10.4.1 Goddard Space Flight Center (GSFC)

NASA - GSFC

Systems Engineering Behavior Study

In support of the SELDP program in the Office of the Chief Engineer at NASA HQ

Carolyn Casey, Matt Jarvis, and Edward Amatucci

10/10/2008

This paper provides a summary of GSFC's *System Engineering Leadership Behavior Study* and resulting *Systems Engineering Competency Model*. The study was conducted as part of a larger, Agency-wide initiative to clarify the "art and science" of Systems Engineering and help NASA field centers make strategic improvements to their Engineering Development and Succession Planning programs. Using interview, behavioral observation, 'shadowing,' and Myer-Briggs Type Indicator (MBTI) data gathered from six of the Center's most respected Systems Engineers, the investigators isolated the specific attitudes, attributes, and behaviors required to perform effectively as a GSFC Systems Engineer. The Competency Model will be used by the *Applied Engineering and Technology Directorate* (AETD) to: 1) identify juniors engineers with the developing skills and aptitudes necessary for a future SE role, and 2) to develop new or enhanced course content for both the *SEED* and *SELDP* development programs.

Abstract

TABLE OF CONTENTS

1. INTRODUCTION

The Goddard Space Flight Center, one of NASA's largest field centers, is a major U.S. laboratory for developing and operating unmanned scientific spacecraft. Home to many of the Nation's most respected and accomplished scientists and engineers, its mission is *to expand mankind's knowledge of the Earth and its environment, the solar system, and the universe through observations from space*. In maintaining the Center's preeminent role in Earth and Space science, the 3171 Civil Servants and 8484 support contractors that comprise the GSFC workforce are committed to excellence in scientific investigation, the development and operation of space systems, and the advancement of essential technologies. In pursuit of this challenge, GSFC:

- Conducts preeminent programs of research in the space and Earth science disciplines using data gathered from orbital, suborbital, ground-based, and laboratory instrumentation;
- Designs, builds, and operates the satellites and highly specialized remote sensing instruments necessary for scientific research;
- Designs and operates spaceflight tracking and data acquisition networks;
- Develops innovative technologies that will lead to advancements in scientific inquiry;
- Develops and maintain advanced information systems for the display, analysis, archiving and distribution of space and Earth science data; and
- Develops National Oceanic and Atmospheric Administration (NOAA) satellite systems that provide environmental data for forecasting and research.

In addition to the work performed at GSFC's 1270-acre facility in Greenbelt, MD, GSFC conducts mission-related operations at several off-site properties, including: the Wallops

Flight Facility near Chincoteague, Virginia; The NASA Goddard Institute for Space Studies (GISS), at Columbia University in New York City; and the the NASA IV&V Facility in Fairmont, WV.

Background

Approximately half of the Civil Servants employed at GSFC are engineers specializing in one or more of the field's numerous sub-disciplines. Some members of the engineering community remain with their 'home' organization, providing matrixed engineering services to a variety of customers on an as-needed basis. Others are assigned to dedicated project teams whose mission is to design and build the highly-specialized data gathering instruments and spacecraft needed by the scientific community to conduct its Earth and space research.

As a general rule, the number of engineers and engineering sub-disciplines needed to develop a particular instrument *system* is determined by its performance requirements as well as whether the work remains in-house or is contracted out-of-house. For larger, more complex instruments requiring a variety of engineered sub-system components, the integration and coordination of project sub-teams is essential. This increasingly critical role is performed by a small, uniquely skilled group of individuals known as *Systems Engineers* (SE). The different roles of a systems engineers, or specialties, include: Mission Systems Engineer (MSE), Spacecraft Systems Engineer (SSE), Ground Systems Engineer (GSE) and Instrument Systems Engineer (ISE). There are various titles, but basically systems engineering could be the systems engineer overseeing the entire mission as a whole or the various subsets or systems within the system. Typically, the MSE directs the technical aspects of the mission and then has SSE, GSE and several ISEs to help build the spacecraft, ground systems and the various instruments for the mission.

In his March, 2007 address at Purdue University, *System Engineering and the "Two Cultures" of Engineering*, NASA Administrator Michael Griffin characterized System Engineering is both an art and a science:

> The development of formal methods has not altered in any way the fundamental nature of design, which still depends, as it did in antiquity, upon the generation of a concept for a process, technique, or device by which a given problem might be solved. The engineering sciences have provided better, and certainly quicker, insight for the designer into the suitability of the concept than can be provided solely by building it and examining its performance in its intended application. But a human being must still intuit the concept. (Griffin, 2007)

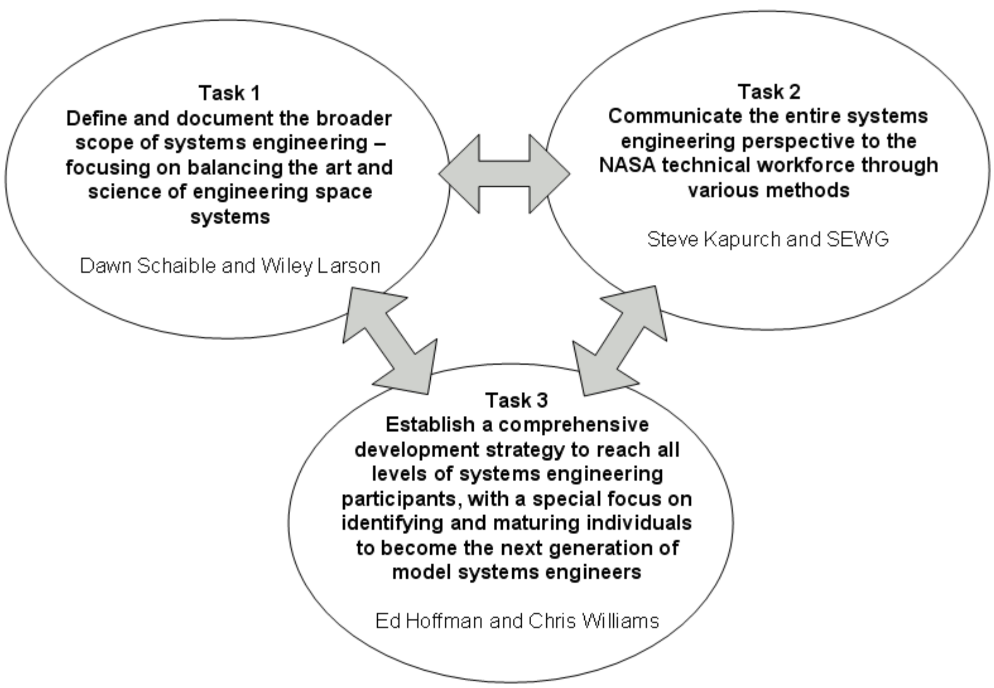
Every year, the task of designing and building a scientific mission becomes more complex and challenging for engineers. There are a number of contributing factors. The first is related to GSFC's scientific mission. As science and technology advance, increasingly sophisticated tools are needed to gather, transmit, and analyze research data.

Another factor is the business environment in which project teams operate. In addition to the technical challenges of translating instrument requirements into unique, state-of-the-art hardware systems, engineering teams must adhere to challenging cost and scheduling requirements.

Third, system engineering is an iterative process. Over time, as the instrument performance requirements of scientists are clarified, the design of a system begins to take shape, and the resources required to deliver the emerging system are compared with available project resources, the Systems Engineer must work with customers and members of the engineering team to modify system and sub-system deliverables to help meet the project constraints.

Finally, the engineers assigned to a project must invest the time and energy necessary to function as a fully integrated *team* with a collective vision and sense of purpose. Once again, the System Engineer plays a key role in making this happen.

With the success of NASA's largest and most important projects resting so heavily on the performance of its Systems Engineers, the Agency conducted a *System Engineering Development Workshop* on March 19-20, 2008 with the NASA Administrator. The purpose of the workshop was to discuss strategies for identifying and promoting a balanced *art/science* view of Systems Engineering (SE). The discussion yielded three distinct, yet highly-integrated, objectives/tasks:



The *GSFC Systems Engineering Leadership Behavior Study*—and subsequent *GSFC Systems Engineering Competency Model*—were carried out as part of Task 3.

2. METHOD

To identify the critical competencies required to perform effectively as a GSFC Systems Engineer, interview, observation, 'shadowing,' and Myers-Briggs Type Indicator (MBTI) assessment data was gathered from six of the Center's most experienced and highly-regard Systems Engineers.

Selection of Participants

Participants were selected by Center Management, based on their project experience (in SE); the performance of spacecraft and instrument systems they were responsible for delivering; their reputations within the Center's science and engineering communities; and other criteria. The six participants were drawn from different organizations and were currently serving as System Engineers on a variety of large, high-profile projects.

Each of GSFC's three Study Investigators (SI)—an engineer from the *Systems Engineering Services & Advanced Concepts Branch* (592); an organizational development consultant matrixed to the *Applied Engineering and Technology* Directorate (500) from the *Organizational Leadership and Culture Office* (111); and an employee/ organizational development consultant from the *Talent Cultivation Office* (114)—were assigned data collection and analysis activities for two of the study's six SE participants.

Interview Data

90-minute digitally-recorded interviews were conducted with participants in locations where interruptions could be minimized. The interviews consisted of three quantitative questions (employing a 10-point Likert scale) and thirteen qualitative (open-ended) questions developed by the Agency for use at each of the NASA field Centers. Prior to their interviews, the SE's were provided electronic copies of the interview questions. (The SI's made it clear that preparation for the interview was not expected or required.) Although some questions were considered redundant by participants, the intent of the Agency's Principal Investigator (PI) was to maximize the number of contexts in which SE attitudes, attributes, and behaviors could be recollected and reported. Upon completion, the digital recordings were posted to a secure website for downloading by an Agency-sponsored transcription service. Completed transcriptions were subsequently returned to GSFC's SI's in both hard-copy and electronic formats.

Observation and "Shadowing" Data

Participants were observed during the course of a 'typical' 8-hour work day, then "shadowed" on an *ad hoc* basis during 'key' meetings, discussions, and presentations. When observing their assigned SE's, the GSFC investigators took detailed notes on SE behaviors, but avoided interaction and made an effort to remain as unobtrusive as possible. When shadowing, the investigator asked questions and offered comments (when appropriate) to gain insight into participant's understanding and interpretation of events in 'real time.' Information provided by SE's during their interviews provided useful framework for the exchange of ideas during shadowing.

Myers-Briggs Type Indicator (MBTI) Data

The Myer-Briggs Type Indicator, a tool for measuring the cognitive styles introduced by psychologist Karl Jung, assesses normal differences along four dimensions of personality:

- An individual's <u>source of energy</u>—*Introversion* (energized by things) or *Extroversion* (energized by people)
- An individual's <u>preferred approach to gathering information</u>—*Sensing* (using information/evidence to draw conclusions) vs. *Intuition* (using instinct/hunches to draw conclusions)
- An individual's <u>preferred approach for making decisions</u>—*Thinking* (basing decisions on rational thought) vs. *Feeling* (basing decisions on emotional reaction)
- An individual's <u>preferred approach to life, work</u>—*Judging* (task orientation) vs. *Perceiving* (process orientation)

Participants completed the assessment instrument on line and were debriefed on the results by Career Coaches from the *Talent Cultivation Office's* (114) *Professional Development Center* (PDC).

Data Analysis

Although *GSFC's Systems Engineering Competency Model* was developed using data from interviews, observations, and shadowing, data analysis activities were limited to the 'coding,' sorting, and re-sorting of interview statements. The process was somewhat labor-intensive and involved seven distinct tasks:

1) Working independently, SI's reviewed their transcription documents and highlighted statements providing information on the attitudes, attributes, and behaviors of SE's. The document created was a coded excel file showing the comment made and then it was "coded" to a behavior. An example of interview coding is shown in Appendix B.
2) Related comments were sorted by the SI's into nine broad thematic groups by 'cutting' highlighted statements from the transcription document (in MS *Word*) and 'pasting' them into MS *Excel* spreadsheet. The nine categories included:

    - Attitudes and Attributes
    - Communication
    - Decision Making
    - Leadership
    - Problem Solving and Critical Thinking
    - Systems Thinking
    - Team Building
    - Technical Acumen
    - Technical Implementation

3) Within each broad competency category, the SI's engaged into more detailed sorting of the transcription statements in mid-level competencies categories.
4) After consolidated their individual spreadsheets into a single document, the SI's compared their broad and mid-level competency categories and reached consensus on a single category scheme.
5) Working together, the SI's refined their competency titles and developed behavioral descriptors for each.
6) The SI's initial draft of the *GSFC Systems Engineering Competency Model* was presented to the six SE's in a Validation Meeting.
7) Based on feedback received from the SE's at the Validation Meeting—and additional written feedback from several SE's after a more detailed review of the model—the *Competency Model* the SI's met to agree on final revisions.

The research design was established by the Agency, based on a similar investigation of SE leadership behaviors at NASA's Jet Propulsion Laboratory (JPL). Although the seven steps were designed as a sequential process, the GSFC Research Team was 'learning on the job' and found it necessary, on several occasions, to revise the work performed on a particular step. Despite these occasional disruptions in process flow, the data gathered from the Center's most distinguished SE's provided a 'rich' source of information with which to develop *GSFC's Systems Engineering Competency Model*.

3. FINDINGS

The *GSFC's Systems Engineering Competency Model* is organized in a four-tiered hierarchical format, as described in Table 1:

Table 1:
Hierarchical Organization of the
GSFC Systems Engineering Competency Model

Level	**Description**	**Example**
<u>Level 1:</u> Thematic Categories	Broad categories that describe how a given set of competencies are used by the SE	Problem Solving and Systems Thinking
<u>Level 2:</u> Competencies	Aggregations of related observable behaviors	Attention to detail
<u>Level 3:</u> Behavioral Descriptions	Descriptions of observable behaviors for each SE competency	Examines system and sub-system operations in minute detail, recognizing that seemingly minor miscalculations can lead to significant problems in system performance
<u>Level 4:</u> SE Interview statements	The interview statements from which a given SE competencies was developed	Another thing about systems engineers, it's a detailed job. Sometimes you have to drill in. Sometimes you have to drill out. But the details kill you in this business and if you don't get them right, that's what's gonna bring you to your knees. So you have to have the insight. That's one of the things. It's the insight to just pick things apart. You do that by having worked details before.

The following summary of GSFC's SE competencies provides information on Levels 1-3. The raw data has been omitted, but is available upon request.

- <u>Attitudes and Attributes</u>
  - Ability to accept blame, criticism
    - Accepts responsibility for the performance of the system. Serves as the focal point for blame and criticism when problems occur with system performance.
  - Ability to anticipate problems
    - Anticipates 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.

- Ability to cross sub-system boundaries; Willingness to leave technical 'comfort zone'
  - Actively explores the technical issues, concepts, and lexicon of sub-system disciplines that are less familiar and comfortable. Asks questions of subject matter experts to build knowledge and understand the interrelationships of sub-systems.
- Ability to deal with politics, financial issues
  - Studies the political and financial issues that impact the Center's missions priorities, resource allocations, and personnel decisions. As a willing and active participant in these discussions, shares knowledge and expertise that shape the Center's political environment is positive ways.
- Ability to find connections and patterns across the system
  - 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.
- Attention to detail
  - Examines system and sub-system operations in minute detail, recognizing that seemingly minor miscalculations can lead to significant problems in system performance.
- Being creative
  - Does not adhere to rigid rules or formulas for system design, but remains vigilant for new ideas and approaches that may lead to successful outcomes.
- Being adaptable, flexible, and open-minded; Viewing the system from multiple perspectives
  - Maintains a clear focus on system deliverables and performance, but is willing and able to adjust the strategy for arriving at those outcomes when new and better options are brought to light.
- Being honest, trustworthy; Having integrity
  - Conducts business in an honest and trustworthy manner by avoiding deception and treating team members fairly. Earns the respect of team members by demonstrating personal integrity.
- Being modest
  - Exhibits modesty--and in so doing, is viewed by the team as a "mere mortal" (albeit, with more seniority and experience). As a mere mortal who has made mistakes, experienced fairure, and does not purport to be an expert in every sub-system discipline, less experienced members of the team are able to identify with the SE more easily.
- Identify what's missing
  - In addition to identifying problems and disconnects with existing system components, the SE looks for necessary system components that are lacking.
- Being self-driven
  - Takes the initiative to solve the problems needed to be solved for the project without being directed.
- Being tenacious
  - Maintains a level of consistency and tenacity to accomplish the assignment successfully.

- Inquisitive nature; Continually learning
  - Demonstrates an ability to ask questions, has a curiousity to seek information and has a healthy quest for knowledge.
- Knowing personal limitations
  - Uses knowledge of personal strengths and limitations to identify the subject matter experts required to provide critical information on specific project sub-systems. Formulates questions that precisely target the required information.
- Organizational skills
  - Uses organizational skills to manage the extensive breadth and depths of responsibilities associated with SE positions at GSFC.
- Willingness to make unpopular decisions
  - Makes difficult or unpopular decisions when necessary, weighing the potential risks to team cohesion and interpersonal relationships against system performance.

- Communication
  - Ability to communicate across sub-systems; Fluency in sub-system 'languages'
    - Studies the issues, concepts, and terminologies of each engineering sub-discipline. Uses this knowledge to communicate across sub-systems and establish a broader, (systemic) frame of reference that is shared by all members of the project team.
  - Facilitating communication across sub-systems
    - Facilitates communication among sub-system leads. Avoids being a "bottleneck" (or conduit) through which communication must flow. Prefers the role of observer, but is vigilant for communication breakdowns among sub-system leads. Helps to bridge gaps when they occur.
  - Gathering information
    - Continually gathers information from team members and external stakeholders that may impact system design and performance. Utilizes formal and informal channels of communication to maximize opportunities for information gathering.
  - Listening skills
    - Uses effective listening skills by creating opportunities for communication; paraphrasing; asking questions for clarification; and understand needs, priorities, and perspectives.
  - Managing information
    - 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.
  - Promoting open, honest communication
    - 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.

- <u>Decision Making</u>
    - Protecting minority opinions
        - Ensures that minority opinions are openly expressed, clearly understood, evaluated objectively, and factored into the decision-making process. In some instances, minority opinions are noted in reports to upper management.
- <u>Leadership</u>
    - Being decisive
        - 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.
    - Being efficient
        - Closely monitors the status of project resources against tasks and deliverables. Designs work processes that save time and maximize human and material resources.
    - Being fair
        - The SE is fair and balances the different perspectives of the group versus the mission goals.
    - Coaching and mentoring
        - Coaches and mentors team members to develop the breadth and depth of their competencies. Asks questions that challenge assumptions, validate conclusions, and explore the thought processes of sub-system leads. Promotes a team culture that places a greater priority on the performance of the system than the performance of its sub-systems.
    - Defining requirements
        - Based on the customer's scientific objectives and outcomes, the SE defines the critical functions of the systems, its sub-system components, and the minimal requirements of each sub-system. As resource requirements are estimated for the emerging system design, modifications to deliverables and requirements are made in an iterative process.
    - Delegating responsibility
        - Delegates responsibility and authority to the lowest possible levels in the project hierarchy--while retaining control of sub-system requirements and system integration functions.
    - Building confidence
        - Builds confidence among team members by delegating responsibility and decision-making authority to sub-system leads--then accepting the decisions they make without resistance or second-guessing.
    - Demonstrating discipline and setting standards; Following prescribed procedures
        - Adheres to 'best practice' industry standards for the engineering and science professions. Clearly conveys the message that all members of the project team expected to do the same.

- Ensuring system integrity
  - Understands that the integrity of the system is his/her primary role. Makes all system planning decisions accordingly, reporting unacceptable project risks to senior management.
- Establishing a chain-of-command
  - Establishes a formal and informal chain of command and the understanding of how to work with both.
- Motivating people
  - Identifying and providing the motivational triggers unique to each members of the team.
- Providing direction; keeping team focused on overarching goal/problem, mission success
  - Keeps the team focused on working toward mission success. Directs the team and is the focal point for the flow of information required to accomplish mission success.
- Reducing stress, anxiety, and fear
  - Helps team members stay focused and productive by shielding them from sources of stress, anxiety, and fear--the pressure to succeed; resource battles; interpersonal conflicts; noisy and chaotic work

- <u>Problem Solving and Critical Thinking</u>
  - Defining criteria for acceptable answers to questions, solutions to problems
    - Responsible for properly framing the solution to the problems for the criteria being considered.
  - Having a 'hands-on' approach
    - Needs to draw from their experiences working directly with hardware in order to see the experiments succeed and fail. This experience base enables the SE to develop the proper feel for succeeding on future projects, knowing when something looks "right" versus "not even close."
  - Identifying/evaluating alternative solutions, work-arounds, back-up plans
    - Proactively develops alternative solutions, work-arounds and back-up plans for the system. This involves both strategies and solutions for dealing with the unexpected.
  - Prioritizing
    - Has to set priorities and maintain the balance for the problems at hand.
  - Retracing problem-solving processes/calculations to confirm conclusions
    - Requires access to all data used to develop the solutions in order to double check the work.
  - Solving problems
    - Understands how to frame the problem in a logical way. They need to identify resources required to solve the problem efficiently.
  - Subdividing the problem
    - Needs to break the problem down into smaller manageable parts.
  - Validating facts/information
    - Needs to question all assumptions that go into the design.
- <u>Systems Thinking</u>
  - Having a systems perspective

        - Has the ability to see the big picture and organize the smaller pieces of the system to develop the most robust solution. The integrity of the system as a whole should not suffer because of over optimizing any of the smaller pieces.
    - Integrating a cohesive whole
        - Focused on developing a system that meets the end-item product objectives and not loose sight of this while integrating the pieces of the system into the whole system.
- <u>Team Building</u>
    - Building relationships
        - Is a good team player and work to get the team as a whole working together.
    - Managing conflict
        - Effectively manages conflict among team members, while ensuring that the decisions made to settle disputes are objective, impartial, and designed for the greater benefit of the system. To the greatest extent possible, team members are encouraged to resolve their own conflicts. When this is not practical, however, the SE listens to and understands all points of view before making a decision, then shares the rationale for the decision.
    - Managing egos, emotions
        - Manages the technical experts working on the project. They are the most experienced in their fields and the SE while respecting that needs to manage the inputs for the common good of the project and the team.
    - Respecting people; Showing respect
        - Demonstrates genuine respect for team members by utilizing their skills and expertise; publicly acknowledging their accomplishments (and when necessary, reprimanding them in private).
    - Trusting others
        - Faithful in his team and demonstrate the trust that they will get the work completed. The SE needs to know when to let someone struggle on an issue so they are able to learn or to jump in and help when required.
- <u>Technical Acumen</u>
    - Experience
        - Experiences of the SE need to include many projects across the full life cycle of the project. These experiences provide the lesson-learned which are critical for the systems engineer to deal with during the development of a complex system.
    - Familiarity with current analytical tools and models
        - Keeps abreast of current analytical tools and models--where to find them, when to apply them, and how to use them.
    - Knowing sources of information/expertise
        - Formally or informally documents the sources of information, knowledge, and expertise that may be called at various stages of the project. Invests the time and effort necessary to build this resource network.
    - Learning from mistakes
        - 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.

    - Technical expertise
        - Has developed the confidence to comprehend the basics in each subsystem that make up a project due to having their technical expertise in their discipline.
- Technical Implementation
    - Assigning roles and responsibilities; Matching talents and assignments
        - Assigning clearly defined roles and responsibilities to each member of the project team. Ensuring that the duties assigned to team members are matched appropriately with their technical backgrounds and experience.
    - Formulating questions/problems that become actionable tasks
        - Formulating the specific questions or problems that will need to be addressed in order to design and deliver a system that meets the needs of its customers--questions or problems around which sub-systems tasks may be developed.
    - Managing risk
        - Assesses system/sub-system risks on an ongoing basis, using analytical models to predict increases or decreases in risk factors that modification to a given sub-system are likely to bring about.
    - Meeting requirements
        - The SE has the responsibility to maintain the set of requirements and insure the project meets them.
    - Taking ownership of roles/responsibilities
        - Demonstrates a commitment to the roles and responsibilities of a NASA SE. Conveys the expectation that every member of the project team is committed to fulfilling their roles and responsibilities. Fosters a work environment in which team members seek personal growth and expansion of their responsibilities.

MBTI Results

Current data of the Myers-Briggs Types Indicator was received from five of the six SE's who participated in the study. Their individual scores are shown in Table 2 (below):

Table 2:
MBTI Results for GSFC SE Study Participants

INTJ	18, 6, 24, 8
INTP	11, 9, 14, 11
ENTP	12, 8, 5, 14
ESTP	16, 3, 1, 2
INTJ	17, 8, 25, 25

Although the sample size is too small for statistical significance, the results showed a balanced distribution of personality types with the *source of energy* (introversion/ extroversion) and *preferred approach to life, work* (judging/perceiving) dimensions.

Within the *preferred approach to gathering information* dimension (Sensing/Intuition), four out of five SE's preferred intuition over sense. Within the *preferred approach for making decisions* dimension, all five SE's preferred thinking over feeling.

4. SUMMARY AND CONCLUSIONS

The six System Engineers who participated in the study were assigned to different projects; had somewhat differing perceptions of their role within the project hierarchy; and performed their SE duties in very different cultural settings. Although they also used different strategies to address the issues and problems faced by all Systems Engineers (managing conflict; validating conclusions; etc.), each of the competencies included in the final version of *GSFC's SE Competency Model* were identified (in one context or another) by the majority of participants. More importantly, the competencies were validated through workplace observations and shadowing.

The SE's studied were an impressive group of individuals, possessing an uncommon broad and deep skill set—in both technical and non-interpersonal areas. They view systems, and the subsystems that comprise them, as a non-linear web of connections and disconnections. They have the ability to view the big picture, zoom down 'into the weeds' to pinpoint problems that have rippling-effects throughout the system. They can also zoom out to examine the performance of the system as a whole—to ensure that it performs as needed to the scientific community. They are individuals with a high degree of curiosity; the ability to solve problems in unorthodox ways; and the ability to promote integrated team cultures that perform at peak levels. They are also very driven to stay focused on the mission requirements and meeting the technical goals for the mission.

The SE competencies identified through this investigation will be used to improve future engineering development programs and help identify the next generation of SE's for the future—junior engineers exhibiting 'high-potential' in the various skill areas needed to be successful as a GSFC Systems Engineer.

5. ACKNOWLEDGEMENTS

First and foremost, GSFC's SE Leadership Behavior Study Team gratefully acknowledges the enthusiastic and good-natured participation of GSFC's six finest Systems Engineers:

Peter Michael Bay (SGT), Mission Systems Engineer for Solar Dynamics Observatory (SDO)
Joseph T. Bolek (599), Chief Flight Systems Engineer for Explores Project
David E. Everett (599), Mission Systems Engineer for Lunar Reconnaissance Orbiter (LRO)
Michael T. Menzel (599), Mission Systems Engineer for James Webb Space Telescope (JWST)
Gary H. Sneiderman (556), Instrument Systems Engineer for Astral H
Peter D. Spidaliere (599), Mission Systems Engineer for Magnetospheric Multiscale (MMS)

The Team also wishes to thank:

Marry-Ellen Derro, Principle Investigator for the Agency’s Consolidated SE Leadership Behavior Study, for her patient support and guidance.

Paulette Cali-Kaviana (JPL), who managed the labor-intensive task of producing six quality interview transcriptions in amazingly short periods of time!

Lynda Jones and Mary Wiggins (SEVATEC), Career Coaches from GSFC’s Professional Development Center (PDC), who helped our SE’s complete their MBTI assessments, then met with them to review the results.

APPENDIX A:

Interview Questions

1. How would you describe the role of the SE?
2. On a scale of 1 to 10—1 being the lowest and 10 being the highest—how important is the SE in the success of a program or project?
3. Create, in behavioral terms, a statement that would describe you as an SE.
4. Identify the attitudes and attributes a “highly regarded” SE possesses.
5. What leadership behaviors does a “highly regarded” SE possess?
6. As an SE, what leadership abilities do you possess?
7. How are these abilities displayed?
8. On a scale of 1 to 10, how important are these abilities to mission success?
9. What general knowledge does a “highly regarded” SE possess?
10. On a scale of 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 to me what goes on in your mind when you are problem solving.
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?

APPENDIX B:

Sample of Interview Coding

NASA SE BEHAVIORAL STUDY-2008 INTERVIEW RESPONSES			
Interviewee	**General Theme**	**Question**	**Code**
		1) How would you describe the role of the SE	
	systems perspective	a technical leader who can visualize the end game and how to get there using the technical and programmatic resources at hand.	blue-grey
	systems perspective	The role of the systems engineer is to integrate the individual pieces into a cohesive whole.	blue-grey
	organize team	It's very easy to take a complex problem and carve it up into individual little subsections or subsystems or whatnot, delegate it out to a broad array of people than have them go off the warpath in, maybe, isolation. The hard part is integrating it all together into something that works and meets the objectives.	dark red
	systems perspective	synthesize from team inputs, including the ultimate customer, what the (end item) objective is and how to get there.	blue-grey
	observant	also be aware of when we go wrong along the way. Anticipate the unanticipated.	green
	expect the unexpected	Expect the unexpected until the unexpected is expected.	gray
		2) On a scale how important is the SE in the success of a program or project?	
	defining requirements	It's all about delivering a product or a system that does some function.	dark yellow
	mission success oriented	They need to integrate all these pieces together. So without that, you aren't gonna have success.	light blue
	technical implementation	Between the point you started PDR, you spend like 15% of a project's budget, but you set the destiny with that little amount. You commit over 50% of the cost of the project and you also commit the technical solution and whatever vulnerability or weaknesses it has, comes right with it. So you do set the destiny.	orange

REFERENCES

Griffin, Michael D. *System Engineering and the "Two Cultures" of Engineering*. Boeing Lecture presented at Purdue University, March 28, 2007.

Myers, Isabel B., and Myers, Peter B., *Gifts Differing*. Consulting Psychologists Press, Inc. Palo Alto, California 1990.