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Michael S. Nolan

Erin E. Bowen

Michael W. Suckow

Morgan E. Hall

Brent D. Bowen

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Michael S. Nolan
Department of Aviation Technology, Purdue University
West Lafayette, IN, USA

Erin E. Bowen
Department of Technology Leadership and Innovation, Purdue University
West Lafayette, IN, USA

Michael W. Suckow
Department of Aviation Technology, Purdue University
West Lafayette, IN, USA

Morgan E. Hall
Department of Aviation Technology, Purdue University
West Lafayette, IN, USA

Brent D. Bowen
Department of Aviation Technology, Purdue University
West Lafayette, IN, USA

Flight data collection systems have been used for many years to help monitor and trend flight parameters to better understand aircraft performance and maintenance. However, this information is rarely used to understand and enhance cognitive/behavioral factors impacting flight and maintenance training. This conceptual paper outlines a strategic research model in the collegiate aviation setting, designed to manage the successful integration of data from technologically-advanced aircraft (TAA) into flight, maintenance, and dispatch training and operations. A critical review of the key issues and approach framework should be discussed in the research community. The model will address issues of organizational change management, training and curriculum modification research to accompany data utilization in conjunction with TAA aircraft integration, safety and human factors issues, and perceptual/attitudinal factors. The model presents a framework for assessing and guiding the potentially revolutionary change inherent when advanced aircraft and their data are integrated into training, maintenance, and operations.

The purpose of this article is to lay the foundation for aviation data integration not only throughout collegiate aviation education, but in the global training context. Such integration not only has the potential to improve training efficiency and performance but also improve overall safety. The persons who engage in the early phase of this innovation (early adopters themselves) will be those who provide leadership as they look to change and enhance aviation education technology and safety. The insertion of technologically advanced aircraft into the existing collegiate aviation setting is a spur to drive a paradigm shift from reactive to proactive/predictive aviation systems, and the authors hope that the present paper provides a framework for managing this fundamental shift in education, technology, and innovation.

Flight data recorders were first mandated by The Civil Aeronautics Administration in 1958 to record the actual flight conditions of the aircraft including; heading, altitude, airspeed, vertical accelerations, and time (Haas, Walker, & Kough, 2008). As the years and technology progressed the amount of information collected from the aircraft increased dramatically and interest grew in the application of this data to improve safety and performance. Today, these data gathering systems have evolved into what is now known as Flight Operational Quality Assurance (FOQA) programs (Haas, Walker, & Kough, 2008). FOQA programs were first implemented by scheduled airlines to increase safety, but economic value was quickly realized as the airlines became more familiar with the data collection process. FOQA-style programs moved through the aviation community from scheduled airline operators to helicopters to commercial Part-135 operators and eventually to the military. The data collection programs were producing results from reduced engine removals and increased fuel management to increased crew efficiency and reduced insurance premiums (Haas, Walker, & Kough, 2008).

Modern flight data collection systems have the capacity to gather information on a wide array of both aircraft system and operator performance components. Today flight and engine parameters are being used to increase the maintenance cycles of engines by monitoring internal temperatures and vibrations and extending the life of airframes by monitoring stresses during flight. One study done on the Red Arrow Flight team of the UK showed that wingman were typically experiencing structural stresses double and triple that of the lead aircraft, something we may never have known without structural recorders (Brooks, 1999). While this is a significant gain from previous reactive maintenance systems, there is limited evidence demonstrating that such data are being used to refine training, design, or display information (Stephens, 2004).

The introduction of flight data collection systems via the conduit of Technologically-Advanced Aircraft (TAA) into general aviation presents a revolutionary shift in the information accessibility of GA operations. The basic definition of a Technologically-Advanced Aircraft is an aircraft containing, at minimum, a moving-map display, an IFR-approved GPS navigator, and an autopilot (AOPA Air Safety Foundation, 2005). In many TA aircraft the aforementioned equipment is accompanied by new-generation avionics, traffic, weather, and terrain avoidance information all with system redundancies. The TA aircraft has certainly made an impact in regards to aircraft production. According to the Aircraft Owners and Pilots Association (AOPA, 2005), in 2004 there were 1,758 light GA pistons manufactured by General Aviation Manufacturers Association (GAMA) member companies, of which ninety-two percent were TAA or contained TAA-like equipment. Today, even though most general aviation aircraft still utilize analog or “steam” gauges, new production of general aviation transportation aircraft such as those manufactured by Cirrus and Diamond are virtually all TAA (AOPA Air Safety Foundation, 2005).

Challenges of TAA Integration

The substantial growth in TAA production for the general aviation sector presents significant training challenges, particularly in the collegiate aviation environment. Initially, financial considerations for integrating advanced aircraft into existing training programs are greater. This includes not only the initial higher purchase price for TA aircraft as compared to their non-TAA counterparts, but maintenance costs for the TA aircraft run at a higher level over the long term. In addition, TAA software and tools often require subscription services with annual costs to maintain accuracy of charts and functionality of databases for TAA data storage. Retraining of the flight instructor workforce to include TAA technology and concomitant revisions to training curricula are also expenditures a collegiate training program must consider as part of the TAA evolution.

While financial considerations of TAA integration may be one challenge facing collegiate aviation, of equal (or perhaps greater) concern are the myriad strategic and conceptual programmatic changes that such technology bring to training. TA aircraft cannot simply be thought of as a new tool to fit into an existing structure, but should rather serve as an impetus for a substantial and critical look at the role of information and information capacity in all aspects of aviation. The defining feature of TA aircraft is that they are "technologically advanced"; that is, students training in such aircraft are required to learn both the technical aspects of flying as well as the utilization of the technology integrated into the aircraft.

Previous research demonstrates that this combination of technology familiarization and flight skill training provide significant initial stress and complexity for the beginner pilot, leading to decreased situational awareness and an increased risk of human factors-related errors (e.g., Wickens et al., 2004). As part of the "SAFER SKIES" initiative the FAA conducted a General Aviation TAA safety study to research the early observed safety issues with TA aircraft. Safety problems were identified in the accidents that the team studied that were typical problems found after an introduction of new technology. The safety problems were also all characteristic of general aviation pilot judgment errors, (Fiduccia et al., 2003) these two factors combined contribute to the large training concern of new TAA pilots; "However, the existing training infrastructure currently is not able to provide the needed training in TAAs," (p.4). One program to identify and develop mitigation strategies for these issues is the SAFER project, a collaboration between Middle Tennessee State University and the NASA Langley Research Center. The SAFER project's goals are to discover improvements and adaptations of the traditional pilot training methods to complement technologically-advanced aircraft. This is researched by taking beginner pilots through their private pilot license and instrument rating in TA aircraft (Craig, Bertrand, Dornan, Gossett, & Thorsby, 2005).

One of the key features of collegiate aviation programs that distinguish them from other, commercially- or professionally-focused programs are their foundation within the academic, university setting. This setting presupposes that collegiate aviation students are present not only to earn the required certifications for their desired aviation career, but also to earn an academic degree with a broad-level base of knowledge. In addition, collegiate instructors possess not only technical expertise and certification, but are immersed in a foundation of scholarship and the continued contributions to aviation as an academic field. Aviation training in the collegiate setting should thus be set within a context of the academic discipline of aviation; the integration of TA aircraft to training makes this context of the highest necessity.

Given the potentially revolutionary nature of TAA inclusion in collegiate aviation, the authors argue that complete integration of the full potential of TAA technology cannot be achieved without the implementation of a strategic research model that provides a framework and context for programmatic evolution. The authors have developed such a research model and are currently working to implement it in a collegiate aviation program at a major research university. While based in a classic input-process-output (IPO) framework with multiple feedback loops, the TAA integration model provides guidance on full integration of TAA capabilities into a collegiate system. Such models have been similarly put forth to assess and improve aviation system performance (e.g., Patankar, Bigda-Peyton, Sabin, Brown, & Kelly, 2005) safety integration among flight crews (e.g., Block, Sabin, & Patankar, 2007) and other subsystems in the aviation industry. Failure to utilize such a model not only limits the research and scientific potential inherent when such data-gathering is an ongoing part of the flight, maintenance, and operations programs, but increases the likelihood that human errors based in the challenging combination of high-technology learning and new skill acquisition (Wickens et al., 2004) will occur.

Technologically Advanced Aircraft Data Integration Model

The TAA data integration model was developed at Purdue University as a multidisciplinary collaboration between the departments of Aviation Technology and Technology Leadership & Innovation. This collaborative development is itself a result of the inclusion of TA aircraft into the existing collegiate aviation setting, and it can be seen in the model's context that further technology integration necessitates an increasingly interdisciplinary interaction such as this. Model development followed the methodological guidelines of the Policy Research Construct (PRC) developed by Bowen and Lu (2004) and utilized many of the strategic collaboration approaches proposed by Bowen, Block, and Patankar (2009).

The TAA model utilizes the PRC flow chart basis for the systematic portrayal of an evidence-based systems-theory approach for integration of TAA into a collegiate aviation program. The matrix portrayed graphically in the conference presentation (and available on requested by contacting the corresponding author, Dr. Erin Bowen) provides an X axis that is based on Objective Performance (as measured by the TAA aircraft) and a Y axis that represents Standards (as codified by the Federal Aviation Regulations (FARs)). This mirrors the policy research construct of Data acquisition feeding Policy analysis as represented by the Practical Test Standards (PTS). With a growing body of data collected from the TAA aircraft, meta-analysis can be conducted to recommend policy actions.

This proposed TAA integration model is presented to provision a baseline for deployment in collegiate aviation programs. While not yet fully defined, the intent is a starting point for a new line of research enabled by TAA deployment in a rapidly increasing capacity. Such a research frame work could allow a consistent evaluation over time similar to that provided in the PRC.

While TAA inclusion is a common spur to the application of the integration model, it does not have to be the only or the initial mechanism for model application in a collegiate setting. What is essential in early data integration is the digitization of key data inputs into the model. Until the majority of data inputs can be placed into a digitally accessible format, the integration potentiality of a single piece of technologically advanced equipment is severely limited. For example, collaborators on the present article are developing methodology for digitizing flight operations, dispatch, maintenance records, and even curriculum data. As with other systems-based models, model input data must be accessible in a common format before connections and feedback loops may evolve.

Interoperability of input data in a shared center follows inherently on the heels of the digitization process. Presently, TAA data integration model developers at Purdue have participated in the creation of an Aviation Data Center (ADC), designed to serve as a common physical and electronic destination that centralizes and maintains interoperable databases of all digitized data. This interoperability is a significant challenge in the TAA data model, as it requires both substantial technical and evaluative capability. However, until the various data components can be related to one another in a meaningful way, the system-level interactions and patterns will remain beyond the view of system managers. It is precisely this goal to observe, track, and modify micro- and macro-level changes to the system that is a key goal of the TAA integration model. This goal shifts the collegiate aviation education setting from a reactive system to a proactive/predictive system; much as maintenance researchers advocate the use of enhanced technological tools to conduct predictive maintenance protocols rather than engaging reactive maintenance behaviors (e.g., Stephens, 2010).

Data digitization and interoperability leads to a growth in collaboration and the establishment of formalized feedback loops in the TAA integration model. These collaborations and loops represent a profound shift in the way collegiate aviation perceives itself, from being a relatively semi-autonomous program to a small piece of a globally complex system. Collaboration may begin on a relatively micro level (as evidenced in the intra-university research collaboration that developed the model itself), but through strategic feedback development should expand to interact with other collegiate programs, industry and government partners, and a global aviation community. The establishment of such collaborative linkages promotes innovation and will require feedback to the model's inputs; for example, growth from collaboration may point to necessary changes/evolutions in educational curriculum or professional training needs.

The collegiate aviation setting has the potential to serve as an opportune test bed for the refinement of the TAA data integration model. Currently, Purdue University researchers are working to implement this model and evaluate system components in order to provide a baseline for scaling to other educational and industry settings. The Purdue Aviation Data Center provides a physical foundation for the digitization and interoperability of the multi-level data inputs into this new technology-based aviation education system. Researchers are identifying and implementing mechanisms for formalizing feedback among system components.

Driving this model in part is the utilization and enhancement of multiple feedback loops at various stages throughout the integration process. While it is easy to encourage such feedback on an informal level, true data integration cannot occur until such reciprocal loops are made explicit and a fully evolved part of the daily function of the collegiate aviation system. In addition, the level of active collaboration within and across the collegiate setting of necessity increases as the feedback loops solidify; this in turn evolves into a model that promotes global interoperability.

The effective organization is likely to be one that demonstrates *alignment* among the different contextual variables in the system; that is, the processes, infrastructure, environment, and rewards systems in place in the organization are designed to support the organization’s values and goals, without being rigidly locked to one another (Semler, 1997; Snow & Hambrick, 1980). For example, an organization may spend several million dollars designing, implementing, and evaluating a training program designed to teach teamwork skills to employees, but if supervisors continue to reward only individual success, strong hands-on managers, and limiting team interaction, the likelihood of that training causing positive organizational change is very slim. Understanding and working to align as many system variables as possible is an essential part of improving organizational effectiveness (Snow & Hambrick, 1980). This logic extends to collegiate aviation training organizations, and the inclusion of TA aircraft makes this logic a mandate for successful integration. If true value is to be achieved from the investment in such technology, then a model that explicitly identifies, tracks, and continuously monitors and evolves the alignment and feedback requirements is required.

Currently integration of TA aircraft in this setting is in the initial phases. Development of a data center research facility at Purdue University provides secured data storage and access for students and research collaborators. An ongoing challenge is creating an integrated database in which system models can be visually created and simulations run on various input scenarios. The purpose of this TAA Integration Model is to provision a model that can be applied universally in the application of a changing collegiate flight education paradigm.

Conclusion

The paradigm shift with the incorporation of TAA in collegiate aviation is the move from treating the collegiate program as a series of connected yet semi-autonomous parts to a fully-integrated system. The research model visibly demonstrates to students, faculty/staff instructors, and relevant stakeholders that shifts in one aspect of the model have the potential to cause ripples throughout the program; ripples that may have safety or performance consequences on the entire system. Collegiate aviation is an ideal setting to develop, test, and refine such an integration model because it benefits from a level of structure and control other aviation industry settings, subject to the whims of commercial pressures, do not have. The authors predict that continued inclusion of TAA and other such tools will spur a drive toward more tightly interconnected program components and require a higher level of academic and professional scholarship, both from students and faculty. TAA data serve as a starting point and impetus for perceiving, treating, and responding to aviation as the complex system that it is, which in turn better prepares TAA-trained students to function in a global aviation setting. The authors present this paper as a proposal to apply rigorous methodology as a foundation for revolutionary change in collegiate aviation. In result of this research for improvement in collegiate aviation education, the first global endeavor for deployment of the model is being presented by coauthors to potential collaborators at Moi University (Kenya) and Qatar Aeronautical College (State of Qatar) prior to the publication of these Proceedings.

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*E. E. Block is now E. E. Bowen and has published scholarly articles in the aviation and psychology literature under both names.