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PROPOSAL FOR USE OF GAMIFICATION TO STIMULATE INTEREST AND COMMITMENT TO SAFETY EDUCATION IN HIGHER LEARNING

36TH INTERNATIONAL SYSTEM SAFETY CONFERENCE

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U.S. ARMY COMBAT CAPABILITIES DEVELOPMENT COMMAND ARMAMENTS CENTER

Weapons and Software Engineering Center

Picatinny Arsenal, New Jersey

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14. ABSTRACT

This report describes the employment of a gaming approach to software safety instruction, which has great promise as a catalyst for the introduction and integration of software safety education to mainstream engineering curricula in higher learning institutions. Brian Connell and David Musgrave from the U.S. Army Combat Capabilities Development Command Armaments Center, Picatinny Arsenal, NJ, presented a tutorial called "MIL-STD-882E Software Safety Analysis: A brief review and a new approach to instruction" at the 35th International System Safety Conference (ISSC) in Albuquerque, NM, in August 2017. This tutorial demonstrated the effectiveness in using a gaming approach, not with interactive graphics, but with multiplayer teams, gaming dice, and round-by-round scoring in the delivery of software safety instruction. This technique leverages the competitive nature of individuals and the strengths of active learning to maximize retention of critical software safety concepts in severity and control assessment and in the assignment of level-of-rigor tasks. It has the added dividend of incorporating programmatic concerns such as budgetary constraints and risk management. The tutorial was well-received by ISSC organizers, receiving a best tutorial award and cultivating the society's interest in this technique as a tool for bringing software safety instruction to institutions of higher learning. In August 2019, Brian returned with a paper and presentation that featured a brief demonstration of a gaming application and proposal for a phased approach to a national competition that begins as a web-based event and culminates in a live contest at the site of the 37th ISSC in Norfolk, VA.

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INTRODUCTION

The engineering workforce of the new millennium has inherited a problem that warrants serious consideration. Education in system and software safety continues to evade engineering curricula in respected higher learning institutions. Although careers in system safety may prove both satisfying and lucrative, few colleges and universities offer academic foundations for safety. Safety concepts and processes are learned primarily through workplace experience without any formal training or classroom instruction.

Organizations such as the Occupational Safety and Health Administration (OSHA) offer online courses and certifications. Online institutions have begun to set up programs and even degrees in safety. However, the coursework and degree programs have yet to garner sufficient consideration to make their way into undergraduate programs at popular and respected colleges and universities. An initiative to infuse safety instruction into mainstream education must be supported by interest and opportunity. Students at the undergraduate level, especially those who have yet to commit to a degree plan, should be exposed to system and software safety principles in the years ahead as confidence in autonomous functions continues to grow in the engineering community.

This report is intended to stimulate interest and support for the use of "gamification" as a very promising instructional tool for software and potentially system safety. It outlines a high-level plan for the introduction of software safety concepts and processes to undergraduate engineers at a number of institutions in the United States, with the expectation that the interest and excitement of a software safety contest will ensure participation and serve as a catalyst for safety instruction components and courses in engineering programs. The report is the culmination of several appearances at the International System Safety Conference (ISSC) in an effort to introduce and promote this teaching approach, as shown in table 1.

Table 1
Conference goals

Date	Conference	Title	Description
August 2017	ISSC #35 – Albuquerque, NM	Proposal for Use of Gamification to Stimulate Interest and Commitment to Safety Education in Higher Learning	• Introduce concept • Demonstrate application of "Gamification" to attendees • Obtain feedback on efficacy and potential
August 2018	ISSC #36 – Phoenix, AZ	Proposal for Use of Gamification to Stimulate Interest and Commitment to Safety Education in Higher Learning	• Summarize approach • Define a plan for promotion by academia, industry, and the society • Propose a timetable and sponsors • Meet principles from Arizona State University
July/August 2019	ISSC #37 – Norfolk, VA	Proposal for Use of Gamification to Stimulate Interest and Commitment To Safety Education in Higher Learning	• Revisit approach and proposal (at request of conference organizers)

BACKGROUND/HISTORY

The U.S. Army Combat Capabilities Development Command (DEVCOM) Armaments Center (AC), Picatinny Arsenal, NJ, has developed a PhD curriculum that is presently in its fifth year of operation. The Armament Graduate School (AGS) is presently seeking accreditation and permission to grant degrees from the U.S. Army and, ultimately, from Congress. One of the required courses in this program is the AGS Armament Software class, which seeks to give students an in-depth understanding of the issues and solutions for software professionals involved in the design, coding, and testing of weapon and fire control systems. Learning objectives for this curriculum include an understanding of software development lifecycle methodologies and software safety concepts. The Agile development philosophy is included in the discussion of lifecycles and development methodologies. Instruction of software safety standards and processes are key components of the AGS Armament Software course.

Training objectives for the Agile development philosophy include an instructional approach adapted from a course presented by Learning Tree International, Inc., Herndon, VA. The approach centers on a gaming technique wherein the class is broken into teams and presented with a set of "stories" that represent software features. Stories carry point values that reflect the estimated effort to complete the task. Stories are then aggregated into larger requirements or subsystems. The game progresses through a series of rounds requiring teams to make decisions about which stories to implement in a given "sprint," with the sprint being a software delivery with useful functional content. Teams are assigned an initial "sprint velocity," that reflects the rate at which the software team can complete these stories in a prescribed time interval. Gaming dice are used to simulate real-world risk and uncertainties associated with sprint successes. A round-by-round scoring approach awards points for completed stories and bonus points for completed requirements. Players (students) are repeatedly confronted with new programmatic developments in the form of opportunities that range from workforce training to new features and requirements. Each opportunity carries risks and rewards in terms of story points lost and gained. Ultimately, the game is won by the team with the most points after several rounds are run.

This "gamification" approach has proven to be a highly effective approach to instruction, as it leverages the competitive nature of individuals and the excitement of random events. Students remain engaged, and their interest level is all but guaranteed by the competition. Gamification is entirely consistent with the notion of active learning being a superior alternative to traditional lecture approaches (ref. 1). If active learning is an effective technique of instruction (ref. 2), then gamification is the tool that gives added assurance of fulfillment of learning objectives. Student feedback at the DEVCOM AC AGS was overwhelmingly positive.

Success in Agile instruction at AGS prompted consideration of gamification for adaptation to software safety instruction. A U.S. Naval software safety process, based on MIL-STD-882E (ref. 3), was used as a framework and useful guide in translating definitions and required tasks into a sequential process (ref. 4). The adaptation to a game format was accomplished by replacing Agile stories with safety features for a military vehicle.

Scoring is based on the smart use of the initial budget of $10,000 to reduce safety risk. In a typical round, students are presented with a set of three to four functionally similar safety features. Students assign a MIL-STD-882E Software Criticality Index (SwCI) to each feature based on their assessment of the severity and control categories for each function. After students submit their own SwCI assignments, they are compared to the SwCI designation provided by a safety subject matter expert (SME). A “miss distance” is then computed. Students assigning an overly conservative SwCI (too low) have effectively overspent on risk reduction and incur financial penalties designed to be commensurate with expenses for excessive testing and analysis. Students who underestimate the safety-significance and assign a higher SwCI than that of the safety SME incur a miss distance of the opposite sign/nature and are then required to roll the gaming die to determine if the mishap related to the safety hazard in question occurred. The gaming die is used as an acknowledgement of random circumstances associated with mishap occurrence and hazard effects. Students making the most suitable SwCI assignments are most likely to minimize spending without incurring undue safety risk and emerge as winners in this competition. Learning objectives are met and frequently exceeded as students not only become well-versed in the process of assigning severity and control categories (SwCI assignments) but also gain an appreciation of the programmatic concerns of budgetary limitations.

Gamification of software safety instruction was demonstrated in a tutorial administered at the 35th ISSC in Albuquerque, NM, in August 2017 by DEVCOM AC engineers David Musgrave and Brian Connell (ref. 5). Brian conceived the idea of adapting gamification to software safety instruction. Musgrave was instrumental in developing the feature sets and scoring approach required to support the learning objectives. Feedback from conference organizers and society officers was positive. It won the best tutorial award at the conference and led to follow-on discussions with the International System Safety Society (ISSS) on the prospects of using gamification to stimulate interest in safety education at institutions of higher learning.

NOTIONAL PLAN FOR USE OF GAMIFICATION TO PROMOTE SOFTWARE SAFETY EDUCATION AND INTEREST

The promise of this approach as an instructional tool brings challenges of a different nature. The technique itself is reasonably mature and lends itself to further refinement in terms of customization to pure academic environments. However, significant coordination and commitment are required to ensure that gamification of software safety instruction realizes its full potential. Emerging from ISSC #35 in August of 2017, a tentative plan was discussed to conduct a web-based event in the latter part of 2018. Winners of the web-based event, which includes interested engineering schools, would be invited to a live event at or near the site of the next ISSC.

The first step in the process is solicitation of learning institutions by Brian with input and support from the ISSS. The subject letter would include an appeal for interested students and an overview of the plan for progression through announcements, web-based and live events at ISSC #37 in Norfolk, VA, in July/August 2019. Preliminary discussions between the DEVCOM AC, ISSS, and learning institutions would likely be enabled by Level One Cooperative Research and Development Agreements (CRADA). The CRADA is a legal agreement between government entities and a private company or university that governs collaborative research efforts. The Level One CRADA simply allows the subject parties to initiate dialogue. After interested learning institutions have been determined, a date will be negotiated for the web event, and commitments will be obtained.

Sponsorship of the competition was discussed at ISSC #36 in Phoenix, AZ, in August 2018. Ideally, support from industries who stand to benefit from software safety education and event sponsorship will be engaged. The automotive, avionics, industrial controls, and medical fields are among the sectors to be approached regarding grants, scholarships, and donations. Additional sources of funding may include federal research grants, Department of Defense (DoD) science and technology funds, university research budgets, and ISSS corporate members. Collective subsidies from these sources should be managed by the ISSS and used to defray travel expenses for students participating in the live event.

The selection of the learning institutions targeted for this solicitation is based on a number of factors. Diverse geography is desirable and, with the ISSS being an international society, global participation is a strong preference. However, travel subsidies must be in place to support international participation. Institutions near ISSC #36 and #37 were contacted with Arizona State University already expressing interest in the competition. Alumni relationships were also leveraged. For example, Brian is an alumnus of Virginia Tech, Stevens Institute, and the University of Texas at Arlington. He reached out to the engineering faculty at these institutions and also contacted the DoD affiliates at West Point, Annapolis, and Colorado Springs. The student body of the AGS was apprised of the competition and canvassed for interest. Universities with close ties to ISSS were involved and academic partnerships between key players in the targeted industries were considered.

CONCLUSIONS

The notional plan described in this report requires detail and commitment before it can be seriously considered and used as a basis for planning events leading to and during the 37th International System Safety Conference (ISSC) in Norfolk, VA, in August 2019. Sponsorship, planning, and participation are among the elements that require further attention. Nonetheless, the interest and confidence in the gamification approach has provided the reason for optimism. This report will most likely be accompanied by a live demonstration of the application of gamification to the software safety instruction at ISSC #36 in Phoenix, AZ, in August 2018. The demonstration should rekindle interest and bolster confidence in the instructional technique. Following the demonstration, a notional plan will be proposed for a national competition. Expectations are high that the interest during this conference (and its related ad-hoc meetings) will provide sufficient clarity to secure the necessary commitments for support of a solicitation and web event.

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