THE SYSTEM BEHIND THE SYSTEM: DEVELOPING SYSTEMS ENGINEERS AT NASA

Christine R. Williams[1] & Ana Reyes[2]

Abstract: *This case study provides a model for developing high-potential, mid-level systems engineers and describes the significant results achieved by NASA. In this study we describe the complex system approach used by NASA to develop technical leaders and the factors that contributed to the program's success. We also shows that by identifying, training, and developing the entire learning system, not just program participants, NASA significantly influenced the participants' ability to make a greater contribution to the organization. This study also introduces a flexible, emergent design process that helped NASA achieve 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%.*

Key Words: Leadership development, program design, mobility assignments, talent management, leadership transition/repatriation, complex system change

Relevant Categories: Flexibility, mobility, adaptiveness, agility, and customization

---

[1] Director, Systems Engineering Leadership Development Director,NASA Headquarters, Mail Code KA000
300 E Street, SW, Washington, DC 20546, christine.r.williams-1@nasa.gov

[2] Partner, New Worlds Enterprise LLP,106 Kenilworth Street, Philadelphia, PA 19147, amreyes@NewWorldsEnterprise.com, http://www.organizationaldynamics.upenn.edu/reyes

1. Introduction

In a recent publication, McCall and Hollenbeck (2010) contend that the elements of leadership development have been well established by research over the past thirty years. 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 In a recent study of twenty thousand high potentials in more than one hundred organizations worldwide, Martin and Schmidtt (2010) found alarming results: 40% of high-potential job transitions continue to result in failure.

This is not because we don't know how to do leadership development but rather because it 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.

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 90% the second year. 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.

2. 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 nearing retirement age.
- Programs residing in multiple cultures without a commonly understood set of processes.
- Systems engineers with knowledge in only one or two areas of the engineering life cycle.
- Underdeveloped leadership, creativity, communication, systems thinking, and problem solving skills.

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).[1]

The goal of SELDP was to develop both the science and art of SE:

- The Science[2]: 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[3]: 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.

3. Learning Program Design

The SELDP design was developed from NASA Systems Engineering Behavior Studies[4] which were conducted to ascertain the behaviors that made highly regarded systems engineers successful. These behaviors were sorted into five prevailing themes: leadership, attitudes and attributes, communication, problem solving and systems thinking, and technical acumen

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 aligned and were connected. Figure 1 below illustrates this system.

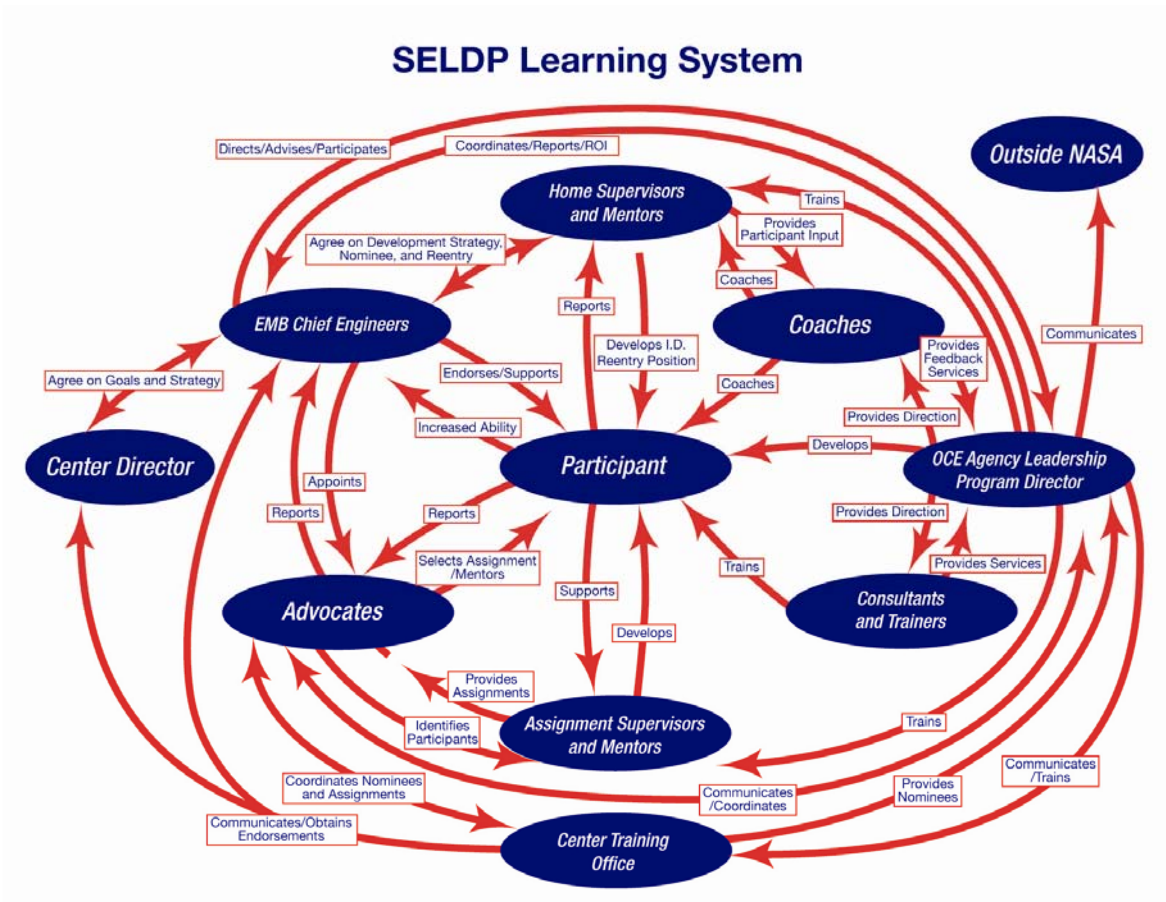

Figure 1. The learning system map identifies each role that influences participant success in the program and the relationships among learning roles in the system.

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

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** in which applicants were assessed on their technical (science of SE) and their leadership and creativity (art of SE) skills and abilities.

- **Developmental mobility assignments** provided hands-on experience designed to broaden and improve their knowledge, skills, and abilities to lead complex agency-wide programs and projects.
- **Gap analyses and assessments** feedback collected from the selection process were provided to participants along with a 360-degree SE assessment developed from the NASA Systems Engineering Behavior study. These were used to create the participants development strategy.
- **Leadership development workshops and training** allowed participants to learn and use leadership models and experiential learning exercises to increase their self-awareness and acquire critical leadership skills.
- **Coaching was ubiquitous.** Five kinds of coaching were used and integrated across the program including: one-on-one, group, class, peer and transition coaching.

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

4. Factors Leading to Program Success

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. Five factors were found to contribute to SELDP's success which 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, assignment matching, advocate role(s), accountable participants, and agility in adapting the program design

4a. Alignment with NASA's Core Business

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 serves as the programs board of directors and selection panel and are involved in all major programmatic decisions, including establishment of goals, 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.

4b. Assignment Matching

The selection of assignments in SELDP was a multipart process. The first matching looked at the SE competencies (http://www.nasa.gov/pdf/303747main_Systems_Engineering_Competencies.pdf) 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 including: project life cycle phases; mission areas, system levels, project levels, leadership experience, and human or robotic experience.

SELDP incorporated 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:

1. High-performing systems engineers had to see and understand the entire SE life cycle. 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.
2. They had to understand how SE worked at other centers because missions were done at multiple centers and with a complex network of outside organizations. This required participants to relocate to other centers for their assignments and work in a new mission area.
3. Participants had to have the opportunity to fail and recover. Assignments needed to stretch the participant's abilities and provide mentoring support so missteps and issues would be caught early and the participant could learn from finding a solution.

Most developmental programs at NASA place the burden and responsibility of defining the developmental assignment on the participant. When participants are responsible for identifying their own assignments, personal preferences and a desire to do more of what they already know how do to weigh more heavily in determining that assignment than aligning organizational and individual developmental needs. Most participants lack the ability to make the best and most objective decision about what they need to reach the next level in their careers.

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. Advocates used this as a first step in matching the participant with the assignment that provided the experience they needed.

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. 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.

4c. 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. Advocates perform gap analysis for each participant, match them to assignments and mentor them throughout their year. 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.

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.

4d. Accountable Participants

All program elements focused on how learning 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. Program 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:

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

Successful participants worked with their managers to help define opportunities or create new options where they could contribute. They also:

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

4e. 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.

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. 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.

5. Conclusion

The five factors noted above are the elements that were deemed most influential in contributing to the success of SELDP. Our findings led us to the following conclusions:

- 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 past approach of separating development from the core business within the human resources function at NASA.
- Employees are seldom the best judge of what is the next best step because they lack experience in higher-level positions, they do not tend to use objective and effective criteria for their assignment choices. Unbiased matching of needs and assignment by senior leaders allows for greater learning.
- Senior experts, fully integrated in the learning role, are invaluable in ensuring success as they provide continuity, better communication throughout the system, and technical and non-technical mentoring.
- A leadership program need to 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.
- A 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. Critical to the emergent process is implementing continual feedback mechanisms and measurement strategies.

6. 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. These individuals did not receive training in the program prior to participants being placed with them. Also, the program did not have clearly defined requirements for these individuals – individuals 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. Clear program guidelines were provided at the start of the program, including program requirements and goals. Second, supervisors will also be included in the annual transition dialogue and training with the engineering directors in the future.

8. References

- McCall, F.A., and Hollenbeck, G.P. (2010), "The Not-So-Secret-Sauce of the Leadership Development Recipe," in Bunker, K.A.; Hall, D.T.; and Kram, K.E. (Eds), *Extraordinary Leadership: Addressing the Gaps in Senior Executive Development*, Jossey-Bass, San Francisco, CA, pp. 155–173.

- Martin, J., and Schmidtt, C. (May, 2010), "How to keep your top talent," *Harvard Business Review*, Vol. 88 Iss. 5, pp. 54–61.

---

[1] 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.
[2] 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.
[3] 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.
[4] This NASA study is available at http://www.nasa.gov/news/reports/NASA_SE_Behavior_Study.html.