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Incorporation of Systems Engineering Into the Undergraduate Aerospace Engineering Curriculum

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The aerospace industry has historically experienced significant system performance underachievement, schedule slips and cost over runs on many major system procurements. In the last thirty years or so a key approach as an attempt to improve both the engineering and programmatic performance has been to increase the implementation of systems engineering disciplines, tools and philosophies into aerospace system development programs. Thus, when bachelor of science level engineering students graduate and start their careers, they are often thrust into systems engineering cultures for which they may not be adequately prepared to be immediate and effective contributors.

Significant formal teaching of systems engineering processes, tools and principles in universities is often considered as an appropriate curriculum for masters and Ph.D. degree level programs. This may be due to the belief that engineers should first be fully grounded in the technical engineering disciplines before they can adequately grasp the broader "systems thinking" which is the basis of systems engineering. However, due to the growing importance of the systems engineering culture in product development, especially for government sponsored programs as well as commercial aerospace programs, the Aerospace Engineering program at Cal Poly Pomona has recently initiated, and is expanding the formal incorporation of systems engineering into the undergraduate curriculum. The need for this initiative has been reinforced by surveys of both the employers of the Cal Ploy Pomona Aerospace Engineering Bachelor of Science graduates and alumni in which basic systems engineering skills were were identified as an important part to help enable new graduates to be productive very early in their careers.

Basic systems engineering concepts such as definition of what a system is, "systems thinking" and Work Breakdown Structure and are informally introduced to freshmen in their introductory aeronautics, astronautics, and propulsion courses.

Then, a thirty hour formal course on the Fundamentals of Systems Engineering is required starting in the beginning quarter of the sophomore year. The concept of "systems thinking" is especially emphasized in terms how each system element's design can influence the other system elements requirements, performance and cost, as well as designing for the entire system life cycle. This course includes student teams simulating a system design project where the students choose an existing aircraft or space system where the actual engineering design and performance information is publically available, and then simulate the system design (or "redesign") by applying industry type systems engineering processes. These processes include needs analysis, requirements definition and management, mission architecture formulation, candidate system architectures definition, Work Breakdown Structure, figures of merit, trade study formation and matrix down select process, functional flow diagramming, manufacturing, maintenance and supportability concepts definition, technology infusion, and risk management. Student exposure to emerging SE tools such as icon driven Model Based Systems Engineering (MBSE) design and simulation programs for sub-system preliminary design like the LMS AMESim are also applied to the system "redesign" project for key sub-system design trades.

Next, a system architecture framework development course including training for the use of the Vitech CORE architecture tool suite is offered to juniors and seniors. This course includes a system architecture design project of an aerospace system, and also expands experience employing model based reasoning and subsystems design tools that are aimed at eventually merging multiple MBSE subsystem models into a single, global system simulation model for rapid complex system trade studies.

The key principles and processes from these systems engineering courses are then tied to a fall quarter senior level course on Program Management of system design programs. This course focuses on formulating student project teams and generating a system design project program management and systems engineering project plan. This plan which is later executed in the winter and spring quarters requires Senior Design Project courses. The Senior Design Project teams usually chose an aircraft or spacecraft system design project from an AIAA or other industry or NASA competition's request for proposal (RFP). Conceptual and later preliminary systems designs are then presented to a panel of industry and government engineering and management experts for formal judging and feedback. A key to successfully creating the system design in the constraint of only two quarters (twenty weeks) is by using the Program Management and system engineering management plan to guide the team's project development and project management.

Also, the systems engineering principles and processes are often used for the required senior research projects, club teams' aircraft and rocket flight project competitions, and other research projects.

The program chair, faculty and industrial advisors believe that the incorporation of system engineering principles and tools into the undergraduate curriculum help better prepare Cal Poly Pomona Aerospace Engineering graduates to be productive and successful in the evolving systems engineering based cultures of their future employers, and in the pursuit of advanced engineering degrees involving systems engineering.

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