Unmanned Aerial Vehicles – A New Challenge for Training System Development

Tony DalSasso, Chief Engineer
Jeffrey Pfledderer, Technical Expert
Special Projects Branch
Training Systems Product Group
Wright-Patterson AFB, Ohio
Tony.DalSasso@wpafb.af.mil
Jeffrey.Pfledderer@wpafb.af.mil

ABSTRACT

Unmanned Aerial Vehicles are an increasingly important resource in the conduct of modern warfare. Systems such as the Air Force's MQ-1 Predator have proven their effectiveness numerous times in recent combat operations. These systems were rapidly developed and fielded, sometimes transitioning from concept demonstration to operational use without the intermediate steps normally accomplished under the traditional system acquisition process. In addition, UAV programs have proven to be very useful testbeds for new and innovative ideas, taking a "what-if" exercise and making it an operational capability almost overnight. This approach stands in stark contrast to manned aircraft upgrade programs, which require a much more time-consuming and exhaustive testing and certification process.

One result of this rapid laboratory-to-field implementation approach has been the lack of robust, fully capable training systems being made available to the warfighters at the time the system is operationally deployed. Training has largely been conducted on an ad-hoc basis using suboptimal resources, resulting in training deficiencies which ultimately may have contributed to mishaps and loss of aircraft. The accelerated process has simply not provided sufficient time or resources to accommodate a traditional training system development. A longer term, but equally significant, problem resulting from this approach has been trainer concurrency management. Keeping up with aircraft changes in such a fast-paced environment poses a significant challenge, even when sufficient planning has been accomplished. However, the abbreviated testing process has shortened the timeframe available to simulator developers to develop concurrency modifications for the trainers. This problem is further compounded by the lack of robustness in the rapidly-fielded initial training systems.

This paper will discuss the unique training system issues resulting from the rapid fielding of such systems, and provide recommendations for implementing timely and effective training systems in this challenging environment.

ABOUT THE AUTHORS

Tony DalSasso is the Chief Engineer of the Special Projects Branch, Training Systems Product Group, Wright-Patterson AFB, OH. The duties of his branch include the evaluation of new training system technologies for applicability to warfighter training needs, coordinating the definition of new training system acquisition programs, and providing specialized technical support to ongoing programs. In his 23 years at Wright-Patterson, Tony has been involved in defining and acquiring the training systems for numerous Air Force weapon systems.

Jeffrey Pfledderer is the Training Systems Tech Expert for the Special Projects Branch, Training Systems Product Group, Wright-Patterson AFB, OH. He currently supports multiple training systems activities, providing Training System Requirements Analysis (TSRA) technical support for the definition of new and existing training system acquisition programs. Past program experience includes the Distributed Mission Operations F-16 Mission Training Center, F-22 Training System, and Special Operations Aircrew Training System programs.

Unmanned Aerial Vehicles – A New Challenge for Training System Development

Tony DalSasso, Chief Engineer
Jeffrey Pfledderer, Technical Expert
Special Projects Branch
Training Systems Product Group
Wright-Patterson AFB, Ohio
Tony.DalSasso@wpafb.af.mil
Jeffrey.Pfledderer@wpafb.af.mil

INTRODUCTION

The United States military is using technology to significantly alter the way in which it conducts warfare in many ways. It has seemingly become acceptable to use the term "transformation" in conjunction with every organizational or process change implemented, regardless of whether it represents a truly substantive change or not. The increasing role of Unmanned Aerial Vehicles (UAVs) is genuinely worthy of the transformation title. These aircraft have revolutionized the way in which Intelligence, Surveillance, and Reconnaissance (ISR) are conducted on the modern battlefield, in turn enabling unprecedented precision in the delivery of weapons, capture of "high value targets" in inhospitable territory, and the achievement of other military objectives.

Three Aspects of Transformation

As with virtually every change to the way the military conducts its missions, the UAV transformation has a corresponding impact on the way in which it conducts its training. Putting this into a training system context, the UAV revolution might be viewed as a triangular relationship, the aspects of which include Acquisition, Operations, and Training[1]. Transformational changes in each of these facets affect, and are affected by, changes in the others.

Operationally, the availability of UAVs has transformed the process of collecting, analyzing, and disseminating intelligence. The recent success of U.S. intelligence agencies in accomplishing high-profile missions can be attributed to the capabilities of these transformational resources.

The acquisition process has, in turn, been transformed by these changes in operational methods, primarily in terms of the urgency which they have imparted on the acquisition community. The linear system development process has been supplanted by an evolutionary one, in which system capabilities are delivered incrementally, rather than all at once. The principal benefit of this approach is that it allows a partial capability to be provided to the warfighter much earlier than under the traditional system acquisition process; it is, to some extent, rooted in a backlash to the increasing timespans encountered in modern weapon system development. UAVs are well suited to this development model. UAV programs take advantage of the Air Force's implicit willingness to assume greater risk of latent design problems than with comparable manned aircraft.

The third side of the transformation triangle, Training, is only now beginning to be addressed. It should be apparent that transformational changes to Operations and Acquisition must be matched by a corresponding transformation in Training. The traditional manner in which training systems are developed, acquired, and operated is unresponsive to the training needs of a system developed under this new paradigm. In order to maintain the desired symmetry, Training must also be transformed. This paper will discuss the required transformation and how it might be accomplished.

UNMANNED AERIAL VEHICLES

The term UAV encompasses a broad range of aircraft with widely diverse missions and characteristics. Presently, there are approximately 50 U.S. companies, universities, and government agencies engaged in the development of over 150 UAV designs [SRA, 2004], in stages ranging from concepts

[1] Arguably, the scope of the "training" aspect ought to be expanded to encompass all of the logistic support elements; but since the topic of this paper is training systems, a simplified example is presented for the purpose of discussion. Conceptually, the same issues apply to the other logistics elements associated with UAV operation and sustainment.

through full rate production. There are fixed and rotary wing UAVs. They vary in size, ranging from hobbyist's models to airliners. The term "Micro Air Vehicles" (MAVs) has been coined to describe the smallest UAVs, which may have a wingspan of six inches or less. Another term, "Endurance UAV," is used to identify those which can fly for 24 hours or more. UAVs' roles have traditionally been aerial intelligence gathering, reconnaissance and surveillance. More recently, UAVs are being given the capability to deliver weapons, most notably the Unmanned Combat Aerial Vehicle (UCAV) presently under development at DARPA.

As a consequence of the wide variety of UAV missions and capabilities, operator and maintainer training requirements vary significantly from one UAV to another. A soldier who carries a simple radio-controlled aircraft in a backpack and flies it using an inexpensive, handheld controller, possibly with no expectation of seeing it return, requires significantly different training than the operator of a multimillion-dollar endurance UAV, which must be flown by someone who has previously had formal pilot training. This paper focuses on the latter class of UAVs, which are remotely operated by military pilots seated at special control stations. The two such systems currently under development (and operationally employed to a certain extent) by the U. S. Air Force are the MQ-1 Predator and the RQ-4 Global Hawk.

Predator

The RQ-/MQ-1 Predator is a medium-altitude, long-endurance UAV with the primary mission of "conducting armed reconnaissance against critical, perishable targets" [USAF, 2001]. Its crew consists of a pilot and two sensor operators (SOs), who control the aircraft from a Ground Control Station (GCS) via line-of-sight or satellite link. The aircraft is equipped with day television and infrared cameras, and a synthetic aperture radar. While the RQ-1 version is used for ISR only, the multi-mission MQ-1 is also equipped with a multispectral targeting system and two Hellfire antitank missiles. The MQ-9 (generally referred to as the Predator B) is a larger, faster, longer-range derivative of the MQ-1 which is currently being evaluated by the Air Force.

Global Hawk

In contrast to the multi-mission Predator, the Global Hawk is strictly a high-altitude reconnaissance platform which can "autonomously taxi, take off, fly, remain on station capturing imagery, return and land" [USAF, 2003]. Unlike the Predator, which has flight controls similar to those of an aircraft, the Global Hawk is flown entirely by computer. Once airborne, the aircraft is fully autonomous, but both its sensors and mission plan can be retasked on the fly by the pilots. The Global Hawk is strictly an ISR vehicle, which does not carry any weapons.

These two aircraft provide a unique capability to the warfighter – the operational side of the transformation triangle. Next, we will review the process by which these systems came into being, which comprises the acquisition transformation.

EVOLUTIONARY ACQUISITION AND SPIRAL DEVELOPMENT

The recently revised DoD Instruction 5000.2, Operation of the Defense Acquisition System [OSD, 2003b], defines "Evolutionary Acquisition" as the preferred DoD strategy for rapid acquisition of mature technology for the warfighter. It is an incremental process for delivering capability in stages, explicitly acknowledging the need for successive enhancements to reach an end state. Two approaches to implementing this strategy have been defined, "Spiral Development" and "Incremental Development." The essential difference between these two alternatives is the presence or absence of a specific requirement defining the ultimate end state. In the "incremental" process, the end requirement is known at program initiation, and the system is developed in stages aimed toward meeting this specific goal. Conversely, the "spiral" process is a more open-ended approach, wherein the ultimate end state is undefined at program initiation. In this process, feedback is solicited from the users after each increment of capability is delivered, allowing the requirements to evolve along with the solution. The two UAVs discussed have followed the spiral development model.

DoDD 5000.1 describes the Spiral Development process as follows: "In this process, a desired capability is identified, but the end-state requirements are not known at program initiation. Those requirements are refined through demonstration and risk management; there is continuous user feedback; and each increment provides the user the best possible capability. The requirements for future increments depend on feedback from users and technology maturation." In effect, this approach allows the acquiring agency to provide the warfighters with the best capability available at a given point in time, and explicitly acknowledges an issue that we in the acquisition business have wrestled with for years: the inability of long weapon system development cycles to cope with the dynamic nature of operational requirements and technologies. Ideally, a spiral development approach will allow new user requirements to be implemented in the weapon system, even as they evolve over time. It also provides a mechanism to accommodate newer technologies, with the objective of keeping the system supportable and cost-effective even as it develops.

From a traditional systems engineering perspective, the spiral model might be considered a high risk approach, due to its lack of a clear objective from the onset. In theory, under spiral development, enormous resources could potentially be wasted on false starts and dead-end development paths. This is inherently incompatible with the highly political process used to obtain funding for weapon system development. Another perceived problem with the spiral process arises from its open-endedness; one might think that as long as the users can keep coming up with new requirements, the program may never get out of the concept development stage. The potential existence of multiple baselines, or no baselines at all, will make transition into the more traditional production and sustainment phases exceptionally difficult. These issues are actively being addressed by the proponents of the process.

Despite its drawbacks, the spiral model is very attractive for several reasons. Foremost among these is its ability to field a capability, albeit limited, within a relatively short time span. Modern weapon systems have become so complex that it is not unusual for a development and production program to span several decades before achieving an operational capability. The traditional acquisition system is not resilient enough to absorb the effects of major development obstacles, which inevitably occur whenever new ground is being broken. This results in schedule delays and high program costs, necessitates legacy systems being relied upon well beyond their planned service lives, and may possibly even lead to the obsolescence and irrelevance of a particular technology even before it is fielded. An evolutionary acquisition process can preclude this situation, not only allowing but encouraging changes in direction when such roadblocks occur.

SPIRAL MODEL APPLICABILITY TO UAVS

The benefits of spiral development are well suited to the UAV application. In a warfighting situation, there is no such thing as too much intelligence information, and even incomplete information can endow its possessor with a tactical advantage. The warfighter is therefore elated to have the use of any intelligence gathering platform, even one which satisfies only a subset of his needs. The spiral model is the mechanism which enables the acquiring agency to provide this partial solution. The acceptability of an incomplete solution is therefore one way in which UAVs fit the spiral strategy.

In addition, the fact that the vehicle is free of a human occupant also facilitates the early application of a relatively immature system. Normally conservative and risk-averse when it comes to the operational employment of a new weapon system, it is conceivable that the military may be willing to accept a somewhat higher risk of failure with UAVs. In contrast to a manned aircraft, many UAVs are relatively inexpensive, and are much less likely to inflict casualties should they experience a catastrophic failure. These factors make it acceptable to deliver and employ a system which may harbor operational deficiencies, as are more likely to exist in a spiral development than a traditional acquisition. The tradeoff in this case favors the risky approach: while the risks are great, the potential benefits are even greater.

For these reasons, a spiral approach was selected for the development of the Air Force's two primary UAV systems. The Advanced Concept Technology Demonstration (ACTD) program, managed by the Defense Advanced Research Projects Agency, was chartered with the exploration and rapid fielding of new technologies which might provide significant new capabilities to the warfighter. Both Predator and Global Hawk can trace their roots to the ACTD program, with goals of demonstrating the concepts of long endurance UAVs operating at medium and high altitudes, respectively. Descriptions of these projects may be found on the ACTD website [OSD, 2004]. Both programs have since transitioned from DARPA to Air Force management.

Spiral development has proven its merit under these two ACTDs, and this success has been a major factor in the institutionalization of the process under the revised DoD 5000-series regulations discussed earlier. Unfortunately, there is a downside to this approach, which has potentially significant repercussions on the development of a corresponding training system.

TRAINING SYSTEMS UNDER SPIRAL DEVELOPMENT

It is well understood that the spiral model gains its efficiency by implementing the most critical capabilities earliest, and deferring less critical capabilities until later in the lifecycle. What is not universally agreed upon is the definition of what is "most critical"; the answer to this question depends upon who is asked. From a training expert's perspective, training is obviously a critical capability, deserving of early implementation. Unfortunately, this viewpoint is not necessarily shared by all the decision makers. In a perfect world, the training capability could be successfully implemented in parallel to the weapon system, using an analogous evolutionary acquisition approach. In reality, however, resource limitations force that capabilities be prioritized, and the lowest ones deferred. When taken in the context of the weapon system as a whole, the training system is itself often perceived as a low priority capability. This attitude is not entirely without merit; after all, investment in a training capability to support a concept which may never come to fruition can easily divert resources from activities for which the results are more immediate and assured. However, completely neglecting training until later spirals really isn't the answer, either. Some compromise needs to be found that ensures training system development is treated as an integral part of the weapon system capability.

The process presently used by the Air Force to define training systems, known as Instructional System Development (ISD), is documented in Air Force Manual 36-2234 and its companion implementation guidance, the thirteen volume Air Force Handbook 36-2235, "Information for Designers of Instructional Systems." This is a well-proven methodology which has been used successfully to develop training systems for various Air Force weapon systems for over a decade. Other key process guidance exists as Air Force Instruction 36-2251, "Management of Air Force Training Systems," which identifies the Training System Requirements Analysis (TSRA) process as the mechanism for establishing and addressing training system requirements. An efficient TSRA relies on knowing the specifics of how the operational system works and is employed.

The process by which the Air Force's current UAVs are being developed is somewhat incompatible with the ISD/TSRA approach. The spiral model intentionally defers the implementation of less well defined capabilities until later development iterations. As stated earlier, training tends to be poorly defined in the initial stages of system development, often leading to the conclusion that it should be deferred. This problem is exacerbated by the fact that the spiral development approach itself contributes to a poor understanding of training requirements. For the TSRA process to be most effective, ideally the weapon system capabilities would be defined prior to training system initiation. In reality, this is frequently not the case, especially when the training system is being developed concurrently with the weapon system, even when using a traditional linear development approach. An evolutionary development approach makes the training requirements definition problem even worse, and actually encourages it to persist.

For example, the Predator started as an ACTD project, and was demonstrated to be a useful asset while still in development, through its use over the Balkans. Emphasis was clearly directed toward fielding an initial airframe capability, and advancing the combat capability to support various newly defined mission requirements. A total training system approach - although maybe not totally an afterthought, given the developmental nature of the Predator - appears not to have been thoroughly explored at the inception of the program; in fact, no simulator funding was provided by the Air Combat Command until the fiscal 2005 budget. Rather than integrating a formal TSRA and disciplined training system development effort into the overall program, a total training systems approach was effectively delayed for as long as possible. Eventually, a UAV training research project then in progress at the Air Force Research Laboratory was called into service as an operational trainer [AFRL, 2004]. This device, designated the Multi-Task Trainer, filled a void for several years, but was not designed to meet the growing student throughput demand, nor was it able to keep pace with the complexity of the ever-increasing capabilities being demonstrated and aggressively being added to the Predator system. This situation is likely to persist; examination of the UAV Roadmap appears to offer no relief for the aggressive fielding of follow-on UAV variants.

CURRENT UAV TRAINERS

Following the discussion presented thus far, the reader has probably concluded that the UAV systems currently in operation by the Air Force do not have robust associated training systems. Regrettably, this is indeed the case. Both the MQ-1 and RQ-4 platforms are supported by trainers which have been acquired and are supported on a very informal, ad hoc basis, subject to sporadic availability of funds and providing only a partial solution to the overall training need. This is not to say that they are completely inadequate; indeed, they are reasonably effective, given the circumstances under which they have been developed. But they are by no means optimum. Without being developed under the auspices of the rigorous TSRA process, their training utility is limited, requiring the use of the operational aircraft to accomplish a greater proportion of training than might otherwise be done on the simulator. Also, they are maintained only to the extent permitted by the very limited funding available, and cannot effectively be kept concurrent with the corresponding UAV vehicles.

CONTINUING TREND

As far as UAV development is concerned, the spiral model is here to stay. During a press conference announcing the release of the Defense Department's UAV Roadmap, the Deputy, UAV Planning Task Force for Acquisition, Technology and Logistics said, "…UCAV in general appears to be a program that will be laid out in spiral development acquisition. We will probably deliver some initial capability that will be fairly limited. The intent will be to get systems out to the field that fill a niche capability, and I've described some of those mission areas where we need support. But then we would expect the department and the services to grow that capability to expand that to other mission areas." [News, 2003]. Thus, the treatment of training systems within spiral UAV development programs is a continuing issue which will need to be addressed.

ELEVATING THE IMPORTANCE OF TRAINING

It is apparent that future UAVs, and eventually other Air Force systems, will embrace spiral development as the methodology of choice. As this happens, one of the most significant obstacles that will need to be overcome is the prevalent cultural attitude that training development is a minimally important aspect of weapon system development, and that it can be safely deferred until later spirals. It is easy to see how the ACTD environment can lead to such a conclusion. Under spiral development, those capabilities which don't give the greatest "bang for the buck" are apt to be given lower priority. Unless training is identified as a critical capability, it is at risk of being deferred. The only way to elevate the training requirement to a higher priority is to demonstrate that the lack of a robust training system at initial system deployment will create a problem.

The Department of Defense's "Unmanned Aerial Vehicle Roadmap 2002-2027" [OSD, 2003a] provides some insight into the relationship between training and mishap rates. UAV mishap rates are historically higher than those of manned aircraft. Notably, operator training has been identified as one of the three primary factors determined to be responsible for 80 percent of the mishaps encountered by UAVs across the DoD. The Roadmap suggests that benefits gained through reliability improvements in these three areas could likely outweigh the costs of their implementation; in other words, the cost of implementing improved operator training systems is expected to be less than the cost associated with the mishaps that they would prevent. The Roadmap also encourages greater emphasis on simulation, in order to reduce the cost of training and improve student throughput.

Together, these facts highlight the need for a disciplined approach to training system definition, even as the UAV system is initially developed and fielded. The mishap data indicates that the existing ad-hoc approach to operator training is deficient. This suggests that a more rigorous training system definition process needs to be implemented, to assure that all training requirements are addressed. The recognition that simulation-based training can provide a more cost effective solution than flying time, further suggests that this process needs to examine media alternatives from the onset. From these factors, one may conclude that a training system requirements analysis should be conducted, and that it should be initiated at an early phase of the program.

This raises the question of how comprehensive an initial TSRA, and subsequent training system development program, needs to be. In principle, there is nothing wrong with the strategy of defining an operational capability before committing to develop a training system for it. To achieve the goal of fielding the new capability as rapidly as possible, the development activities must be streamlined to eliminate every activity that does not contribute directly to the objective. It is hard to argue that a comprehensive training capability falls into this category. This is especially true in the case of UAV programs, where there may be more willingness to accept the risk of a mishap due to inadequately trained personnel.

Another consideration supporting the deferment of trainer development is the relative volatility of the ACTD weapon system as a result of its immaturity. One of the major benefits of the evolutionary development approach is the ability to test capabilities in the field before committing to full-rate production. This concept carries with it the very distinct possibility that the capability fielded initially will require substantial modification prior to being fielded in its ultimate production configuration, or even be determined to be unsuccessful and cancelled altogether. It would undoubtedly be a waste of resources for a training system developer to chase such a "moving target" with no clear indication that the effort would yield a useful product.

Thus, the training system acquirer is in an apparent no-win situation: start early, before the system evolves to its final operational configuration, and field a trainer on time, but only at great expense and with a lot of changes enroute; or start later, after the system design stabilizes, and develop a training system at minimal expense but late to need. Neither of these is a particularly attractive alternative.

Evolutionary Trainer Development

It needs to be recognized that, like the capabilities of the parent weapon system, the capabilities of the training system will need to evolve. This implies that there will be "scrap and rework" on the training system. It is easy to see how this solution would appear unsatisfactory to the weapon system program manager, who would likely be reluctant to invest resources in a temporary training system solution[2].

The UAV Roadmap concisely summarizes this issue in the following statement: "ACTDs are focused on quickly putting a capability into a theater commander's hands for his evaluation *before committing resources for the attendant training…*" (emphasis added). From the training developer's perspective, it is easy to see how this philosophy creates a major problem.

So how does the training community stay on-course and be responsive to fielding a training system capability that supports aggressive capability growth? The traditional training system development model, although built to be flexible, will need to bend to meet the evolutionary acquisition approach. As indicated earlier, the Air Force uses the ISD process for developing education and training. ISD is a flexible systematic process for planning, developing, implementing, and managing instructional systems. It employs a proven approach to ensure personnel are taught the knowledge, skills, and attitudes essential for successful job performance. The ISD process consists of an analysis, design, development, and an implementation phase with a continual evaluation feedback loop throughout each phase of the process. The ISD process supports the Air Force policy of developing military training programs that satisfy mission generated training requirements using the most cost-efficient method possible. The upfront TSRA is conducted for newly developed systems or on major modifications to existing systems, to define the training system requirements and associated risks. The TSRA process identifies the weapons system mission and associated tasks that are required to be trained. The tasks are converted to training objectives, and allocated to the optimal media to meet these objectives. The outcome is a defined set of training requirements with a preliminary set of system requirements defining the curriculum, media required and system-level training device fidelity. The TSRA process typically starts at the onset of a program and continues throughout the weapon system design phase. The question is how the training systems development process can be made to seamlessly integrate within the evolutionary acquisition spiral development construct.

To accommodate the integration of the weapon system and training system development processes, the training systems development effort must be an integral part of each added increment of capability. The baseline training system requirements analysis should begin with the initial spiral development effort of the weapon system. TSRA results will provide training system options to pursue to meet the initial fielded capability and offer a path for continued growth. As follow-on spirals progress, the weapon system program office needs to ensure that training systems impacts are fully investigated for potential modifications to the baseline training system. This approach is not so different from how changes to fielded training system programs are accomplished today. The difference is that the current change process generally assumes that the trainer development lags the weapon system, enabling trainer developers to utilize weapon system information to drive the training system design. When systems are fielded while still in development they may not have the appropriate supporting design data, adequately documented baseline, or performed

[2] In the case of the Predator, this is already taking place to some extent. At present, a contract action is underway to replace the Multi-Task Trainer developed by the Air Force Research Laboratory, which had been used as the primary training device since its development. All of the resources spent in developing, producing, and sustaining the MTT will essentially be thrown away, and a new system development initiated from scratch.

adequate training and support planning to establish a firm baseline to build and provide follow-on support for the training system. To make matters worse, the baseline rapidly changes to accommodate new increments of capability.

CHALLENGES

There are two significant challenges facing the developer of any training system: maintaining a trainer configuration which continually reflects the operating characteristics of the simulated weapon system, and acquiring the design data needed to both develop the system initially and maintain this concurrency. These problems are amplified in the spiral development environment, as discussed in the following paragraphs.

Concurrency

To provide effective training, and avoid introducing misinformation leading to negative training, a training system must usually reflect as nearly as possible the configuration and functionality of the parent weapon system which it simulates. The maintenance of this state is a complex, multi-faceted problem which is generally referred to as trainer concurrency. Concurrency is a recurring issue which affects virtually every training system development to some extent. Experience has shown that concurrency management must be a formal, ongoing process. It is simply not possible to allow the weapon system to evolve and expect the training system to catch up. Concurrency is a difficult problem, and a perennial source of user dissatisfaction, even under the best of conditions. Numerous approaches to concurrency management have been tried over the years, with varying degrees of success.

Existing concurrency approaches normally rely upon the existence of a relatively lengthy testing cycle, which gives the trainer developer time to incorporate aircraft changes into the simulators and course curriculum. This strategy is defeated to some extent by the abbreviated testing cycle which occurs with some UAVs, which gives the trainer developer less time to respond to an upcoming change before it is fielded. Change frequency is also a complicating factor. Unlike aircraft changes which are normally incorporated as annual or biennial block updates, UAV configuration changes may be made several times a year, making trainer concurrency an even more daunting task.

Advance planning is the key to any successful concurrency implementation. It unrealistic to expect to wait until a weapon system reaches its final operational configuration, before starting to think about trainer updates. Indeed, under the spiral development model as implemented on today's UAV platforms, there may never be such an animal as a "final configuration;" the system will very likely continue to evolve throughout its lifespan.

It is difficult to field a training system and keep it concurrent with a weapon system which has rapidly changing requirements. To do this, the requirements analysis process should be accomplished at the start of each weapon system program and establish the training requirements for the initial increment of capability. As follow-on spirals are undertaken, a requirements analysis should be conducted to assess their impacts on trainer modification, just as if starting a new system. The requirements analysis process should be a practice that is employed for each and every spiral effort. Provisions for weapon system data need to be a part of the core capability that is being fielded and continually maintained throughout each follow-on spiral. Relationships must be set up between the training system and the weapon system providers, for building the core capability, and to foster fast data exchange. The training system contractor should know what changes are planned and when they are going to be implemented, and start to aggressively work to modify the training system to accommodate new capabilities, as described by the requirements analysis efforts.

Data Availability

Another recurring problem, plaguing many training system development programs, is data - or more specifically, the lack of data. An effective trainer cannot be developed without intimate knowledge of the system being simulated. Data can come in many different forms, from descriptive documents to engineering drawings to software. Data problems generally fall into two categories: either the needed information does not exist in usable form, or the data exists but is not accessible to the trainer developer for some reason. In either case, the trainer developer is hamstrung by the lack of the information he needs to design the trainer. When this occurs, he is often forced to reverse-engineer the trainer from the documented performance characteristics of the aircraft.

Even when the needed data exists, its ownership can be another problem. In contrast with most manned military aircraft, the UAVs used by the military contain significant commercial off-the-shelf (COTS) technology, and may even be derived directly from COTS UAVs. The implication of this situation is that the government may not own, or even have the rights to use, the underlying technologies in any application other than the aircraft itself.

Obtaining the necessary source data to design the trainer initially is often a formidable problem in itself. Maintaining the flow of such information, as well as the process to rapidly incorporate it into the trainer to keep up with changes to the weapon system in a timely fashion, can present an even greater challenge, contributing to the concurrency challenge discussed above.

FUTURE TRENDS

As if the current atmosphere weren't already challenging enough, by every indication this environment will not only continue in its current state, but is expected to grow in the years ahead. Several potential issues facing the training community in the out-years include the following:

Increasing UAV Interoperability

The DoD UAV Roadmap [OSD, 2003a] emphasizes the future trend toward integration among the Task, Post, Process, and Use (TPPU) cycles associated with currently independent UAV systems. Presently, each service maintains a Distributed Common Ground System (DCGS) to support its intelligence collection function, of which interface to its respective UAV platforms is a part. The transition to a joint, network centric DCGS encompassing all of these separate entities has begun, but it is predicted that the transition to this fully integrated system will occur in the 2010-2027 timeframe. The roadmap identifies training as one of the serious shortfalls, and recommends that DoD services and agencies POM for training program development within the FYDP [UAV Roadmap, Appendix H, Page 173].

While the roadmap specifically addresses the training shortfall from the perspective of the intelligence analyst community, the challenge of this evolution to training systems is even greater.

Student Population

The unique characteristics of UAV operation introduce several new considerations to the process of training system development. UAVs are flown by operators in a benign environment, which lacks the demanding physiological constraints associated with manned aircraft. This potentially enables relaxation of some of the restrictions normally imposed on military pilots. It is conceivable that individuals who are technically capable of piloting an aircraft but have been disqualified from flying for some reason (such as a medical condition), could be qualified to fly UAVs. Taken one step further, one can imagine that some UAV operations which do not require significant piloting skills (such as loitering over unpopulated areas under VFR conditions) might even be performed by unrated personnel, reserving the more demanding tasks such as takeoff and landing for rated crewmembers. This is not the current operational policy, but technically not beyond the realm of possibility for future UAV systems.

As early as 1997, the Air Force Research Laboratory was investigating whether enlisted personnel could serve as UAV operators in lieu of rated pilots [Hall, 1997]. This study, which surveyed Predator operators, concluded that the Air Force decision to use only rated pilots to fly that platform was appropriate, but did not yield conclusive results which could be applied to other unmanned systems.

Another AFRL study [Weeks, 2000] investigated the disparity among the military services with regard to the qualifications required of UAV operators. This study revealed a variety of qualification requirements for the different UAV platforms across services. While the Air Force requires instrument-rated pilots for the Predator and Global Hawk, the Army's Hunter and Navy's Pioneer may be operated by enlisted members with no manned aircraft piloting experience. These differences are largely due to the operating envelopes of the different platforms; the Air Force's UAVs generally operate at higher altitudes, and in controlled airspace, whereas the smaller UAVs do not. The Air Force's policy is driven by FAA regulations for operation within Class A airspace, which require UAV operators to have an instrument rating. While these restrictions affect domestic training operations, they might not necessarily apply in deployed operational locations. Thus, in theory, there may be a potential for the evolution of a two-tiered operator cadre, with rated pilots flying the UAV when required, but delegating operation to non-rated members under less restrictive conditions. The long endurance of systems such as the Predator and Global Hawk, in combination with a shortfall in qualified pilots, could make this an attractive option for sustained operations. Should such a scenario emerge, the training system would need to evolve, in order to provide training for operators with significantly varying backgrounds.

Embedded Training Opportunities

By nature, UAVs provide an opportunity for exceptionally close harmonization between the operational system and its associated trainers. Since the UAV crew operates the aircraft from a remotely located console, and receives all knowledge of the aircraft's physical environment through display screens, from a human interaction standpoint the UAV console more closely resembles a ground-based simulator than a manned aircraft. This effect is amplified by the fact that the ground-based operator console, not requiring the ruggedization associated with flightworthy hardware, can often be largely constructed of commercially available components, such as those typically used in training devices.

This situation creates the potential for an almost seamless transition from training device to operational equipment. The trainer can easily be designed to perfectly replicate the physical environment experienced by the operational UAV pilot. Further, the fidelity of real-time image generation is such that the video presentation seen by the operator of the actual equipment can be replicated almost exactly in a simulator. The end result of these effects is that a training device can be designed which is virtually indistinguishable from the actual equipment, from the operator's perspective. The obvious benefit is that such a setup enables very effective transfer of training from the simulator to the operational system. If the device looks and behaves exactly as the operational equipment, the student is unlikely to develop any bad habits or "sim-isms" from training in the simulator.

Regardless, it is important to provide a training system which accurately models the UAV system being trained, especially because of the way in which UAV operation differs from flying a manned aircraft. The Air Combat Command has been quoted as saying that the ground control station for an unmanned aircraft can provide the pilot with situational awareness which is "oftentimes better than it would be in a manned aircraft" [Colucci, 2004]. However, specific flying tasks may be more difficult, according to the commander of the 15th Reconnaissance Squadron at Nellis AFB, who has stated that "Flying the Predator is harder than flying a manned aircraft in many ways... there's no sound, no 'seat-of-the-pants' feel to it, and the peripheral vision is limited" [Garamone, 2002a].

Less obvious, but perhaps equally valuable, is that the architecture of the operational system also facilitates significant commonality between operational equipment and the trainer. It is conceivable that a single control console might even be used in two different modes: operational mode, when it is linked through a communications system to an actual UAV platform, and training mode, when it is linked only to a simulation of these external components. In addition to virtually eliminating any potential for mismatches between trainer and operational equipment, another benefit of this approach would be its ability to minimize the total amount of hardware required, thereby reducing facility and logistic support requirements and their associated costs. Under this scenario, concurrency would still need to be addressed (the simulation portion of the trainer would need to be kept concurrent with the operational hardware it replaces), but the magnitude of the problem would be reduced.

CONCLUSION

This paper has described the challenging environment which the current UAV development process creates for the training system developer. Given its successes, there is no reason to suspect that the trend toward greater use of spiral development will reverse; on the contrary, its use is likely to become more prevalent as time goes on. It is therefore inevitable that the current approach to the development of training systems will require a corresponding evolution.

The elimination of training considerations from the UAV development program altogether – or as a minimum, deferring them until late spirals – is not going to remain an acceptable approach. A middle ground must be found.

The current training system requirements analysis and development cycle is not responsive enough to support the short turnaround times necessary to sustain a spiral model. It is no longer possible to wait until the weapon system reaches a stable level of maturity, before beginning the TSRA. The training system development community must adopt a spiral approach to trainer development, which is coordinated with and mirrors the evolutionary acquisition process employed by the parent weapon system.

This paper has only scratched the surface of the challenges associated with UAV trainer development. In general terms, it might be stated that the development of a UAV training system includes all of the usual issues faced during the course of manned aircraft trainer development, and then some. But in some ways, the issues currently seen in UAV trainer development are a harbinger of things to come across the acquisition community as a whole. The evolutionary acquisition process has been integrated into the mainstream of weapons system acquisition, through its prominent inclusion in the new 5000 series regulations. While the appropriateness of this blanket endorsement on the basis of limited success in a number of ACTD programs might be a debatable point to some, it is regardless the direction in which the acquisition community has been directed to proceed. It is, therefore, the environment within which training system developers will need to operate, and we must begin moving in that direction.

REFERENCES

[AFRL, 2004] Uninhabited Air Vehicle Behavioral Research and Training System Development, downloaded May 2004 from website http://www.mesa.afmc.af.mil, Air Force Research Laboratory, Mesa, AZ.

[Colucci, 2004] Colucci, Frank, Air Force Refines Training Programs for UAV Operators, *National Defense*, National Defense Industrial Association, Arlington, VA, May 2004.

[Garamone, 2002a] From U.S. Civil War to Afghanistan: A Short History of UAVs, American Forces Information Service New Articles, April 16, 2002.

[Garamone, 2002b] Flying an Unmanned Aerial Vehicle, American Forces Information Service New Articles, April 23, 2002.

[News, 2003]: Unmanned Aerial Vehicle Roadmap Report, U.S. DOD News Transcript, Presenter: Deputy, UAV Planning Task Force for Acquisition, Technology and Logistics, March 18, 2003.

[Hall, 1998] Hall, Ellen M., Tirre, William C., USAF Air Vehicle Operator Training Requirements Study, report number AFRL-HE-BR-SR-1998-0001, Air Force Research Laboratory, Brooks AFB, TX, February 1998.

[OSD, 2003a] Unmanned Aerial Vehicles Roadmap, Office of the Secretary of Defense, Undersecretary of Defense for Acquisition, Technology and Logistics, Washington DC, 11 March 2003.

[OSD, 2003b] Operation of the Defense Acquisition System, Department of Defense Instruction Number 5000.2, Office of the Secretary of Defense, Undersecretary of Defense for Acquisition, Technology and Logistics, Washington, DC, 12 May 2003.

[OSD, 2004] FY 1995 Project Descriptions, downloaded May 2004 from website http://www.acq.osd.mil/actd/, Office of the Secretary of Defense, Undersecretary for Acquisition, Technology and Logistics, Washington, DC.

[Ryder, 2001] Ryder, Joan M., Scolaro, Jacqueline A., and Stokes, James M., An Instructional Agent for UAV Controller Training, CHI Systems, Inc., originally published in Proceedings of UAVs – Sixteenth International Conference, University of Bristol, UK, downloaded May 2004 from website

[Schreiber, 2002] Schreiber, Brian T., Lyon, Don R., Martin, Elizabeth L., and Confer, Herk A., Impact of Prior Flight Experience on Learning Predator UAV Operator Skills, report number AFRL-HE-AZ-TR-2002-0026, Air Force Research Laboratory, Mesa, AZ, February 2002.

[SRA, 2004] Vehicles, webpage http://www.uavforum.com/vehicles/vehicles.htm, SRA International Inc., Alexandria, VA, May 2004.

[USAF, 2001] Fact Sheet - RQ-/MQ-1 Predator Unmanned Aerial Vehicle, United States Air Force, Air Combat Command, Langley AFB, VA, July 2001.

[USAF, 2003a] Fact Sheet - Global Hawk, United States Air Force, Aeronautical Systems Center, Wright-Patterson AFB, OH, April 2003.

[USAF, 2003b] AFI 36-2251, Management of Air Force Training Systems, 20 March 2003.