. This development requires an understanding of the characteristics or behaviors that enable employees to be highly effective SEs.

This study was conducted to identify the characteristics or behaviors frequently observed in highly regarded SEs at NASA. Data from this study will be used to design or update systems engineering training, development, coaching and mentoring programs to develop these behaviors in SEs. This data will also help NASA Engineering Leadership to more quickly identify and support the development of high potential future SE leaders.

Centers identified "highly regarded Systems Engineers" to participate in a study to determine the behaviors that contributed to their success. The selected SEs were individuals that the centers determined as the "go to person" with regards to systems engineering. The number of interviewees varied by NASA Center. The methodology and protocol for this study mirrored a study previously conducted by the Jet Propulsion Laboratory (JPL).

In spite of the fact that the practice of systems engineering varies across centers, the behaviors of highly effective system engineers were very consistent. The consistent behaviors exhibited by NASA/JPL highly effective SEs fall into five broad top themes: leadership, attitudes and attributes, communication, problem solving and systems thinking, and technical acumen. Within each of these broad theme areas, specific descriptors of these behaviors were identified along with examples of actual behaviors associated with these theme descriptions.

The findings of this study provide a firm basis on which to build strong systems engineering competencies that will support individual development and program and project needs across NASA. The awareness and understanding of these specific behaviors will also help advance the field of systems engineering development outside NASA by providing greater focus on the human dynamics that, when combined with technical knowledge and abilities, contribute to successful engineering projects and mission success.

2.0 Introduction

2.1 Purpose

The purpose of the NASA Systems Engineering Behavior Study is to identify the characteristics or behaviors frequently observed in highly regarded SEs at NASA. The information gained from this study will be used to accelerate the development of these critical behaviors in this population in order to assure mission success and to develop the next generation of highly regarded SEs.

Data from this study will be used to design or update systems engineering training, development, coaching and mentoring programs to develop these behaviors in SEs across the agency. This study data will allow NASA to begin to introduce elements of leadership training earlier in the training process, thereby helping individuals with a propensity towards systems engineering leadership to emerge sooner.

Knowing specifically which characteristics or behaviors to target for development also provides the Agency with a more scientifically based model from which to measure the impact of training and development programs and to assess their influence on mission performance.

Additionally, this study was intended to provide NASA's Engineering Leadership with a valid and reliable template from which to assess employees' systems engineering capabilities as they relate to these behaviors, and to identify areas for development and improvement.

2.2 Background

In March 2008, the Office of the Chief Engineer held a meeting with some of NASA's top SEs for the purpose of developing shared understanding and agreement regarding the practice of systems engineering across the Agency. Historically there have been many definitions and descriptions of systems engineering used across the Agency. In fact, the actual practice of systems engineering varies across NASA. However, for the most part, SEs agree that:

> *Systems engineering is the art and science of developing an operable system that can meet requirements within imposed constraints. It is holistic and integrative and incorporates and balances the contributions of structural, electrical mechanism-design, and power engineers, plus many other disciplines, including systems safety, to produce a coherent whole that no single discipline dominates. Systems engineering is about tradeoffs and compromises, about generalists rather than specialists.*

Almost all NASA SEs also agree that systems engineering is a critical core competency in enabling the current and future success of NASA missions. This study was undertaken to understand what core behaviors are needed to build strong systems engineers.

Several actions were initiated at the March 2008 meeting to begin this development process, including updating the Academy of Program/Project and Engineering Leadership (APPEL) curriculum and establishing the Systems Engineering Leadership Development Program (SELDP) to enable top SEs to engage in hands-on, developmental "stretch" assignments that would broaden and enhance their capabilities. Foundational to these development enhancements was an understanding of the systems engineering leadership behaviors that needed to be developed in order for SEs to progress from good to great.

In order to achieve this understanding, NASA initiated a Systems Engineering Behavior Study designed to identify the behaviors that separate superior SEs at NASA from average SEs. This study looked at 38 "highly regarded" practicing systems engineers to determine the behaviors that helped make them successful.

3.0 Methodology

3.1 Behavior Study Approach

The NASA Systems Engineering Working Group (SEWG), the NASA Engineering Management Board (EMB) and senior management selected "highly regarded systems engineers" from their respective Centers to participate in a study to determine: What are the behaviors of highly regarded SEs? The methodology leverages the organizational development expertise and work previously done at JPL for the Systems Engineering Advancement (SEA) Project [5], in general, and the Systems Engineering On-The-Job Training (OJT) Program [3], [6], in particular. The selected SEs were individuals the center determined as the "go to person" with regards to systems engineering. The number of interviewees varied by Center. The names of SE participants by Center are shown in Table 12 in Appendix 1.

The Centers, along with NASA APPEL, provided team members for the study. Based on availability and the number of SEs to study, several centers provided more than one study team member. The technical background of these study team members included training and experience in one or more of the following disciplines: engineering, organizational development, psychology, and training and development. The names of study team members are shown in Appendix 2.

The SEs were interviewed, shadowed and observed by one of the study team members. The interviews were conducted in conference rooms or private offices, and were recorded. The interviews lasted from one to one-and-a-half hours. The questions were vetted and approved by the NASA Chief Engineer prior to the start of the study. Participants were asked the same questions, with follow-up questions based on initial answers. The interview questions were divided into three categories: context, relation to self and personal awareness, and the future of systems engineering. The interview questions are shown in Figure 1 below.

The shadow process included a minimum of one day of shadowing the SE performing their day-to-day activities. In addition, the study team members were invited to meetings/events the SE was either leading or participating in. The events observed included, but were not limited to, concept reviews, systems and subsystem reviews, document change reviews, project team meetings, Tiger Team meetings, and individual "quiet hours."

The interviews were transcribed, and the results were compiled and analyzed for common themes. The study team members held a validation and verification (V&V) meeting with the interviewees to gain feedback and to make changes as needed. A center report was created whenever the center had four or more SEs participating in the study. Centers with reports include GSFC, JSC, JPL, LaRC, MSFC and SSC. Data from all the centers, with the exception of KSC, has been rolled up into an Agency-wide report. Figure 2 shows these process milestones.

Context Questions

1. How would you describe the role of the SE?
2. On a scale of 1 to 10, how important is the SE in the success of a program/project?

Relation to Self and Personal Awareness

3. Create, in behavioral terms, a statement that would describe you as a SE.
4. Identify the attitudes and attributes a “highly regarded” SE possesses.
5. What leadership behaviors does a “highly regarded” SE possess?
6. As a SE, what leadership abilities do you possess?
7. On a scale from 1 to 10, how important are these abilities to mission success?
8. How are these abilities displayed?
9. What general knowledge does a “highly regarded” SE possess?
10. On a scale from 1 to 10, how important is this knowledge to mission success?
11. What values drive you as a leader?
12. How are these values reflected in your attitude?
13. Describe what goes on in your mind when you are problem solving.

Projecting Forward

14. What do you look for in determining if someone will make a good SE?
15. How will the job of an SE be different 10 years from now?
16. What will the future SE need to know and do differently?

Figure 1 SE Interview Questions

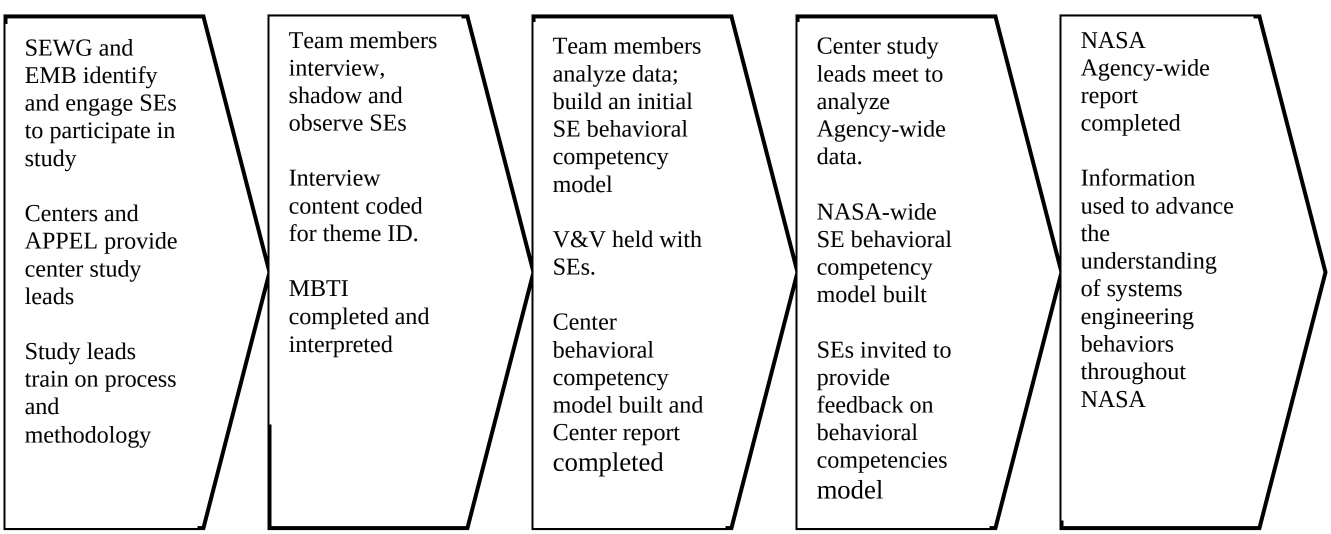


Figure 2 SE Behavior Study Process Milestones

3.2 Developing the Behavioral Competency Model Framework

Three levels of behaviors were identified as described in Table 1. The data was grouped into top behavioral competencies with middle competencies and associated behaviors. This process was done at the center level as well.

Table 1 Behavioral Competency Model Framework

Level	**Description**	**Example**
Top: Themes	Collections of competencies	Attitudes and Attributes
Middle: Competencies	Aggregations of related observable behaviors	Seeks information and uses the art of questioning
Lowest: Actual Behaviors	Observable behaviors	Asks difficult questions of discipline or subsystem experts regarding boundaries, conditions, and assumptions to ensure continuity across all systems, and to ensure the proposed solution is an integrated solution and fundamentally makes sense

4.0 Agency Findings

The behaviors exhibited by NASA's highly valued SEs fall into five broad top themes with associated competencies and their observable behaviors. The broad themes are leadership, attitudes and attributes, communication, problem solving and systems thinking, and technical acumen, as shown in Table 2. The findings are known as the NASA Systems Engineering Behavioral Competency Model. The detailed behaviors associated with the themes and competencies are shown by theme in Table 3 through Table 7 below.

Table 2 NASA SE Behavioral Competency Model – Themes and Competencies

Top Level Themes	Middle Competencies
Leadership	Appreciates/Recognizes Others
	Builds Team Cohesion
	Understands the Human Dynamics of a Team
	Creates Vision and Direction
	Ensures System Integrity
	Possesses Influencing Skills
	Sees Situations Objectively
	Coaches and Mentors
	Delegates
	Ensures Resources are Available
Attitudes & Attributes	Remains Inquisitive and Curious
	Seeks Information and Uses the Art of Questioning
	Advances Ideas
	Gains Respect Credibility, and Trust
	Possesses Self-Confidence
	Has a Comprehensive View
	Possesses a Positive Attitude and Dedication to Mission Success
	Is Aware of Personal Limitations
	Adapts to Change and Uncertainty
	Uses Intuition/ Sensing
	Is Able to Deal with Politics, Financial Issues, and Customer Needs
Communication	Listens Effectively and Translates Information
	Communicates Effectively Through Personal Interaction
	Facilitates an Environment of Open and Honest Communication
	Uses Visuals to Communicate Complex Interactions
	Communicates Through Story Telling and Analogies
	Is Comfortable with Making Decisions
Problem Solving & Systems Thinking	Identifies the Real Problem
	Assimilates, Analyzes, and Synthesizes Data
	Thinks Systemically
	Has the Ability to Find Connections and Patterns Across the System
	Sets Priorities
	Keeps the Focus on Mission Requirements
	Possesses Creativity and Problem Solving Abilities
	Validates Facts, Information and Assumptions
	Remains Open Minded and Objective
	Draws on Past Experiences
	Manages Risk
Technical Acumen	Possesses Technical Competence and Has Comprehensive Previous Experience
	Learns from Successes and Failures

Table 3 Leadership Theme, Competencies and Behaviors

Middle Competencies	Actual Behaviors
Appreciates/ Recognizes Others	• Articulates the relevance of the team's work and its overall contribution to the success of the program and organization. • Fairly represents individual and team contributions and gives credit where credit is due. Acknowledges work performed by others and verbally expresses appreciation.
Builds Team Cohesion	• Knows that resolving differing opinions is important to clarify the problem and foster better understanding. Works to ensure vigorous debate is allowed among people with different views, goals, and objectives to build a common framework. • Establishes healthy relationships to foster team cohesion, strong mission focus, and system perspective by asking team members to provide input and voice concerns. • Models open, non-defensive behavior with others. • Notices when others are uncomfortable and communicates acceptance with open, relaxed inquiry by making positive, encouraging comments to others throughout meetings.
Understands the Human Dynamics of a Team	• Motivates team by consistently communicating progress and understanding of the challenges and opportunities faced by the system design. • Supports team's success by consistently asking: How can I help you? What do you need to succeed? What tools do you need to do your job? • Ensures that all the disciplines interact and work together by meeting regularly and communicating progress often. • Genuinely respects people and their talents by encouraging and challenging them to do their best work. • Understands that people assimilate information differently. Builds rapport with others by adapting communication styles appropriate for the recipients. • Builds upon past experiences in successfully leading various systems engineering teams.
Creates Vision and Direction	• Keeps the team on track by holding a big picture view of what needs to be accomplished in order to reach mission requirements. • Listens to the assessments and concerns of all team members realizing each person has a point of view that is important to them, and continually reminds them of the higher goal. • Ensures each team member understands their roles and responsibilities. • Articulates to the team what constitutes system and mission success and their relationship to each other.
Ensures System Integrity	• Understands the integrity of the system is a primary role. Makes system planning decisions accordingly, reporting unacceptable project risks to senior management. • Accepts responsibility for the performance of the system. Serves as the focal point for blame and criticism when problems occur with system performance.
Possesses Influencing Skills	• Understands the political forces that affect the project and disseminates the relevant information to subsystem engineers and others, as needed.

	• Influences actions of personnel not under their direct management control by creating synergy among and with people. • Builds a base of contacts, information sources, knowledge, and expertise that may be called upon at various stages of the project. Invests the time and effort necessary to build this resource network.
Sees Situations Objectively	• Assumes responsibility for own actions without blaming others for mistakes or misrepresenting one's self. • Understands some of the best ideas can come from a mix of people. Does not assume there is only one right answer. • Remains objective so as not to be hindered by irrelevant, outside influences.
Coaches and Mentors	• Coaches and mentors team members and less experienced systems engineers to develop the breadth and depth of their competencies by giving specific positive and negative feedback for developmental purposes. • Recognizes "high potential" individuals by understanding and identifying the presence of skills and traits needed to be successful in the field. • Challenges individuals to do their best work by giving assignments that build their capabilities. • Asks questions that challenge assumptions, validate conclusions, and explore thought processes. • Promotes a team culture that places a greater priority on the performance of the system than the performance of its subsystems.
Delegates	• Delegates responsibility and authority to the lowest possible levels while retaining control of subsystem requirements and system integration functions. • Builds confidence among team members by delegating responsibility and decision-making authority to subsystem leads and then accepting the decisions they make without resistance or second-guessing.
Ensures Resources are Available	• Ensures that the team has the right tools, knowledge, and resources in order to get the job done. • Keeps abreast of current analytical tools and models by knowing where to find them, when to apply them, and how to use them. • Utilizes data archiving tools and processes to organize, simplify, and distribute information effectively. Ensures that the information team members use to make decisions and coordinate activities is reliable and trustworthy. Uses formal channels of communication to place reasonable limits on the number of people from whom information is gathered.

Table 4 Attitudes and Attributes Theme, Competencies and Behaviors

Middle Competencies	Actual Behaviors
Remains Inquisitive and Curious	• Is naturally inquisitive and curious, and is largely driven by that curiosity. Is fearless and has an authentic and persistent desire to understand how everything works and how it relates to everything else. Can quickly connect dots and identify weak spots. • Seeks to understand the big picture and interrelationship of the parts. Moves without boundaries from one topic to another, to discover what else needs to be known, what might be overlooked. • Actively explores the technical issues, concepts, and lexicon of subsystem disciplines that are less familiar and comfortable.
Seeks Information and Uses the Art of Questioning	• Asks difficult questions of discipline or subsystem experts regarding boundaries, conditions, and assumptions to ensure continuity across all systems and to ensure that the proposed solution is an integrated solution and fundamentally makes sense. • Asks questions, at appropriate times and in various ways, to ensure consistency of answers and to reveal if others understand what constitutes system success. Probes an area if inconsistency is revealed. • Asks questions artfully. Uses a series of questions that build upon each other to help identify the root of a problem or solutions. • Asks “Why?” “Why did we decide to do it that way?” “What were the alternative solutions, and did we do trade studies that helped us determine why this was the best solution?” • Confident in knowing what they do know and willing to state it and admit what is not known; seeks specialists to fill in missing pieces.
Advances Ideas	• Restates, reframes, and clarifies others’ questions to ensure understanding among group members by questioning and measuring an idea against system requirements. • Fosters open two-way discussions. Brainstorms with others to solicit various viewpoints. Allows and encourages people to state opinions while listening for connections and disconnects in logic. • Engages the team by explaining how the solution or approach was reached.
Gains Respect Credibility, and Trust	• Uses respectful tone, words and body language. • Follows through on commitments and serves as an advocate for the team. • Demonstrates understanding and appreciation of the challenges others face. • Earns the respect of team members by demonstrating personal integrity. Conducts business in an honest and trustworthy manner by avoiding deception and treating team members fairly. • Sees trust of self and others as a pervasive element required to achieve success. • Earns trust and respect of others by having a strong understanding of the system’s technical requirements and assigns work based on the individual’s skills and abilities. Understands that not everyone is an “A player”. • Lets team members do their job. Tells them what has to be done, but not how to do it.

Possesses Self-Confidence	• Willing to speak up, regardless of who is present to ensure the most technically sound decision is made for the good of the overall system. • Demonstrates a positive attitude and exhibits confidence. • Sits back and listens to group discussions while building models and connections and/or identifying disconnects.
Has a Comprehensive View	• Takes responsibility for the whole life-cycle, the whole system and all its parts. Understands the whole job and that it is never done. • Strikes a balance between what must happen to obtain success and what must not happen to avert failure.
Possesses a Positive Attitude and Dedication to Mission Success	• Encourages a success oriented environment by displaying passion, excitement and enthusiasm about the work and the challenges faced by the system. • Is dedicated to mission success by working until the job is successfully completed even if that means working long hours to ensure the job is done. • Creates a “can do” atmosphere by providing positive feedback and is empathetic toward team members. Encourages others with their “can do” attitude.
Is Aware of Personal Limitations	• Seeks guidance from experts. Knows what they know and what they don’t know and seeks others to fill in missing data. • Acknowledges technical limitations to others. Does this with ease.
Adapts to Change and Uncertainty	• Presses on with the project and ensures that the implications of change are addressed throughout the entire system in the face of ever-changing requirements. • May make decisions with incomplete or imperfect data. • Understands that change is inevitable and takes appropriate actions quickly. May assemble other technical experts to brainstorm various avenues and approaches to support the change. • Remains calm under pressure. Looks at things pragmatically and understands what's going on. Doesn't over-react.
Uses Intuition/ Sensing	• Uses both intuition and sensing when evaluating a problem or making a decision. Does not rely solely on data. May use of "gut feeling" if data is inconclusive. • Moves concepts and ideas easily through artificial boundaries. Uses intuition and the senses to penetrate the system and discover or synthesize solutions to a problem.
Is Able to Deal with Politics, Financial Issues, and Customer Needs	• Is politically savvy. Understands the larger forces at work. Studies the political and financial issues and impacts. • Shares and uses knowledge and expertise that shapes the political and financial environment in positive ways. • Balances tasks and deliverables against resources and designs processes that save time and money. • Possesses the ability to interface with the customer and successfully lead discussions to create an understanding of system status across various levels, both up, down and across.

Table 5 Communication Theme, Competencies, Behaviors

Middle Competencies	Actual Behaviors
Listens Effectively and Translates Information	• Sees the system from various perspectives. Listens and acts as translator between parties (subsystems, Project, vendors and other customers), ensuring each gets the necessary information from others. • Communicates project status to management and other key internal and external stakeholders. Clearly communicates requirements to providers of the subsystem elements. • Is an excellent listener. Is keenly aware of what is being said and of omissions. Listens for themes that continue to surface. Then there comes a point where the SE will begin to penetrate by asking questions. If questions are not adequately answered, the SE will begin to focus on the potential soft spot. • Listens to identify critical elements or parameters of the problem. Listens for information that leads to connections between system elements and information that disrupts connections. • Clarifies and simplifies ideas under discussion by offering and/or requesting "summation" statements.
Communicates Effectively Through Personal Interaction	• Consistently communicates progress and gains understanding from others on what challenges and successes are faced by the systems design. May meet face to face on a daily, sometimes hourly basis, to ensure everyone is in the loop understand the systems requirements. • Prefers personal interaction over e-mail. Uses face-to-face interaction as a primary communication channel to hear concerns, share information, build rapport, create buy-in and create relationships within a team. • Communicates in a clear and concise manner. • Facilitates effective communication in team meetings and throughout the project by regularly interacting with people on the team and getting them together to ensure everyone is up-to-date.
Facilitates an Environment of Open and Honest Communication	• Welcomes divergent opinions by creating an atmosphere where team members feel the freedom to openly express their opinions. Encourages and respects differing opinions in order to drive convergence on decisions. • Promotes open, honest communication by asking questions, protecting proprietary information, protecting minority opinions, and incorporating valuable ideas that are shared in the system design. Identifies and takes steps to remove communication barriers that are unique to particular individuals or groups. • Patiently listens to each of the team members/discipline experts in order to assure that everyone gets heard--that all diverse and dissenting opinions are considered. Listens to all who want to speak, does not communicate irritation and does not shut people down. • Effectively facilitate teams, meetings and disagreements. Asks clarifying, probing and penetrating questions to ensure all information is out on the table. • Demonstrates accessibility and approachability by having an open door policy.
Uses Visuals to Communicate	• Graphically pulls together ideas, issues, and observations to better understand and explain all systems and interfaces and to solve complex

Complex Interactions	problems. Uses visuals, such as Venn diagrams, models, pictures, charts, metaphors, archetypes, and other relevant representations, to communicate complex problems or to display the interconnections of sub-elements. • Keeps everyone involved by keeping accurate records of big and small picture aspects affecting the system and distributing information in advance.
Communicates Through Story Telling and Analogies	• Uses personnel experiences to build connections and provide explanations by using engineering and non-engineering stories and analogies. For example, creates analogies from historical events, everyday experiences and “life lessons” to better explain concepts and ideas to others. • Shares experiences and “lessons learned” with others to support future systems design.
Is Comfortable with Making Decisions	• Makes decisions in a confident and timely manner when appropriate – with or without complete or optimal information – allowing team members to maintain forward progress on their assigned tasks. • Carefully monitors the impact of decisions on system performance, backtracking and changing direction if necessary. When the team's forward progress is not at stake, the SE may choose to postpone decision-making and engage in more detailed analysis. • Stays on point until ideas are heard, recognizes when enough data is gathered to make a decision, and then moves on. Willing to revisit decision if new data warrants it. • Makes difficult or unpopular decisions, keeping the best interest of the system in mind, weighing the potential risks to team cohesion and interpersonal relationships against system performance.

Table 6 Problem Solving and Systems Thinking Theme, Competencies and Behaviors

Middle Competencies	Actual Behaviors
Identifies the Real Problem	• Identifies the critical problem to be solved by asking questions and identifying the key requirements. • Recognizes what is technically right among many good ideas by viewing a problem across system boundaries and comparing each design to the other. • Frames the problem in a logical way and identifies resources required to solve the problem efficiently. • Solves problems with the team by listening for the issue, pinpoints problem areas, makes recommendations, and then steps out. Avoids side trips and unnecessary minutiae and focuses on important issues.
Assimilates, Analyzes, and Synthesizes Data	• Assimilates and distills large quantities of data and ensures all of the data is on the table to solve a problem or make a decision. Ensures decisions made are supported with data. • Breaks data into smaller pieces or parameters, prioritizes the parameters, then synthesizes the data to reach an answer or solution. • Has the ability to rapidly recall data. • Approaches and solves problems in a systematic manner by using tools, processes, procedures in order to find solutions.
Thinks Systemically	• Looks across the entire system and facilitates trades and compromises to get a balanced design. Ensures that the integrity of the system as a whole does not suffer because of over optimizing any of the smaller pieces. • Sees multi-view representations of systems to understand how the pieces fit together and interact. Visualizes systems in 3-D. Draws a picture in his or her mind, or on paper. • Is able to look deep enough into a problem without losing focus on the big picture. Sees the big picture while at the same time demonstrating an overall awareness of the details. • Breaks the problem down into smaller manageable parts. • Understands how the system works, what it was designed to do, its functions and requirements. Is able to analyze the systems data. Traces implications of a problem in a step-by-step manner across the system.
Has the Ability to Find Connections and Patterns Across the System	• Integrates and provides a connection between the various engineering segments of the project. Is able to identify connections from separate elements of the project that others would not notice and brings these connections to the team's attention as a means to assist in solving underlying issues. • Examines and explores the implications of how technical decisions being made affect the bigger system architecture. Sees the ripple effect of changing requirements or making changes to any element of the system. • Able to see system interfaces. Identifies the impact that changes to one sub-system are having--or might have--on other sub-systems. Locates and corrects sub-system 'disconnects' or 'inconsistencies' that are having a negative impact on system performance.
Sets Priorities	• Sets technical priorities in order to maintain the balance for the problems at hand while achieving system requirements.
Keeps the Focus on Mission	• Is focused on developing a system that meets the end-item product objectives and does not lose sight of this while integrating the pieces of the

Requirements	system into the whole system. • Studies, understands, and articulates the project's overall objectives. Knows what the system must do and be in order to accomplish its objectives. • Sets technical priorities with principal investigator and subsystem engineers to achieve system requirements.
Possesses Creativity and Problem Solving Abilities	• Enjoys and is energized by fully concentrating on a problem for long stretches, until solutions are formed and implemented. Possesses passion for problem solving. • Takes the initiative to solve the problems. • Solves problems with the team by listening to the issues, pinpointing problem areas, making technical recommendations; may help implement the solution. • Does not adhere to rigid rules or formulas for system design, but may create new ideas and approaches that are necessary to deal successfully with system constraints.
Validates Facts, Information and Assumptions	• Breaks data into smaller pieces or parameters. Prioritizes the parameters then synthesizes the data to reach an answer or solution by examining system and sub-system operations in minute detail. Recognizing that seemingly minor miscalculations can lead to significant problems in system performance. • Questions all assumptions that go into the design. • Looks for, and anticipates, problems or issues in the system in places that may not be covered with the right kind of data to make a decision. • Looks for answers that may not be readily apparent from just looking at the data alone. Does not rely solely on data.
Remains Open Minded and Objective	• Receptive to hearing diverse/varying opinions. Is willing to re-think/re-work an issue or to change direction when new information or a better idea is presented. • Evaluates decisions objectively. Maintains flexibility by avoiding 'ownership' of a particular strategy or point of view.
Draws on Past Experiences	• Draws from his or her hands-on experiences to develop the proper feel for succeeding on future projects, knowing when something looks "right" versus "not even close" from past successes and failures. • Solves problems with a balance of innovative developments and proven heritage products. May rely on experience and existing design as guides, but sees each opportunity as a canvas to design new solutions. • Uses experience, history, intuition, and sensing in order to assess the situation and develop a solution.
Manages Risk	• Uses past experiences to anticipate potential problems that may impact system performance. • Identifies the key indicators and methods of testing for each type of problem. • Develops mitigation strategies for addressing the problems, should they arise. • Is risk savvy. Understands that risk is perpetual and needs to be managed.

Table 7 Technical Acumen Theme, Competencies and Behaviors

Middle Competencies	Actual Behaviors
Possesses Technical Competence and Has Comprehensive Previous Experience	• Shares his or her project experience, and acts as a reliable resource to the team and serves as the 'go to' person. • Demonstrates the depth of technical knowledge and expertise necessary to perform, manage, and coordinate work-related activities. • Possesses a strong, fundamental understanding of engineering principles along with a cross-disciplinary background. • Engages specialists for their technical knowledge and abilities. • Demonstrates ability to focus on details while keeping the big picture in mind. Is able to shift focus between the two with ease. • Uses an iterative process to refine the design to accomplish the system requirements
Learns from Successes and Failures	• Shares with others lessons learned. Lessons come from a strong base of engineering experiences across the full life-cycle. • Documents and studies the successes and failures of both the current and previously developed systems. Uses this information to make decisions that reduce risk and maximize the probability of success. • Is willing to learn from past failures as well as successes. Understands both are important.

5.0 Myers-Briggs Type Indicator and Temperament Results

5.1 Description of Myers-Briggs Type Indicator

The Myers-Briggs Type Indicator (MBTI®) [11] was administered to each of the highly regarded SEs in order to identify their personality or psychological type. Of the 38 SEs who participated in the behavioral study, 34 completed the MBTI®. Based on David Keirsey's work on Temperament [7], the MBTI® results can be broken down into one of four temperaments: Intuitive-Thinking (NT), Sensing-Judging (SJ), Sensing-Perceiving (SP) and Intuitive-Feeling (NF), as shown in Table 14 in Appendix 3.

5.2 MBTI® and Temperament Results

The study population has twice as many NTs (56%) as SPs (26%), followed by SJs (19%), and one participant with the NF temperament. Over half of the respondents were Introverts. Unlike the previous study at JPL, NASA centers had 9 SPs and 1 NF, while JPL had neither of these types or temperaments represented in their study. In order to maintain confidentiality, Center and participant names are not indicated. See Table 8 for the MBTI® and Temperament results.

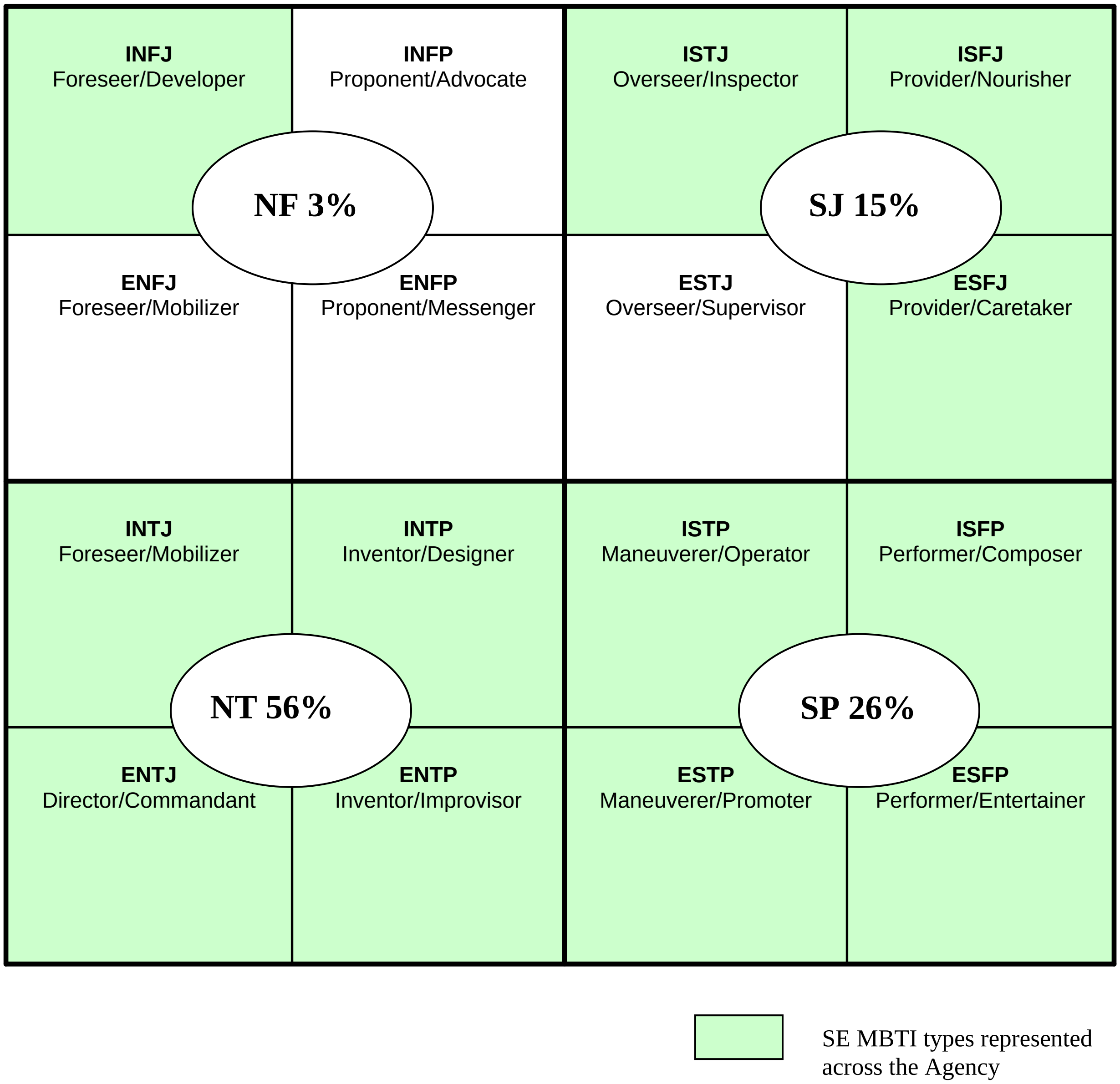
Table 8 Agency-wide Systems Engineering MBTI® Scores by Temperament

Temperaments	# by Category	% of Total	Actual Scores (e.g., INTJ where I=5, N=10, T=7, and J=8)
NT (Intuitive / Thinkers)	**19**	**56%**	
INTJ	6		**5, 10, 7, 6 31, 5, 37, 13 18, 6, 24, 8 31, 29, 45, 51 17, 8, 25, 25 **(scores not available)**
INTP	8		**30, 5, 5, 19 11, 9, 14, 11 12, 16, 15, 8 7, 25, 39, 31 16, 24, 30, 2 4, 9, 6, 1 4, 16, 14, 12 **(scores not available)**
ENTJ	1		**13, 39, 15, 31**
ENTP	4		**12, 8, 5, 14 3, 15, 21, 23 15, 4, 6, 7 11, 29, 27, 31**
SP (Sensing / Perceiving)	**9**	**26%**	
ISTP	3		**19, 6, 8, 2 29, 5, 27, 2 6, 14, 18, 3**
ESTP	5		**30, 5, 24, 1 14, 26, 5, 6 16, 3, 1, 2 17, 10, 20, 12 25, 5, 8, 12**
ESFP	1		**8, 19, 3, 4**
SJ (Sensing / Judging)	**5**	**15%**	
ISTJ	3		**7, 11, 28, 29 53, 13, 63, 39 26, 26, 30, 30**
ISFJ	1		**21, 23, 1, 39**
ESFJ	1		**13, 3, 5, 37**
NF (Intuitive/ Feeler)	**1**	**3%**	
INFJ	1		**25, 6, 3, 28**

All but one Center showed a broad range of MBTI® types. The fact that one center had respondents with the same MBTI® type was most likely due to the small sample size, i.e., only two respondents. See Figure 3 for NASA-wide Systems Engineering MBTI® types represented in this study.

While these findings are interesting, this sample size is too small to draw any definitive conclusions. Continued work in this area will need to include additional highly regarded SEs across the Centers in comparison with those who might not be considered good candidates to be SEs.

Figure 3 MBTI® Types Occurring in SEs Studied Across the Agency



6.0 Next Steps

The OCE will share these study findings widely both inside and outside of NASA. Conference papers and presentations are being developed, and this report will be posted to the Workforce page of the Systems Engineering Community of Practice on the NASA Engineering Network (NEN) at the following URL http://nen.nasa.gov

In addition, both the APPEL and SELDP curriculums will be updated to incorporate the development of these behaviors. As part of this effort, a 360-degree Systems Engineering Behavior Instrument will be created and utilized to assess and track individual skill development. The SELDP will incorporate executive coaching based on the findings of this assessment instrument to accelerate the development of key systems engineering leadership skills during the SELDP year.

The findings of this study bring a new dimension to the understanding of effective Systems Engineering. Little has been explored or studied on the behavioral dimensions of this discipline, and therefore, the OCE is anxious to share these finding with the larger systems engineering community. Articles are being written for outside publications and these findings are already being presented at Systems Engineering Conferences.

7.0 Summary and Conclusions

There is a shared set of specific behaviors at NASA that enable individuals to excel as system engineers. These behaviors are observable and measurable. And, while these behaviors come naturally to some individuals, they are skills that potentially can be developed and learned. The SELDP is predicated on the growth mindset identified by Dweck [4] in which one sees himself or herself as a work in progress with opportunities for growth. It asserts that with effort, SEs can grow, change and learn new behaviors and skills. See Table 15 in Appendix 4.0 for a comparison of the growth vs. the fixed mindset. All the SEs who were interviewed exhibited the growth mindset.

Highly successful SEs possess a foundation of advanced technical knowledge in one or more areas. While this knowledge provides the essential footing, it is the softer, less definable skills that set these individuals apart. Creativity, curiosity, mixed with self-confidence, persistence and a knowledge of human dynamics, allows the highly regarded SEs to be successful. They have the ability to ask the questions, identify what is missing, pinpoint the soft spots in a design, then help to identify a solution to the problem. The SEs understand what must happen to obtain success and what must happen to avert failure. They are drawn to the challenge of solving complex problems by possessing an approach that is comprehensive and intentionally does not favor any particular sub-element of a system. They look across the entire system and facilitate trades and compromises to get a balance, optimized design. They exhibit excellent human relations skills, and understand how to create a vision for the team by keeping the team on track by holding a big picture view of what needs to be accomplished in order to reach mission requirements. They clearly demonstrate the growth mindset in all its many facets. These findings are consistent with the literature on highly successful and effective people [1], [2], [8], [9], [10].

The results of the initial JPL SE Behavioral Study and the Agency-wide study are similar. The results of the Agency-wide study indicate that while there are many separate Center cultures at NASA, there are also shared systems engineering behaviors that provide NASA great opportunities on which to build. Identifying and making these similarities explicit through the use of studies such as this, creates a common language and a way to build on the strengths of one of the largest brain trusts in the world. The similarities in the findings across NASA were unmistakable in proving this point.

On a discipline level, this study provides the Office of the Chief Engineer with specific, scientifically-based answers that will allow them to create learning models and strategies that will strengthen systems engineering across the Agency and build more targeted programs and policies to support mission success.

On a local level, those Centers that have produced Center-wide reports now have greater understanding of what works, and can develop ways to reproduce this success through local SE programs, mentoring and other opportunities.

On an individual level, system engineering employees can build and structure their career choices and learning options. An awareness of how they compare to the best-of-the-best will allow them and their supervisors to make more effective choices in building their development strategies.

Most NASA systems engineers stated that good systems engineering does not come from a degree in Systems Engineering, but from hands-on learning and doing, working closely with other successful SEs. They felt strongly that in ten years, the art of systems engineering and the needed SE behaviors would be the same, but that some processes and tools might be different, and that certainly the systems themselves would be larger and more complex.

While SEs need training in all three axes of the SE competency model – process knowledge, technical knowledge, and personal behaviors – the personal behaviors component is where the maximum leverage is gained. That is what separates the merely good SEs from the highly regarded and successful SEs. Unfortunately, the typical SE training program largely ignores the behavior component to the detriment of SEs. Hence, the results of this study show the need for a major paradigm shift in training SEs.

There are clearly identifiable behaviors that highly successful SEs exhibit. It is not only possible, but highly desirable, to openly communicate what those behaviors are and to encourage members of the systems engineering community to develop them. The awareness and understanding learned from this study will help advance the SE discipline not only within NASA itself, but also across the engineering community at large.

While the NASA SELDP is a start in developing the next generation of SEs, this is by no means the end, but rather only a beginning. The agency would gain value by taking this information and seriously considering inculcating these behaviors into all training for the SE Community.

8.0 Acknowledgements

Many people have contributed to the success of the study and deserve recognition, including the SEs who participated in this study and the team members who dedicated themselves to advancing the understanding of the “art of systems engineering.”

Table 9 Systems Engineers in NASA SE Behavior Study

Name	Role
Michael Ospring	Group Leader for Mechanical Systems and Analysis
Stephen Jensen	Program Chief Engineer SOFIA
James Free	Task Verification Manager Orion
Todd Tofil	Lead Systems Engineer CONNECT
Richard Wiedenmannott	Systems Engineer Integrated Environmental Test (IET) Facility (part of Orion CEV)
Peter Mike Bay	Mission Systems Engineer for Solar Dynamics Observatory
Gary Sneiderman	Instrument Systems Engineer for Astral H
David Everett	Mission Systems Engineer for Lunar Reconnaissance Orbiter
Pete Spidaliere	Mission Systems Engineer for Magnetospheric Multiscale
Joseph Bolek	Chief Flight Systems Engineer for Explores Project
Michael Menzel	Mission Systems Engineer for James Webb Space Telescope
Walt Guy	Manager of System Architecture and Integrations Office
Chris Hardcastle	Director, Constellation Program Systems Engineering & Integration
Don Noah	Manager, Space Shuttle Program Systems Engineering & Integration
John Connolly	Lead, Altair Vehicle Engineering & Integration
Kent Joosten	Assist. Manager Constellation Office of the Program Systems Engineer
Julie Kramer	Chief Engineer, Orion
Gentry Lee	Chief Engineer for Solar System Exploration, SE Fellow
Cece Guiar	Formulation Project SE for Astrophysics
Riley Duren	Chief Engineer, Kepler
Nagin Cox	Assist. Flight SE Manager on MSL and Group Supervisor
Duncan MacPherson	Systems Engineering Fellow
Glenn Reeves	Flight Software COG E for MSL Flight
Rob Manning	Chief Engineer MSL, MEP
Charles Whetsel	Project Systems Engineer, MSL
Jeff Yu	Project Architect, Advanced MIR Development Project
James Corliss	Project Engineer for Orion Landing System Advanced Development Project and ASG Experimental Facilities Development
Kurt Detweiler	Flight Test Lead Systems Engineer, Ares 1-X
John Stadler	Orion Launch Orbit Abort System Vehicle Lead Engineer
Henry Wright	Aerospace Technologist, Ares 1-X
T. David Wood	Chief Engineer, SRB
Scott Croomes	Center Deputy Chief Engineer
Garry Lyles	Associate Director for Technical Management
Dinah Williams	Sr. Systems Engineer in Spacecraft and Vehicle Systems Development
Bartt Herbert	Chief Engineer
Brad Messer	Chief of Systems Engineer and Integration Division
Nickey Raines	Deputy Chief Engineer
Steven A. Taylor	Deputy Chief of Systems Engineer and Integration Division

Table 10 NASA SE Behavior Study Team Members

Name	Affiliation
Rick Turner	Study Team Member, Marshall Space Flight Center
Jason Nelson	Study Team Member, Johnson Space Center
Jose Bolton	Study Team Member, Johnson Space Center
Katherine Thomas	Study Team Member, Academy of Program, Project and Engineering Leadership
Donna Wilson	Study Team Member, Academy of Program, Project and Engineering Leadership
Matt Kohut	Study Team Member, Academy of Program, Project and Engineering Leadership
Kathy Christian	Study Team Member, Dryden Flight Research Center
Ed Amatucci	Study Team Member, Goddard Space Flight Center
Carolyn Casey	Study Team Member, Goddard Space Flight Center
Matt Jarvis	Study Team Member, Goddard Space Flight Center
Marty Parker	Study Team Member, Kennedy Space Center
Mary Ellen Derro	Study Team Member, Jet Propulsion Laboratory

In addition, this study would not have been possible without the support from the following people:

Table 11 Sponsors, Stakeholders and Supporters of the NASA SE Behavior Study

Name	Affiliation and Role
Michael Griffin	NASA Administrator
Mike Ryschkewitsch	NASA Chief Engineer
Gregory Robinson	NASA Deputy Chief Engineer
Stephen Kapurch	NASA Systems Engineering Program Executive Officer, NASA Systems Engineering Working Group (SEWG), Chair
John Blowers	JPL Section Manager, Professional Development Section
Ross Jones	JPL Rep. to NASA Systems Engineering Working Group
Edward Hoffman	NASA Academy of Program, Project and Engineering Leadership (APPEL), Director
Wiley Larson	Stevens Institute of Technology, Director, Space Systems Engineering
Dawn Schaible	NASA Engineering and Safety Center, Manager, Systems Engineering Office
various	NASA Systems Engineering Working Group Members
Maureen Dale	RGI, Logistics Manager
Paulette Cali-Kaviana and Dennis Brundige,	JPL, Transcription Services
Lynda Jones and Mary Wiggins	GSFC, (SEVATEC), Career Coaches

9.0 References

[1] Stephen R. Covey, *The Seven Habits of Highly Effective People*, Simon & Schuster, Inc., New York, NY, 1989, ISBN 0-671-66398-4

[2] Stephen R. Covey, *The Eighth Habit: From Effectiveness To Greatness*, Simon & Schuster, New York, NY, 2004, ISBN 0-684-84665-9.

[3] Mary Ellen Derro, "Coaching Valuable Systems Engineering Behaviors,", IEEE Aerospace Conference, March 2008.

[4] Carol S. Dweck, *Mindset: The New Psychology of Success*, Random House, 2006, ISBN-13:978-1400062751.

[5] P. A. "Trisha" Jansma and Ross Jones, "Advancing the Practice Of Systems Engineering at JPL", IEEE Aerospace Conference, March 2006.

[6] P. A. "Trisha" Jansma and Mary Ellen Derro, "If You Want Good Systems Engineers, Sometimes You Have To Grow Your Own", IEEE Aerospace Conference, March 2007.

[7] Keirsey Temperament and Myers Briggs, http://www.teamtechnology.co.uk/keirsey-analysis.html, Sep 2008.

[8] John Maxwell, *The 21 Irrefutable Laws of Leadership*, Thomas Nelson, Inc., Nashville, TN, 1998, ISBN 0-7852-7431-6

[9] John Maxwell, *The 360 Degree Leader*, Thomas Nelson, Inc., Nashville, TN, 2005, ISBN 0-7852-6092-7

[10] John Maxwell, *Thinking for a Change: 11 Ways Highly Successful People Approach Life and Work*, Warner Books, Inc., New York, 2003, ISBN 0-446-52957-5

[11] Isabel B. Myers and Peter Myers, *Gifts Differing*: Understanding Personality Type, Consulting Psychologist Press, Inc., Palo Alto, California, 1990, ISBN-13: 9780891060741

10.0 Appendices

10.1 Appendix 1 Systems Engineering Interviewees

Table 12 Names of Systems Engineering Interviewees at each NASA Center

Center	Interviewees	Current Position
ARC	Michael Ospring	Group Leader for Mechanical Systems and Analysis
DFRC	Stephen Jensen	SOFIA Program Chief Engineer
GRC	James Free	Orion Task Verification Manager
	Todd Tofil	CONNECT Lead Systems Engineer
	Richard Wiedenmannott	
GSFC	Peter Mike Bay	Mission Systems Engineer for Solar Dynamics Observatory
	Gary Sneiderman	Instrument Systems Engineer for Astral H
	David Everett	Mission Systems Engineer for Lunar Reconnaissance Orbiter
	Pete Spidaliere	Mission Systems Engineer for Magnetospheric Multiscale
	Joseph Bolek	Chief Flight Systems Engineer for Explores Project
	Michael Menzel	Mission Systems Engineer for James Webb Space Telescope
JSC	Walt Guy	Office Manager of System Architecture and Integrations Office
	Chris Hardcastle	Director, Constellation Program Systems Engineering & Integration
	Don Noah	Manager, Space Shuttle Program Systems Engineering & Integration
	John Connolly	Lead, Altair Vehicle Engineering & Integration
	Kent Joosten	Assistant Manager Constellation Office of the Program Systems Engineer
	Julie Kramer	Chief Engineer, Orion
JPL	Gentry Lee	Chief Engineer for Solar System Exploration, Systems Engineering Fellow
	Cece Guiar	Formulation Project SE for Astrophysics
	Riley Duren	Chief Engineer, Kepler
	Nagin Cox	Assist. Flight SE Manager on MSL and Group Supervisor
	Duncan MacPherson	Systems Engineering Fellow
	Glenn Reeves	Flight Software COG E for MSL Flight
	Rob Manning	Chief Engineer MSL, MEP
	Charles Whetsel	Project Systems Engineer, MSL
	Jeff Yu	Project Architect, Advanced MIR Development Project
LaRC	James Corliss	Project Engineer for Orion Landing System Advanced Development Project and ASG Experimental Facilities Development
	Kurt Detweiler	Flight Test Lead System Engineer, Ares 1-X
	John Stadler	Orion Launch Orbit Abort System Vehicle Lead Engineer
	Henry Wright	
MSFC	T. David Wood	SRB Chief Engineer
	Scott Croomes	Center Deputy Chief Engineer
	Garry Lyles	Associate Director for Technical Management
	Dinah Williams	Senior Systems Engineer in Spacecraft and Vehicle Systems Development
SSC	Bartt Herbert	Chief Engineer
	Brad Messer	Chief of Systems Engineer and Integration Division
	Nickey Raines	Deputy Chief Engineer

	Steven A. Taylor	Deputy Chief of Systems Engineer and Integration Division

10.2 Appendix 2 Center Study Team Members

Table 13 Center Study Team Members

Center Studied	**Study Team Members**	**Home Center**
ARC	Mary Ellen Derro	JPL
DFRC	Kathy Christian	DFRC
GRC	Matt Kohut	APPEL
	Donna Wilson	APPEL
GSFC	Ed Amatucci	GSFC
	Carolyn Casey	GSFC
	Matt Jarvis	GSFC
JPL	Mary Ellen Derro	JPL
JSC	Jose Bolton	JSC
	Jason Nelson	JSC
KSC	Marty Parker	KSC
LaRC	Katherine Thomas	APPEL
	Donna Wilson	APPEL
MSFC	Rick Turner	MSFC
	Rose Opengart	MSFC
SSC	Katherine Thomas	APPEL
	Donna Wilson	APPEL
Managing Roles		
Study Director	Christine Williams	HQ/OCE
Study Director and Technical Lead	Mary Ellen Derro	JPL
Logistics Manager	Maureen Dale	HQ/RGI

10.3 Appendix 3 MBTI Description

Table 14 Myers-Briggs Type Indicator (MBTI®) Mental Processes and Orientations

Natural energy orientation	**Extraverted (E)** Face is directed towards the **OUTER** world of activities, excitements, people, and things. • Act first, think/reflect later • Feel deprived when cutoff from interaction with the outside world • Usually open to and motivated by outside world of people and things • Enjoy wide variety and change in people relationships	**Introverted (I)** Face is directed inward to the **INNER** world of thoughts, interests, ideas, and imagination. • Think/reflect first, then act • Regularly require an amount of "private time" to recharge batteries • Motivated internally, mind is sometimes so active it is "closed" to outside world • Prefer one-to-one communication and relationships
Way of perceiving or understanding and taking in information	**Sensing (S)** The **Sensing** side of our brain notices the sights, sounds, smells and all the sensory details of the **PRESENT**. It categorizes, organizes, records and stores the specifics from the here and now. It is **REALITY** based, dealing with "what is." It also provides the specific details of memory and recollections from **PAST** events. • Mentally live in the Now, attending to present opportunities • Using common sense and creating practical solutions is automatic-instinctual • Memory recall is rich in detail of facts and past events • Best improvise from past experience • Like clear and concrete information; dislike guessing when facts are "fuzzy"	**Intuitive (N)** The **Intuitive** side of our brain seeks to understand, interpret and form **OVERALL** patterns of all the information that is collected and records these patterns and relationships. It speculates on **POSSIBILITIES**, including looking into and forecasting the **FUTURE**. It is imaginative and conceptual. • Mentally live in the Future, attending to future possibilities • Using imagination and creating/inventing new possibilities is automatic-instinctual • Memory recall emphasizes patterns, contexts, and connections • Best improvise from theoretical understanding • Comfortable with ambiguous, fuzzy data and with guessing its meaning.
Way of forming judgments and making choices and decisions	**Thinking (T)** The **Thinking** side of our brain analyzes information in a **DETACHED**, objective fashion. It operates from factual principles, deduces and forms conclusions systematically. It is our logical nature. • Instinctively search for facts and logic in a decision situation. • Naturally notices tasks and work to be accomplished. • Easily able to provide an objective and critical analysis. • Accept conflict as a natural, normal part of relationships with people.	**Feeling (F)** The **Feeling** side of our brain forms conclusions in an **ATTACHED** and somewhat global manner, based on likes/dislikes, impact on others, and human and aesthetic values. It is our subjective nature. • Instinctively employ personal feelings and impact on people in decision situations • Naturally sensitive to people's needs and reactions. • Naturally seek consensus and popular opinions. • Unsettled by conflict; have almost a toxic reaction to disharmony.
Action orientation towards the outside world	**Judging (J)** A **Judging** style approaches the outside world **WITH A PLAN** and is oriented towards organizing one's surroundings, being prepared, making decisions and reaching closure and completion. • Plan many of the details in advance before moving into action. • Focus on task-related action; complete meaningful segments before moving on. • Work best and avoid stress when keep ahead of deadlines. • Naturally use targets, dates and standard routines to manage life.	**Perceiving (P)** A **Perceiving** style takes the outside world **AS IT COMES** and is adopting and adapting, flexible, open-ended and receptive to new opportunities and changing game plans. • Comfortable moving into action without a plan; plan on-the-go. • Like to multitask, have variety, mix work and play. • Naturally tolerant of time pressure; work best close to the deadlines. • Instinctively avoid commitments which interfere with flexibility, freedom and variety

10.4 Appendix 4 Description of the Fixed vs. the Growth Mindset

Table 15 Fixed Mindset vs. Growth Mindset

	Fixed Mindset	**Growth Mindset**
Intelligence	Intelligence is static. Leads to a desire to look smart.	Intelligence can be developed. Leads to a desire to learn and grow.
Challenges	Avoids challenges	Embraces challenges
Obstacles	Gives up easily	Persists in the face of setbacks
Effort	Sees effort as fruitless or worse	Sees effort as the path to mastery
Criticism	Ignores useful negative feedback	Learns from criticism
Success of Others	Feels threatened by the success of others	Finds lessons and inspiration in the success of others
Results	May plateau early and achieve less than their full potential	Reaches ever higher levels of achievement
View	Confirms deterministic view of the world	Gives greater sense of free will

10.5 Appendix 4 Center Reports

Centers that did not interview four or more individuals did not produce a Center report. It was determined that without at least four individuals, the data set was too small to provide reliable findings. Therefore, Center reports are not available for the following three centers:

- Ames Research Center (ARC)
- Dryden Flight Research Center (DFRC)
- Glenn Research Center (GRC)

Also, as mentioned previously, findings from the Kennedy Space Center (KSC) were not available for inclusion in this report.

Note: To view the Center Reports, please go to the NASA Engineering Network (NEN) website at http://nen.nasa.gov and select the Systems Engineering Community of Practice (SE CoP). Then select the Workforce tab to view the reports.

10.5.1 Goddard Space Flight Center (GSFC) Report

10.5.2 Johnson Space Center (JSC) Report

10.5.3 Jet Propulsion Laboratory (JPL) Report

10.5.4 Langley Research Center (LRC) Report

10.5.5 Marshall Space Flight Center (MSFC) Report

10.5.6 Stennis Space Center (SSC) Report