Evolution Of the Systems Engineering Education Development (SEED) Program at NASA Goddard Space Flight Center

Fourteenth Annual International Symposium of the
International Council On Systems Engineering (INCOSE)
21 June – 24 June 2004

Thomas C. Bagg, III
QSS Group, Inc.
7404 Executive Place, Suite 400
Seabrook, MD 20706
301-867-0063
tbagg@qssmeds.com

Raymond L. Granata
QSS Group, Inc.
7404 Executive Place, Suite 400
Seabrook, MD 20706
301-867-0143
rgranata@qssmeds.com

Mark D. Brumfield
NASA Goddard Space Flight Center
Code 590
Greenbelt, MD 20771

Carolyn A. Casey
NASA Goddard Space Flight Center
Code 501
Greenbelt, MD 20771

Donald E. Jamison
NASA Goddard Space Flight Center
Code 581
Greenbelt, MD 20771

Stuart Heller
1554 Goldenrain Ct
Reston, VA 20190
703.819.2466
drmove@earthlink.net
www.martialartofinfluence.com

Abstract. The Systems Engineering Education Development (SEED) Program at NASA Goddard Space Flight Center develops systems engineers from existing discipline engineers. The program has evolved significantly since the report to INCOSE in 2003. This paper describes the SEED Program as it is now, outlines the changes over the last year, discusses current status and results, and shows the value of human systems and leadership skills for practicing systems engineers.

SEED Program

Goals. The Systems Engineering Education Development (SEED) Program of the National Aeronautics and Space Administration (NASA) Goddard Space Flight Center (GSFC) was designed to achieve the following goals:

1. Develop Systems Engineers from GSFC professionals with engineering, science, and information technology background.
2. Provide GSFC with highly trained personnel skilled in the development of space and ground systems who can meet critical systems engineering needs.
3. Provide exposure to new and different perspectives on systems engineering.

4. Broaden individual skills to enhance performance as a Systems Engineer.
5. Prepare Mentees for the Leadership aspects of Systems Engineering.

Description (NASA 2003b). The Systems Engineering Education Development (SEED) Program is designed to develop Systems Engineers for the NASA GSFC environment from incumbent mid-level (GS-13) professionals. The SEED Program is based on four fundamental elements: mentoring by senior systems engineers, a curriculum of courses, on the job training through rotational assignments, and human systems leadership training. The SEED program is designed to have Mentees complete their tenure in two to three years. During the program, the participants are exposed to many areas of systems engineering through educational courses and task assignments. They also participate in leadership and technical workshops. Graduates receive non-competitive consideration for a senior level (GS-14) engineering position.

Selection. New classes of SEED Mentees are formed through a competitive selection process. Civil servant applicants that meet the GS-13 AeroSpace Technologist competencies as listed in the announcement are interviewed. Selected Mentees are detailed full time to the SEED Program Manager for the duration of the program. The detail assignments place the Mentees under the formal technical direction of the SEED Program Manager, and removes them from duty assignments by their home organizations. This detailing of Mentees gives the SEED Program the flexibility to schedule rotational assignments and classes as needed. The SEED Program plan is to have a new class of four Mentees annually.

Development of SEED Mentees.

Mentee development begins with an initial assessment, technical development takes place in two phases, and leadership development, mentoring and coaching are continuous throughout the program. The SEED Mentee development is described in detail below and illustrated in Figure 1 SEED Mentee Development process.

Assessment. Mentees begin their SEED experience with an initial assessment that documents the Mentees' current experience and skills. Mentees are paired with Mentors through a series of social interactions and mutual selection exercises. Technical experience is evaluated against a set of systems engineering competencies. Leadership experience and style is assessed using a variety of instruments including Leadership Architect Competency Evaluation, 4-D (Four Dimensional Leadership), DISC (Dominance, Influence, Steadiness, Compliance), MBTI (Myers Briggs personality Type Indicator), FIRO-B (Fundamental Interpersonal Relations Orientation - Behavior), Strong Interest Inventory, and a series of Human Systems and Leadership workshops. Based on the results obtained via the assessment, the SEED Program is then individually tailored to address the experience and knowledge gaps displayed by each Mentee. This tailoring is documented in an agreed-upon Individual Development Plan (IDP). The IDP identifies the priorities for technical and leadership development needed to function as a systems engineer at NASA GSFC and serves as graduation criteria for the Mentee.

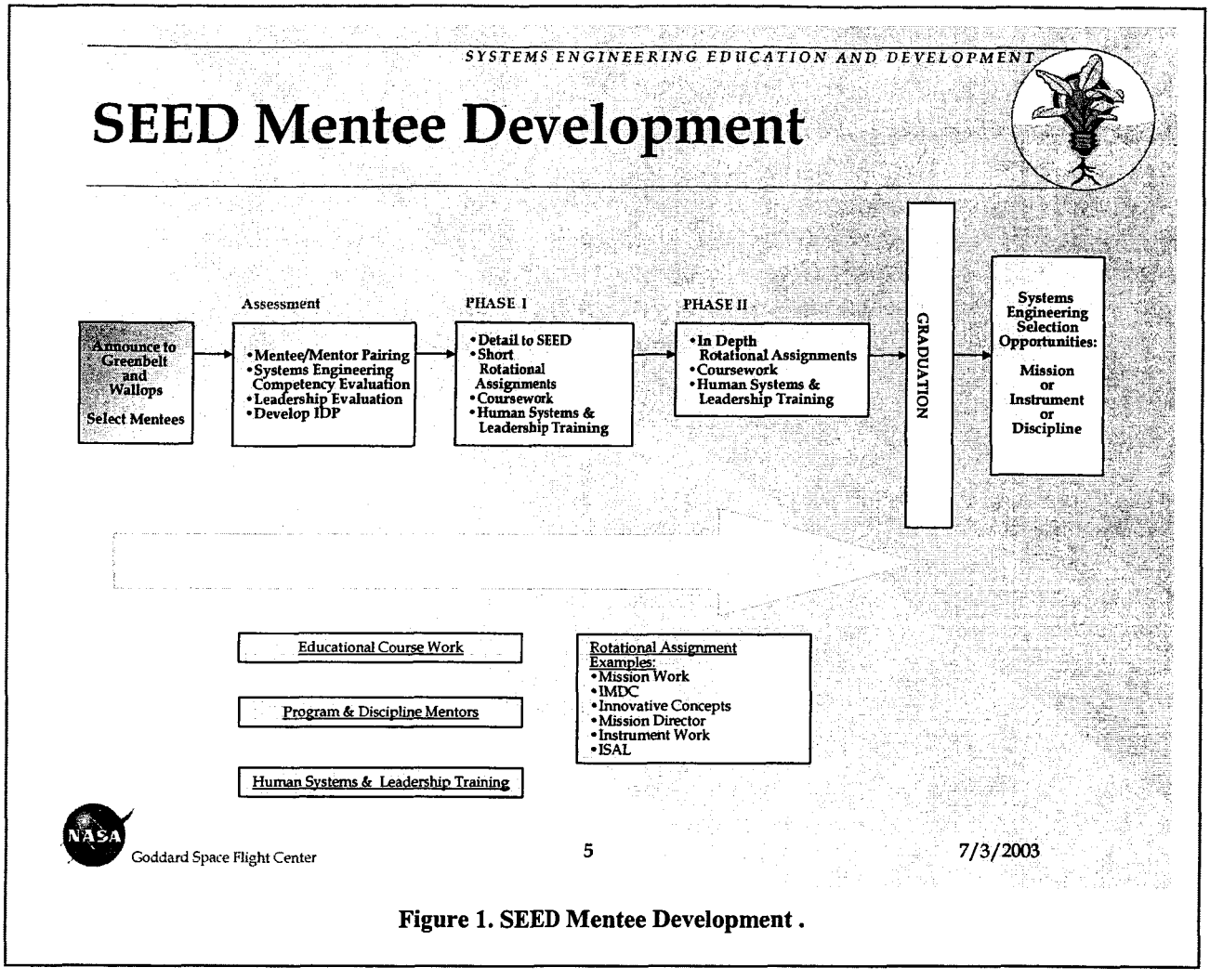

Figure 1. SEED Mentee Development .

Phase I. Phase I introduces the Mentees to Systems Engineering and begins to broaden their experience.

The classes (See Curriculum below) provide a structured foundation of systems engineering fundamentals.

Rotational assignments are within a flight project or mission area, and are selected to broaden the Mentee's experience across multiple disciplines, subsystems, and phases of the mission life cycle. Rotational assignments are four to six months in duration The ideal would be to provide experience in all phases of the life cycle, all major subsystems of a space mission, and all disciplines used in a space mission. Since this is not possible in four to six rotations, assignments are selected to fill major gaps in the Mentee's experience. Mentees are directed and guided through each assignment by Assignment Mentors with appropriate expertise for that assignment. This process also develops a network of useful contacts across GSFC. Formal agreements between the SEED Program and the Project identify the Mentee and Assignment Mentor, document the duration, goals, responsibilities, and products of the assignment, and indicate the expected skills and experiences for the Mentee.

Phase II. Phase II provides in-depth experience working as a systems engineer under the direction of a senior systems engineer. The Phase II rotational assignment is of a longer duration. Additional classes are available as needed.

Mentoring and Coaching. There are several levels of mentoring, guidance, and support that Mentees receive throughout their participation in the program. (1) The Program Mentor is a senior level systems engineer. The Mentor helps to identify competency gaps in technical and leadership areas, provides direction and guidance in selection of the appropriate rotational assignments to reduce those gaps and provides guidance to resolve any organizational issues or technical problems. The Program Mentor guides the Mentee throughout their entire participation in the SEED Program. (2) Assignment Mentors are discipline experts that are identified for each rotational assignment. They guide the Mentee through the technical performance of the assignment. (3) ProfessionalPersonal Coaches use a wide range of processes and practices in working with the Mentees to increase their leadership, communication and life skills competencies. SEED uses professionally certified NASA employee and external consultant coaches. Mentees schedule individual sessions with their coaches on a regular or as-needed basis.

SEED Curriculum. The curriculum is designed to provide a formal foundation for systems engineering at GSFC. The following core technical classes or equivalent experience are required:

1. Technical Managers Training - Overview of GSFC organization, culture, and work processes.
2. Systems Engineering - Overview of Systems Engineering processes, products, tools, the Systems Engineering Life Cycle, and the systems viewpoint.*
3. Systems Requirements - Introduction to the issues and processes for generating system requirements.*
4. Instrument Systems - Introduction to sensors and instruments for space missions.
5. Risk Management - Introduction to the issues of risk management*
6. Space Mission Design and Analysis (5 options) - Introduction to the major subsystems and design criteria for a space mission*

The classes marked with an asterisk (*) are provided through the NASA Academy of Program and Project Leadership. The remaining two classes were developed at GSFC since they were not already available. Additional technical courses are available and all Mentees are encouraged to further their engineering education.

Leadership Development

SEED uses a variety of leadership assessment and training instruments and workshops. The DISC (Dominance, Influence, Steadiness, Compliance), MBTI (Myers Briggs personality Type Indicator), FIRO-B (Fundamental Interpersonal Relations Orientation -Behavior), and Strong Interest Inventory instruments are well known to councillors and coaches. The Human Systems and Leadership Development workshops, Lominger Leadership Competency Evaluation, and 4-D (Four Dimensional Leadership) are described here since they are less well known.

Human Systems and Leadership Development (HSLD). When first asked, most engineers or technical thinkers will state that technical competency is, overwhelmingly, the most important factor in professional success. However, in practice and after serious thought, the answer is two-fold. An equally important factor in professional success is Human Factors, the discipline that focuses on the communications interfaces between people and between people and systems (Leibrandt 2002).

The fundamental premise of HSLD is: "I am a system." In other words, the same principles that we use to study and optimize any system are applied to the human system.

To quote Peter Drucker, author of The Effective Executive, "*Your first and foremost job as a leader is to take charge of your own energy and then help orchestrate the energy of those around you.*"

The HSLD Program is a human technology that bypasses the historical problems of teaching analytically oriented thinkers how to develop the necessary skills of a physical presence that enhances confidence, team building, emotional intelligence, conflict management, and cross-cultural communication.

The core strategy of this approach is to use oneself as the laboratory. Using a language of movement developed by Dr. Stuart Heller, in his decades long Human Factors research, you create analogue simulations of the issues and skills you want to explore and develop. Working in this way maximizes the objective component of human interaction while simultaneously developing the subjective dimension. In addition, the participants develop a generalized grasp of systems thinking and the leadership skills necessary for success.

Human Systems and Leadership Development has three major components:

1. A three-day intensive workshop to communicate the principles, strategies, and models as well as teaching the core techniques for producing rapid and real self retooling.
2. Monthly group sessions to teach people how to use what they are learning for real time situations as well as team and individual skill development.
3. Monthly one-on-one sessions where each participant focuses on their unique situation and goals.

"*Nothing happens until something moves.*" — Albert Einstein (Heller, 1994).

In keeping with the importance of whole system thinking for the systems engineering mindset, the SEED program is taking a systems approach to the development of the leadership skills that will serve the Systems Engineer of the future, thereby cultivating a new kind of leader. In the past the leadership style was directive. For NASA's leadership to be successful, the focus has to shift to interacting effectively with each other, in a human systems way, as validated by the Columbia Accident Investigation Board Report (CAIB 2003).

Four Dimensional Leadership. The Four Dimensional Leadership model is a Cultural and Leadership style assessment. 4-D evaluates 12 factors of overall effectiveness along the four dimensions of Valuing, Relating, Directing, and Visioning. The 4-D workshop introduces the four styles, discusses typical behaviors of each style that limit performance and effectiveness, ways to recognize your own and others styles, and techniques to work with others of different styles. 4-D was developed by Dr. Charles Pellerin, a former Director of Astrophysics for NASA, and is based on experiences with both successful and failed projects. (Pellerin 2003)

Leadership Architect. The Leadership Architect includes a comprehensive set of leadership competencies, each with descriptions of skilled use, over/under use, and training suggestions. GSFC Systems Engineering managers selected the 10 most important of these for systems engineers at GSFC. Peers, mentors, and supervisors evaluate the Mentees annually on these 10 competencies using a 360 evaluation format. A complete report is developed which identifies the strengths and weaknesses of each Mentee's leadership qualities, and provides recommendations for developing needed competencies. The Leadership Architect was developed by Lominger. (Lominger 2003).

SEED Management Team.

The SEED Management Team oversees the program including its schedule, resources, and metrics. It provides administrative support, coaching resources and the overall training development process. It establishes and approves rotational assignments and requisite classes. The team serves as the interface to GSFC management and other GSFC organizations. The SEED Management Team consists of the Program Manager, Program Administrator, Leadership Development Coordinator, contractor support, and others on an ad-hoc basis as needed.

Documentation.

The SEED Program documentation consists of:

1. The SEED Program Plan describes the SEED Management Team actions to develop and run the SEED Program. The Plan describes what the SEED Management Team will do.
2. The SEED Program Handbook serves as a reference of how the SEED program is run. The Handbook contains SEED processes and examples of Admission Criteria, Vacancy Announcement, Individual Development Plan, rotation assignment write-ups and agreement forms, and an acronym list.
3. The SEED Program Brochure is used to market the SEED Program among GSFC engineering staff.
4. The SEED Program presentation archive contains all presentations used to brief management on status, to introduce the program to prospective Mentees, and to describe the program to outside organizations such as INCOSE and AIAA.
5. Various reports are maintained such as annual status reports, meeting notes, and papers submitted to organizations such as INCOSE.
6. SEED maintains all records in a secure, on-line database system known as Virtual Systems Development Environment (VSDE). All participants have access to the system via the Internet.

SEED Program Evolution

The SEED Program has evolved from its inception and continues to evolve today. This section documents the major changes to the program throughout its history.

1999. The need for more and better Systems Engineering was recognized at GSFC. A team of knowledge experts formulated a pilot program and used the DACUM process to develop a curriculum (Ohio 2003). The SEED Pilot program began with four Mentees. Management of SEED was added to the responsibilities of the Deputy Division Chief for Systems Engineering.

2000. It was recognized that the program needed more support, and a Revitalization Team with broad skills, experience, and organizational representation was created to revitalize the program. Revitalization Team members interviewed the Pilot Mentees for what was and what was not working. The Revitalization Team determined the following:

1. The SEED Program requires dedicated management support.
2. The SEED Program needs a dedicated Administrator.
3. The SEED Program needs a structured approach to rotations and classes.

4. Separate tracks for Missions Systems Engineering and Instruments Systems Engineering of the pilot program limits training flexibility and forces the Mentees to chose a track at the beginning of the program.
5. Supervisors should not be mentors of their employees.
6. The SEED Program needs stable resources.

2001 and 2002. Based on these findings, the Revitalization Team made the following revisions to the core program:

1. The Revitalization Team wrote a SEED Management Plan for development of the program.
2. The Revitalization Team revised the organization and defined the responsibilities of each member of SEED management. A full time Program Administrator and the Leadership Development Coordinator were appointed and provided with contractor support. The Revitalization Team was renamed the SEED Management Team.
3. The dual Mission and Instrument tracks were merged. The main difference between Missions Systems Engineers and Instruments Systems Engineers is the scope of their responsibility. Both need to understand the responsibility of the other. Both Mission and Instrument systems engineers are trained in as much of the full breadth of engineering on space missions as possible, in order to have a better understanding to select their career focus.
4. The SEED Management Team documented all program details and processes in the SEED Program Handbook. (See documentation above.)
5. A class of 6 Mentees was selected in December 2001, began in January 2002, and is known as the Class of 2002.
6. The SEED Management Team began to negotiate contracts with the Projects for rotational assignments. These contracts state the Mentee, the Assignment Mentor, a Statement of Work with objectives and deliverables, and the expected duration of the assignment. These contracts make it clear to all parties the temporary nature of the rotational assignment and the criteria for successful completion.
7. A Human Systems and Leadership component was added to SEED with both assessment and development components.
8. Gap analyses of both technical and leadership competencies were performed for each Mentee and Individual Development Plans were generated by the Mentees with consultation by their Mentors and approval by the SEED Management Team.

2002 and 2003. The then current state of the program was documented in the SEED Case Study paper (Bagg 2003) presented at the 2003 INCOSE International Symposium. The SEED Program continues to change. SEED is currently preparing the Class of 2002 Mentees for graduation, and preparing to release an announcement for a new class of Mentees in 2004.

2003. The Assessment Step was developed for use with the new class in 2004. This assessment will identify major gaps in Mentees' technical and leadership skills, and document the agreed upon minimum criteria for graduation.

Current SEED Status and Results

The Class of 2002 Mentees are now in their third or fourth rotational assignment, and feel that they learned a lot from the assignments. Program managers have found the Mentees extremely useful to them in the performance of their rotational assignments. Mentees have made good progress in class work, meeting approximately 80% of the total core course requirements. All

have participated in the Human Systems and Leadership section of SEED. Those that also practice the Human Systems and Leadership techniques have noticeable changes in their behavior. They report more confidence and increased personal effectiveness. Most Mentor/Mentee pairs met twice monthly with Mentees reporting helpful support and Mentors reporting gaining as much as they gave (NASA 2003a). All participants of SEED have received inquires about this program from others that would like to be included in future classes. The SEED Program now has its first two graduates. Both received offers of positions that they would not have qualified for prior to their participation in SEED. One of the SEED Pilot Program Mentees has been promoted to Branch Chief of the Guidance Navigation and Control Systems Engineering Branch at GSFC.

The SEED Program is still growing. SEED Management Team is continually trying to improve the program through reviews with participants, and investigation of other similar programs for ideas to incorporate.

Conclusions

There are three conclusions we can draw from our experience with the first two years of the SEED Program. People skills are as important as technical skills for systems engineers at NASA GSFC. Leadership skills were highly instrumental for competitive selection of a SEED Mentee as Senior Instrument Systems Engineer as demonstrated by the number of interview questions that were on leadership issues.SEED, like any complex educational program, needs to continually review and revise itself. The SEED program has changed significantly since admission of the Class of 2002, and even more so since the Pilot program. Availability and content of formal classes changes and the program must have the flexibility to take advantage of new offerings and loss of prior offerings.

The main conclusion is that the SEED program is working. All parties involved can see the growth of the Mentees in their abilities to perform both the technical and leadership sides of systems engineering. There is a future for SEED as the program already addresses many of the leadership and systems engineering issues raised by the Columbia Accident Investigation Board (CAIB 2003), and there are some discussions underway to expand SEED to a NASA wide program.

SEED is developing systems engineers that have the confidence and skills to meet the future needs of NASA GSFC.

Acronyms

4-D	Four Dimensional Leadership
AIAA	American Institute of Aeronautics and Astronautics
BA	Bachelor of Arts
BS	Bachelor of Science
CAIB	Columbia Accident Investigation Board
COSTAR	Corrective Optics Space Telescope Axial Replacement
DACUM	Develop a Curriculum. (Ohio State University process)

DISC	Dominance, Influence, Steadiness, Compliance
FIRO-B	Fundamental Interpersonal Relations Orientation - Behavior
GS-	General Schedule (US Government pay scale)
GSFC	Goddard Space Flight Center
HLSD	Human Systems and Leadership Development
IDP	Individual Development Plans
IMDC	Integrated Mission Development Center
INCOSE	International Council on Systems Engineering
ISAL	Instrument Systems Analysis Laboratory
MBTI	Myers Briggs personality Type Indicator
MESAD	Mission Engineering and Systems Analysis Division
MS	Master of Science
MSD	Mechanical Systems Division
NASA	National Aeronautics and Space Administration
POES	Polar Orbiting Environmental Satellite
QSS	QSS Group, Inc. (Corporate name, not an acronym)
SEBoK	Systems Engineering Body of Knowledge (INCOSE)
SEED	Systems Engineering Education Development
TMT	Technical Managers Training
VSDE	Virtual Systems Development Environment

References

Bagg, T.C., Granata, R.L., Brumfield, M.D., Casey, C.A., and Jamison, D.E., "Systems Engineering Education Development (SEED) Case Study." *Technical Proceedings of the Thirteenth Annual International Symposium of the International Council on Systems Engineering (INCOSE)* (Crystal City, VA, June to 3 July 2003). NASA GSFC, pp 935-944.

Columbia Accident Investigation Board (CAIB), *Report Volume I.* Technical Report to NASA, August 2003, `http://www.caib.us/news/report/`.

Heller, Stuart and Sheppard Surrenda, David, *Retooling on the Run: Real Change for Leaders with No Time.* Frog LTD, Berkeley, California, 1994.

Leibrandt,R., "A Guide to the Systems Engineering Body of Knowledge (SEBoK) Introduction." *INSIGHT.* (April 2002). International Council on Systems Engineering (INCOSE), pp 7-18.

Lominger, *Leadership Architect®.* 2003, `http://www.lominger.com/6`.

NASA GSFC, MESA/Code 590., "SEED Mentor and Mentee Interviews." Unpublished notes, NASA GSFC, August and September 2003.

NASA GSFC, MESA/Code 590., "Systems Engineering Education Development (SEED)

Program Handbook." NASA GSFC, November 2003.
Ohio State University, *DACUM*. 2003. http://www.dacum.com/ohio/index.htm.
Pellerin, C., *Four Dimensional Leadership*. 2003. http://www.4-dl.com/.

Biography

Thomas C. Bagg, III is a Senior Systems Engineer at QSS Group, Inc. He has 26 years of experience in the development and testing of aerospace and defense systems. He was awarded the NASA Contractor Excellence Award in 2002 and nominated again in 2003 for his work developing the Systems Engineering Education Development (SEED) Program for NASA at the Goddard Space Flight Center. He is a member of the INCOSE Education and Research Technical Committee, the Space Systems Working Group, and served as Co-Chair of the INCOSE Telecommunications Working Group of the Systems Engineering Applications Technical Committee. He is a member of the INCOSE Chesapeake Chapter. He runs rocket launches for local schools and scout troops, and runs an annual Space Night at his local elementary school for educational outreach. Tom received his BA in Physics from Lafayette College, and his MS in Systems Management from Capitol College.

Raymond L. Granata is a systems engineer at QSS Group, Inc. He has 47 years of experience in the planning, development, integration, test, and operations of aerospace space systems. His last major task at NASA GSFC was as Program Administrator of the Systems Engineering Education Development (SEED) program. He served as Co-Chair of the INCOSE Space Systems Working Group of the Systems Engineering Applications Technical Committee. Ray received his BS in Physics from University of Portland, and did graduate work in Physics at University of Chicago.

Mark Brumfield is the Associate Division Chief for the Mission Engineering and Systems Analysis Division (MESAD) at NASAs Goddard Space Flight Center. The MESAD is responsible for end-to-end Mission Systems Engineering for all of the Goddard missions. Mark has 17 years experience in computer engineering, missile dynamic modeling, robotics, systems engineering, instrument systems engineering, project management, and organization management. He was a systems engineer for the instrument responsible for correcting the flawed mirror for the Hubble Space Telescope, Corrective Optics Space Telescope Axial Replacement (COSTAR) . He was the Instrument Systems Manager for the Polar Orbiting Environmental Satellite (POES) Program. He is the Program Manger for the Systems Engineering Education Development (SEED) Program. Mark received his BS in Mechanical Engineering from Purdue University and his M.S. in Mechanical Engineering specializing in both robotics and aerospace from The George Washington University.

Donald E. Jamison is the Program Administrator of the Systems Engineering Education Development (SEED) Program. He has 45 years of experience in information technology. He has participated and managed the development of hardware and software for space data processing, communications, and command and control systems for the government and industry. He has bachelor degrees in electrical engineering and business, and masters degrees with concentrations in operations research, business and computer systems.

Carolyn Casey is head of the Leadership Development for the Systems Engineering Educational Development (SEED) program at the NASA Goddard Space Flight Center. She has managed Technical Managers Training (TMT) Programs for over 14 years and has provided Communication and Leadership skills training to technical organizations for over 22 years. Carolyn provides cutting edge approaches to Leadership Development, Coaching, Knowledge Capture and Training. Her work with the Knowledge Capture Program, which was a forerunner to the SEED program, received a NASA Best Practices award. She designed, developed and implemented a Self Pace Learning Center at Goddard Space Flight Center. This facility has provided thousands of hours of in house training for government and contractor employees.

Carolyn received her BA in Psychology from University of Maryland Baltimore County and her MS in Applied Behavioral Science from Johns Hopkins University. She received her coaching training from The Coaches Institute of California and is a member of the International Coaches Federation. Carolyn is the recent recipient of the Goddard Excellence Award for Diversity Enhancement.

Stuart Heller is the CEO of WALKING YOUR TALK and developer of the Human Systems component of the SEED Leadership Program. He has applied Operations Research thinking to the difficult human issues of leadership, conflict, change, and character. When integrated with his forty years of East/West body/mind research, this became a sophisticated yet easy to apply learning technology. This human technology, blending language and motion, has also been successfully applied to the education of professional coaches, including the Newfield Network. He has worked with executives, teams, and corporations across the U.S. and abroad, including: NutraSweet, McDonalds, World Bank, AMS, ATTIBI, and Salus Intl – a U.S./Russian company as well as with several U.S. Government agencies. He designed a master's degree program in movement psychology for the first accredited graduate program in Clinical Holistic Health. The author of two books, he has a B.A. in mathematics, a M.S. in operations research, and a Ph.D in psychology. He was also awarded sixth degree black belts in two different martial arts.