Session 2502

A Safe, Responsible, and Accountable Approach to Teaching Airplane Design

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Papers relating to the teaching of capstone aircraft design courses typically focus on either pedagogy[1] (suggested topics and tools) or on how aircraft design should be incorporated into the overall aerospace engineering curriculum [2-4]. This paper proposes that the topics of flight safety and professional responsibility and accountability be given increased emphasis in existing aircraft design courses. The intention is not to replace existing course topics, but rather to suggest re-casting them in the frameworks of flight safety and professional responsibility. Techniques for incorporating these concepts in the classroom environment are presented.

SAFETY AND SURVIVABILITY

"Meeting the specs at or below cost" is a traditional yardstick and motivation for aircraft preliminary design. However, safety and survivability considerations can no longer take a back seat to performance and cost considerations:

> "Based on projected fleet growth, by the year 2010 one jet transport hull loss will occur *per week* unless strong, preventative measures are taken by the industry to reduce accidents." [5]

This scenario is based upon current and projected demands for public air transportation. If, at a minimum, it is desired to hold the total fatality level constant in spite of the projected increase in activity, then the only solution is to increase the relative safety beyond current levels.

Acceptable levels of safety arise as a result of societal tradeoffs between the number of fatalities and the costs incurred to lower them. Engineers, educators, and students should be aware that the total numbers of people killed are important not only in human terms, but also in terms of public perception of safety. As evidenced recently by direct intervention from the executive office of the U.S. Government [6], public opinion and temperament ultimately dictate aviation activity and safety levels, both in the marketplace and in the polling place.

It will take a major effort on the part of the air traffic control system, airplane air and ground crews, airplane design management, and airplane design engineers to achieve the desired safety levels. Accident investigation is a core component, but learning and applying the lessons from past accidents is not an end to itself:

> "The safety record of the world's airlines will decline in the next 20 years unless the industry focuses more on *preventing* accidents than determining what caused them, according to a study conducted by the Boeing Commercial Airplane Group." [5]

What is required are aircraft which have been designed to avoid specific, undesirable characteristics in tangible hazardous situations (either human or weather induced), and which are survivable in those situations which cannot be avoided.

Although many factors such as flight operations, maintenance, weather, and personnel contribute to aviation safety, the scope of this paper is limited to design related factors only. In point of fact this goes far beyond just pure configuration design; it requires the design engineer to be familiar with how the airplane will be operated as well. Students must be exposed to safety regulations such as one engine inoperative (OEI), takeoff rotation, stick force-to-speed gradient, etc. at an early stage. Requiring students to be familiar with major FAA and Military regulations instills safety where safety should start: with the people who design and build the aircraft.

Chapter 13 of Part IV of Reference 7 specific rules and methods for incorporating survivability and safety into the aircraft design process.

PROFESSIONAL RESPONSIBILITY, ACCOUNTABILITY, AND ETHICS

This should be an aspect of *every* course in the engineering curriculum, not just aircraft design. Today more than ever before engineering responsibility needs to be promoted because of public sensitivity to environmental issues such as flight safety; aircraft noise; excessive fuel dumping during operations; and ozone layer depletion. These issues have a tremendous impact on the industry. References 8 and 9 are highly recommended. With regard to flight safety, the following viewpoint is proposed by this author:

The onus of professional responsibility and accountability rests with the aircraft design engineer. As long as the attitude persists that an accident is the ultimate fault of or can be pinned-on another individual or group (all too often of which is the aircrew), then current and future safety levels will not improve.

Pointing the finger, finding a scapegoat, shirking responsibility, and passing the buck are attitudes which have no place in the industry and academia. Stepping up and taking responsibility and accountability for ones' own work must replace C.Y.A. as standard operating procedure.

Although the cause of many accidents have ultimately been traced to the actions taken by aircrew in a given situation, the aircraft design engineer does in fact have direct control over many design aspects which influence aircrew actions. Examples include cockpit design; layout and location of flight critical controls, switches, and displays; mechanical design of pressure hatches, emergency exits, landing gear, and braking systems; layout and location of fuel and electrical systems, and flying qualitites. At all stages of the aircraft design process, the design engineer should ask himself "How can I reduce the workload on the aircrew so that they can perform their already demanding job more efficiently and therefore more safely?" But the introduction of increasingly autonomous flight systems demands that design engineers also be aware of human factors and the effects of displays and pilot cues:

> "In 1994 nearly 1,300 passengers and crew were killed in civil aircraft accidents. The problem for the aircraft and systems industry is that while they can develop specific systems to counter specific dangers, their role in solving problems associated with the complex issue of human/machine interface is still hazy." [10]

Many systems now help the aircrew close the loop, but keeping track of augmented flight modes and their effect on the vehicle is a major concern [11].

Although perceived by many as a natural or inherent understanding, engineering ethics must be *taught*. Typical issues which aircraft design students should be required to addresses in open discussions in the classroom include: "How safe is ‘Safe Enough’?" "If it is not practical or possible to design for zero accidents, then how many fatalities are acceptable?"; "Should we design and operate aircraft which carry 1,000+ passengers in spite of the potential for large loss of life should one of them crash?". Although rhetorical in nature these questions serve to stimulate critical thinking.

COURSE STRUCTURE

At Western Michigan University AE 469 Airplane Design is a three credit hour course (three one-hour lectures per week). The primary textbook is Reference 7, and the primary software is Reference 12. The engineering prerequisites are AE 450 Flight Vehicle Performance, and AE 460 Airplane Stability and Control. Co-requisites are AE 459 Flight Test Engineering and Design; ME 571 Gas Dynamics; and ME 480 Mechanical and Aeronautical Engineering Project. Students select a request for proposal from one of the two provided by the instructor, and then design an airplane which satisfies (as far as possible) the mission specifications. The requests for proposal are taken from the current year’s AIAA Undergraduate Individual and Team Airplane Design Requests For Proposals. Students document the progress of their designs by writing a series of five regularly scheduled progress reports, and by mid-term and end-of-term in-class oral presentations. The due date and required content by topic for each of the five reports is provided to the students on the first day of class. The due dates are selected so that all five reports are due at equal three week intervals throughout the semester. Student performance is evaluated using the five design reports and two oral presentations. There is no final exam.

SUMMARY

To reduce current and future fatality rates of public air transportation an engineering mind set centered on flight safety and professional responsibility and accountability is needed. This mind set is required of personnel in air traffic control, aircraft air and ground crews, airplane design management, and especially aircraft design engineers and therefore aircraft design students. This paper proposes that the major responsibility and accountability for flight safety rest with the aircraft design engineers since these individuals wield the most leverage for incorporating safety during the preliminary design process. Transferring this concept to the classroom is an expedient for achieving improved levels of flight safety.

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