Purdue's Engineer of 2020
Seed Grant Funding for 2008-2009
Purdue University

Project Title: Multidisciplinary Insights for Learning Engineering Aerospace Design (MILEAD)

Target Attribute(s) to be studied/implemented:

We will study and implement many elements of the "target attributes" identified by Purdue University College of Engineering.

- Abilities: teamwork; communication; decision-making; leadership; recognize and manage changes; synthesize engineering, business, and societal perspectives.
- Knowledge Areas: engineering fundamentals; open-ended design and problem solving skills; multidisciplinarity within/beyond engineering; integration of analytical, problem solving, and design skills.
- Qualities: adaptable in a changing environment

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A. Project Description:

Objective

We envision a new digital library created and shared by a network of instructors, students, departments, and industry experts via web portals and virtual worlds. The work supports our long-term goal of improving design education by providing students with a new dimension of design knowledge. The use of cyber-infrastructure could connect students directly to experts and peers to support their learning the art of design practice more effectively. The rich digital library we envision needs to be seeded with educationally appropriate resources to demonstrate its potential for intentional learning at the undergraduate engineering level. ***For the PE 2020, we propose demonstrating one way this cyber enabling technology could be used to develop learners' ability to synthesis their ideas informed by others.*** This ability enhances learners' effectiveness in collaborative design experiences leading to innovations they could not conceive on their own. We will evaluate the progressive refinement of learners' ability to blend others' ideas with their own to generate innovative conceptual designs.

Introduction

As the body of collective human knowledge expands, innovators are increasingly becoming specialized to achieve new breakthroughs. New micro-devices for sensing, communication, and biomedical applications are examples. However, the key to innovation in the synthesis of large-scale *complex systems* lies in the ability to combine individual specialties, often across diverse disciplines. Thus, the best complex systems design engineers in the next generation must be the best system integrators and collaborators. Designing a complex engineering system, such as a new interplanetary spacecraft or commercial aircraft, already requires real-time sharing among engineers in a dozen different disciplines. Furthermore, industrial globalization has made the innovation a distributed one, where firms often collaborate on one project while competing on others. It is no longer cost effective for firms to position scientists and engineers in the same place to maximize its design productivity; yet, close proximity is needed to foster the collaboration necessary for innovation in complex systems [Rich, 1994].

However, the effective use of virtual environments in this new design setting largely remains beyond reach, and the knowledge of how learners exploit collaboration among peers and with experts in such environments is poorly understood. Under a seed grant from this initiative, we will focus specifically on the efficacy of expert experience by faculty and advanced students on the complexities of design. To achieve the PE 2020 target attributes effectively and synergistically, our focused activities in the proposed project leverage our concurrent effort to teach an engineering design course in a Serious Game format. We design and evaluate our approach using our expertise in education theory and methods, particularly in the area of technology-supported teaching and innovation.

The PE 2020 Committee identifies *target attributes* for students facing the challenges of the twenty-first century [Hunt Tally, 2007]. In addition to the technical skills, these target attributes include teamwork, and communication skills as well as abilities to synthesize engineering, business, and societal issues. Successful synthesis requires sensitivity to other's perspectives along with the ability to identify connections to allow new ideas to emerge from the team. *Our conjecture is that this ability can be intentionally developed through traditional academic learning environments and in virtual worlds.*

With these goals in mind, we propose to develop a revolutionary educational tool based on digital content shared by the cyber-social network. To achieve the PE 2020 target attributes effectively and synergistically, the proposed project will be integrated into our concurrent effort to teach an engineering design course via virtual worlds. Specifically, ***we aim to illustrate the potential for using video interviews with experts from faculty, industry and senior undergraduates to develop learners' critical ability to identify and synthesize their ideas with others.***

Context: AAE251 Introduction to Aerospace Design in a Virtual World

We believe that the Introduction to Aerospace Design (AAE 251), a sophomore-level engineering course offered twice a year in the School of Aeronautics and Astronautics, will be the ideal platform for developing several of the target attributes identified by the PE 2020 Committee. Students in AAE 251

form cross-functional teams, a type of group organization that has played a significant role in modern workplaces [Gee, et al., 1996; Parker, 2002], to design aerospace vehicles via collaboration across disciplines (e.g. aerodynamics, propulsion, structure, dynamics and control). Students working in cross-functional teams must share their work to integrate smoothly beyond their own specialized area. Throughout the semester, students give technical presentations and submit group reports, progressively improving their verbal and written communication skills via feedback from their peers and the instructor. Although the course teaches various technical skills (e.g. engineering fundamentals, analytical skills, problem solving skills), it is the *synthesis of multi-disciplinary* engineering design (including business and societal considerations) that distinguishes AAE 251 from other courses at this level.

We are currently developing a MPO (multi-player online) serious-game version of AAE 251 via a seed grant from the Purdue Discovery Learning Center. The digital delivery system intends to effectively introduce learners to the design profession of aerospace engineering, increase the authenticity of teaming, and provide a process for measuring students' development in approaching and solving novel problems. The process of design is well-tailored for a game so that learners can productively engage in a series of "quests" (or challenges) involving collaborative design teams, research-and-design activities on specific components, and system-integration activities to bring the entire design together. We are combining current theories of learning and instruction with the principles of game design to provide a powerful new learning experience that prepares learners for the future.

In the past few years, numerous academic institutions began investigating the use of virtual worlds where students participate through avatars, or players' alter ego. More than a hundred universities currently offer classes in Second Life, a virtual world developed by the Linden Lab, and educators are forming communities to coalesce ideas on education via Second Life. Groups are designing their own spaces within these virtual worlds to enhance the experience between the "players" in the system. We too are experimenting with a variety of gameplay experiences that lead to intentional learning related to our goals for the course. One of these experiences is to develop learners' ability to productively interact with team members in pursuit of the game objective. Additional, smaller individual activities provide opportunities to obtain core knowledge. For example, once they are given quests to pursue, they should start with brainstorming ideas. Refining these ideas could occur through review of suggestions, or perspectives, provided by a panel of experts. *Through extended play with these quests, learners could develop the ability to better communicate their ideas with others, learn to adapt their ideas with others, and work toward identifying new ideas beyond what the individual could conceive.*

Also, experience shows that virtual worlds are conducive to live events that require real-time interaction, such as meetings, conversations, lectures, and presentations [Lagorio, 2007]. Unlike conventional image-absent chat client, speaking, hearing, and seeing other people's non-verbal responses (nodding, smiling, restlessly shifting, etc.) in the virtual worlds mimics the sensation of being there in person [Lagorio, 2007]. *These non-verbal cues are critical to supporting and sustaining a group's interaction.* Furthermore, when a team member has questions, the answer could be immediately demonstrated (by "show and tell"), rather than redirecting the questioner to studying the material alone, thus making the learning a social and collaborative experiences [Ondrejka, 2008]. *This process of sharing ideas and receiving rapid feedback on these ideas is fundamental to sustaining an individual and teams engagement with the process. This has implications for the gameplay in our virtual world. An important part of the process regarding the digital content we will develop is the follow-on conversation the team has about the multiple perspectives shared by the experts. When students anchor their conversation around specific events in the virtual world, relative to a shared goal like their quest, then they are more likely to be productive at identifying potential outcomes.*

Context: Developing Adaptive-ness Through Multiple Perspectives

The PE 2020 attributes relate to developing engineering expertise that is prepared for future learning. In recent years, more is becoming known about the nature of expertise and how it develops. Experts appear to display effortless application of knowledge and skills to solve problems. Their experience and depth of knowledge make problem solving in their domain very routine [Chi, 1982;

Hatano, 1986]. Therefore, they have the ability to identify potential solutions to problems without conducting much additional research [Wineberg, 1991]—a quality we desire our students to display and what we typically test them on. We sequester them without resources and ask them to solve problems using only their prior knowledge. Experts also have the ability to adapt to new situations. The ability of knowing what to do when you don't know something [Bransford and Schwartz, 1999] is a more critical outcome of instruction than just replicating and applying facts and concepts to familiar problems. These are skills that demonstrate preparation for future learning [Bransford and Schwartz 1999; Schwartz, Bransford and Sears, 2006]. This "adaptive expertise" is what transfers knowledge learned in one situation to generate new knowledge necessary to approach a novel situation. *Adaptive expertise involves accessing knowledge, concepts and skills developed from familiar situations, and looking beyond ones' own perspective to recognize alternative ideas.* This metacogntive ability to look outside-the-box (and ones own perceptions) to synthesize ones own ideas with other participants' requires developing a sensitivity to effectively evaluate one's ideas with alternatives relative to a specific task. This ability to synthesize ideas as a team lies at the heart of a successful conceptual design.

An instructional cycle called STAR.Legacy (Software Technology for Action and Reflection) [e.g. Schwartz, Brophy, Lin & Bransford, 1999] shown in Figure 1 has good results for developing learners perspective taking and being introduced to an academic and professional community. In this model of instruction, as in AAE 251, learners are given an open-ended, ill-structured problem to solve. The complexity and ambiguity of the challenge leads to more than one possible solution. Learners in our class begin by Generating Ideas and questions about what more they need to know to identify potential options. Next, they compare and contrast their ideas with Multiple Perspectives provided by "experts" familiar with aspects of the challenge. In a possible learning scenario enabled by this project, these perspectives may be short video clips (less than two minutes) of "experts" introducing themselves and sharing their insights to the problem. The array of experts provides a diverse perspective on the challenge. These experts could be faculty within a department, former students of the course, graduate students, or representatives from industry. These initial stages of the cycle provide an excellent orientation to the problem space. This learning cycle prepares students to engage in iterative cycles of acting on what they know and reflecting on how they might improve.

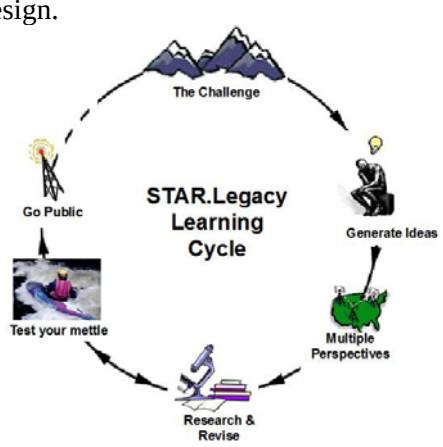


Figure 1- STAR.Legacy Cycle

Previous studies of the STAR.Legacy in domains of bioengineering, bioethics, and educational psychology have indicted the potential for using multiple perspectives [Schwartz et al, 2000; Bransford, et al, 2006]. Learners will typically generate ideas related to one or two perspectives are intrigued by perspectives they would have never considered. In our proposed project, therefore, *we see great potential in developing a library of video cases of faculty, advanced students and industry experts sharing their thoughts and ideas to a series of challenges that are part of an introductory engineering-design course.*

Proposed Project

The digital content developed through our project will include short video interviews with faculty members to share their research interests, classes they teach, as well as useful information for the course design project. Also, clips from people from industry will provide perspective on the design and how it is cultivated in an industrial setting. Such a collection of videos, even short ones lasting a few minutes, help students learn engineering fundamentals in the context of broader view, and can introduce our faculty more vividly and communicate information more effectively to students. Delivered through multiple hosts (web portal, learning module in a learning-management system, or a Virtual World), the digital resources form the hub of a social network. In a web portal or virtual world, students and experts are quickly connected together by the keywords and the links created by the user. Such cyber infrastructure opens doors for new collaborations between educators and researchers across departments and institutions

which is part of longer term vision for this project. The speed and scale with which such web portals can connect people is staggering. (For instance, once a video is uploaded in *YouTube*, videos with related contents are quickly linked as a result of collective information aggregation.) Researchers in Purdue's nanoHUB use a similar metaphor for supporting research. This kind of enterprise requires cultivation over time and needs to be seeded with quality examples. This project will produce those examples.

As Fig. 2 shows, our digital resources will be first tested in AAE 251 and other AAE courses using existing technology at Purdue (i.e., Blackboard) and through advanced learning technologies (i.e., multi user virtual worlds). Students will soon become the content providers themselves. Leveraging the Serious-gaming initiative, we will evaluate the effectiveness of our revolutionary teaching tool from educational theories and empirical results. *The findings from this proposal will provide us with important insights about the affordances of both traditional academic learning spaces and the evolution of technology mediated learning spaces that provide different pace and mechanism for teams to collaborate.* We will share our results with the broader community at academic conferences and in published journal articles.

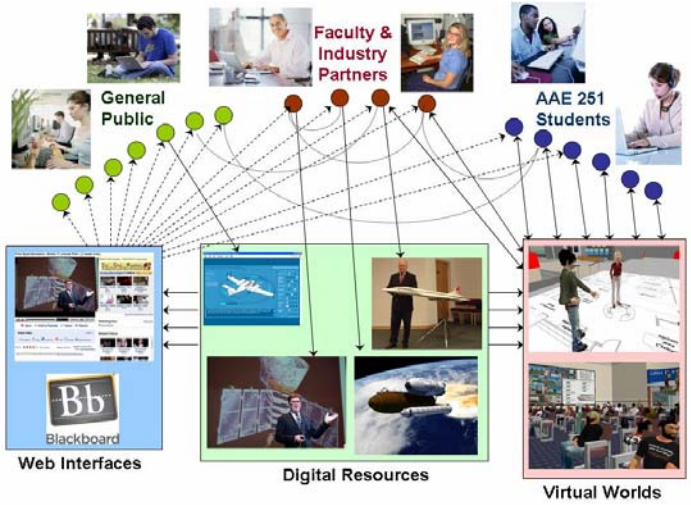


Fig. 2: Schematic of Proposed Concept. Digital resources (e.g. Video Lectures, Demonstrations, and Visualized Simulations) are developed through collaboration with faculty and industry partners. These resources are made available via the Virtual World for AAE 251 students and for the general public (including faculty, industry partners, and former, current, and future AAE 251 students). Through the Proposed Cyber-Infrastructure the Faculty and the Industry Partners Can Give Real-Time Feedback, Forming Communities Across Geographically Dispersed Locations.

Our proposed effort will be carried by two students (one graduate, one undergraduate) supported by Dr. Daniel DeLaurentis, Assistant Professor in AAE, Dr. Sean Brophy, Associate Professor in School of Engineering Education, and Dr. Kathleen Howell, Professor in AAE. Additionally, Prof. William Crossley from AAE, an instructor for Senior Design, has pledged his participation in order to forge and foster the Soph-Senior Design connection for the project. Dr. DeLaurentis, the current instructor for AAE 251, has expertise in complex systems design and networked systems. Dr. Brophy, whose expertise includes technology-supported learning environments, will lead evaluating the effectiveness of our teaching and innovation tool. Dr. Howell, a world-renowned researcher in astrodynamics and mission design, will integrate her courses and research as test beds (in addition to AAE 251) and serve as pilot participant for expert clips. Dr. Masa Okutsu, Post-doctoral Researcher in AAE, brings experiences in aerospace mission design and will coordinate developing the digital contents via collaborations with research groups on campus and with our industry partners.

Evaluation

The new digital content will be used in both the present course format and in the virtual world to achieve the learning outcomes related to PE 2020, developing and synthesizing others perspectives with ones one ideas. The first study will use learning modules delivered through the Blackboard Learning Management system as part of a shortened STAR.Legacy cycle. As an assignment before lecture, students complete an online module that presents a design challenge. Students generate ideas and questions related to the design challenge. Then, half the students will view the multiple perspectives that we've produced and compare their response with the other perspectives. Unlike previous studies, we will

also ask students to explain how they would refine their response based on what they learned from the perspectives. All students would then participate in the traditional lectures and homework assignments. After participating in these learning opportunities (about 1 week), all students will be asked to review the perspectives again and compare them with their initial responses. We will then ask all students to complete a short exit survey on their perceptions of challenge and the potential of the perspective as a catalyst to their thinking about alternative solutions. The experiment will be repeated across multiple challenges. We anticipate students will increase the number of alternative ideas and conditions considered with each new challenge they encounter. Further, we anticipate that learners who do not review multiple perspectives after generating ideas are less likely to pick up critical content for the learning activities. Content analysis of the learning materials and student's responses will provide the data necessary to determine if a difference exists between the groups.

Once the virtual world is completed, we will initiate "quests" for students to participate in a second study. Currently, our vision for the game play will begin with the presentation of a "quest" during a meeting with their boss. The boss will ask for their initial thoughts and questions about the quest. Then she will recommend the "players" sit in on a panel discussion of experts (i.e., our video based multiple perspectives) who are talking about the "quest" and to send her new ideas afterword. The protocol for this condition replicates the sequence of activities used in the first study but involves a more authentic workflow that might be experiences on the job. A third condition with this study could involve an in-depth study of how the group develops and refines an idea after sharing the experience of listening to the experts. The real time, anchored event could have a significant impact on their group dynamics, but this is outside the scope of this project and will be explored as part of future funding.

Dissemination

Results of this study will be reported at the American Society of Engineering Education and the Journal of Engineering Education. In addition, our results will be presented during technology and learning conference on campus (e.g. ITaP's brown bad seminar and technology conference in the Spring). We see this work being instrumental for an NSF CDI grant we are currently writing.

Intellectual Merit

Through our project, we tap into the body of collective knowledge on campus and in industry to form communities of educators, researchers, and students, connected by the cyber social network. Through our pedagogical use of these resources, we achieve several of the PE 2020 attributes. Learners are encouraged to be innovative and generative based on what they know, and to ask questions about what more they need to know. They learn to listen better to what others are offering and to synthesize with their own. The challenges provide grounding experiences through ideas and tips provided by "experts" in the videos. While the amount of digital content that can traffic into the virtual world is staggering, the web portal will facilitate quickly locating relevant materials and transferring information to the learners just in time and on demand (rather than being constrained to a rigid lesson schedule). We will make these learning resources accessible to all students via the web portal. Our project will serve as the demonstrator for the new model for innovation, education, and collaboration in the university environment.

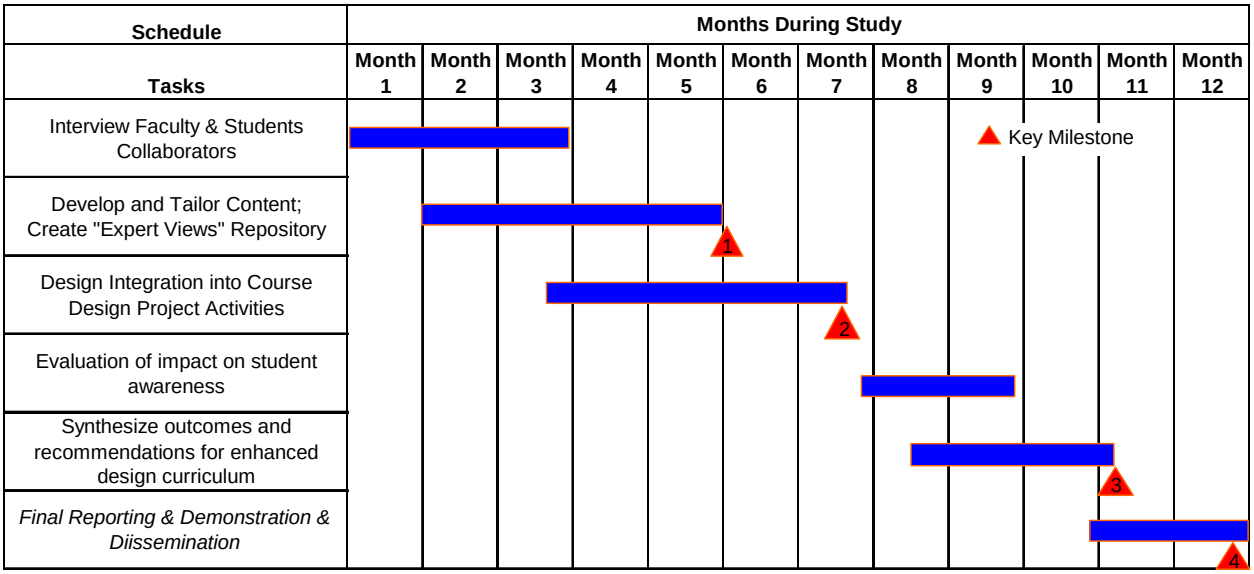
Broader Impact

With the staggering speed and scale with which our cyber-enabled education and innovation model can spread, the impact on the engineering education and research can extend beyond Purdue's Engineers of 2020 program. In our proposal, the peer-to-peer learning is accelerated by the network of communities, digital content and virtual worlds connecting a variety of educational levels and fields as well as industry partners. The communities of educators and research groups formed through our project provide new opportunities for collaborations in teaching and in research.

We anticipate that our pedagogical approach will provide other instructors with ideas about how to leverage expertise on campus and how to use resources like Blackboard to support instruction. The technological bridge between the digital resources and the virtual game will be an excellent resource enhancing the kinds of access to information that a learner experience in the virtual world.

B. Timeline and Implementation Strategy

We display below a timeline of major activities with milestones. The more detailed implementation strategy is described in the 'Proposed Project' section above.



C. Personnel Requirements

Portion of FTE that each faculty member will dedicate to the project

Faculty member	Summer 08	Fall 08	Spring 09
Daniel DeLaurentis	1 week	3%	3%
Sean Brophy	1 week	3%	3%
Kathleen Howell		1.5%	1.5%

D. Budget

Faculty/Staff Member Funding Please indicate the funding (dollars and time) you are requesting for the grant for this project)			
	Grant funds requested		
Faculty/Staff Name:	% Time	Fringe Benefits	$$
Masa Okutsu-Post Doc	15.60	2457.26	6365.97
Subtotal Faculty/Staff Funding		$ 2457.26	$ 6365.97

Graduate Students				
	Grant funds requested			
Type of position	% Time	Insurance + Fee Remit	Fringe Benefits	$$
Graduate Student	50	7603.44	148.74	24790.54
Subtotal Graduate Student Personnel		$ 7603.44	$ 148.74	$ 24790.54

Undergraduate Student Funding *Please indicate the student resources (funding, time) requested from the grant for this project.*			
	Grant funds requested		
Type of position	Hrs/week	Fringe Benefits	$$
Undergraduate Student	15	676.39	7957.46
Subtotal Undergraduate Student Personnel		676.39	7957.46

Equipment $ Software Funding *Please list all specialized equipment and software required for the project. (Do not include standard computer equipment and commonly-available software, e.g. Microsoft Office, Microsoft Windows). Mark whether any of the equipment or software is provided by the department. (Note that only 10% of the funds can be used to purchase equipment and it needs to be dedicated to the goals of the project.*	
Name of Equipment	Funds Requested
Video equipment/associated software	$1500.00
Subtotal Equipment	$1500.00
Name of Software	
Subtotal Software	$0.00
Other miscellaneous items (Computer media, cables, etc)	
Subtotal miscellaneous	$0.00
Other expenses	
Subtotal other expenses	

E. Budget Justification

The success of this project depends on the amount of digital resources and their relevancy to the learners. One ½ time graduate student and one undergraduate student (15 hours/wk) will work closely with the post-doc, coordinating with the experts and students to develop, edit, and upload digital resources. Our post-doctoral researcher will devote significant effort (16% of working time, though more time the better) to blueprint how numerous expertise sources on campus and in industry will tie into the teaching objective of AAE 251. Furthermore, he will assist developing and evaluating the lesson plan for this course delivered via virtual world for the first time this fall. Other than video equipment/software, any equipment or software needed is already available to us via department resources and/or our DLC Serious Games grant project.

F. References

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Wineburg, S. S. (1991). Historical problem solving: A study of the cognitive processes used in the evaluation of documentary and pictorial evidence. Journal of Educational Psychology, 83, 73-87.

G. PI Biosketch (1-2 pages following similar format used for NSF grants)

DANIEL DELAURENTIS

Professional Preparation

Florida Institute of Technology	Aerospace Engineering	BSAE	1992
Georgia Institute of Technology	Aerospace Engineering	MSAE	1993
Georgia Institute of Technology	Aerospace Engineering	PhD	1998

Appointments

August 2004 - present: Assistant Professor, School of Aero/Astro Engineering, Purdue University
Sept. 2003 - July 2004: Visiting Assistant Professor, School of Aerospace Engineering, Georgia Tech
Jan. 1999 - Aug. 2003: Research Engineer II, School of Aerospace Engineering, Georgia Tech

Publications

(i) Five publications most closely related to the proposed project

- DeLaurentis, D., Fry, D., "System-of-Systems Approach for Understanding Future Airport Requirements," *Transportation Planning and Technology*, Volume 31, Issue 1 February 2008 , pages 69 - 92..
- DeLaurentis, D., Callaway, R., "A System-of-Systems Perspective for Future Public Policy," *Review of Policy Research*, Vol. 21, Issue 6, Nov. 2004. pp. 829-837
- J. Lewe, D. DeLaurentis, D. Mavris, D. Schrage, "Modeling Abstraction and Hypothesis of a Transportation Architecture," *Journal of Air Transportation*. Vol. 11, No.3, Fall, 2006. [Sorensen BEST Paper Award for 2006]
- DeLaurentis, D., Crossley, W., "A Taxonomy-based Perspective for Systems of Systems Design Methods," Proceedings of IEEE System, Man, & Cybernetics Conference, Hawaii, Oct. 10-12, 2005. Paper 0-7803-9298-1/05.
- DeLaurentis, D., "Framework for Representing the Role of Human Systems in the Complexity of a System-of-Systems," Handbook of Digital Human Modeling for Applied Ergonomics and Human Factors Engineering, Vince Duffy, Editor, in press and to appear Spring 2008.

(ii) Other publications related to the proposed project

- Utturwar, A., Rallabhandi, S., DeLaurentis, D., Mavris, D., "A Two-Step Optimization Approach for Technology Selection," *Engineering Optimization*, Vol. 38, No. 8, Dec., 2006. pp. 889 – 908
- Peeta, S., Paz, A., DeLaurentis, D., "Stated Preference Analysis of a New Microjet On-demand Air Service," accepted and in press with *Transportation Research Part A: Policy & Practice*, to appear Spring 2008.
- DeLaurentis, D., Kang, T., Lim, S., "Solution Space Modeling and Characterization for Conceptual Air Vehicles," *AIAA Journal of Aircraft*, Vol. 41, No. 1, Jan-Feb, 2004. pp. 73-84.
- Agusdinata, D., DeLaurentis, D., "Specification of System-of-systems for Policymaking in the Energy Sector," accepted in *Integrated Assessment*, to appear early 2008.

Synergistic Activities

- **Technical Program Co-Chair** for the 2007 IEEE International Conference on System-of-Systems Engineering, San Antonio TX, April 16-18, 2007.

- **Organizer (with W. Crossley)**, *Methods for Designing, Planning, and Operating System-of-Systems*, a Workshop sponsored by the Air Force Office of Scientific Research (AFOSR), Indianapolis, IN, May, 2006.
- **Organizer (with R. Callaway)**, *System-of-Systems "Summer Conversation"*, a Symposium held at Potomac Institute for Policy Studies in Washington D.C., July 2004
- **Innovations in Teaching and Training**: Received $150K research grant award from Purdue's Discovery Learning Center (DLC), with faculty colleagues from Dept. of Engineering Education (Sean Brophy) and Electrical Engineering (David Ebert), to create a "Serious Game" version of the sophomore aerospace engineering design course. If successful, this will be one of the very few courses available in this format and represent a major advancement in the use of digital technology and virtual worlds for advanced learning especially in the STEM disciplines.
- **Academic Outreach:**
    - "The Role of Complexity in System-of-Systems Engineering," 2007 Conference of the International Society for Industrial Ecology (ISIE), Toronto, June 20, 2007. **(Invited Plenary)**
    - **Delft University of Technology –** Seminar for the Technology, Policy & Management Faculty, September, 2006
    - **University of Notre Dame –** Seminar for the Mechanical and Aerospace Engineering Department, April, 2006
- **Senior Member**, American Institute of Aeronautics and Astronautics (AIAA), 1988-present.
    - **Technical Program Chair** for the 9th AIAA/ISSMO Symposium on Multidisciplinary Analysis and Optimization, held in Atlanta, GA in September, 2002
    - **Member (1999-Present)**- Incoming Chair of Air Transportation Systems Technical Committee (TC) of the (AIAA); past member of the Multidisciplinary Design Optimization TC.

Collaborators & Other Affiliations

(i) Collaborators

- Sean Brophy, David Ebert, Srini Peeta, William Crossley, Barrett Caldwell-Purdue University
- George Donohue – George Mason University
- Datu Agusdinata, TU Delft TPM Faculty
- Robert Callaway, PhaseOne Communications Inc.
- Don Fry, Aero/Astro Engineering, Purdue University
- En-Pei Han, Aero/Astro Engineering, Purdue University
- Mo Jamshidi, Univ. Texas – San Antonio
- Tim Kang, Jung-Ho Lewe, Samson Lim - Georgia Tech
- Dimitri Mavris, Daniel Schrage- Aerospace Engineering, Georgia Tech
- Aditya Utturwar, IIT Bombay

(ii) Graduate Advisors

- Anthony Calise, Aerospace Engineering, Georgia Tech
- Daniel Schrage, Aerospace Engineering, Georgia Tech

(iii) Thesis Advisors (Completed)

- Oleg Sindiy, Aero/Astro Engineering, Purdue University

Number of thesis students currently being advised = 6

SEAN P. BROPHY

PROFESSIONAL PREPARATION

The University of Michigan - Mechanical Engineering, BSME, 1982.
DePaul University - Computer Science (Artificial Intelligence), MSCS, 1992.
Vanderbilt University - Education and Human Development, PhD 1998.

PROFESSIONAL EXPERIENCE

2005 – Present	Assistant Professor in the Department of Engineering Education – Purdue University
1999 - 2005	Research Assistant Professor in the Department of Biomedical Engineering – Vanderbilt University
1998 - Present	Postdoctoral Scholar with the Center for Innovative Learning Technologies (CILT) – Vanderbilt University
1992 - 1998	Research Associate - Learning Technology Center of Vanderbilt University
1991 - 1992	Control Systems Engineer - DAI Technologies, Inc. Lyle Illinois
1990 - 1991	Programmer - The Institute for the Learning Sciences (ILS) at Northwestern University
1990 - 1991	Teaching Assistant and Tutor - DePaul University
1983 - 1989	Lead Engineer - Williams International

PUBLICATION

Roselli, R. J. and Brophy, S. (2006). Effectiveness of Challenge-Based Instruction in Biomechanics. Journal of Engineering Education. 95(4). P 311-333.

Brophy, S. P. (2003) Constructing Shareable Learning Materials in Bioengineering Education. IEEE Engineering in Medicine & Biology Magazine. 22(4), p 66-70.

Brophy, S. P. (2000). Establishing effective collaboration for knowledge building with technology supports. In Victoria Risko & Karen Bromley (Eds) Collaboration for Diverse Learners: Viewpoints and Practices. Reading Association:Newark, DA.

Bransford, J. D., Brophy, S. P., & Williams, S.M. (2000). When Computer Technologies Meet the Learning Sciences: Issues & Opportunities. Applied Developmental Psychology, 21(1).

Brophy, S. P., Biswas, G., Katzlberger, T., Bransford, J. D. & Schwartz, D. L. (1999) Teachable Agents: Combining insights from learning theory and computer science. Proceedings of the 1999 Artificial Intelligence in Education Annual Conference, Le Mans, France.

Schwartz, D. L, Brophy, S., Lin, X. & Bransford, J. D. (1999) Software for managing complex learning: Examples from an educational psychology course. Educational Technology Research and Development. 47(2). p 39-60

Brophy, S. P., & Schwartz, D. L. (1998) Interactive analogies. In D. Edelson & Eric Domeshek (Eds.), Proceedings from the 1996 International Conference on the Learning Sciences (pp. 351-356). Evanston, IL: Association for the Advancement of Computing in Education.

Brophy, S. P.(1998). *Learning scientific principles through problem solving in computer supported and laboratory environments.* (unpublished dissertation, Vanderbilt University).

SYNERGISTIC ACTIVITIES

The Biomedical Engineering department at Vanderbilt University is a member of an Engineering Research Center (see - www.vanth.org) to improve biomedical engineering education. Members of the Learning Science thrust work collaboratively with domain experts to explore new methods of instruction and issues of learning.

The INSPIRE funded by the Bechtel Foundation is for fundamental research associated with teaching and learning of engineering in preK-5 grade learners.

Developing advances learning environments for complex domain like aerospace design in collaboration with Dan DeLaurentis. Working to integrate technologies from the ERC mentioned above.

COLLABORATORS (Last 48 mo.)

John Bransford (University of Washington), Dan DeLaurentis (Purdue), lLarry Howard (ISIS at Vanderbilt University), P.K Imbrie (Purdue), Stacy Klein (Vanderbilt/University School of Nashville), Taylor Martin (University of Texas), James Pellegrino (University of Illinois), Anthony Petrosino (University of Texas), Robert Roselli (Vanderbilt University), Nancy Vye (University of Washington)

Graduate Advisor: Robert Sherwood (Vanderbilt University)

Post Doctoral Advisor: John Bransford (Vanderbilt University) Center for Innovative Learning Technologies

KATHLEEN CONNOR HOWELL
Hsu Lo Professor of Aeronautical and Astronautical Engineering
School of Aeronautics and Astronautics, Purdue University, Tel: (765) 494-5786

A. GENERAL INFORMATION

Education

B.S. — Iowa State University, Aerospace Engineering, 1973
M.S. — Stanford University, Aeronautical and Astronautical Engineering, 1977
Ph.D. — Stanford University, Aeronautical and Astronautical Sciences, 1983
Graduate Advisor: John V. Breakwell

Professional Experience

Academic: Jan-Aug 1982 Visiting Assistant Professor, Purdue University, Aeronautics & Astronautics
Aug 1982-Aug 1988 Assistant Professor, Purdue University, Aeronautics & Astronautics
Aug 1988-Aug 1997 Associate Professor, Purdue University, Aeronautics & Astronautics
Aug 1997-present Professor, Purdue University, Aeronautics & Astronautics

Industrial: June 1973-September 1976, Procter and Gamble Manufacturing Company, Kansas City, Kansas
1978, 1979, 1980, Engineer, Jet Propulsion Laboratory, Pasadena, California (Summer)
1983 USAF/ASEE Summer Faculty Fellow, Air Force Rocket Propulsion Laboratory, Lancaster, California

Representative Awards and Honors

E.F. Bruhn Teaching Award, Aero/Astro (AAE), Purdue University, 1984, 1987, 1990, 1995, 2002, and 2005.

A.A. Potter Best Teacher in Engineering Award, Purdue University, 1984 (AAE nominee 1984, 1987, 1991, 1996, 2003 and 2006).

Presidential Young Investigator Award, National Science Foundation, 1984.

Dow Outstanding Young Faculty Award (Illinois-Indiana) American Society for Engineering Education, 1986.

New Engineering Educator Excellence Award, American Society for Engineering Education, 1987.

NASA ACRP Fellow, Advanced Concepts Research Projects Program, 1996.

Purdue Book of Great Teachers, 1999.

Fellow, American Astronautical Society, 1999.

One of Five Finalists, 13th Annual Discover Magazine Innovation Award (Aerospace Finalist), 2002.

Named as one of the '50 Most Important Women in Science' by Discover Magazine, November 2002.

TRIANA Mission Achievement Award, NASA Goddard Space Flight Center, 2002.

Associate Fellow, AIAA, 2004.

American Astronautical Society Dirk Brouwer Award: For Significant Technical Contributions to Space Flight Mechanics and Astrodynamics, 2004.

International Astronautical Federation, IAC Astrodynamics Symposium, John V. Breakwell Memorial Award and Lecture 2007.

Academic and Professional Memberships

American Astronautical Society (AAS), American Geophysical Union (AGU), American Institute of Aeronautics and Astronautics (AIAA), American Society for Engineering Education (ASEE), Sigma Gamma Tau, Sigma Xi (the Scientific Research Society)

B. RESEARCH

Publications – Over 100 publications in various national and international forums including the following:

[1] Barden, B.T., and Howell, K.C., "Fundamental Motions Near Collinear Libration Points and Their Transitions," *Journal of the Astronautical Sciences*, Vol. 46, No. 4, Oct-Dec 1998, pp. 361-378.

[2] Ely, T.A., and Howell, K.C., "East-West Stationkeeping of Satellite Orbits with Resonant Tesseral Harmonics," *Acta Astronautica*, Vol. 46, No. 1, January 2000, pp. 1-15.

[3] Howell, K.C., Marchand, B.G., and Lo, M.W., "Temporary Satellite Capture of Short-Period Jupiter Family Comets from the Perspective of Dynamical Systems," *Journal of the Astronautical Sciences*, Vol. 49, No. 4, October-December 2001, pp. 539-557. (Best Paper Award)

[4] Howell, K.C., and Marchand. B.G., "Natural Formations and Control Strategies for Non-Natural Formations near the Libration Points," *Dynamical Systems; an International Journal*, Special Issue: "Dynamical Systems in Dynamical Astronomy and Space Mission Design," 2004 (Invited).

[5] Howell, K.C., and Marchand, B.G., "Control Strategies for Formation Flight in the Vicinity of a Libration Point Orbit," *Journal of Guidance, Control, and Dynamics*, Vol. 28, No. 6, November-December 2005, pp. 1210-1219.

[6] Howell, K.C., and Kakoi, M., "Transfers between the Earth-Moon and Sun-Earth Systems using Manifolds and Transit Orbits," *Acta Astronautica*, Vol. 59, 2006, pp. 367-380.

[7] Howell, K., Beckman, M., Patterson, C., and Folta, D., "Representations of Invariant Manifolds for Applications in Three-Body Systems," *Journal of the Astronautical Sciences*, Vol. 54, No. 1, January-March 2006.

[8] Grebow, D., Ozimek, M., Howell, K., and Folta, D., "Multi-Body Orbit Architectures for Lunar South Pole Coverage," AAS/AIAA Space Flight Mechanics Meeting, Tampa, Florida, January 2006.

[9] Howell, K., and Millard, L., "Control of Satellite Imaging Formations in Multi-Body Regimes," IAF 57th International Astronautical Congress, Valencia, Spain, October 2006, Paper No. IAC-06-C1.8.01.

[10] Millard, L. and Howell, K., "Control of Interferometric Spacecraft Arrays for (u,v) Plane Coverage in Multi-Body Regimes," AAS/AIAA Space Flight Mechanics Meeting, Sedona, Arizona, January 2007. (Best Paper Award)

Recent Collaborators:

D. Folta (NASA Goddard Space Flight Center), N. Strange (Jet Propulsion Laboratory), B. Marchand (University of Texas–Austin), R.Wilson (Jet Propulsion Laboratory), J. Longuski (Purdue University)

Co-Editors: J. Crassidis (University at Buffalo–SUNY), J. Junkins (Texas A&M University), L. Markley (NASA Goddard Space Flight Center), F. Hoots (Aerospace Corporation), B. Williams (KinetX), L. D'Amario (Jet Propulsion Laboratory)

Invited Presentations and Seminars – National and International Venues including:

[1] "Halo Orbits and Other Libration Point Trajectories," MIT, Cambridge, Massachusetts, December 1991.

[2] "Station-Keeping of Halo Orbits and Related Problems," Space Research Institute of the Russian Academy of Sciences, Moscow, Russia, February 1992.

[3] "Trajectory Design Strategies in the Vicinity of the Sun-Earth Libration Points," Department de Matematica Aplicada i Ana lisi, Universitat de Barcelona, Barcelona, Spain, January 1996.

[4] Plenary Speaker, Fifth SIAM Conference on Applications of Dynamical Systems, Snowbird, Utah, May 1999.

[5] "The Lagrange Points and the Exploration of Space: Fundamental Dynamics," Special NASA Working Group, Presentation to NASA Headquarters Personnel, JPL, Pasadena, California, October 2000.

[6] "The Timing Condition and Trajectory Design," University of Paderborn, Germany, 2002.

[7] "Spacecraft Mission Design in Multi-Body Regimes and the Application of Dynamical Systems," NSF IGERT Program: Dynamics of Complex Systems in Science and Engineering, Northwestern University, 2004.

[8] "Design Strategies for Libration Point Missions: Theory to Applications," 6th International Congress on Industrial and Applied Mathematics, Zurich, Switzerland, July, 2007.

Special Panels and Review Teams – NASA Mission Reviews and Other Program Assessments Including:

MAP (Microwave Anisotropy Probe) Mission Trajectory Design Peer Review Panel, NASA Goddard Space Flight Center, December 1999 and September 2002 (Chairperson).

NASA Red Team, MAP Mission, Office of the GSFC Director of Flight Assurance, 2000-2001.

TRIANA Mission Trajectory Design Peer Review Panel, NASA Goddard Space Flight Center, Sept 2001.

NASA Solar Sail Technical Assessment Group (TAG), In-Space Propulsion Technical Assessment Area of the NASA Advanced Space Transportation Program at Marshall Space Flight Center, 2002, 2003.

National Research Council Committee on the National Aerospace Initiative, August – December 2003.

Review Panel, "Technology Maturity Criteria", Jupiter Icy Moons Orbiter Project, Jet Propulsion Laboratory, 2004.

WMAP Shadow Avoidance Maneuver Peer Review, NASA Goddard Space Flight Center, 2006.

C. SERVICE

Service in support of Aeronautics and Astronautics and Purdue University: Departmental Committees; seminars and committees associated with the Women in Engineering Program; Search Committees; Teaching Academy, Promotions Committees, Associate Dean of Engineering Research Advisory Committee.

Service to Professional Organizations and the Professional Community: Board of Directors, American Astronautical Society (1993-2001); Editor-in-Chief, *The Journal of the Astronautical Science* (1992-2008); AIAA Astrodynamics Technical Committee (1985-1992); AAS Spaceflight Mechanics Technical Committee (1995-2001, 2004-2008); Astrodynamics Technical Committee, International Astronautical Federation (1999-2005); National and International Program Committees; Reviewer for technical publications and proposals to various organizations.

Current and Pending Support

(See GPG Section II.D.8 for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: **Daniel A Delaurentis**

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: System-Of Systems Engineering: A New Systems Analysis for Integrated Design(Fellowship for Donald Fry)

Source of Support: National Aeronautics and Space Administration

Total Award Amount: $30,000 Total Award Period Covered: 8/1/07-7/31/08

Location of Project: West Lafayette, Indiana

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Network Restructuring Scenarios for ATO Forecasts

Source of Support: Federal Aviation Administration

Total Award Amount: $50,000 Total Award Period Covered: 5/1/07-12/31/07

Location of Project: West Lafayette, Indiana

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr: .25

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Development of AEA251 Intro to Aerospace Design as a Multi-player Online Serious Game

Source of Support: Lily Endowment

Total Award Amount: $105,000 Total Award Period Covered: 12/1/04-12/31/08

Location of Project: West Lafayette, Indiana

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr: 1.0

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: A System of Systems Approach for Modeling Infectious Disease Outbreaks

Source of Support: Purdue Research Foundation

Total Award Amount: $15,712 Total Award Period Covered: 9/1/06-5/31/09

Location of Project: West Lafayette, Indiana

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Dependency Analysis and New Concepts for Metroplex Operation

Source of Support: George Mason University

Total Award Amount: $195,000 Total Award Period Covered: 8/1/07-9/30/09

Location of Project: West Lafayette, Indiana

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr: .50

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*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Current and Pending Support

(See GPG Section II.D.8 for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: **Daniel A Delaurentis**	Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Research on Defense Acquisition Management for System of Systems

Source of Support: Naval Postgraduate School

Total Award Amount: $100,000 Total Award Period Covered: 10/1/07-9/30/08

Location of Project: Purdue University

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Development and Testing of Innovative Health Management Tools for Damage Detection, Evaluation, and

Source of Support: CACI, International

Total Award Amount: $30,000 Total Award Period Covered: 8/1/07-4/15/09

Location of Project: Purdue University

Person-Months Per Year Committed to the Project. Cal: Acad: 10% Sumr: 0

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: System-of-Systems Approach for Assessing New Technologies in NGATS

Source of Support: National Aeronautics and Space Administration

Total Award Amount: $260,000 Total Award Period Covered: 10/1/07-09/30/09

Location of Project: Purdue University

Person-Months Per Year Committed to the Project. Cal: Acad: 5% Sumr: .75

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.