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NASA's System Behind the System: Developing Systems Engineers

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Abstract

The purpose of this paper is to share NASA's model for developing high-potential, mid-level systems engineers and the results achieved. It describes the complex system approach to technical leadership development and factors that contributed to the program's success. Findings show that identifying, training, and developing the entire learning system—not just program participants—significantly affected the participants' ability to make a greater contribution to the organization. NASA achieved an 80% first year, and 90% second year, success rate of individuals transitioning into more complex and difficult positions upon returning to their organizations. Comparatively, the average failure rate for executive transition is 40%. NASA's findings are applicable to other organizations. Developing potential leaders by involving the entire system in which the individual works, while holding their leadership accountable, produces qualified leaders ready to meet the organization's ongoing challenges.

Comments

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ABSTRACT

The purpose of this paper is to share NASA's model for developing high-potential, mid-level systems engineers and the results achieved. It describes the complex system approach to technical leadership development and factors that contributed to the program's success. Findings show that identifying, training, and developing the entire learning system—not just program participants—significantly affected the participants' ability to make a greater contribution to the organization. NASA achieved an 80% first year, and 90% second year, success rate of individuals transitioning into more complex and difficult positions upon returning to their organizations. Comparatively, the average failure rate for executive transition is 40%. NASA's findings are applicable to other organizations. Developing potential leaders by involving the entire system in which the individual works, while holding their leadership accountable, produces qualified leaders ready to meet the organization's ongoing challenges.

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INTRODUCTION

In a recent publication, McCall and Hollenbeck contend that the elements of leadership development have been well established by research over the past thirty years. [**i**] These elements include a programmatic link to strategy, planned developmental job experiences, individual and collective development components, feedback systems such as 360s, high-potential identification systems, and succession planning. Yet executive failures remain at a 40% average, not because we don't know how to do it but rather because leadership development requires "selecting" organizational leaders who are willing and able to lead the development process. This means coordinating the above elements over the long period of experience, practice, and performance that is required for leadership mastery by any set of high potentials. The Systems Engineering Leadership Development Program (SELDP) provides one example of such leadership where these elements are treated as a system.

The Bureau of Labor Statistics predicts that the population aged 55 and over will grow by 30% in the next decade. The number of 45- to 54-year-olds will decrease by 4.4% and the number of 35- to 44-year-old workers will remain flat. [ii] These demographics demand accelerated succession planning to meet future organizational leadership requirements. Coming out of the current economic downturn will further aggravate the impending leadership scarcity as increased ability to move around reignites the war for talent [iii]. In response to this human-resource environment, companies have created accelerated high-potential talent[iv] development programs. In a recent study of twenty thousand high potentials in more than one hundred organizations worldwide, Martin and Schmidtt found alarming results [v]: 40% of high-potential job transitions continue to result in failure. Furthermore, during the economic downturn between 2007 and 2009:

- The disengagement of high potentials grew from 12% to 21%.
- 33% of high potentials reported that they were not putting full effort into their jobs.
- 25% of high potentials were planning on leaving their organization in the next year.
- 20% believed their aspirations and their organizations' aspirations for them were not aligned.
- 70% of identified high performers lacked the necessary skills and attributes to succeed in higher-level roles.

In this context, NASA initiated SELDP to accelerate the development of high-potential, mid-level systems engineers. First-year results revealed an unprecedented 80% of participants transitioned into challenging positions that used their learning within four months of returning to their home centers, and 33% were promoted within six months. Not only does this present a different high-potential picture than the above bulleted findings, it also presents a contrast to past NASA leadership programs that achieved only an average of 25% of individuals transitioning into new challenges within eighteen months of their return to their centers. What did SELDP do differently?

This paper will discuss the SEDLP origins, objectives, and learning system; its emergent program design; and, most importantly, five key factors deemed by stakeholders to underlie initial program success and their implications for other leadership development programs.

PROGRAM ORIGINS AND OBJECTIVES

In 2008, NASA's agency leadership identified systems engineering as a critical core competency and developed an agency-wide systems engineering strategy to ensure the workforce would be ready and able to lead the world in space exploration, scientific discovery, technology development, and managerial excellence. NASA leadership undertook this effort because they saw a number of factors that could have a potentially adverse impact on leading future mission success. These factors included the following:

A large number of NASA's best systems engineers were nearing retirement age, and few up-and-coming engineers with a comprehensive, end-to-end understanding of systems engineering were ready to take their places.

Entire programs no longer resided in one culture or commonly understood set of processes. Most programs and projects were being conducted collaboratively across NASA centers and with outside organizations (including international, federal, commercial, and academic partners). These cultural and procedural differences caused confusion and misunderstandings, making it challenging for engineers to work well together.

Most systems engineers were experts in one engineering discipline and the one or two areas of the engineering life cycle on which their center focused. In most cases it was difficult for an engineer to gain the broad experience needed to become a highly effective chief engineer without going beyond his or her home center.

The systems engineering world at NASA was highly focused on technical knowledge and processes. The less tangible skills of leadership, creativity, communication, systems thinking, and problem solving were underdeveloped in most engineers. NASA's leaders agreed that these skills were the key differentiators between good and great systems engineers.

As a result, most systems engineers had a narrow perspective and limited system-wide understanding and experience. The goals of SELDP were to broaden and enhance systems engineering technical and leadership skills quickly by providing targeted, hands-on experience and leadership training through cross-center mobility assignments for NASA's high-potential engineers. The program was conceived and supported by NASA's leadership, including the Administrator and Engineering Management Board (EMB). [vi]

The systems engineering (SE) strategy required that NASA develop a consistent, agency-wide understanding of SE from numerous definitions that varied according to local center culture and individual experience. This effort resulted in a general agreement that SE is both an art and a science. [vii]

The Office of the Chief Engineer was given responsibility of aligning and integrating the following three aspects of the NASA SE framework:

Common Technological Processes: Created policies that established requirements for performing, supporting, and evaluating SE.

Tools and Methods: Communities of practice, handbooks, and best practices and assessments.

Workforce Knowledge and Skills: Project management and SE competencies, professional experiences, and educational opportunities, including SELDP.

These three aspects of NASA's systems engineering framework are aligned and integrated through the Office of the Chief Engineer.

SELDP was designed to build on the SE training and development activities that already existed across NASA. An agency-wide team of systems engineers and development specialists reviewed courses and development programs to identify learning gaps and ensure that SELDP leveraged and built upon what already existed. The goal was to develop both the science and art of SE:

The Science [viii]: Provide hands-on technical experience not available at the participant's location and expand their understanding of how SE processes vary across centers.

The Art [ix]: Provide cross-agency experience to learn the engineering culture of other centers and build targeted leadership skills and capabilities, including creativity, flexibility, critical thinking, and dealing with complexity.

LEARNING PROGRAM DESIGN

The SELDP design was developed from studies conducted to ascertain the behaviors of highly regarded systems engineers, those whom their peers and NASA's leaders regarded as "go to" people. The "NASA Systems Engineering Behavior Study"x involved interviewing, shadowing, and observing thirty-eight of NASA's most highly regarded systems engineers to determine the behaviors that helped to make them successful. These behaviors were sorted into groupings, or competencies. The competencies were further sorted into five prevailing themes:

- Leadership
- Attitudes and attributes
- Communication
- Problem solving and systems thinking
- Technical acumen

Identifying and understanding these competencies and their associated behaviors allowed NASA to align all elements of the program under a single framework.

The design team used this behavior study as the foundation for developing a complex and comprehensive social learning system, ensuring all parts of the system were aligned and connected. Figure 1 below illustrates this system.

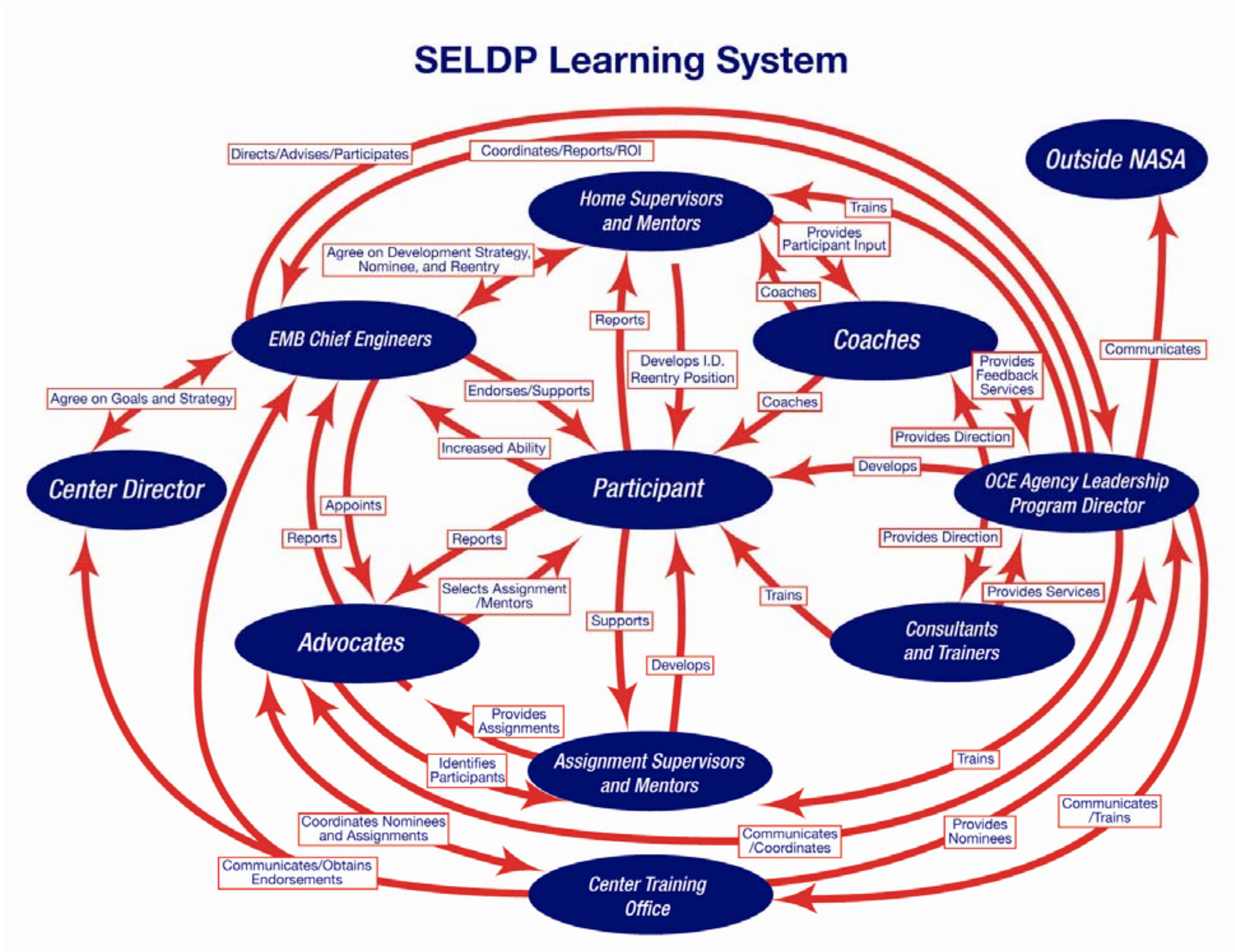

Figure 2. The learning system map identifies each role that influences participant success in the program and the relationships among learning roles in the system.

Legend: Circles define roles; lines delineate relationships, arrows show who is responsible to whom, and white boxes define responsibilities.

Positions	**Responsibilities and Relationships**
Office of the Chief Engineer Agency Leadership/Program Director	Defined learning needs, established program goals, and coordinated with the SELDP Board. The SELDP director was responsible for training and coordinating with all parts of the learning system.
EMB	Implemented the program at the local level, provided leadership guidance, and identified and endorsed high-potential candidates.
Center Directors	Coordinated with the EMB on the goals and strategy for using SELDP to develop their employees.
Home Supervisors and Mentors	Identified potential candidates and defined how participants might contribute upon return. Provided input into participants' developmental assessment needs.
Advocates	Appointed by the EMB. Coordinated candidate identification, mentored participants throughout the year, and

	provided status updates to the EMB.
Center Training Coordinators	Responsible for local coordination of candidate selection with all parts of the system.
Participants	Responsible for learning, performing assignments, and communicating their status with their home center. Accountable for returning to their centers with abilities and readiness to perform at the next highest level.
Assignment Supervisors and Mentors	Identified potential developmental assignments and responsible for developing the participants while on assignment.
Consultants and Trainers	Responsible for training and developing participants and providing advice on recommended program changes.
Coaches	Provided one-on-one and group coaching to participants. Facilitated discussion between participants and supervisors and mentors. Provided feedback and recommendations for program changes.
Outside NASA	Shared program information and findings with outside organizations.

Table 1. System Map Interrelationships

As illustrated by the learning system map in Figure 2, this program involved many interrelated learning activities. Key program design elements included the following.

Participant identification and selection was a two-part process. Applicants were assessed on both their technical (science of SE) and their leadership and creativity (art of SE) skills and abilities.

Developmental mobility assignments provided hands-on experience outside participants' home centers with assignments designed to broaden and improve their knowledge, skills, and abilities to lead complex agency-wide programs and projects. Unlike most mobility assignments, participants did not select their own assignment. Instead, a board of highly skilled systems engineers, known as advocates, made the assignment selections.

Gap analyses and assessments were created using feedback collected from each part of the selection process and were provided to participants. Participants were also given the 360-degree SE assessment developed from the NASA Systems Engineering Behavior study described above. This information was used to create the participants development strategy upon entering the program. At the end of the program the 360 was used again along with a formal end of year report providing guidance for the participant's developmental next steps.

Feedback from program managers, coaches, assignment supervisors, and mentors was used to refine participants' transition strategies back to their home centers.

Leadership development workshops and training allowed participants to learn and use leadership models and experiential learning exercises to increase their self-awareness and skill development tailored workshops included train in critical skill areas, communications, systems thinking, executive presence, and other topics determined to meet participant needs. They also included a benchmark of world-class industry and government SE organizations.

Coaching was ubiquitous. Five kinds of coaching were used and integrated across the program. A cadre of three master-certified coaches, who were familiar with NASA, were selected by the program director to support the program. Great care was taken to develop a trusting and safe environment because, in many cases, coaching was performed in the classroom in front of other participants so the entire class could learn from the individual's experience and insight. Coaching methodologies included the following:

One-on-One Coaching: Each participant was allocated twelve hours of one-on-one coaching.

Group Coaching: Coaches facilitated group sessions during workshops where participants could learn by observing how others were coached.

Class Coaching: During program events and workshops, consultants, coaches, and program leaders provided in-the-moment observations and coaching.

Peer Coaching: Participants were encouraged to observe each other and trained to give each other one-on-one peer coaching. This became an essential part of every class-wide event.

Transition Coaching: Finally, participants were allocated an additional twelve hours of one-on-one coaching after they graduated from the program to help them effectively transition back to their home centers.

The "NASA Systems Engineering Behavior Study" looked at this unique field of engineering and focused on highly successful individuals that participants knew and respected. This approach added to perceptions of coaching relevance and credibility, which were very important in the engineering culture. The combination of high-caliber coaches and a focus on evidence-based coaching made participants more open to the coaching process, willing to learn about themselves and to make the changes necessary to achieve their goals. For example, one participant who was highly skeptical about the coaching process in the beginning said, "I 'drank the Kool-Aid' and found out I liked it. Coaching has been a very beneficial learning experience."

While the program design was critical to the learning process, we found that it was actually the structures and relationships supporting the program that contributed most to the program's success.

FACTORS LEADING TO PROGRAM SUCCESS

As noted above, this program was based on an emergent design process. At the end of the first program year, extensive interviews were conducted with everyone involved in the learning system, including participants, supervisors, mentors, advocates, and engineering directors. Five factors were found to contribute to the successful transition of the first class of SELDP participants to their home centers:

- Alignment with NASA's core business
- Assignment matching
- Advocate role(s)
- Accountable participants
- Agility in adapting the program design

Successful transition was defined as placing participants in positions that used their learning in an expanded role that was at a higher or more complex/difficult level than before their participation in the program.

Alignment with NASA's Core Business

The NASA Administrator, who saw a growing need to accelerate the development of systems engineering as a core competency critical to mission success, requested identification of the need for SELDP as well as funding support. While learning-program development is typically assigned to the human-resources function, the individuals responsible for the SE function took responsibility for creating and sponsoring SELDP. The EMB was involved in all major programmatic decisions, including establishment of goals, identification and selection of participants, program design and implementation, and transition of participants into positions that served mission needs.

The focus on effective transition back to the home center began as part of the nomination process. Center nominees were selected because they were ready for the next step in their careers and needed broader experience to be effective. NASA's Chief Engineer and EMB Chair reminded the members of the EMB, "If it does not hurt, you are not identifying the right people." He knew that it would be difficult for centers to lose their best up-and-coming systems engineers for six months to one year. He also knew that NASA and the centers would reap the greatest return from the accelerated development of these individuals.

EMB members served as the selection panel and chose individuals who possessed both technical (the science) and leadership (the art) abilities in SE. Ethan Baumann, a participant from Dryden Flight Research Center, noted, "I knew when I was selected that I was being developed with the goal of preparing me for a leadership position in Dryden Flight Research Center's core business areas of flight-test and systems integration."

Three months before graduation, the Office of the Chief Engineer developed written guidelines and held a teleconference with the EMB members to review specific actions they could take to ensure participants' successful transitions. EMB members also provided reports on each participant at the end of the year, which summarized individual learning and recommended next steps. Scott Glubke, from Goddard Space Flight Center, said, "My EMB member viewed this program as more than a one-year development. He expected continued development and training after I returned to further develop my systems engineering and leadership skills to be more of a resource to the center and the agency."

Assignment Matching

The selection of assignments in SELDP was a multipart process. The first matching looked at the SE competencies (Attachment A) needed by the participant and those available in a given assignment. The second considered six additional dimensions that would broaden and expand the participant's overall experience (Attachment B).

Since the program was collaboratively designed and owned by individuals with expertise in both SE and learning and development, SELDP was able to incorporate program design elements based in actual line-management experiences at the agency. The resulting program differed from all other leadership-development program designs at NASA. Three insights from the SE behavior study of high-performing systems engineers were critical:

High-performing systems engineers had to see and understand the entire SE life cycle. This meant that SELDP had to place participants in assignments where they had to broaden their exposure and therefore did not know how to do the job they were being assigned.

They had to understand how SE worked at other centers because missions were now being done at multiple centers across the agency and with a more complex network of outside organizations. This required participants to relocate to other centers for their assignments. SELDP also required participants to work in a new mission area. (For example, a participant working in aeronautics might be placed in a human spaceflight [HSF] or robotics assignment, and vice versa.)

Participants had to have the opportunity to fail and recover. Assignments needed to stretch the participant's technical and leadership abilities and provide support along the way in the form of mentoring, so missteps and issues would be caught early and the participant could learn from finding a solution. For example, a participant may be given the task of creating a design that was not needed for several weeks to allow for review and redesign versus being given responsibility for a design that was due within the next week.

Most developmental programs at NASA place the burden and responsibility of defining the developmental assignment on the participant. These assignments are usually agreed to by the participant's supervisor or manager, but this tends to be *pro forma* and not as a result of an in-depth developmental gap analysis. When participants are responsible for identifying their own assignments, the following elements weigh more heavily in determining that assignment than aligning organizational and individual developmental needs:

- Personal preferences (for work, location, or family preferences).
- Doing what they already do well at a new location.
- Doing what they already do well at the next level up.

This occurs mostly because participants choose their assignments based on their previous experiences. They lack the experience to make the best and most objective decision about what is needed to reach the next level in their careers. Jim Ryan from Stennis Space Center found that "pre-SELDP assessments determined that I needed a horizon-building experience which would expose me to the rigorous practice of the whole range of systems engineering processes. My SELDP assignment gave me a view of the whole range of project processes and technical issues."

SELDP created a rigor about this matching process and gap analysis that the design team did not find in other programs in government or industry. To reduce any bias by participants or advocates in the assignment-identification process, NASA developed a software program that would match a participant's developmental need (identified through gap analysis) and the experience offered by each assignment (Attachment A). Advocates used the results of this matching process as the first step in identifying the assignments that would best provide the experience needed by the participant.

SELDP advocates ensured that participants were placed in stretch assignments—in areas where they had little or no previous experience and would expand their understanding of SE and NASA's engineering culture. For example, if a participant had spent his or her career defining requirements in the early phases of projects, he or she would have little understanding of the struggles those requirements created in later operational phases of a project life cycle. Experience in the implementation phases would help that employee gain new understanding and become more effective at writing requirements in the future. One participant noted, "I am still amazed that the assignment-matching group was able to identify a suitable assignment based on a short interview and application form. My assignment fully addressed the gaps in exposure to the rest of the agency and how large programs operate."

The concept of these assignments was a hard sell at first. NASA was asking high-performing individuals to take on work they knew nothing about while adapting to a new center's culture. Supervisors and mentors were also being asked to take on employees who had no experience with the jobs that participants would undertake in their assignments. To make this process work, NASA's engineering leaders had to win the trust of participants. Leaders had to send the message that it was okay for participants to fail as part of the learning process. Leaders also had to convince supervisors at NASA centers across the agency that while they might not be getting the expert they needed, they were getting a brilliant, high-performing engineer who would learn quickly and be able to contribute in a short time. The success of the first class helped make the case for current and future SELDP participants.

The advocates were critical for working with center engineering managers to identify developmental assignments. Assignments were designed to provide challenging experiences and hold participants accountable for some element of the project or program—all involved real work on important programs and projects, not developmental exercises.

Advocate Role(s)

An SELDP advocate was a chief or senior systems engineer appointed by a center's engineering director to serve as a mentor and advisor for program participants. Once engineering directors selected high-potential participants, the NASA-wide advocate team worked to perform the gap analysis for each participant and to match them to the best available assignment. They also helped create SELDP developmental plans for each participant to fill those gaps. Advocates stayed engaged with participants throughout their year to ensure their developmental plans were being implemented. Advocates also kept the center engineering director apprised of participants' progress. "It was important to have an 'anchor' back at my home center that allowed me to stay in the loop while I was away," said Natalie Goldin of Glenn Research Center. Advocates also served as technical advisors to the program and possessed the following attributes:

- Demonstrated experience and ability with complex SE projects
- Passion for professional development
- Good people/communication skills
- Extensive knowledge of the center nominees and the proposed developmental assignments

Because the advocates had previously been mid-level engineers facing the same challenges as the participants, they were able to understand the technical and leadership challenges participants faced. This enabled advocates to mentor their center participants while the participants were away and the participants who came to the advocate's center for assignments. Connie Carrington of the Marshall Space Flight Center said of her assignment advocate, "He had an innate ability to understand where issues might occur with my assignment." The more an advocate communicated with a participant throughout the year, the more effectively the participant was able to transition back to their home center.

Since this program was developing participant leadership competencies, coaching and mentoring were used to help participants solve problems that arose in their developmental assignments. When participants were unable to resolve issues themselves, advocates quickly intervened and helped participants get back on track to ensure optimization of the participants' developmental time. Lessons learned from previous programs showed that a clear resolution process was necessary to ensure that participants gained the experience they needed and that NASA achieved its intended return on investment.

Accountable Participants

From the start of the SELDP year, the program workshops and coaching elements focused on how learning (technical knowledge, leadership skills development, broader perspective) would be applied upon return to improve SE and contribute to mission success. Holding participants accountable for applying their learning was an expectation that was established upon their selection, and advocates reinforced this by addressing organizational needs with participants upon the identification of their developmental assignments. Throughout the year, participants were encouraged to take the long view and think of how they would apply their experiences upon return. A structured re-entry workshop also provided transition skills to help ensure participant success. These activities set the tone for participants to think of the broader impact of their learning and continually assess how it could be applied to their center and the agency as a whole upon return.

Participants who were most successful in finding a challenging new position upon return possessed the following attributes:

- Maintained open and frequent communication with their management. They kept their management fully informed of their activities.
- Continued to link personal and organizational goals. They asked for advice on which experiences and knowledge would potentially be most useful to their organization.
- Often discussed how their learning might be applied back home, and also clearly expressed their personal and professional desires.

Along with their learning experiences, this greater awareness resulted in participants ensuring that their newly acquired skills were put to good use. Rather than waiting for their management to find them a more challenging job, the majority of participants worked with their managers to help define opportunities or create new options where they could contribute. "I feel like I have been very successful in my return, and I credit a large part of that success to holding myself accountable for making the most out of the learning experience and finding opportunities to apply that learning upon return home," noted one participant. Participants who made successful transitions also:

- Expanded their discussions to other outside organizations where their new knowledge and skills might be used.
- Took initiative and saw themselves as a partner by designing options for their managers' consideration.
- Stayed open and flexible.
- Displayed gratitude for having been through the program rather than a sense of entitlement.

One participant from the Johnson Space Center found where he could best contribute was in a position held by another employee who was also looking for a new opportunity. He worked with that employee to identify a new position that did not exist and would fulfill her needs. Together they approached the center's engineering leadership and proposed the new plan, which would allow both employees to engage in new and challenging assignments and meet the needs of the center.

Agility in Adapting the Program Design

The SELDP design team used an emergent design process throughout the first year to build on each learning event as it happened. This iterative process allowed program managers to be highly responsive, adapting and adjusting the program as they discovered which learning activities had the greatest impact and applicability. This allowed them to ensure that first-year participants received the best learning available, rather than waiting to analyze the results of the first year at the end and making course corrections for the next class. It also allowed program managers to co-create learning elements with the class that would meet their emerging needs. Russell Stoewe from Kennedy Space Center found that "though most programs stand by their initial framework and change only periodically once they see some stabilization in agency goals, SELDP was more fluid and 'real-time' adaptive."

Social innovation resulted from this rapid-prototyping model of outlining, piloting, and improving each element of the program—based on debriefings, surveys, and feedback—in real time. The program was created from conception to launch in six months. Once the framework and goals were established, the program design and events were iterative. With each step the program managers practiced continuous improvement, collecting feedback from all parts of the system to strengthen and accelerate the training. The advantage of working from a framework instead of a fully completed design was that the program was not locked into a specific approach and could adapt to changing needs. Dave Mayer, a program advocate, said, "The agility to make course corrections (and the support to allow them to be made) are necessary to address any missteps and make the best from the situations." The difference between good SE and great SE is how you deal with mistakes/changes, and SELDP provides a flexible framework that allows this to happen.

CONCLUSION

The five factors noted above are the elements that were deemed most influential in contributing to the success of SELDP. Functional alignment allowed those responsible for mission success to fully integrate the development of their employees into their overall organizational strategy. This approach contrasted with the more typical approach of separating development from the core business within the human resources function at NASA.

An unbiased matching of needs and developmental assignments by senior leaders who had been in those positions allowed for greater learning but only when assignment supervisors and mentors understood the learning goals and had the leadership and communication skills needed to fully engage the participant.

Our findings led us to the following conclusions:

Employees are seldom the best judge of what is the next best step because, lacking experience in higher-level positions, they do not use the most objective and effective criteria for their assignment choices.

Senior experts, fully integrated in the learning role, are invaluable in ensuring success. The SELDP advocates provided continuity, improved communication throughout the system, and provided valuable mentoring—both technical and non-technical. Participants' needs were quickly and best identified and addressed when someone was on site with them.

A leadership program should always emphasize that the participants are expected to be and act as leaders, which means they are accountable for their own success both during and after the program. They must also be given the support and encouragement to expand, take risks, and increase their ability to contribute.

Finally, adopting a more flexible and agile approach to learning and development allows a program to constantly adapt to changing conditions and emerging needs. Agility fosters creativity and innovation by taking a try-a-little, test-a-little methodology. Critical to the emergent process is implementing continual feedback mechanisms and measurement strategies. It provides the data to support the changes and to continue to gain management trust and support along the way.

Next Steps

SELDP just ended its third year, and NASA is continuing to use the emergent design process to assess and update the program. As a result of the surveys conducted, NASA found that it was critical for mentors and supervisors to both understand the program and have the right skills to support the participants throughout the process.

Assignment mentors have been increasingly identified as the key individuals who enable or inhibit a participant's learning and exposure. Mentors were usually assigned because of their technical knowledge. While this knowledge is important, the ability of the mentor to engage, challenge, and communicate with the participant was found to be more important than technical knowledge. Establishing a personal relationship and being accessible helped to make the participants comfortable asking questions, trying solutions, and quickly recovering from failure. Without this personal relationship and the time for one-on-one communication, the environment became strained and participants struggled to get their footing on a project. As a result, valuable learning time was lost. In addition to technical knowledge, participants also needed mentors who had good leadership and communication skills to show them how to engage others and get the best thinking from teams. They wanted mentors who excelled in both the "art and science" of SE.

In almost all cases, the key individuals who enabled the participants to have successful transitions to a more challenging role were their home supervisors. While the program's first year focused mostly on EMB members for enabling the transition, they often delegated this responsibility to the participants' supervisors. Program managers realized the transition process was highly effective when there was a clear set of goals among the chief engineer and the employee's supervisors and managers. Where this condition did not exist, the transition was more apt to be difficult or fail.

These situations confirmed what program managers already knew: the learning system needed all parts communicating well and functioning optimally. For the second year, program managers adopted an additional focus: to "support all the people who support our participants." To support mentors, program and mentoring skills training was added. NASA also enlisted the participants to help identify the key characteristics and behaviors most essential to an effective mentor. These attributes will be used to help advocates identify skilled mentors who can best meet participants' needs.

Several steps are being taken to support the home supervisors in helping them set up successful transitions for the participants. First, clear program guidelines were provided at the start of the program, including program requirements and goals. Second, more coaching hours will be dedicated to supporting supervisors in developing transition strategies for participants and ensuring alignment of expectations. Supervisors will also be included in the annual transition dialogue and training with the engineering directors in the future.

ATTACHMENT A: COMPETENCY AREAS

Each competency has four levels; advocates work with participants to assess what level they are at on each competency. Each developmental assignment is rated; the top ten competencies a person can gain on the assignment at what level are determined and this provides the initial matching process.

1.0: Concepts and Architecture
Sub-competencies
- 1.1 Mission Needs Statement
- 1.2 System Environments
- 1.3 Trade Studies
- 1.4 System Architecture

2.0: System Design
Sub-competencies
- 2.1 Stakeholder Expectation Definition and Management
- 2.2 Technical Requirements Definition
- 2.3 Logical Decomposition
- 2.4 Design Solution Definition

3.0: Production, Product Transition, and Operations
Sub-competencies
- 3.1 Product Implementation
- 3.2 Product Integration
- 3.3 Product Verification
- 3.4 Product Validation
- 3.5 Product Transition
- 3.6 Operations

4.0: Technical Management
Sub-competencies
- 4.1 Technical Planning
- 4.2 Requirements Management
- 4.3 Interface Management
- 4.4 Technical Risk Management
- 4.5 Configuration Management
- 4.6 Technical Data Management
- 4.7 Technical Assessment
- 4.8 Technical Decision Analysis

5.0: Project Management and Control
Sub-competencies
- 5.1 Acquisition Strategies and Procurement
- 5.2 Resource Management
- 5.3 Contract Management
- 5.4 System Engineering Management

6.0: NASA Internal and External Environments
Sub-competencies
- 6.1 Agency Structure, Mission, and Internal Goals
- 6.2 NASA PM/SE Procedures and Guidelines
- 6.3 External Relationships

7.0: Human Capital Management
Sub-competencies
- 7.1 Technical Staffing and Performance
- 7.2 Team Dynamics and Management

8.0: Security, Safety, and Mission Assurance
Sub-competencies
- 8.1 Security
- 8.2 Safety and Mission Assurance

9.0: Professional and Leadership Development
Sub-competencies
- 9.1 Mentoring and Coaching
- 9.2 Communication
- 9.3 Leadership

10.0: Knowledge Management
Sub-competencies
- 10.1 Knowledge Capture and Transfer

ATTACHMENT B: DEFINING SYSTEMS ENGINEERING EXPERIENCE

In addition to the competencies below, the following elements are considered in the assignment matching process.

A. Life-Cycle Phases
- Formulation
- Phase A: Concept Studies
- Phase A: Concept and Technology Development
- Phase B: Preliminary Design and Technical Completion
- Implementation
- Phase C: Final Design and Fabrication
- Phase D: System Assembly, Integration, Test, and Launch
- Phase E: Operations and Sustainment

Phase F: Closeout

B. Mission

- Aeronautics Research
- Exploration
- Sciences
- Space Operations

C. Level

- Subsystem
- System
- Instrument
- Vehicle

D. Project Level

- Task
- Element
- Project
- Program

E. Leadership Experience

- Team-Level Participant
- Team-Level Lead
- Supervisory
- Center-Level Exposure
- Center-Level Experience
- Agency-Level Exposure
- Agency-Level Experience
- Government-Wide Experience

F. Human or Robotic

- Human
- Robotic

REFERENCES

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ii Bureau of Labor Statistics, Occupational Outlook Handbook, 2010–11 Edition, Overview of the 2008–18 Projections, Population, available at http://www.bls.gov/oco/oco2003.htm (accessed 16 July 2011).

[iii] Michaels, E., Handfield-Jones, H., Axelrod, E., The War for Talent, Harvard Business Press, 2001.

iv At NASA, individuals with proven engineering expertise who demonstrate a high potential for leadership and creativity are considered to be the talent pool for the Systems Engineering Leadership Development Program.

[5] Jean Martin, Conrad Schmidt, How to Keep Your Top Talent, Harvard Business Review, May 01, 2010, 9pgs

[vi] The NASA Engineering Management Board (EMB) consists of the Agency leaders responsible for engineering, engineering processes, and engineering technology. The EMB provides advice and counsel, and makes recommendations relating to maintaining and improving all aspects of engineering capabilities to ensure engineering excellence.

[vii] A NASA paper, "The Art and Science of Systems Engineering," can be found at http://www.nasa.gov/pdf/311198main_Art_and_Sci_of_SE_LONG_1_20_09.pdf.

[viii] The science of systems engineering is systems management. Systems management focuses on rigorously and efficiently managing the development and operation of complex systems. Effective systems management requires applying a systematic and disciplined approach that is quantifiable, recursive, repeatable, and demonstrable.

[ix] The art is technical leadership. Technical leadership includes broad technical domain knowledge, engineering instinct, problem solving, creativity, and leadership and communication skills needed to develop new missions and systems. It focuses on systems design and technical integrity throughout the life cycle. A system's complexity and the severity of its constraints drive the need for systems engineering.

x This NASA study is available at http://www.nasa.gov/news/reports/NASA_SE_Behavior_Study.html

BIOGRAPHY'S

Christine R. Williams serves as the director of Systems Engineering Leadership Development within the NASA Academy of Program/Project and Engineering Leadership. In this role, she designs and implements agency-wide programs and conducts studies focused on enabling NASA program and engineering leaders to achieve mission success. Ms. Ms. Williams's programs are considered world class by both industry and government standards, and she has been invited to speak internationally on topics of leadership development, executive coaching, and the application of advances in neuroscience to improve employee learning. After receiving her BS in oceanography, she graduated summa cum laude from The Johns Hopkins University with an MS in organizational development and applied behavioral science. Among her many awards, Ms. Williams received the Leadership in Action Award from the Council for Excellence in Government, and NASA's Outstanding Leadership Medal, External Achievement, Creative Management, and Innovative Management awards.

Ana Reyes is a founding partner of New Worlds Enterprise, a global leadership development and organizational consulting firm, and an affiliated faculty in the Organizational Dynamics program at the University of Pennsylvania. She works as an executive coach, organizational consultant, and educator specializing in global leadership development, culturally complex collaboration, virtual organization development, and applied ethnographic assessment. . Her professional interests focus on the engagement of culturally diverse leaders and their teams in the twenty-first century human-development challenges of building international businesses and mind-sets, mastering geographically dispersed teamwork, humanizing technology-mediated collaboration and communication, and coaching individuals and groups, often across distance and time. Dr. Reyes earned a BS in biology and psychology from Boston College, an MA in clinical/community psychology, and a PhD in clinical and organizational psychology from the University of Maryland.