CONCURRENCY – A MOVING TARGET

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ABSTRACT

Concurrency is a significant challenge to the aircraft simulation industry. Concurrency is achieved when the simulator configuration is kept current with, or slightly ahead of, the aircraft configuration. This allows aircrews and maintenance personnel to train on new systems before they experience them on the aircraft. The most important consideration in designing for concurrency is simulating the avionics systems such that future changes to the aircraft configuration and software can be incorporated into the simulator with minimal time and resources. With the proliferation of avionics modernization programs and Global Air Traffic Management (GATM) driven upgrades, concurrency has an even greater significance. The C-130 and C-5 Avionics Modernization Programs (AMP), AH/MH-6M Mission Enhanced Little Bird (MELB) upgrade, H-60R/S Common Cockpit upgrade, and the EA-6B Improved Capabilities III (ICAP3) program are just a few current examples. This paper describes one of the primary tools available to help achieve concurrency objectives – ARINC Report 610, *Guidance for Use of Avionics Equipment and Software in Simulators*. Although a commercial document, ARINC Report 610 can be effectively applied to military programs. There is no equivalent military guidance document. This paper describes the history of ARINC Report 610, from its initial publication in 1987, through the release of revision B in December 2001. The rationale behind the A and B revisions is described, and supplemental guidance information is provided. Finally, the paper suggests how to use ARINC Report 610 on military simulator development programs.

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INTRODUCTION

Concurrency is achieved when the simulator configuration is kept current with, or slightly ahead of, the aircraft configuration. This allows aircrews and maintenance personnel to train on new systems before they experience them on the aircraft. Many procurement specifications now include the requirement that the initial simulator design be implemented such that future changes to the aircraft configuration and software can be incorporated into the simulator with minimal time and resources. With the upsurge in new airframes, avionics modernization programs, and Global Air Traffic Management (GATM) driven upgrades, concurrency has an even greater significance. Incorporating frequent avionics changes (primarily software) in a timely fashion is a significant challenge to the simulation industry and, as it relates to training aircrews on the current aircraft configuration, a significant safety issue.

Scope

This paper describes one of the primary tools available to help achieve concurrency design objectives – ARINC Report 610, *Guidance for Use of Avionics Equipment and Software in Simulators*. Although a civil aviation document, ARINC Report 610 can be effectively applied to military programs. There is no equivalent military guidance document. This paper describes the history of ARINC Report 610, from its initial publication in 1987, through the release of revision B in December 2001. The rationale behind the A and B revisions is described, and supplemental guidance information is provided. Finally, the paper suggests how to use ARINC Report 610 on military simulator development programs.

Significance

The list of aircraft undergoing major avionics upgrades seems endless. The C-130, C-5, H-6, H-47, H-60, and EA-6B are just a few examples. With the constant advances in navigation, communication, identification, and weapons systems, aircraft upgrades will be with us forever. Given the complexity of today's avionics, it's essential that flight crews train on the systems before experiencing them in the aircraft. In short, concurrency is a significant safety issue.

HISTORY AND OBJECTIVES

ARINC Report 610 has several objectives, but the primary reason it was created, and continues to be periodically updated, is concurrency. This section briefly reviews the history and rationale behind the three releases.

ARINC Report 610

The Airlines Electronic Engineering Committee (AEEC) first adopted ARINC Report 610 (referred to hereafter as 610) in August 1986 [1]. The AEEC is sponsored by Aeronautical Radio Inc. (ARINC), a corporation in which the United States scheduled airlines are the principal stockholders. Other stockholders include a variety of air transport companies, aircraft manufacturers and foreign flag airlines. The AEEC, composed of airline technical representatives, formulates standards for electronic equipment and systems for the airlines. In November 1990, Supplement 1 (610-1) was added, which introduced an appendix describing a suggested simulator interface for the evolving Traffic Alert and Collision Avoidance System (TCAS).

The primary goal of 610 was to encourage, and provide guidance for, the direct use of applicable airborne equipment in simulators. The objectives included optimized training, assured fidelity of operation, readily available spares, and concurrent aircraft and simulator operational software. In order to achieve their goal, the writers believed that all those involved in the process (avionics designers, simulator designers, airframe manufacturers, and airline simulator users) required a fundamental understanding of simulator design, operation, and training. In addition to implementation guidance, 610 provided this understanding. Due to the revolution in embedded computer technology in the 1980s, avionics equipment dramatically increased in complexity, resulting in frequent operational software updates. This trend elevated concurrency to the top of the objectives list.

ARINC Report 610A

ARINC Report 610A was adopted by the AEEC in December 1993 [2]. Its primary objectives were identical to those of 610. The update was motivated by further advances in avionics technology. It was also intended to encourage wider acceptance by providing more in-depth guidance (610 contained 46 pages, 610A has 188). Simulator fidelity expectations had also grown over the years. The Boeing 777 development was underway, and it had a heavy influence on the contents of 610A. The 777 avionics and simulator manufacturers were well represented among the writers. The 777 introduced the concept of Integrated Modular Avionics (IMA), and the new ARINC 629 interface standard. These technologies required special considerations when used in a simulator. In 1997, Supplement 1 covering the Communications Management Unit (CMU) was issued.

ARINC Report 610B

ARINC Report 610B was adopted by the AEEC in October 2001 [3]. Once again its primary objectives were the same as earlier versions. New avionics systems, such as Electronic Checklists and Terrain Avoidance Warning Systems (TAWS) were covered for the first time. 610B is a 28-page document, down from the 188 pages in 610A. What happened? The reduced page count was partially due to technical developments and trends in simulation approaches (e.g., greater use of commercial off the shelf (COTS) standards and equipment). The key reason, however, was that industry had not adopted many of the recommendations contained in 610A, mainly due to the perceived cost of full compliance [4]. Some areas of 610A were difficult to understand, and the level of detail provided gave it the flavor of a specification, rather than a guidance document.

In general, 610B focuses on simulator function objectives, rather than implementation specifics. Chapters 5 and 6 of 610A, which provided detailed templates for serial communications between simulator host computers and stimulated avionics, were removed. They were replaced by a brief discussion of recommended industry standard interface protocols. Note that, for the first time, MIL-STD-1553 (Command/Response Multiplex Data Bus) was included in the discussions. First introduced in 1975, 1553 continues to dominate the serial communications needs on military aircraft.

Appendices A through K were also removed in the 610B version. They provided implementation details for each type of avionics equipment (e.g., Flight Management Systems and Display Systems). Since few, if any, applications adopted all the specific recommendations, the 610B writers decided the general guidance provided in Chapter 4 was sufficient. They also wanted to allow flexibility in the implementation, since each application was unique to some degree.

The five training scenarios presented in Appendix L were replaced by one scenario in the 610B release. The writers believed the single, recurrent training scenario provided avionics engineers with a sufficient understanding of the use of simulator functions during a training session.

Of particular note is the number of simulator functions defined in each of the three versions. 610 defines 17 functions, 610A defines 32, and 610B defines 22. The number of freeze functions (e.g., Flight Freeze and Altitude Freeze), set/slew functions (e.g., Weight Change and Airspeed Change), and control functions (e.g., Snapshot Take, Speed Times N and Reposition to Initial Conditions) have remained relatively constant. The fault functions (e.g., Fault Memory Clear and Fault Memory Download) were first introduced in 610A, as a result of the advancements in fault reporting and diagnostics technology. These were largely retained in 610B, as they are useful in achieving optimized training on today's sophisticated maintenance tools, such as portable PCs. 610A also introduced several simulator validation and certification functions (e.g., Pitch Freeze and Vertical Speed Change). These were removed in 610B, as they generally required no active support from the avionics equipment.

Note that all three versions (610, 610A and 610B) remain on the books at ARINC. All three can be referenced, but 610B should be used on all future programs.

EVOLUTION AND RATIONALE

As noted in the summaries above, all versions of 610 share the same primary objective – concurrency. The fundamental guidance in this area has not changed since the initial release in 1987. The secondary objectives have also remained steady (optimized training, fidelity, and spares availability). The motivation behind each of these objectives is described briefly in this section.

Concurrency

Although the methods used to achieve it may be debated, keeping simulators in the same configuration as the aircraft is crucial. Obviously, flight crews need to be trained in the aircraft configuration they fly. There have been situations where the simulator configuration lagged the aircraft configuration by months and, in some cases, years. In addition to safety concerns, this results in user dissatisfaction with the simulators. Many factors contributed to the disparity, such as lack of configuration control, failure to consider simulator needs when ordering aircraft parts, and simulator procurement methods. These are process factors, and they have seen much improvement in recent years. It's not uncommon to find an Integrated Product Team (IPT) on major programs dedicated to addressing these factors. For example, the C-130J Maintenance and Aircrew Training System (MATS) program has a 'Concurrency IPT'. They developed a Concurrency Management Process and report regularly at program reviews.

However, the simulator avionics architecture (design) is the primary concurrency factor and the one most often not addressed. Recent trends have raised the importance of this factor even more. Today's avionics systems are software intensive with substantially more functionality contained in a single box. As software complexity and functionality grows, updates become more frequent. For prototype avionics systems, it's not uncommon to see a multiyear plan reflecting a series of incremental releases, each with enhanced functionality. Constant technology advances and new operational requirements, such as GATM, have contributed to the almost constant flow of avionics upgrades. The simulator design must accommodate frequent changes if concurrency is to be achieved.

Optimized Training

Although not as expensive as an aircraft, developing and maintaining a simulator represents a substantial investment. Demand for time on full fidelity simulators is normally very high. Couple this with the need to minimize the time a flight crew spends in refresher training (time away from their duties), and "optimized training" becomes an obvious goal. One example of how this goal is achieved (cited in 610B) is repositioning to localizer intercept following an Instrument Landing System (ILS) approach. By instantaneously repositioning the simulator following touchdown or missed approach, and bypassing the downwind leg, five approaches can be flown in 20 minutes instead of 60. To realize these savings, the avionics equipment used in the simulator must accept the instantaneous reposition, and continue to function properly.

Another example in the commercial domain is Line Oriented Flight Training (LOFT), in which the simulator is used to "fly" a complete profile, replicating line operations, rather than training for individual procedures in isolation. This is somewhat equivalent to mission training in the military domain, where crew coordination and interaction with other aircraft are important. During the cruise phase of a long leg, activating the Speed Times N function can save simulator time without radically impacting the fidelity of the mission. Again, the avionics equipment must support this function in order to realize the savings.

Finally, given the new requirements that virtual devices participate in collective and distributed mission training, it's even more important that an entire scenario not sit idle waiting for a black box to be reinitialized following a freeze or instantaneous reposition.

Fidelity

In most cases, using unmodified aircraft avionics in the simulator virtually guarantees the system performance matches that of the aircraft. This facilitates the simulator accreditation process. Highly complex avionics equipment, such as a Flight Management System, is often impossible to simulate at a high level of fidelity due to production schedules, rapidly changing designs, proprietary data, or the enormous demands placed on simulator host computer resources.

Spares Availability

Use of unmodified aircraft avionics allows the simulator training centers to use the aircraft equipment spares pipeline. Of course this can work both ways, that is, avionics can be pulled from the simulator (lower priority) for use on an aircraft.

IMPLEMENTATION AND OBSTACLES

Contrary to most interpretations, compliance with 610B does not require that support for the simulator functions be embedded in the flightworthy Operational Flight Program (OFP). This approach is historically referred to as adding software "hooks" in the OFP to interface with the simulator host computer. The hooks, together with a serial interface channel between the simulator host computer and avionics equipment, support the exchange of simulator function data (activation commands and associated parameters). The term "hooks" is not used in 610B, and it is not necessarily representative of the types of OFP modifications that are required. The term tends to understate the cost and level of effort associated with the modifications. Its use can lead to the false conclusion that the level of effort involved in embedding support for the simulator functions in the OFP is trivial, and therefore not a significant cost or schedule issue (and therefore a low priority). "Adding software hooks" implies an after-the-fact overlay and, in most cases, is not the best approach for modern software architectures, or for addressing safety concerns.

It's also best to avoid use of the term "compliance", as 610B is a guidance document. If the avionics equipment can be used in a simulator and achieve the objectives summarized in the preceding section, then the guidance has been followed – irrespective of how this was achieved. Nonetheless, the writers of 610, 610A and 610B, representing the civil aviation training industry, believed that embedding support for the simulator functions in the flightworthy software carries the best chance of achieving concurrency over the long haul. This belief was based on years of experience with various approaches [5]. For example, in some cases, a separate simulator unique version of the OFP was developed. It included support for the 610 functions and was maintained separately from the flightworthy OFP. Unfortunately, however, it was not maintained and, over time, diverged substantially from the flightworthy OFP. This was primarily due to funding and resource priorities (training was not a priority).

In the military domain, two arguments are usually presented against modifying flightworthy OFPs, and they are described here.

The Safety Argument

Safety of flight is often cited as the primary reason for not embedding 610B functionality (hooks) in flightworthy OFPs. Having "training" software onboard the aircraft just doesn't feel safe. Safety should always be the top concern in any analysis concerning flight. However, consider the following discussion on this subject.

First, the concept should be separated from the implementation. That is, for embedded 610B functionality, is the safety concern with the concept, or that the concept may be poorly (unsafely) implemented? If the former, are there technical reasons, or is it just the mental image of simulator functions inadvertently activating in flight (Flight Freeze!)? Most avionics systems are software intensive, and lives depend on the proper combination and execution of ones and zeros. Embedded 610B functionality is just additional ones and zeros that must perform only their intended purpose. Even without embedded 610B functionality, one can contrive scenarios resulting from avionics software "failures" that are much more terrifying than Flight Freeze. Adding additional software functionality, irrespective of its intended purpose, should not be cause for concern. Note that the U.S. Army has identified Embedded Training (ET) as a key ingredient in its Future Operating Capability (FOC) [6]. The plan is to design training functionality into operational systems to enable soldiers to train using organic equipment while in the field or at the home station. Near term requirements include integrating ET functions within current warfighting systems. The "onboard" embedded training will sense what the weapon system is doing, inject simulated stimuli, and communicate with the surrounding infrastructure. ET is considered an essential element in training the future Objective Force. The extent to which ET will be used in aircraft is yet to be determined but, nonetheless, the safety concerns with regard to ground-based weapons systems will be overcome.

As regards poor (unsafe) implementation of the 610B functionality, the intent is that the software modifications be designed and developed to the same rigorous standards as the operational software in the avionics equipment. In fact, the same engineering team that develops and maintains the flightworthy OFP should develop the 610 software. DO-178B, *Software Considerations in Airborne Systems and Equipment Certification*, must apply to all the software in a box, including the 610B functionality. DO-178B, published by the Radio Technical Commission for Aeronautics (RTCA) in 1992, "provides guidance for determining, in a consistent manner and with an acceptable level of confidence, that the software aspects of airborne systems and equipment comply with airworthiness requirements" [7]. DO-178B defines five levels of software criticality, ranging from Catastrophic (A) to No Effect (E).

From a software architecture standpoint, integrating the 610B functionality during the avionics conceptual design provides the best opportunity to ensure safety concerns are addressed. Proper partitioning of software components, and rigorous verification and validation (including flight tests), should be carried out. The 610B functionality should be professionally integrated by the avionics software developers, not "overlaid" by someone unfamiliar with the software architecture. If this approach is followed, there should be no reason to doubt the implementation.

To address safety concerns, 610B recommends use of a program pin and keep alive signal to guard against inadvertent activation of the embedded training functionality. The program pin provides a hardware mechanism to tell the avionics if it is installed in an aircraft or simulator. The keep alive signal, received from the simulator host computer via a serial interface, is continuously monitored by the avionics equipment to determine if it is operating in a simulator. If either the program pin or keep alive signal are absent, the avionics will "disable" all training software. In addition, appreciating safety concerns, 610B intentionally avoids recommending embedded support for simulated malfunctions.

Finally, note that the list of commercial aircraft "flying" Flight Management Systems (FMSs) with embedded support for 610 functions includes: Airbus A300, A310, A330/340; Boeing B717, B747-300/400, B757, B767, B777; Bombardier Dash 8-100/300, Learjet 31A/45/60, Embraer ERJ-145, Hawker 800, Cessna Excel, and McDonnell Douglas MD-10, MD-11.

The Cost Argument

The costs associated with implementation and testing are usually cited as the second reason for not embedding 610 functions in flightworthy OFPs. There are costs associated with any software development effort, and this concern should not be dismissed outright. However, three points are worth highlighting on this issue:

1. When performing the cost-benefit analysis, be sure to include optimized training, fidelity, spares availability, and concurrency among the benefits.

2. The earlier in the avionics development cycle that the 610B functions are embedded, the less the associated costs. It's much easier to design in the functionality up-front, rather than retrofit it after the fact (predicting the impacts on existing code is difficult).

3. Avoid unnecessary OFP changes. Perform a 610 analysis (more later) before implementing the design.

Alternate Methods

As mentioned, 610B does not require that the simulator functions be embedded within the flightworthy OFP, although this is the preferred method for achieving concurrency. Alternate methods include using specially designed simulator hardware and software to manipulate the inputs and outputs of the avionics equipment, or producing a separate "for simulator use only" version of the OFP with embedded 610B functionality. Others include rehosting the avionics executable code, or retargeting the source code, to a COTS processor, and then adding the 610B functionality. The viability of the various alternatives is unique to each program, and depends on things such as funding, schedules, training priorities, avionics architecture and functionality, and simulator/avionics developer relationships. In some cases, doing nothing is adequate – provided the analysis determines the avionics equipment will handle activation of the simulator functions properly. Note that with this approach, however, future releases of the OFPs must be reanalyzed, since new functionality may have been added that won't properly handle the simulator functions. In each instance, an analysis is required to develop the best solution. Once an approach is selected, diligence is required during the implementation (each of the methods mentioned can succeed or fail based on the quality of the implementation).

MILITARY VERSUS CIVIL TRAINING

Although largely applicable to military training, the fact that 610B is a commercial document should be considered during the analysis. Airline training center representatives were dominant in establishing its content, and much of the guidance provided reflects the way they train. Military training methods can differ in many respects, and this should be considered during the planning and analysis process. Training methods also vary among the armed services, and within services based on aircraft type and mission (e.g., transport versus attack aircraft). Some noteworthy differences in methods between civil and military training that may impact the significance placed on each of the 610B functions are:

- Aside from the possible exception of LOFT scenarios, there is no "mission" training in the commercial domain.

- Airliners don't fly in formation, drop paratroops, or conduct air-to-air refueling.

- Aside from landings and takeoffs, airliners avoid lower altitudes (which may bear on the TAWS analysis).

- Commercial simulators almost always have the instructor station on board. Military simulators are a mix of both on board and off board instructor stations.

- The instructor in a commercial simulator rarely occupies one of the crew positions during training.

- Record Replay generally sees limited use in commercial training.

- Commercial simulators don't conduct mission rehearsal exercises.

- Post flight debriefs are less important in commercial training.

- Commercial simulators do not participate in collective Live-Virtual-Constructive exercises, or Distributed Mission Training.

USING 610B ON MILITARY PROGRAMS

As mentioned earlier, 610B guidance should be considered early in the requirements phase when upgrading aircraft with new or modified avionics. This usually doesn't happen. More often than not, training and simulation needs are not addressed until the avionics designs are well down stream. This tends to limit options and increase costs. However, even in these cases, 610B can provide valuable guidance.

To illustrate this, the Army's AH/MH-6M Mission Enhanced Little Bird (MELB) project will be described. Not to pick on a Little Bird, but this project is topical and typical, as regards 610 issues. (Due to the types of missions flown by the MELB, there is little else typical about this project.)

The MELB helicopters are undergoing a substantial upgrade that includes new avionics. The simulator contract was just awarded (March 2002), following three-months of negotiations. The aircraft avionics development effort has been underway for roughly two years, and is in the final stages of integration and test. There was no requirement placed on the avionics vendor to accommodate, or even consider, simulator training. The first conversation between simulator and avionics engineers occurred during the recently concluded simulator contract negotiations.

Although the opportunity to incorporate 610B functions during the avionics conceptual design phase had long since passed, 610B is still being used for guidance during the simulator development effort as described in the following paragraphs.

Simulator and avionics engineers will meet and discuss the proposed simulator architecture. The MELB avionics suite includes a broad range of communication, navigation, identification, and weapons systems. The "simulate/stimulate" rationale for each system will be reviewed. "Simulate", in this context, means replicating the avionics functionality using simulator unique hardware and/or software. "Stimulate" means using the actual aircraft avionics equipment in the simulator. The primary factors that steer the decision to simulate or stimulate are listed here, as they bear directly on concurrency and the analysis process:

<u>Buyer Requirements</u>: Sometimes the simulator customer dictates whether a particular system will be simulated or stimulated.

<u>Requirement for Special Interfaces</u>: If uniquely designed signal conditioning cards are required in order to stimulate the aircraft equipment, significantly increasing simulator cost and complexity, simulation may be the best approach.

<u>Sensors and Emitters</u>: Avionics that emit/receive signals or RF energy, sense pressures, volumes, atmospheric conditions, or contain gyroscopes are almost always simulated.

<u>Availability of Data</u>: Often, detailed avionics design data is not available from the manufacturer. This may force a stimulation approach.

<u>Development Cost</u>: The cost to develop a simulation, versus stimulation, is considered. Some systems are straightforward and can be simulated at a reasonable cost, when compared to the cost of the avionics equipment (including spares and life cycle costs). With the trend towards the use of common commercial hardware, the cost of military avionics equipment has declined substantially in recent years, which favors stimulation. Some systems are very complex and would cost much more to simulate (for use on just one or two simulators) than to stimulate.

<u>Fidelity</u>: In certain cases, where the actual hardware (for example Cockpit Displays) is difficult to replicate, stimulation may be the only way to achieve required realism.

<u>Maintenance</u>: When avionics is replicated with simulator unique hardware, such as a simulated Electronic Flight Instrument System (EFIS), the added cost of the unique hardware, spares, and associated maintenance may override the benefits of simulation.

<u>Availability of Aircraft Equipment</u>: Occasionally, due to long lead times, real aircraft equipment cannot be acquired in a time frame that supports simulator development. This is often discovered after contract award, when orders are placed. This requires working with the simulator customer to consider workarounds, including possible changes

from stimulation to simulation, on a case-by-case basis.

Life Cycle Expectations: What is the expected life of the simulated system? If it's scheduled to be replaced by a GATM upgrade in a year, for example, then it may not make sense to expend the effort to produce a software simulation or to install hooks in the OFP.

Concurrency: Which approach will minimize the time and costs associated with future upgrades?

As guidance, paragraph 3.1 of 610B lists the avionics equipment that is normally modeled in software (simulated) by simulator manufacturers.

Following the simulate/stimulate discussions, the MELB meeting will continue with the simulator engineers describing the unique conditions (freezes, slews, resets, and instantaneous repositions) that will be encountered by the stimulated avionics used in the simulator. As guidance, Paragraph 2.0 of 610B describes these conditions. The simulator engineers will also describe the special functions used in the simulator to support optimized training. As guidance, Paragraph 4.0 of 610B describes each function and how it is used.

The simulator engineers will then describe the type of data needed to determine each stimulated avionic systems' reaction to the special functions. Generally, this data includes the normal documentation associated with a design project (e.g., Software Design and Interface Control Documents). The need to periodically query the avionics engineers during the subsequent analysis process will be highlighted. They have the intimate knowledge of the avionics software design, and are therefore better equipped to predict its behavior when exposed to simulator functions. This will conclude the initial meeting.

The simulator engineers will then perform a preliminary analysis for each of the stimulated avionics systems. Each of the 22 functions described in Paragraph 4.0 of 610B will be reviewed for applicability to each stimulated equipment type. For those functions judged applicable, the desired equipment reactions will be compared with the predicted reactions. As a simple example, when the Flight Freeze function is active, it is desirable that the stimulated Control Display Unit (CDU) continue to accept flight crew modifications to the flight plan and performance data. The analysis will evaluate the design, and predict if the CDU will allow these entries during Flight Freeze. Use of the word "predict" signifies that actual performance, in many cases, cannot be explicitly determined based on data alone. Operation in the simulator during hardware/software integration provides the final validation. If the avionics manufacturer has an existing test bench at their facility, they may be asked to conduct some simple tests to confirm the data analysis.

Once the stimulated equipment operation has been reviewed against the goals established in 610B, the results will be summarized and presented to the customer (simulator end user) at the Preliminary Design Review (PDR). Those items deemed problematic (i.e. may detract from achieving optimized training) will be highlighted. For these items, a preliminary estimate of the impact on training will be included in this report (e.g., excessive time spent reinitializing a black box following an instantaneous reposition to localizer intercept).

Following the PDR report, further analysis will continue in an IPT working group format. The working group will include representatives from simulator engineering, the procurement agency and, most importantly, the end user. Given the wide variation in the way each unit trains, and the MELB's unique mission, end user inputs are absolutely essential to properly evaluate training effectiveness issues. Based on additional knowledge and data obtained during the detailed design phase, the summary of predicted equipment behavior will be refined. Training impact estimates will also be refined. For those impacts deemed major by the working group, fixes will be identified and evaluated. These could include operational workarounds, additional simulator hardware and/or software to maximize control over the stimulated avionics, or requiring the avionics manufacturer to incorporate support for some of the 610B functions in the OFP. Note that yet another avionics upgrade is planned for the MELB. It's known as the Common Avionics Architecture System (CAAS) program and will incorporate common avionics systems in the MH-60, MH-47, and MELB [8]. CAAS will weigh heavily in the evaluation of short-term fixes.

A final summary, along with consensus recommendations from the working group on how to proceed, will be presented at the Critical Design Review (CDR). This concludes the analysis process. 610B will then be used to guide the implementation and verification process, serving as a reference for engineers and developers encountering stimulated avionics issues for the first time.

As a final point in the MELB example, in cases where 610B issues are considered after the fact, it's vital to minimize the cost and schedule impacts of modifying OFPs (money, staff, and schedule were not allocated for this purpose). Applying the following five-step thought process during the working group analysis should aid in achieving this objective.

1. Using 610B, review the expected performance of the equipment for each of the 22 simulator functions.
2. What is the predicted equipment performance (without OFP modifications) for each function?
3. If the predicted performance does not match the expected performance, is the predicted performance, nonetheless, acceptable (i.e. will minimally impact optimized training)?
4. If the predicted equipment performance does not match the expected performance, and the predicted performance is not acceptable, is there a way to force acceptable performance without OFP modifications (e.g., use of simulator host computer software to manipulate the inputs and outputs of the equipment, or use of the simulator host computer to act as a control display unit during repositions)?
5. If the answer to step 4 is "no", then what level of OFP modifications are required (estimate of lines of code, interface requirements, test requirements, etc.)?

Note that when this five-step analysis process was used on the C-130J program, the conclusion reached was that no OFP modifications were required [9].

RECOMMENDATIONS

The obvious recommendation surfacing from this paper is that simulation and training needs, specifically 610 issues, should be considered as early in the aircraft avionics development cycle as possible. A secondary recommendation is that, irrespective of when these needs are considered, ARINC Report 610B should be used to guide the analysis process. It provides a concise education for those new to such issues, facilitates communications, and provides performance targets. Guidance, communications, and education are essential ingredients in achieving concurrency objectives.

Involving simulator and training interests early in the development cycle represents a healthy challenge, primarily due to procurement methods. Conducting a fair competition tends to rule out heavy involvement by multiple simulator companies early on in the aircraft avionics definition. This may be the primary reason support for 610 functions has not gained wide acceptance in the military domain. The need, most often identified after a project is funded and scheduled, is viewed as a high-cost, unscheduled, resource draining annoyance with slightly ambiguous returns.

Simulators have increased in fidelity to the point where, for some civil aircraft, a pilot can type transition solely based on simulator training - with zero flight time. Because of the emphasis placed on simulator training, and the financial advantages of optimized training, a couple of methods for dealing with 610 concurrency issues have evolved in the civil aviation industry.

First, in some cases, the airframe manufacturer requires compliance with 610 by their avionics vendors. This may include full implementation of all 610 functions, a specific subset of the functions, or only those functions identified via analysis. The important point is that 610 should be referenced as a guidance document in the avionics procurement specification. Irrespective of the ultimate implementation, this will force consideration of simulator interests early in the program. (Note that the USAF referenced 610A in the recent C-130 AMP procurement specification.)

Second, 610 concurrency issues are recognized by civil aviation as an industry problem, and neutral forums have evolved to address the issues. The working groups that wrote 610 and its revisions consisted of representatives from competing airline, airframe, avionics, and simulator companies. The civil aviation industry also meets annually (Flight Simulator Engineering and Maintenance Conference) to discuss common issues, including concurrency [10]. Military participation in this forum is encouraged. The USAF sponsored GATM Users' Conference is also a good model for a concurrency forum. It has broad participation, and is primarily intended to educate.

CONCLUSION

Concurrency is a significant readiness issue. ARINC Report 610 was developed to help achieve concurrency and should be used for guidance anytime new avionics is being considered.

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