Development Challenges for Adoption of ARINC Functionality in UAS Trainer

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ABSTRACT

With increased proliferation of the Unmanned Aerial Systems (UAS), there is now a need to develop UAS training standards for flight and payload operations. Unfortunately within training systems today there is an acute lack of UAS standards for Operational Flight Program (OFP) training interface functionality when it comes to the Weapon System Training (WST) simulators. Currently, there is an Aeronautical Radio Inc. (ARINC) 610B standard that identifies the requirements needed for the simulator OFP interfaces and functionality. The ARINC standard as it is designed does not address training needs of the UAS community and is primarily human in the loop Pilot centric. This is because UAS OFPs are separated into two pieces: Air Frame and Ground Segment (GS). Thus the Payload Operator requirements and standards for the WST do not exist and are not addressed by ARINC 610B. The UAS operations crew requirements are different from the traditional Pilot centric trainer's approaches as the crew is often composed of the Pilot, Payload Operator, Maintainer and a Tactical Coordinators. The UAS systems have a different CONOPS for air vehicles and hence require a new approach to WST interface development for the OFP. One possible way forward that will be presented here is to propose a modification of ARINC 610B standard and develop equivalent requirements to address the needs of the Payload Operators, Maintainers, and Tactical Coordinators to properly interface with the OFP for WST trainers. Although the HLA, DIS, and other standards are designed to interface with the WST, the interface challenges described in this paper are at a lower level (software development core framework) of implementation and impact the WST form, fit, and function as a training device, rather than communication issues and standards between WST devices.

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INTRODUCTION

The proliferation of the Unmanned Aerial Systems (UAS) creates a need to provide a standard for the Operational Flight Program (OFP) training interface functionality for Weapon System Training (WST) simulators. Training interface functionality within the OFP will allow simulators to achieve concurrency with the UAS. By achieving concurrency it is possible to allow aircrew and maintenance personnel to train on the UAS systems before they experience them in the field. The use of WST simulators for the majority of aircrew and maintenance personnel training will also reduce flight hours on operational UASs. Most of the UAS WST platforms, such as Air Force Global Hawk (GH) and Navy Broad Area Maritime Surveillance (BAMS), have a requirement for concurrency with the fielded weapon system.

Although there is a system requirement for trainer concurrency, there is a lack of a well-defined standard that can support development of OFP trainer interfaces for UAS systems. This is due to the shift from Pilot in the loop to the computer driven and pilot assisted flying events. In addition the UAS system is based on two components; the Air Frame, which is computer driven, and the Ground Segment (GS), which is Air Crew/Maintainer driven.
The GS is comprised of computer server rack mounted Personal Computer (PC) machines that provide command and control for the autonomous Air Frame in form of corrections, feedback, and tasking.
Therefore, this split poses a challenge for OFP development. Where does one inject trainer interfaces for the UAS OFP, on the Air Frame side or the GS side? This paper will use the Aeronautical Radio Inc. (ARINC) 610B standard as a starting point for the identification of the applicable trainer interfaces functionality as well as propose placement between Air Frame and GS. In this placement, the CON-OPS and software systems design from BAMS and Global Hawk will be used as a primary driver for the ARINC 610B functionality decomposition.

ARINC 610B BACKGROUND

ARINC Report 610B, Guidance for Use of Avionics Equipment and Software in Simulators was developed as a civil aviation document. ARINC 610B however, has been effectively applied to many military programs. One of the reasons for implementing ARINC 610B is the concurrency requirement of the program. The goal for the use of the ARINC 610B is to provide guidance for the direct use of applicable airborne equipment in simulators. The objectives include optimized training, assured fidelity of operation, readily available spares, and concurrent aircraft and simulator operational software. Thus ARINC 610B focuses primarily on simulator functional objectives rather than implementation specific requirements needed to support training events [1, 2].

One of the major operational concerns with the implementation of the ARINC 610B standard is its impact to DO-178B, Software Considerations in Airborne Systems and Equipment Certification requirements. DO-178B is used to determine airworthiness of the weapon system platform requirements and is based on five levels of software criticality impact from Catastrophic Level (A) to No Effect Level (E) [3]. To this end the ARINC standard recommends the use of hardware mechanisms such as pins or software keep alive signals to identify that the OFP is in the simulator mode of operations. This approach is used to ensure that during real flight events training interfaces are disabled and will not be accidentally triggered. This approach has been successfully implemented in several of the commercial simulators such as Airbus A300, and Boeing 747/767/777 thus demonstrating that ARINC 610B does not impact safety of flight [4, 6].

UAS DILEMMA

The UAS OFP is divided into two equivalent portions the Air Frame and GS. The ARINC 610B standard as written does not address scenarios of how to split, modify or accommodate the unique needs of the UAS OFP. However the ARINC 610B by its nature is void of specific implementation methods and thus can be adopted for the UAS OFP as well.

To adopt ARINC 610B to fit UAS OFP needs; this paper will discuss two issues: Service Oriented Architecture (SOA) as it is implemented in the GS and GS to Air Frame functionality allocation. This functionality will be discussed as presented in Table 1, which is Table 4.2 of the ARINC 610B standard.

Currently the UAS OFP requirement for the Navy BAMS is to provide embedded training capability support. This requirement is optional for the Air Force Global Hawk UAS, but with future common GS fielding, the embedded requirement will be standard across these two UAS platforms, and thus must be considered. Therefore this paper will assume that both platforms and future UAS GS will have embedded training as one of the core requirements.

Embedded OFP Safety Considerations

As mentioned earlier, the ARINC 610B standard does not impact safety considerations as outlined in DO-178B; however the impacts still need to be considered. The word "embedded" for the UAS is not really the correct term as the dedicated training equipment really stimulates the GS as if it was the real aircraft, and can be part of the GS itself. The "embedded" part of the UAS trainer is more about safety precautions to ensure that the simulated aircraft and its simulated information never cross over to the operational portion of the UAS.

Embedded OFP Functionality Split

One unusual design consideration for the UAS OFP has come about: Where does one place Air Frame performance functionality interfaces into the GS or Air Frame? If this functionality is placed into the GS, then the Operator (Pilot, Sensor Operator, and Tactical Coordinators (TACCO)) will be able to see, manipulate and respond to flying events on their user stations with no considerations for loss of performance of communications or extensive flight characteristics event issues. If this functionality is placed into the Air Frame OFP, then the Operator will be able to perform all the same duties as mentioned earlier in GS and can include communications fidelity training and extensive flight characteristics event issues.

The Air Frame is autonomous, e.g. takeoff and landings are performed automatically, as well as in flight management. There is little Operator control required for Air Frame management, thus choosing the location for placement of the training functionality interface is a developer choice or a user true fidelity requirement/need.

Embedded OFP SOA Considerations

The Global Hawk and BAMS GS OFPs are designed around SOA network centric concepts. This means that the GS OFP design is based on the Internet web services style of development and design. To this end, network traffic management becomes a critical issue for the GS OFP. ARINC 610B does address Ethernet network management, however it does not take into account additional impacts that SOA implementation puts on the system such as loose coupling, dynamic discovery, service consumers/producer linking, etc. The training functionality interfaces within GS OFP must be able to take into account SOA needs, as well as be able to create faults within GS OFP for training purposes, such as preventing discovery of one of the critical services, high traffic management, loss of link to the service, etc., that do not shut down the entire GS.

Air Crew/ Maintainers

The UAS Air Crew is comprised of the Pilot and Sensor Operator for the Air Force Global Hawk UAS, while the Navy BAMS UAS version adds another member to the crew, the TACCO. The Air Crew personnel will be operating the Air Frame from a GS that is located in a building at a USA Main Operating Base. The maintainers, although officially not part of the Air Crew, will be operating side by side from another GS position using a communications or network management station during live flight events. Thus, there is a need to provide training feedback not just for the Pilot but for the rest of the crew members as well. The ARINC 610B limitation is that it assumes that Air Crew is Pilot based rather than team based. To this end it is important to translate the Pilot based descriptions of the ARINC 610B standard to other members of the Air Crew.

One of the additional requirements for BAMS is to have multiple pilots at the same time controlling

additional Air Frames during flight. Thus generating challenges on how to manage multiple Air Frames assets with Air Crew, as well support unique capability for high fidelity UAS operational trainers. The UAS systems versus manned aircraft need to be considered on top of the standard Air Crew settings with the single pilot. Therefore, injecting GS faults and Air Frame management becomes a challenge for implementing this requirement in the trainer through ARINC 610B.

ARINC 610B PARAMETERS

Taking into considerations the above discussion this section will address simulator functions as shown in Table 1. Within each function UAS training functionality concerns will be addressed as well as Air Crew / Maintainer requirements.

Simulator Functions	Simulation Control	Scenario Set-Up	Optimization	Maintenance Set-Up
Total Freeze	X			
Flight Freeze	X			
Fuel Freeze	X			
Latitude/Longitude Freeze	X			
Altitude Freeze	X			
Weight Change		X		
Latitude/Longitude Change		X		
Altitude Change		X		
Airspeed Change		X		
Heading Change		X		
Temperature/ Pressure Change		X		
Wind Change		X		
Reposition to Initial Conditions		X		
Internal System Status Reset		X		
Speed Times N			X	
Snapshot Take			X	
Snapshot Recall			X	
Multiple Snapshot			X	
Fault Memory Clear				X
Fault Logging Parameter Set				X
Fault Memory Download				X
Fault Memory Upload				X

Table 1. ARINC 610B Functional Requirements vs. Category References

Simulation Control

This section describes controls of the dynamic portion of the ARINC 610B standard. Discussion of the functionality for allowing instructor to control the flow of the training scenarios will be presented. In addition this section describes interfaces required to

provide additional support for Air Crew instruction through pause or freeze interface features.

Total Freeze or Flight Freeze
Implementing Total Freeze (TF) or Flight Freeze (FF) for UAS trainer generates additional challenges of not only freezing the Air Frame OFP and the environment but also the GS OFP as well. Thus executing this functionality can have many side implications for the training events if only one part of the OFP is considered. To properly implement TF or FF special care must be taken when adding this functionality to the OFP command and control part of the software for both GS and Air Frame OFP such that erroneous faults will not be displayed as described in ARINC 610B standard.

Safety of Flight Considerations
During development of this functionality, DO-178B is a critical driver, as this feature can have significant safety impacts to the embedded OFP. If this is done incorrectly it can inhibit faults that would otherwise indicate a loss of communications or stall conditions in the UAS GS and would represent a safety hazard. One of the proposed methods to deal with this issue on the Navy BAMS platform is to use equipment that ensures an embedded trainer is properly configured at all times such that it cannot mix training commands/data with the operational aircraft. After ensuring that the system is properly connected for training mode, then special methods within the actual system would be allowed to run in order to prevent faults from being displayed to the student as a result of the TF or FF command being executed.

Networking/SOA
Total freeze for UAS aircraft has some unique challenges to it due to its constant connectivity to external networks. Since UAS GS can be connected to external communication networks like Global Command and Control System – Maritime (GCCS-M), UAS trainers are being pushed to develop simulations that are connected via NIPRNet or SIPRNet that have never been simulated in standalone trainers before. GCCS-M has been available for training on the Navy Continuous Training Environment (NCTE) network, but not for individual trainers. Creating simulations of these services and implementing TF represents a new challenge for the development of trainers. These services would have to be correlated with the entities in the semi-automated forces that are being used in the trainer. Creating these simulations in an embedded trainer creates some small additional challenges due to information assurance and GS fault

detection software. These external sources of information are important for training TACCO situational awareness and determining the next target area on the BAMS platform.

This training functionality interface has to be developed to support all three Air Crew stations simultaneously. Failure to support this functionality uniformly across all stations can result in negative training. For example, the Pilot station is in a FF mode while the Sensor Operator is showing that the Air Frame has moved 50 miles down the track and thus now taking pictures of the wrong sector, meanwhile the TACCO received coordination requirements for the Air Frame itself that are out of sync.

Fuel Freeze
This functionality is performed in almost the same fashion as manned aircraft. Although there are similarities, special care must be taken if the Air Frame simulation software is in the process of changing fuel levels while the GS performs an independent fuel estimation of the actual Air Frame fuel levels, then the trainer would have to adjust accordingly. In this example there is additional logic required for synchronization between GS OFP and Air Frame OFP for fuel levels. The same logic applies to the rest of the ARINC 610B parameters.

This type of fuel synchronization automation is required for some UAS systems. This is a known training requirement, especially under certain fault injection scenarios and recoveries. The Pilot must be able to determine when the automated aircraft will be able to make a safe landing and when it must be aborted.

This training functionality interface has to be developed to support Pilot, and TACCO Air Crew stations. The Sensor Operator station will not require this functionality.

Latitude/Longitude Freeze and Altitude Freeze
Latitude/Longitude and Altitude freeze represent some of the same challenges as that of TF or FF in that special considerations are required in the UAS simulation and the GS OFP in order to be supported. Thus BAMS, Global Hawk, and Firescout GS OFPs command and monitor the Air Frame status to ensure that GS control events have been successfully executed. If the Air Frame does not increase altitude as it was requested by the GS, then Air Frame errors could occur. Thus when implementing this functionality in the trainer, extra care must be exerted

to support this functionality. If there is a disconnect between GS and Air Frame as a result of these errors or faults for command execution and synchronization, that would otherwise occur from an anticipated action being performed by the UAS during flight, then those errors would have to be suppressed in not only the Air Frame but in the GS as well.

As mentioned earlier the UAS unique requirement for using several Pilots controlling multiple Air Frames in the same GS, provides a challenge for own ship model simulation. As a result the GS must be able to interact simultaneously with many Air Frames and support all options of changing the simulated Air Frame, lat/long, altitude, airspeed, and heading. The GS must be able to target individual Air Frames in some instances, as well as all Air Frames in the other instances. Thus, when developing freeze functionality it would imply that the freeze must also address freezing one or all of the Air Frames own ship's criteria required for the training event.

This training functionality interface has to be developed to support all three Air Crew stations simultaneously. Failure to support this functionality uniformly across all stations can result in negative training. For example, the Pilot station is in a latitude/longitude or altitude freeze mode while the Sensor Operator is showing that the Air Frame has moved down the track and is now taking pictures of the wrong sector or with the wrong zoom factor.

Scenario Setup

This section describes Air Frame reposition and various other training scenario setup commands that the UAS trainer shall support. This section provides support for training of unique tasks required such as takeoff and landing automated commands execution. This section describes portions of the training requirements that are most likely to be done through repetitive training events.

Weight Change
Weight changes in an UAS trainer are important for training heavy and light landings. Air Frames that are lighter in weight do not glide as well when compared to Air Frames that are fully fueled. For UAS that have fuel as their primary contributor to the weight of the aircraft, the training for the differences in landing approaches is important (even in automated landing aircraft). This is due to the requirement for the UAS Pilot, who only receives feedback through displays, to be aware of the Air

Frame conditions. If the Air Frame cannot maintain a minimum altitude in order to perform a safe landing, then the pilot would need to abort the landing. Although BAMS and Global Hawk land automatically; if the aircraft has an engine failure and shows signs that it cannot recover by maintaining enough altitude for landing then the Pilot must intervene and choose an alternate airport or a place that will save the aircraft without endangering lives (AKA "the crash site"). This scenario demonstrates the need to provide support for this training functionality despite flying a fully automated Air Frame system.

This training functionality interface has to be developed to support the Pilot Air Crew station only. The other two stations will not require this functionality.

Latitude/Longitude, Altitude, Airspeed, and Heading Change
Latitude/Longitude, Altitude, Airspeed, and Heading functionality modification would require incremental changes to both the Air Frame and the GS. This is due to the Air Frame design. For example, Global Hawk requires the Air Frame automated systems to stay within certain areas, based on the pre-planned waypoints. The Pilot on the GS segment will then have limited control options for deviation from the said mission waypoints.

Changing mission waypoints or forcing the Air Frame to deviate too much might result in either automated return to base emergency procedures to be initiated by the Air Frame or a complete loss of Asset as it might lose its location in relationship to the pre-planned waypoints scenario. Thus, when implementing this functionality in the UAS trainer additional considerations for mission planning waypoint management have to be addressed. The UAS trainer must be able to support both, incremental change and waypoint management change that will alter said parameters.

This training functionality interface has to be developed to support all three Air Crew stations simultaneously.

Temperature/Pressure and Wind Changes
Temperature, Pressure, and Wind changes are similar in nature for UASs as they are for manned aircraft with a few exceptions. When turbulence occurs in a manned aircraft, it rarely is so bad that it causes damage to the aircraft and not the crew. Therefore, this type of scenario is rarely trained for in manned

aircraft. However with a UAS, a Pilot needs to be aware of the amount of g-forces due to turbulence occurring with the aircraft before it is severely damaged.

When a Pilot suspects possible damage to a manned aircraft, it is sometimes possible to assess the damage by looking out the window, feel vibrations, or hear sounds. On the other hand, UAS do not have those options and could require the aircraft to return to base. Therefore, it is necessary to be able adjust the weather outside the aircraft to the point that it could cause damage to the aircraft with sudden changes. The adjusted weather changes should allow the Pilot to react to the extreme conditions and remove the aircraft from the dangerous weather pattern.

This training functionality interface has to be developed to support the Pilot Air Crew station only. The other two stations will not require this functionality.

Reposition to Initial Conditions and Internal System Status Reset
The UAS, reposition or reset functions have a completely different meaning than with manned aircraft. This is due to an additional set of considerations such as; Air Frame only reposition/reset, GS only reposition/reset, and both GS and Air Frame reposition/reset. Other considerations are with respect to the waypoint management and having ability to reposition to emergency scenario conditions such as Air Frame leaving the waypoints, or being just outside one.

In discussing reposition/reset of either GS or Air Frame OFP, synchronization between them always has to be considered for the training event. Thus when the instructor initiates a reposition/reset, extra care must be taken to take into account on both sides of the OFP. Failure to do so will result in negative training events and present a possible scenario that will never exist in real world operations.

Hence, the UAS primarily flies by waypoint and Pilots mostly supervise and manage waypoints in flight. When executing reposition/reset, mission management profiles have to be considered. The instructor has to have the ability to not only manually reposition/reset the Air Frame or GS, but to be able to create and manage waypoints as well, such as being able to create, delete, and modify interim or mission waypoints or have the ability to reset the said waypoints.

This training functionality interface has to be developed to support all three Air Crew stations simultaneously.

Optimization

This section describes training functionality of the ARINC 610B that provides for increased training value of the time spent in the simulator for the UAS Air Crew. This section also offers much needed trainer interface functionalities for the validation and qualification of the simulator or improvements of the training events such as speed times N to get to the actual mission air space of interest.

Speed Times N
The ARINC 610B capability of speed times N is particularly interesting in UAS trainers. Just like trainers that use hardware in the loop, UAS GS software must accept data at up to ten times the speed of normal operation. However, an entire GS using SOA framework with lots of different computers provides an extreme amount of potential conflicts when enabled. Thus extreme care must be taken to ensure that all the simulated information representing other Air Frames (3 per orbit) must either increase or decrease their speed times N or ensure that conflicts do not occur.

This becomes even more interesting as the GS OFP should operate at regular speed, while it must be able to handle Air Frame OFP speed times N changes. In addition, the GS OFP is SOA based and extra care must be taken for increased traffic management as a result of the Air Frame OFP speed time's N increase in data throughput as well as changes in how SOA services consume or produce information within the GS OFP. Should the GS OFP design decide to support the speed times N as well, it will have to deal with network internal SOA synchronizations issues and timing management of critical services that if not developed with ARINC 610B considerations up front will not be capable of supporting such increases in speed.

This training functionality interface has to be developed to support all three Air Crew stations simultaneously. Failure to support this functionality uniformly across all station can result in negative training. For example, if the Pilot station is at speed times 3 and the Sensor Operator station is at speed times 2, while the TACCO station is at speed times 1, the crew will be unable to perform as a cohesive unit because they will all be at different points in the same mission.

Snapshot Take

UAS trainers have the added component of the GS, which requires a more intricate approach of what information is required to be copied for the Air Frame and GS. The UAS OFP is comprised of GS and Air Frame which requires taking a snapshot of both components. Taking a snapshot of the GS settings (especially in an embedded trainer) requires that the system software be designed to support recording of all the settings needed to take a snapshot. Inherently, systems that are not directly connected or controlled by the trainer would not be able to be recorded. Recording the settings of the Sensor Operator station has a lot of information that is important. UAS primary missions are often times for intelligence, surveillance, and reconnaissance (ISR) and record a lot of tracking data in both Air Frame and the GS. As a result, the sheer volume of information for recording both the GS and Air Frame information tracking data to support such a massive effort will require a lot of storage capacity, as well as software development effort to be able to capture record and manage this information in the WST.

Another issue to consider for UAS trainers is external network communications. For example, air traffic information that is supplied to the GS for the Air Frame at the time of the snapshot. This type of information should be recorded as well, and is considered to be part of the training scenario.

This training functionality interface has to be developed to support all three Air Crew stations simultaneously.

Snapshot Recall

Snapshot recall in UAS trainers need to be able to recall the conditions, memory, and entities of both the GS and Air Frame OFP. As stated in ARINC 610B, the GS OFP equipment and software should still be accessible to the student while recalling the snapshot in order to restore the conditions back to the original settings of the snapshot.

Snapshot recall in UAS trainers is similar to snapshot take with regard to requiring software functionality to be a part of the GS OFP. There would be additional work in order to provide instruction directly to the user on the student's screen within the OFP, but it is typically best to keep the amount of instruction dependencies low within the OFP due to cost and schedule. A more practical solution for providing instructions to students on changing man-machine settings (CNIA (Controls Not In Agreement)) would

be to utilize other screens in the GS OFP trainer to display appropriate instructions for each student.

By integrating the snapshot recall function into the GS OFP, the UAS trainer can be embedded or require little to no modifications when delivered as part of the OFP delivery. Although, this is similar to manned aircraft for reuse of the same software for both aircraft and simulator; there are a few differences. One of these differences is the BAMS requirement for the embedded UAS trainer to be able to switch from training to operational mode with minimal impact to the OFP availability. By using the same OFP software for training and operational modes, the BAMS GS does not have to use different software for each mode and reduces the transition time. Thus, the most difficult task with snapshot recall in an embedded trainer is preventing faults from occurring within the GS OFP.

This training functionality interface has to be developed to support all three Air Crew stations simultaneously.

Multiple Snapshot

Multiple snapshot functionality is similar to any other trainer, in that it requires both snapshot take and recall to be implemented. The multiple snapshot capability is typically needed for any UAS that is designed for long flight times. BAMS and Global Hawk have the ability for such a long period of time that different crews may launch and land the same Air Frame. As such, these trainers tend to need multiple snapshots to train various phases of flight in a shorter period of time. The same limitations as the snapshot recall exist for this functionality.

This training functionality interface has to be developed to support all three Air Crew stations simultaneously.

Maintenance Set-Up

This section describes additional functionality required to be supported for maintenance training. With the UAS systems the line between maintenance and Air Crew operations is blurred, thus causing this functionality to be sprinkled across all ARINC 610B trainer interfaces. Because the Air Frame is mostly autonomous and Air Crew interactions are limited, a great deal of the training has to do with fault management. This section is used to setup training events in scenarios where realistic faults have been logged and executed in the right sequence.

Fault Logging Parameter Clear
Fault logging parameter clear, for the purposes of UAS maintenance trainers, has most of its needed capabilities within the Air Frame OFP and GS OFP, as well as some of maintenance equipment, such as the Vehicle Test Controller on the Global Hawk. The Air Frame OFP would need to be able to support input provided by the simulator host computer in a similar manner as the manned aircraft. In addition, platforms such as Global Hawk and BAMS are ISR systems with a sensor OFP on board the Air Frame that performs tracking either by an automated means or by user input, which could also log sensor faults. The reason for maintenance equipment to have training software capabilities is to extend the life of non-volatile memory used to store all faults across the lifecycle of the equipment.

GS OFP fault logging and clearing has to consider not only the Air Frame OFP, sensor OFP, and maintenance equipment of the Air Frame, but the internal GS OFP as well. The GS OFP is a SOA driven framework architecture and there is an extensive set of fault issues that have to be logged, managed, and cleared that are GS OFP specific. Thus, internal networking faults, hardware/software takeover faults, as well as local computer maintenance faults of the GS OFP systems create additional challenges for implementation of this feature.

This training functionality interface has to be developed to support all three Air Crew stations simultaneously.

Fault Logging Parameter Set
Setting the values of the parameters associated with the simulated faults is very similar to manned aircraft. Therefore an ability to insert a simulated fault into a maintenance trainer requires an ability to put into memory a history of problems that could appear with that fault. In addition to the Air Frame OFP changes, UAS systems could have integrated Automated Health Monitoring (AHM) devices that produce system reports. Thus maintainers would have to be provided with the output of those reports in most of their lesson plans. Creating replicas of the reports can be performed on an ad hoc basis, thereby allowing the instructor to have more leverage to alter the training plans. Creating ad hoc AHM reports representative of the simulated faults for the purposes of maintenance training with automated software may be cost prohibitive, therefore special care must be taken.

Another consideration for the fault logging parameter set is that the GS is a Commercial Off The Shelf (COTS) system. These systems are identical to the standard server/workstation setup of the regular office. Thus they can be maintained by information technology specialists in a similar fashion. The issue is which faults should be trained by the UAS versus which faults should be outsourced as standard IT training. To date there is no clear answer and will be specific to a specific UAS solution as ARINC 610B guidance does not take into consideration IT based aircraft.

This training functionality interface has to be developed to support all three Air Crew stations simultaneously.

Fault Memory Download/Upload
UAS maintenance trainers are similar to manned systems in every way when it comes to these functional requirements except that there is no cockpit to display faults. The maintenance actions typically performed in the cockpit to verify that the Air Frame equipment is functioning properly would be performed on test equipment, such as the Global Hawk Vehicle Test Controller. It is important to remember that the GS equipment and personnel are not necessarily anywhere near the area where maintenance is being performed on an Air Frame.

The second set of fault memory upload and download is on the GS itself. Unlike the Air Frame equipment, the GS design by its nature can have an exponentially larger set of faults from; operating system (Red Hat Linux, Microsoft Windows), to hardware support systems, and UAS specific GS OFP faults, etc. In addition GS generally stores Air Frame faults from the previous and ongoing flight events. Thus when performing fault memory download/upload it is important to have an ability to stratify these faults into several sub categories. The stratification will allow for improved management of the training events depending on the mission or maintenance action requirements for the system issue.

This training functionality interface has to be developed to support all three Air Crew stations simultaneously.

Additional UAS Considerations for the ARINC 610B Standard

What has been presented so far in this paper is based on the areas covered by the ARINC 610B standard. However, there are few areas that require additional

consideration that are not covered by ARINC 610B but are critical to the UAS systems. The two that will be presented here are the AHM and communications simulation issues that are integral part of the UAS design.

Automated Health Monitoring

The AHM systems on the UAS create a new set of challenges, and are not addressed by the ARINC 610B standard directly. The AHM systems and fault insertion such as: real faults, simulated-real faults, and simulated faults must be addressed by the training system interface functionality of the UAS. This is due to the fact that many new systems have an AHM that can alert ground personnel such as Air Crew/ Maintainers of anything wrong before the Air Frame even returns to base. Training in a system that has AHM allows in many cases for the trainer to automatically determine the point of failure for the maintenance personnel of the trainer.

Embedded UAS trainers have the additional challenge of ensuring that real faults and none of the simulated faults are reported for maintenance. In other words, a simulated engine failure in the trainer should not make it through to AHM system, but a network card failure on the computer that is running the Air Frame simulation should be reported. Thus, the operational trainer should still provide the same level of fidelity of faults that are reported to the student while flying the Air Frame. Similar to maintenance trainers, the trainer should be able to clear the faults prior to the next training session. In the case of embedded operational trainers it is extremely important that simulated faults do not get reported as real faults that require maintenance.

Communications Change

UAS systems require a command and control link between the GS and the Air Frame. The communication link between the GS and the Air Frame passes sensor data and situational awareness aviation tools (IFF, ADS-B) information.
Maintaining a quality communications signal is critical to maintaining control of the Air Frame as well as receiving information for completing the mission. In a trainer, the simulated communications between the student's station and the Air Frame should have the same limitations as in real world operations.

Communication Fidelity of Signal

Changing the lag time between the Air Frame and the GS is important for training students how to control an Air Frame that may or may not perform its commands immediately. The lag change simulates a reduction or increase in the delay of the communications between the GS and the simulated Air Frame. The communications lag should not produce errors as the lag changes. UAS communications have a limited bandwidth when communicating with either line of sight or satellite communications. Decreases in bandwidth negatively affect the performance of command and control of the Air Frame. Thus decrease in bandwidth reduces overall situational awareness for both the Pilot and the Sensor operators. Therefore, if there is less bandwidth, then it is harder for sensor operators to get detailed ISR data. The signal to noise ratio should also be adjustable to simulate interference (weather, fog, and sandstorm). All of the communication channels should have the same characteristics as the real Air Frame. For example, the direct line of sight communications will usually have no noticeable lag and more bandwidth when compared to satellite communications that has some lag and limited bandwidth. If bank angles of UAS effect signal received, then it should be reflected in the trainer. Communications coverage, quality of signal, time delay, and other parameters are controlled from the IOS.

Communications Freeze

Trainers for UAS systems should typically have the ability to train for a loss of control of the aircraft and loss of data feed for sensors. In some trainers, the entire communications coverage is fully automated to allow the instructor more time to focus on how the student performs in the given scenario. However when performing certain training scenarios, the student should be able to be focused primarily on the performance of that event and not staying within a specific area of communications to control the aircraft. ARINC 610B does not provide guidance in this area. A communications freeze should maintain the update rate, delay of signal, signal to noise ratio, and angle of coverage.

CONCLUSION

This paper presents how the ARINC 610B standard can be applied to the UAS trainers. In addition, a discussion of UAS system impacts for implementing this standard is presented as well. Finally, a short discussion of UAS trainer tasks not addressed by the standard has been presented. This paper intent is to provide initial support and guidance for the UAS training interface development and implementation of the required functionality for the full mission training capabilities of the War fighter.

This paper presentation of the ARINC 610B demonstrated that the current standard for supporting trainer functionality in UAS OFP is not sufficient. Thus there are several recommendations or alternative solutions to be considered.

First recommendation is to supplement the current ARINC 610B standard to include UAS specific functionality needs. With this approach a more inclusive document can be produced that will cover both the manned and unmanned systems. This can be accomplished through creation of UAS specific guidance sections within ARINC 610B standard and identification of what is applicable or non applicable to the desired training system.

Another recommendation is to create a completely separate UAS only standard based on ARINC 610B for the unmanned class of systems. By doing so, more detailed and tailored guidance or standard can be developed that will improve and provide better tailoring options to the end user rather than the generic solutions presented earlier.

A last recommendation is to leverage UAS Control Segment (UCS) working group and other relevant groups to develop a brand new training system standard for implementing training interfaces based on the current operational needs and change in the way operational missions are conducted with UAS as opposed to a manned flight missions.

In conclusion, more analysis is needed to develop or define a UAS specific standard for trainer interface development as part of an extension of ARINC 610B or as a new standard.

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