AN ADVANCED LEARNING ENVIRONMENT FOR THE AEROSPACE INDUSTRY

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BACKGROUND

Solving the fundamental problem of transferring knowledge from an aging workforce is a significant trend sweeping across many of the industry segments started in the mid 1900's. This is particularly true in the aerospace industry. While knowledge capture and management efforts have been underway in the segment for a while, many are company specific and do not fully leverage the collective knowledge of industry, academia, and government. All of these areas hold key components of the overall knowledge pool. Managing and organizing this knowledge and disseminating it to a broad audience can be a challenge.

Many of the aerospace community's technical workforce, including program managers, engineers, and technicians will reach retirement age within the next five to ten years. As these experienced and valued aerospace specialists depart NASA programs through retirement, the aerospace community will be significantly and adversely affected by the loss of a critical knowledge base within the workforce, unless that knowledge can be captured and incorporated into effective, evolving learning systems.

One of the key tactics used to meet this challenge is to provide a unified, online corporate university. Taking advantage of the global reach of the Internet allows for economies of scale. The Florida Space Research Institute s (FSRI's) *Advanced Learning Environment* (*ALE*) takes advantage of the technology as well as leveraging broad access across industry, academia and government. The *ALE* is an entirely web-based virtual learning environment complete with training, collaboration, and community resources.

The long-term goal of the *Advanced Learning Environment* program is to provide effective means of training professionals and technicians in a broad range of engineering areas critical to the future of the nation s aerospace sector. Currently, a comprehensive aerospace technician curriculum is available comprising over 50 discrete e-learning modules and encompassing more than 35 hours of student instruction. Technician training modules include such topics as:

- Introduction to Cleanrooms (3 hours)
- Aerospace 101 (8 hours)
- Digital Electronics (5 hours)
- Fundamentals of Instrumentation (22 hours)

In addition, the *Advanced Learning Environment* will ultimately focus on two tracks of aerospace engineering education for its students to follow. First is the aerospace operations engineer track, which will concentrate on the education of the current and future aerospace operations engineers, educating those engineers in processes such as cryogenics and rocket propulsion. The second *ALE* track is designed for the aerospace research and design engineer. In the initial years, the first of the tracks will be developed with particular emphasis on the cryogenics operations so critical to launch operations. This complex domain represents all of the instructional, knowledge capture, and knowledge representation challenges that must be addressed in the broader engineering context.

The *Advanced Learning Environment* requires a synergistic coupling of advanced instructional technologies with information and simulation technologies. This concept integrates three learning environments: the expert-managed, the self-paced, and the collaborative environments, which, when brought together, form the *Advanced Learning Environment*.

In the expert-managed environment, the instructor presents an overview of the subject matter, using advanced visualization facilities, and asks penetrating questions to develop the students' critical thinking and creativity skills. The expert-managed environment allows group processing activities and both peer-to-peer and student-to-instructor interaction.

In the self-paced environment, the student explores the details of the topic using an intelligent tutoring system with a virtual instructor acting as facilitator. The self-paced environment offers the advantage of being available at any time from any location with the minimum equipment. Facilities are provided to enhance understanding of applicable physical principles and for computer simulation of physical experiments and phenomenon. An intelligent tutor (adaptive learning system) is utilized to test the level of comprehension and knowledge of the student and will determine if repetition of the material is appropriate. The use of assessment instruments will ensure the validity of the instruction (this applies to the expert-managed environment, as well).

In the collaborative environment, facilities, such as those used for tele-presence, connect geographically dispersed students and instructors, from different disciplines, working on a joint project. The collaborative environment includes visualization and multimedia with intelligent software agents, virtual reality, and advanced human-computer interface/communication technologies, including perceptual user interfaces and natural language communication.

The technical content utilized in each environment is generated as reusable modules or "content objects". An expert or experts in a specific topic, working in collaboration with multimedia and instructional technology experts, develop each "object". The mini-learning modules are packaged into different disciplinary and interdisciplinary courses and programs, levels of detail, and domains, and are then stored in a web-based relational data-base. This design provides the flexibility for new interdisciplinary programs to be developed with multiple reuses of the objects available to meet multiple current needs, as well as future needs, as they evolve. Future needs might well include topics such as revolutionary spaceport technologies or mission needs that have not yet been identified.

The realization of an advanced distributed learning environment requires a consortium of learning institutions partnered with technology providers such as vendors of intelligent software agents, virtual reality, advanced human computer interfaces, and authoring tools. Working with learning institutions and the technology providers are industry users who can define their needs. A fully integrated multi-disciplined program management team bring these three partners together.

The careful definition of learning outcomes, the target audience, and the technology processes, in an interactive manner, will insure that proper design and development of supporting technologies for the *Advanced Learning Environment*. Then, the continuous monitoring of the effectiveness of the *ALE* will insure that all program goals are met, providing for on-going life cycle maintenance.

ALE Screen Images

E-LEARNING AS AN EMBEDDED PART OF THE SOLUTION

The acquisition of the incumbent knowledge has been (and will continue to be) gathered via traditional font-end analysis techniques, including task analyses and learning analyses (future strategies include concept mapping/knowledge engineering as discussed later in this paper). This acquired knowledge is then distilled into key learning/performance objectives and developed into two types of web-enabled delivery: asynchronous and synchronous.

By far, the majority of content currently contained within the *ALE* is asynchronous, self-paced training. Over 30 total hours of content is available, delivered through more than 50 discrete learning modules (each of which is accompanied by a corresponding pretest and posttest assessment).

The design and structure of the individual learning objects (the unit of instruction that a user launches) is driven by several over-arching tenets:

1. The instruction should be of value to the aerospace community, either in the Technician or Engineering realms. The *ALE* has striven to work with subject matter experts currently working in the field to identify appropriate training topics and validate their accurate treatment. This goal is consistent with FSRI s legislative requirement to be an industry-driven organization.

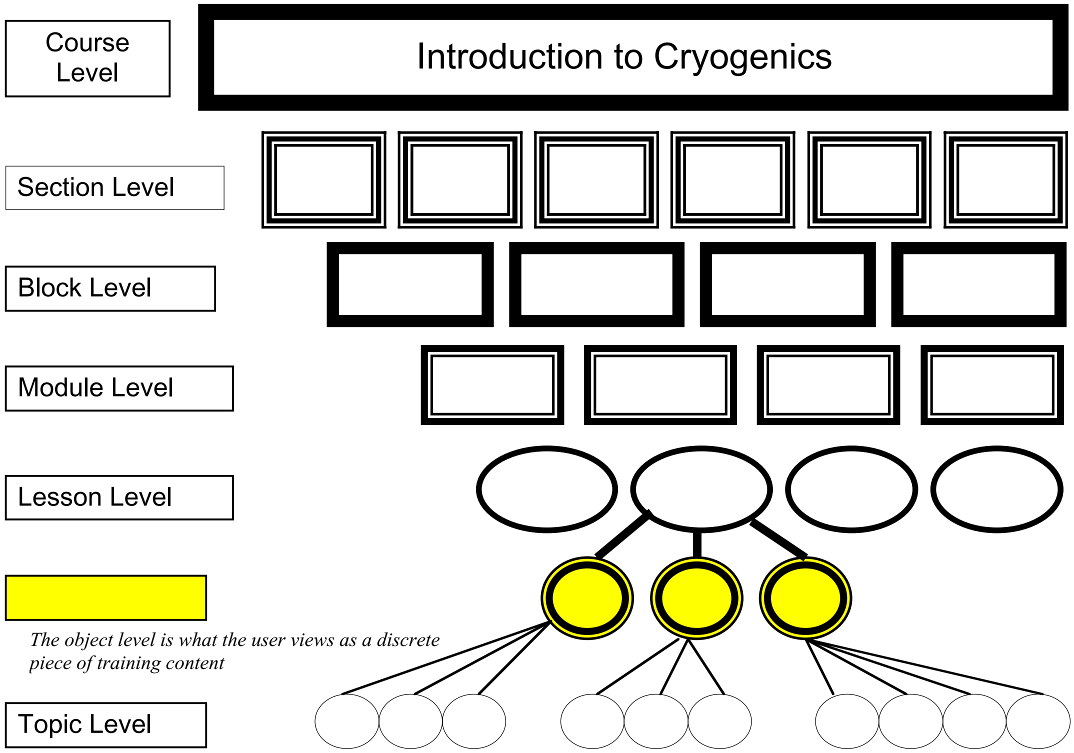
2. The instruction should be short, ideally completed in a single sitting (such as during a lunch hour). Most modules are approximately 20 minutes long.

3. The instruction should be engaging, both from an applicability standpoint, but also in its strategic use of multimedia technology. Although trade-offs are required whenever a baseline technical platform is determined, FSRI decided to include the use of Internet plug-ins in order maximize the illustrative/ interactive nature of computer-based training. Not all plug-ins are required for all learning modules; however, any required plug-in players are free and easily downloaded from commercial Internet sites. Some of the players incorporated within the *ALE* are Macromedia s Flash, Adobe s Acrobat, and Cycore s Cult 3D. Video and audio capabilities are also included in the *ALE* s media strategy.

The structure of the over-all curricula is hierarchical. A simple curriculum might consist of a series of modules (which would be synonymous with learning objects), each containing individual instructional topics. A more complex curriculum, such as that being developed as part of the *ALE* s Introduction to Cryogenics program, requires a more detailed hierarchy. The cryogenics program is composed of large sections, which consist of blocks. The blocks are made up of modules, which, in turn, are comprised of lessons. The components of the lessons are perhaps the most important part of the learning hierarchy. Lessons are made up of objects.

Objects are also known as Shareable Content Objects (SCOs) or Learning Objects (LOs). Objects are the lowest-level element that a student would launch as a discrete piece of learning content. Objects are linked directly to an enabling learning objective and address one or more topics.

The structural hierarchy is illustrated below.



Curriculum Structural Hierarchy

Other instructional assets within the *ALE* include synchronous web-classes and collaboration forums. A key to the success of live, web-facilitated instruction is its integration into the learning process as an intrinsic element, and not merely a one-time, transactional event. Viewing both asynchronous and synchronous offerings as complementary tools to achieve a single goal helps to maximize each technique s unique strengths.

An example of this approach is FSRI s curriculum on Propulsion Theory. FSRI is in the process of developing a 3-hour program on Propulsion Theory, with support from subject matter experts at Pratt & Whitney.

Although housed within the aerospace technician curriculum, the Propulsion Theory modules are really designed as an introductory primer for anyone interested in rocket propulsion. The program begins with the basics of Newton s laws and progresses through abstract concepts, concrete examples, and complex simulations to provide a short yet detailed overview of propulsion theory.

Propulsion Theory consists of four asynchronous e-learning modules and one synchronous web class. The asynchronous modules are designed to each stand alone as an individual learning object or be bundled together with other modules to create a prescriptive learning path customized for the individual user. The five Propulsion Theory modules are:

Module 1: Newton's Laws of Motion. This module focuses exclusively on Newton s laws. This information is crucial all subsequent understanding.

Module 2: The Forces of Propulsion. This module covers specific propulsion forces such as unbalanced force, Newton's laws as they relate to reaction engines, the rocket equation, effective velocity, and specific impulse.

Module 3: Solid Propellant Rockets. This module addresses solid propellant fuel types and engine design.

Module 4: Liquid Propellant Rockets. This module discusses liquid propellant fuel types and engine design.

Module 5: Equations and Practical Applications. This is a live web session facilitated by Dr. Samuel Durrance, Executive Director of the Florida Space Research Institute and a former astronaut with over

615 hours in space. Dr. Durrance will discuss propulsion-related equations and some practical applications of the theoretical concepts. Not only will the live session be repeated as necessary for new students, it will also be recorded and stored as an asynchronous event.

In addition, FSRI has built into the *ALE* the capability for users to collaborate on project work remotely. This is accomplished through the combination of bulletin board discussions, real-time text chat, and electronic conference rooms.

TECHNICAL STRATEGY

As previously mentioned, the *ALE* is a robust online environment, aggregating a wide array of capabilities into a single offering. The *ALE* encompasses all instructional media and learning modalities, including:

- Asynchronous e-learning modules
- Asynchronous assessments
- Asynchronous community collaboration (threaded discussion boards)
- Synchronous facilitator-led, web-based training
- Synchronous assessments (live, on-line)
- Synchronous community collaboration (embedded real-time chat)
- Synchronous small group collaboration (virtual meeting rooms utilizing voice over-IP with electronic white boards and application sharing capability)
- High-end graphics
- Video
- Audio
- Virtual 3D environments
- Flash-based embedded instructional interactions
- Shocked Authorware interactive learning modules and assessments
- Competency mapping and skill gap management
- Certification management
- SCORM-compliant data capture (an e-learning standard established by the Department of Defense)
- Multiple data reporting capabilities
- Embedded e-mail feedback feature

When developing the *ALE*, FSRI was faced with the not-uncommon challenge of an extremely aggressive deadline. Because the development timeline was so tight, it was quickly decided that the solution would be found not in creating a new, proprietary system from scratch, but from the intelligent integration of commercial, off-the-shelf (COTS) applications into a cohesive system.

In order to meet both the schedule requirements and the functional requirements for learning and knowledge transfer, a system that supports a variety of learning interventions and management functions was deployed. FSRI solicited proposals from a variety of developers and ultimately selected the University360 corporate university solution from Latitude360, a division of RWD Technologies. The system is unique in that it follows a best-of-breed COTS product strategy to meet all of the functional requirements of FSRI's *ALE*. Plus, it was able to be quickly implemented and customized for FSRI. The *ALE* includes the following major technical components:

HW/SW infrastructure for hosted model

Key to the rapid deployment of the hosted learning solution was a collection of existing hardware and software. This included a server farm located in AT&T's data center, Bandwidth-On-Demand tm service, and Oracle database software. Another key component is the University360 Message Broker architecture that can transfer records between the various components of the system. This hardware, software, and network baseline made it possible to rapidly configure key system components for the advanced learning environment.

Saba

Saba is the preintegrated LMS (Learning Management System) solution for tracking learner records, competencies, course catalog content, curriculum, and advanced reporting. Saba is also used as a primary portal interface for accessing all other types of learning from the learning catalog. For instance, a learner can select from scheduled, classroom instructor-led classes; self-paced eLearning, virtual classroom, collaboration discussion boards, online exams, and resources available for checkout. Registering learners in the University360 environment is accomplished through a Saba interface and automatically transferred to the other components of the system through a message broker architecture that links the components together.

Centra

Centra is the main virtual classroom component that is integrated with the University360 solution. With

Centra, instructors can share learning materials with students in realtime and provide collaboration at a distance. Learners see PowerPoint slides, text slides, Web pages, surveys, application sharing from the instructor, and annotations. Additionally, these realtime sessions can be recorded for later playback and review.

Certification.Net

For testing and assessment services, the Certification.Net test delivery service is integrated with the other tools in the University360 solution suite. SCORM compliant tests data can be processed and transferred to the main learner record in Saba. Surveys, assessments, and exams can be delivered from the system. The system features many question types including links to performance-based skill questions and can provide valid psychometric reporting data on the pooled questions and their performance. Detailed prescriptive feedback is also provided through the system.

WebBoard

The Collaboration component of the system is based on WebBoard from Akiva. Capabilities include posting to discussion boards, chat functions, broadcast e-mail distribution, search, and rudimentary document and file storage capabilities, all from a Web-based interface. The collaboration capabilities can be accessed from the Saba catalog, or directly from the main portal page.

Preintegration

It would be impossible to integrate all of these components in a short 10-12 week timeframe and a reasonable cost. The cost and time savings comes from the preintegration made possible by the message broker transfer agent that connects all of these components. With preintegration in University360, it was possible to configure the system, rather than customize it. Configuration included a private label look-and-feel based on FSRI's logo, colors, and identity, and the addition of two custom portal areas to accommodate FSRI s current and future needs.

FSRI was very aware of the need to develop a system that not only served the current student population but also accommodates future growth. Scalability and capacity were key considerations.

The ability to manage competency of diverse audiences and a wide set of training and educational resources, whether Classroom, Web, CD, or paper-based A/V materials also provide significant flexibility to meet a variety of needs of an organization, or multiple clients. Best of all, actualization of blended solutions that form a well-rounded learning, knowledge, and performance offering are possible based on the flexible content model.

FUTURE PROGRAMS

FSRI is currently planning a program for knowledge capture of cryogenics expertise that will build upon the current prototype effort. Partnering again with the Institute for Simulation and Training at the University of Central Florida, as well as with the Institute for Human and Machine Cognition (IHMC), located at the University of West Florida in Pensacola, FL, FSRI intends to utilize concept map methodologies to elicit and document the embedded expertise of the cryogenics experts at the Kennedy Space Center.

The curriculum will initially concentrate on post-college training of cryogenic engineers. Cryogenics is a highly complex field in which Kennedy Space Center currently invests three years of on-the-job training to qualify new cryogenic specialists. It is important to provide a learning methodology which shortens this training cycle and which also preserves the most important expert knowledge of those who have been performing Shuttle-related cryogenic work for years and who will reach retirement age within the next few years.

Project Objective

The specific goals of the planned work will be four-fold:

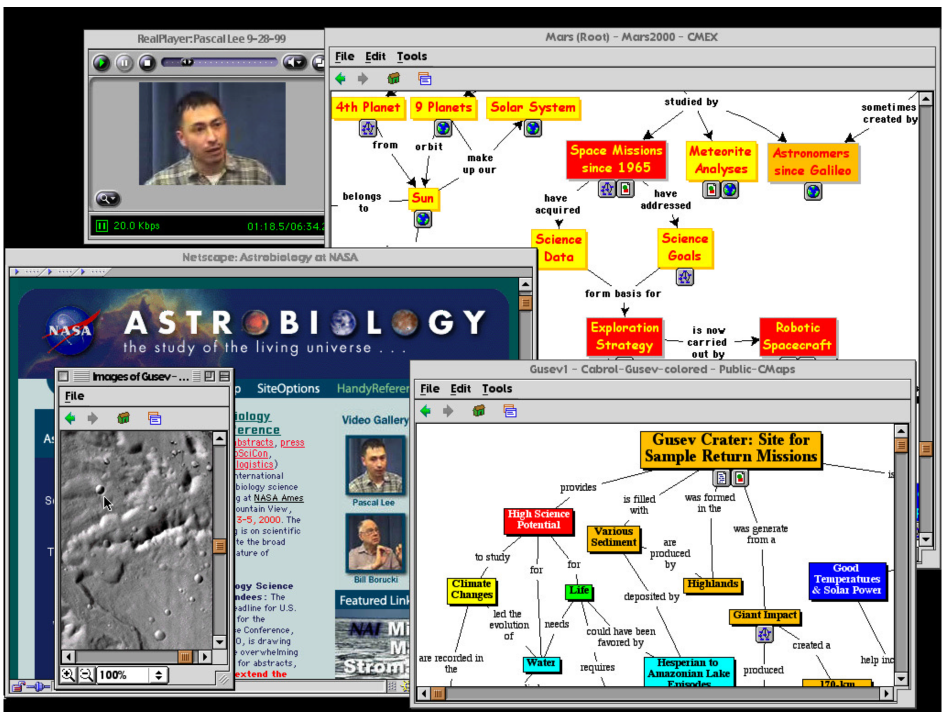
1. Establish the usability of IHMC s concept maps as a mechanism to design independent cryogenics knowledge modules that can be brought together as a course;
2. Adapt concept maps to a problem-based learning environment to prepare cryogenics engineers for the situational variability that they will encounter in the real world;
3. Utilize concept mapping as the basis for knowledge elicitation and representation of the most critical expert cryogenics knowledge to be retained for future training and reference; and
4. Incorporate complex cryogenics simulations and e-learning modules into the concept map structure as additional instructional resources.

Brief Project Description

The planned initiative is a research and development effort that will build upon the foundation already developed for FSRI s next generation *Advanced Learning Environment* (*ALE*).

Computer systems typically require the human user to conform to the needs of the machine. The proposed work expands on the most recent developments in computer-mediated learning to create an electronic training and performance support environment for cryogenics engineering in which the computer conforms to the needs of the human user.

The primary focus of this effort is to research the effectiveness of an expanded concept map strategy to capture the knowledge of a complex engineering domain and then utilize it as a delivery mechanism for eventual training and performance support. This initiative will provide even more robust media and instructional modalities to the concept map application, via the incorporation of simulations and web-based e-learning objects. A prototype will be developed.



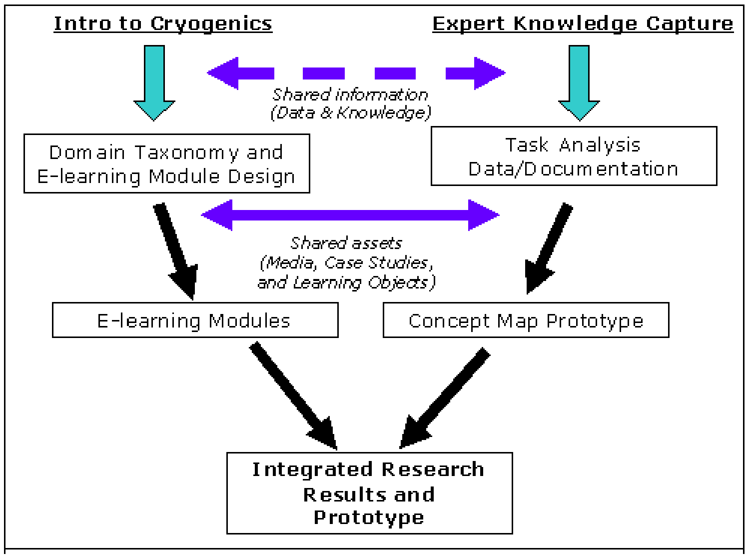
Example Concept Map About Mars

Project Discussion

Concept mapping is a revolutionary approach to learning. Utilizing non-linear representations of interrelated nodes, the learner can better understand the context of information and how concepts relate to other concepts. Although current electronic concept map applications include text, graphics, photos, and media, this project proposes to include two additional media components that have not yet been included in concept map presentations: complex cryogenics simulations and discrete cryogenics-related web-based learning objects. The research associated with this project will evaluate the hypothesized increase in learning effectiveness with this next generation concept map strategy.

Because the training sections of the *ALE* will be developed in an object-oriented model, the individual assets and components created specifically for particular cryogenics courses will be available for incorporation into the concept maps (which will serve primarily as a repository of embedded knowledge). The research will explore the feasibility and effectiveness of enhanced concept maps as a structure for an electronic cryogenics performance support system.

Two parallel paths will be developed concurrently. The first path will develop short, discrete learning objects as a result of traditional instructional systems analysis and design. The second path will capture incumbent expert knowledge via concept mapping. As the two efforts develop, they will begin to converge as learning objects and other training resources (such as online simulations) are embedded within the concept maps.



High-level cryogenics research and development strategy

ALE AS A MODEL

The development of the *Advanced Learning Environment* was managed in such a way as to allow maximum reusability in two critical areas.

Internally

Within the *ALE*, the content objects, media assets, and instructional resources were intentionally constructed to allow for reusability in a variety of contexts. Although not a true learning content management system in its execution, the *ALE*s design positions the portal for evolution to a true LCMS.

In the meantime, objects are purposefully modular to allow them to be arranged into a customized, prescriptive learning path based upon an individual learner s unique needs or interests. Performance support tools have been designed and constructed so that they can be separated from the instructional objects and made available as an on-the-job resource outside of any formal training. Each learner s *ALE* experience is unique, although the components of that experience are culled from a single pool.

Externally

The *ALE* was also designed to act as a model for other industries or organizations to use for similar requirements. Certainly, other non-aerospace-related military and federal organizations are facing similar knowledge acquisition and dissemination challenges. Similarly, private industry, including such significant sectors as manufacturing and medicine are also confronted with the same issues. Another important area that could benefit from an *ALE* model is within the state-level education systems, utilizing the *ALE* paradigm for teacher professional development and in-service training requirements.

Other Considerations

Continual life-cycle maintenance and capability upgrades are part of ongoing operations and support planning, including the development of additional content modules. Furthermore, in addition to component upgrades and extension features like wireless content and learning content management system (LCMS) functions, many future expansions of the system and services are possible. Because of the message broker architecture, it is possible to add links to enterprise-scale applications such as knowledge management systems, CRM, ERP, and document management systems.

The architecture also offers the flexibility to transfer the system from a hosted solution to a behind-the-firewall solution if required.

ALE as a Model of Public-Private Partnerships

The development of the *ALE* involves a number of partners in addition to the Florida Space Research Institute. FSRI s partners include the federal government, the Florida state government, private industry, and several academic institutions. The *ALE* is a microcosm of the larger role that FSRI plays within Florida, facilitating partnerships between academia, industry, and government. The *ALE* s current list of partners includes:

- NASA Kennedy Space Center
- Workforce Florida, Inc.
- RWD Technologies / Latitude 360
- Steel Beach Productions
- Institute for Simulation and Training/ University of Central Florida
- Brevard Community College
- University of Florida
- NASA contractors
- Aerospace Technology Advisory Committee
- Institute for Human and Machine Cognition / University of West Florida
- NASA Langley Research Center

CONCLUSION

The demographics of today s typical aerospace worker are worrisome. Aerospace workers are an aging population and the skills that incumbents have acquired via years on the job will soon be leaving the industry due to retirement and attrition. A new, younger group of workers is preparing to replace them in mission-critical roles. This new workforce must have the proper training and tools to be effective. Not providing this new workforce with proper training and tools potentially risks crew safety as well as significant financial consequences.

The development of the *Advanced Learning Environment* is an extremely effective strategy to provide this new workforce with the training and tools necessary to not only sustain today s level of productivity and performance, but even improve upon them due to the cutting-edge strategies and technologies being proposed

The *ALE* serves a crucial role in not only training new aerospace workers, but also in supporting incumbent workers. The *Advanced Learning Environment* is a resource that is available and valuable long after the initial training program has been completed. Its intention is to encourage a culture of learning via a robust virtual community.