Paper ID #35334

Developing training programs for Airworthiness Engineering

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Developing Education Programs

for

Airworthiness Engineering

1 Large scale Airlift Humanitarian Efforts Enabled by Engineering and Airworthiness Disciplines.

1.1 Background

Aircraft of all types provide resources to support humanitarian efforts throughout the world. Humanitarian missions from the United States military have been recorded as far back as 1919, when Army planes delivered food and supplies to flood victims along the Rio Grande in Texas [1]. Ever since these early days of aviation the U.S. has engaged in missions that provided critical supply relief to populations ravaged by either conflicts or natural disasters and relocated refugees to safe havens.

One of the most notable examples of aircraft utilization for humanitarian relief was the Berlin airlift operation immediately following the end of World War II. The city of Berlin and its French, U.S. and U.K. sectors were isolated within Soviet occupied East Germany. A political blockade prevented food and supplies transportation by rail or road to the Allied sections of Berlin. To sustain these areas, France, U.S. and U.K. circumvented the blockade through "Operation Vittles" an air transportation program that delivered more than 2.3 million tons of food, fuel and supplies to the residents of West Berlin. More than 278,000 airdrops were made by American aircrews, accounting for about 189,000 flights, and virtually 600,000 flying hours.[2]

A more recent example began on December 26, 2004. That day a tsunami was triggered by an earthquake off the coast of Sumatra measuring 9.3 on the Richter scale. This event devastated SE Asia and East Africa. More than 225,000 people were killed and 1.7 million were left homeless. Immediately, Operation Unified Assistance (OUA), a multinational humanitarian assistance/disaster relief (HA/DR) effort, organized the first relief response until a more sustainable operation could be established. OAU included the U.S. Department of Defense and other non-U.S. militaries and agencies, international organizations, and governmental and nongovernmental organizations. [3] Airlift operations were organized in a hub and spoke system. C-5 Galaxy and C-17 Globemaster III aircraft delivered equipment and relief supplies to a central base; C-17, C-130H, KC-130s transport aircraft were deployed to bring HH-60G helicopters and supplies to airports near the affected areas; and final leg where HH60s were used to bring supplies and relief personnel directly to and from disaster areas. HH60s also transported injured many individuals from outlying areas to hospitals. Other air missions included search and rescue and reconnaissance missions to locate those in need of assistance.

Advanced unmanned aircraft systems (UAS) operations such as Zipline's blood and vaccine delivery in Ghana and Rwanda, are overcoming infrastructural challenges for humanitarian needs where road transportation is slow and by human-piloted aircraft operations are not possible. UAS transportation can overcome these challenges by delivering medical supplies quickly, unencumbered by poor roads and lacking airport facilities. It is important to note that UAS, despite their size and capabilities, also require adherence to airworthiness engineering approaches for safety and reliability.

1.2 Coronavirus Disease 2019 (COVID-19)

Aviation has also helped with the COVID crisis response. Cargo operations from commercial carriers in general continued and contributed to the global humanitarian efforts providing 46,400 special cargo flights and transporting 1.5 million tons of COVID-19 related cargo between the onset of the pandemic and October 2020. This included medical equipment, such as PPE and ventilators, to areas in need during the height of the pandemic response. [4]

Since the COVID-19 vaccines have been approved, transportation needs have expanded including utilization of commercial aviation to support global distribution. Many of the approved vaccines require strict low temperature environments during transportation that are beyond normal equipment capabilities for commercial aircraft. Therefore, engineers had to address the introduction of dedicated equipment as well as infrastructure to mitigate the risk of spoilage. Commercial logistics carriers and military aircraft have also played major roles in transporting PPE, medical equipment, and vaccines.

As all these examples show, when aircraft are deployed for humanitarian efforts, both design and airworthiness engineering considerations are critical to ensure safety of flight. Engineers must have the airworthiness education and experience necessary to assure safety of flight for pilots, passengers, people, and property overflown as well as to provide mission success. Safeguarding the critical supplies and cargo that aircraft carry and ensuring it is delivered to where it is needed is vital to every humanitarian mission.

2 Need for Airworthiness Education

Engineers and professionals who understand the science of airworthiness are critical to safety, functionality, and certification of aircraft. Until recently, training in airworthiness engineering was accomplished through company and agency training programs, mentorship, and tacit knowledge sharing. Formal education for undergraduate, graduate, and professional levels in airworthiness was not available as a formal discipline. Aerospace engineering programs educated individuals on the fundamentals of engineering, aircraft design and manufacturing, but not the skillsets and requirements for the airworthiness certification of aircraft and safety of flight assurance. Over time, with the increasing numbers of aircraft and the growing number of new aircraft programs, the need for knowledgeable and experienced airworthiness engineers has significantly increased. This combined with concerns associated with retirements in the aging workforce, it has become obvious to government and industry that a need exists for a more focused effort to educate today's workforce and that of the future in the precepts of Airworthiness Engineering (AWE). The number of professionals who have this needed experience and qualifications are very limited and thus there has developed a clear need to create a baseline for formal educational programs in Airworthiness Engineering for undergraduate, graduate, and professional levels of attainment.

As a result of the limited number of professionals well versed in AWE, combined with the growing complexities associated with new aircraft, the time it takes to develop and certify an aircraft has substantially increased. The original 747 began in March 1966, was first flown on September 30, 1968, and was certified on December 30, 1969 [5]. That is a development program of 3.5 years and flight test program of just over one. In contrast the 787 began July 2003, was first flown on December 15, 2009, was certified on August 26, 2011 [6]. That is a development program of 8.25 years and a flight test program of just under two years. These longer timelines may have been shortened with additional resources, but would certainly have required, and benefited from, a larger number of trained AWE professionals. These professionals would be involved throughout the design process as airworthiness considerations influence the earliest stages of aircraft design.

The Aerospace Industries Association (AIA) in partnership with the Federal Aviation Administration (FAA), U.S. Department of Defense, and Embry Riddle Aeronautical University, took on a project to invigorate and expand the airworthiness talent pool, to define common curricula for Airworthiness Engineering programs and to define professional levels based on experience and responsibility. This effort would ensure and improve airworthiness compliance and safety for civil and military aerospace systems and embed the airworthiness discipline as part of the design and development life cycle of aircraft. As demands for certification of new aircraft-type entrants, such as UAS and advancements in Advanced Air Mobility (AAM), there will be an increase in demand for airworthiness professionals employed by both the FAA and aircraft designers / manufacturers to process aircraft certifications. Legislation is in place to leverage airworthiness experience within industry by authorizing the FAA to grant manufacturers specific delegations consistent with demonstrated expertise and the needs of the FAA. These organizational delegations are granted through an Organization Designation Authorization (ODA) which requires the ODA holder to ensure company procedures comply with applicable FAA requirements. Pursuant to this expectation, it is sensible that academia include Airworthiness Engineering and Professional training programs into their engineering disciplines to meet these emerging workforce demands.

3 Airworthiness Regulations

Throughout the history of aviation, accidents have always been a driver for change, improvement and enhanced safety. Initially, the response to accidents was driven by the OEM and the need for continued operations. It soon became clear that government oversight was required for aviation safety, and in 1926 the Air Commerce Act was passed, then in 1934, the Bureau of Air Commerce was formed. This act and bureau developed guidelines and rules for the development of aircraft and the rules they would be operated by. By 1958 the Federal Aviation Agency was formed as an independent agency responsible for aviation safety. [7]

The FAA, combined with efforts of SAE, RTCA and OEMs, have been improving the safety of the aviation industry ever since. Consequently, the documents and guidelines regarding aviation certification and regulation have been growing in length and complexity due to a number of accidents and incidents. A good example of a rule making related accident is the fatigue cracking of the DeHavilland Comet structure. At the time, the new pressurized fuselage cycling created cracks at the skin-window interface. As a result the “Fail Safe” design standards were developed and implemented by the OEMs and have evolved from Amendment 3-2 of the Civil Air Regulations (CAR), Part 3, effective August 12,1957 and to the current AC-23-13A. [7]

The current aviation regulations and guidelines are covered (not a complete list) by the following documents:

- FAA Regulations: 14 CFR Parts 21, 23, 25, 26, 27, 29, 33, etc.

- “Guidelines for Development of Civil Aircraft and Systems”, SAE ARP 4754A
- “Excellence in Procedure for Safety Assessment”, SAE ARP 4761
- ”Software Considerations in Airborne Systems and Equipment Certification”, RTCA DO-178
- “Certification Guidance for Installation of Non-Essential, Non-Required Aircraft Cabin Systems & Equipment”, RTCA DO-313
- “Type Certification - With Change 6”, FAA Order 8110.4
- Airworthiness Certification of Aircraft” FAA Order 8130.2

The complexity and thoroughness of these documents is beyond the understanding of a single individual and typically takes years in a career to understand only small portions of the documents. Currently most airworthiness engineers develop understanding and knowledge at OEMs after starting a career in a particular discipline such as Aerodynamics, Structures, Flight Test, etc.… That on-the-job style training has proved to be effective as the regulations and knowledge grew at the same time as many of those engineers were in the beginning of their careers.

4 Standards Approach to harmonizing curricula

4.1 Aerospace Industries Association National Aerospace Standards (NAS)

The Aerospace Industries Association (AIA) is a trade association that represents US aerospace manufacturers. In addition, AIA is a Standards Developing Organization (SDO) that develops and publishes National Aerospace Standards (NAS).

NAS standards have been developed by the aerospace industry since 1941. Committees and working groups that develop these standards are comprised of subject matter experts from industry and the FAA who work together to create and maintain the NAS Standards. NAS Standards cover a wide variety of subject areas including recently published NAS9945: “Airworthiness Engineering Training & Education”, published in July 2020 [8]. This standard provides common sets of requirements and qualifications for airworthiness engineering and certification roles at multiple professional levels. NAS9945 provides a comprehensive overview of the civilian and military skill sets, knowledge, and responsibility expectation that Airworthiness engineers and professionals will need at various levels throughout their careers.

To support NAS9945, AIA has initiated efforts to publish the following associated standards, which will provide more detailed guidance for Airworthiness education programs.

- Airworthiness Engineering Academic Curricula (NAS9945-1)
- Airworthiness Engineering Education & Training – Civil Aviation (NAS9945-2)
- Airworthiness Engineering Education & Training – Military / Defense (NAS9945-3)
- Airworthiness Engineering Education & Training – Emerging Technologies (NAS9945-4)

By providing standard definitions and expectations of education curricula and professional levels of Airworthiness Engineering related roles, Industry, academia, airlines, and government will all have a foundation on which to build a stronger and more knowledgeable airworthiness workforce.

4.2 ASTM International Standards

ASTM is a globally recognized standards developer [9]. It's ASTM International recently published Doc No. F-3457, "Standard Guide for Aircraft Certification Education Standards for Engineers and Professionals in Aerospace Industry", was developed to provide subject and content knowledge requirements for aircraft certification educational training courses for engineers and professionals in the aerospace industry.

5 Airworthiness Engineering Academic Curricula: NAS9945-1

The NAS Airworthiness Engineering Academic Curricula (NAS9945-1) is being developed in partnership between the aerospace and defense industry represented by members of the AIA, academic representatives, and the U.S government. NAS9945-1 will outline common airworthiness engineering education and training programs, guidelines and curricula that meet the requirements of industry and government.

NAS9945-1 provides minimum requirements for airworthiness engineering content and curricular structure for academic institutions and their faculty. The scope of the document encompasses a common set of curricula criteria and suggested content for airworthiness engineering academic courses at the bachelors and post-graduate levels, to include a certificate program for both the on-campus and on-line programs.

Since airworthiness engineering education programs are currently in the beginning stages, the recommendation of the NAS9945 team will be a new focused curriculum that any university may incorporate into their respective engineering programs. The only existing program began in august 2020 as a part of the Embry Riddle Aeronautical University Part of the guidelines will be to incorporate the ABET engineering requirements in the context of both standard aerospace engineering undergraduate curriculum and the new airworthiness engineering learning outcomes. Areas of concentration for traditional existing engineering degrees will also be outlined. It is a challenge to determine where topics may be removed or reduced in one program to enhance the other since the two are not mutually exclusive

An AWE program will follow the recommended ABET engineering curricula and can be tailored to almost any engineering program. This will include a minimum of the following in each category:

- 30 hours of college level mathematics;
- 45 hours of physical sciences;
- 12 hours of general education requirements; and
- 33 hours of upper level engineering and regulatory focused classes.

Similar to a traditional engineering curricula, these 33 hours would include basic structures, fluids, material science, advanced statics and dynamics (including controls), flight mechanics, and laboratory training. Each institution may tailor their curricula consistent with the focus, strengths, and research in the respective departments and colleges.

The main additions or changes to the bachelor coursework will be specific required and elective classes (in the 33 upper-level hours) dedicated to the understanding and application of the airworthiness standards and concepts discussed previously in this paper. The following are a few example of classes that could be developed and added to the curricula to enhance the AWE aspect of the programs.

- An elective class focused on regulations and that exposes undergraduates to the regulatory process and associated understanding required for proper compliance. For example, this could include the administrative aspects of FAA Order 8100 series of documentation. The class would then take the students through the required data collection (analytical, laboratory, test bench, and flight test data) as specified by the respective Advisory Circular guidance for each discipline or type certification.
- A second elective class would cover the basics of system safety aspects which would include COS, FMEA, and FMECA hazard analyses. This could include redundancy requirements and minimum safe control including risk analysis.
- Finally, a third elective could include more system engineering aspects of the design process including manufacturing, maintenance, project management, project organization, case studies, and ethics.

The capstone project for the degree would be focused on the real-world application of the airworthiness standards. It would apply the knowledge stated above in a design problem that would focus on the airworthiness and regulatory aspects of the aerospace design process. It would include the suggestions of the NAS9945 series and ASTM F3457-20. The students would participate in a mock certification project where they would need to show specific compliance with a TC, STC, or TSO project. Another pedagogy involves AWE students working conjunction with a traditional aerospace student cohort, with the AWE students playing the role of the ACO or ODA finding compliance of a product designed by others. This would flip the focus, but then extend the learning outside of the AWE curricula. This program will provide a basis for graduates to begin a career directly out of school in airworthiness under the direction of other airworthiness professionals.

The postgraduate and certificate programs would then expand the basic understanding from the bachelor program into specific areas of focus within aircraft certification and the airworthiness standards. Graduate programs will be required to include an advanced mathematics requirement that would complement the AWE focus with statistics or uncertainty analysis. The student would focus in a specific discipline. For example, a student could enhance their knowledge of structural design through the study of finite element analysis, advanced testing methodology, mechanic of materials, materials science, and advanced manufacturing.

In addition, the program would include the following content: correlation and analysis of test data, regulatory agencies and the rule making process, advanced safety analysis (fault tree, COS, FMEA, and FMECA), and advanced study of technical disciplines (aerodynamics, stability and control, structures, and mechanical systems). As a result, the graduate programs would include AWE focus areas such as, air-system engineering, structures specialization, and etc.… This would provide graduates with skills and knowledge that will enable him or her to join industry airworthiness departments in specific disciplines with minimal supervision from practicing airworthiness professionals.

One of the most important factors of developing these guidelines is ensuring the qualifications of the faculty and instructors. As the need for airworthiness engineers is great, utilizing airworthiness professionals for education is not practical in the near term. In addition, the majority of faculty currently in practice do not have industry experience in airworthiness. It will be the recommendation of the NAS9945 team that faculty teaching AWE will receive additional education and practice in airworthiness engineering and aircraft certification. This would include participation in case studies and ethical standards related to airworthiness. To fill the current gap in experience, airworthiness engineering subject matter experts currently practicing in industry should be used to educate the students and future faculty in this program. This working together approach is expected to enhance the efforts of all involved and optimize the educational experience of those completing their educations.

6 References

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[8] NAS9945: Airworthiness Engineering Training & Education (aia-aerospace.org)

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7 Glossary

AAM	Advance Air Mobility
ABET	Accreditation Board for Engineering and Technology
ACO	Aircraft Certification Office
AIA	Aerospace Industries Association
ASTM International	Formally known as the American Society for Testing and Materials
AWE	Airworthiness Engineer(ing)
CFR	Code of Federal Regulations
COS	Continues Operational Safety
FAA	Federal Aviation Administration
FMEA	Failure Mode and Effects Analysis
FMECA	Failure Mode Effects and Criticality Analysis
IATA	The International Air Transport Association
NAS	National Aerospace Standard
ODA	Organization Designation Authority
OEM	Original Equipment Manufacturer
RTCA	formerly known as Radio Technical Commission for Aeronautics
SAE International	Formally known as the Society Automotive Engineers
STC	Supplemental Type Certificate
TC	Type Certificate
TSO	Technical Standard Orders
UAS	Unmanned Air System