SPECIALIZED UNDERGRADUATE PILOT TRAINING SYSTEM

AN OVERVIEW OF SYSTEMS DEVELOPMENT

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ABSTRACT

Over the last fifteen years, a number of studies have been performed that looked at the way the United States Air Force (USAF) trains its pilots. Several of these studies concluded that, if training were specialized, the USAF could realize significant cost savings while improving the quality of training. Air Training Command (ATC) has decided to implement Specialized Undergraduate Pilot Training (SUPT) starting in FY92. SUPT will allow ATC to split pilot training into a tanker-transport track and a fighter-bomber track. The students in each track will concentrate on the type of flying in the type of aircraft that most closely resembles the system they will fly upon completion of training. Studies are currently underway that will define the new undergraduate pilot training system. This paper gives an overview of SUPT and a methodology for defining and addressing the issues associated with its implementation. We conclude that use of a sound systems engineering methodology is essential to understanding large, complex training systems, especially the interrelationships between functions and information flows within the system. Other papers in this session will describe in more detail the implementation of the methodology and illustrate some preliminary results.

SUPT - WHAT IS IT?

We initially address the basic philosophy driving the change to SUPT - Specialized Undergraduate Pilot Training - and the associated conceptual model that is driving the USAF planning and eventual acquisition. We are considering SUPT as a training system in its own right, one that is made up of several training subsystems that will be acquired over a period of 20-plus years. The training system concept is critical to insuring that the Air Training Command (ATC) receives an integrated total pilot training package that delivers the desired product to its customer major commands, as we shall see.

SUPT grew out of a basic change in philosophy relative to training pilots. The concept is not new, but the current environment where all phases of the current system are becoming obsolete at once has given the USAF the opportunity to effect the change in a cost-effective and systematic manner. The current undergraduate pilot training (UPT) system historically has been the best in the world - there is nothing wrong with the skill and professionalism of today's Air Force pilots. What is happening is pilot skills are becoming more specialized at the same time training costs are dramatically increasing. SUPT strives to train the special skills a pilot needs to eventually transition to his operational flying job as early as possible in his development, assuming that the training he receives in ATC is the least costly of any he will receive subsequent to pilot training. In effect, ATC wants to
1. Specialize the training a pilot receives at UPT to better prepare him to enter mission-specific training, while

2. As much as possible, move the required training to the left in the training continuum to take advantage of the cheaper training aircraft and flying time. This means moving as much of the mission-specific training as possible to UPT.

Collateral benefits of SUPT are threefold. First, it allows ATC the flexibility to respond to changes in specific user requirements without affecting the training of other pilots. Second, it permits the design of a new training system under true training system concepts. That is, focus is placed on tightly defining the input and desired output and letting the delta, or desired training requirements, define the intervening "black box." Third, a systematic implementation of SUPT removes some of the load on elements of the current system, extending the structural lives of current aircraft, thereby allowing a smooth financial transition. That is, all airplanes and associated training systems are not replaced at once.

Figure 1 shows the SUPT system. The training transformation occurs within the system boundaries. The qualitative definitions of the input and output are well defined. Subsystem boundaries, or phase transitions within the SUPT system, are not defined by points in time, but are defined by desired input and output skills and knowledge (S+K). They represent (ideally) an optimal transition from one phase to another based on

1. Skill identification and analysis,

2. Media allocation methodologies, and

3. System trade-offs based on life-cycle costs (LCC) or "training effectiveness."

It is apparent that critical to the design of an effective training system is the identification of specific input and desired output S+K. In general, then the change in these S+K is the training requirement. If the delta S+K is ill defined, our training system may not do its job. Media allocation to the training requirement is based on the delta and the level of learning that is required. Keeping in mind that we also want to train using the least expensive training medium, it becomes clear that the training requirement and desired level of learning are critical to proper media allocation.

From a top level, Figure 1 shows how student pilots flow through the SUPT system. All pilots go through the primary phase - the Primary Aircraft Training System (PATS), which is closely related to the current T-37 phase of training. The above considerations dictate that a relatively inexpensive mode of training would be the most cost-effective, since top-level, basic flying skills are being taught. Skill repetition is needed, with either lots of flying hours or some split between high-fidelity simulator and aircraft. If a low cost, simple aircraft trainer can be identified, S+K analysis might even suggest eliminating full mission simulators in favor of more flying time. Input S+K and traits are currently being defined through ongoing research; output S+K will be defined through a series of trade-offs and S+K analyses of the subsequent phases of training. Primary training will occur at all five SUPT Air Force bases.

The next two phases - the Tanker-Transport Training System (TTTS) and the Bomber-Fighter Training System (BFTS) - characterize the specialized training aspect of SUPT. The input to each of these phases is defined as the output from PATS, determined from the considerations mentioned previously. The desired output from each phase is ideally defined by the customer; that is, the desired level and type of S+K the user desires his pilot to have before he enters mission-specific or aircraft transition training. Again, if the user can move some of this training to the less expensive ATC training environment, the Air Force benefits
from the more cost-effective training. Training system concept studies - top-level Instructional Systems Development (ISD) front-end analyses - are being used to perform the desired trade-offs between phases of SUPT.

The TTTS is entering the acquisition phase. The TTTS program implementation is the key to SUPT implementation and represents the greatest departure from the current UPT system. In the past, UPT has concentrated on the basic flying skills - VFR contact flying, basic instrument cross-check, formation (emphasizing precision flying skills as opposed to tactics), and VFR/basic IFR navigation. Crew coordination training is not possible in the current training environment. Other than minimal cross-country and instrument approach training, IFR navigation is not trained to proficiency. TTTS will train these new S+K to the approximately 60% of the SUPT students that will eventually fly multi-engine, multi-crew aircraft. Formation will be taught, but tailored to the specific mission of the TT pilot. Instrument procedures and crew coordination will be stressed. The type of training that currently occurs at Technical Training Units for C-5s, for example, can at least now be introduced in TTTS.

SYSTEMS APPROACH TO SUPT

As we discuss the detailed conceptual studies on PATS and BFTS that are ongoing or complete, keep in mind one key point. Even though the studies appear to approach each phase independently, our plans for the future approach the SUPT as a training system. This is necessary to continue the goal of moving the training to the left in the training continuum consistent with a number of criteria. Our initial studies on PATS and BFTS will help us identify those criteria, including pinpointing the best point to transition from one phase to another in terms of acquired S+K. The focus remains, however, on the desired S+K of the output student from the total training system. Future planning and studies will address the integration issues once each phase is better understood.

Why is this so important? Our phase studies work through an S+K analysis on the way to a media allocation and identification of functional elements of the system. A further functional capabilities analysis of each phase highlights common functional elements between each phase. With our systems viewpoint in planning for acquisition, we can insure functional elements are not duplicated during the lengthy acquisition process.

The jury is still out on the SUPT acquisition strategy. Funding realities may preclude the acquisition of the system as a total system. In any case, our planning will continue to address the system issues - at the SUPT system level - as they emerge.

TRAINING SYSTEM CONCEPT DEVELOPMENT

The Instructional Systems Development (ISD) process, illustrated in Figure 2 and addressed in more detail in a subsequent paper in this session, is a proven, sound, systems engineering methodology for training system design. Since it really is a process, it continues to work - an improvement process engine - throughout the training system life cycle. Two functions within the ISD process are central to its success:

1. Defining training requirements to the proper level of detail, then establishing traceability from these requirements to training system functional capability.

2. A process feedback mechanism that insures the system is dynamic - that is, responsive to its own performance and outside-induced changes.
The ISD process is very labor intensive and time consuming, since training requirements generally are defined to a level of detail that deals with the actual human behavior that requires modification during the training process and the required cues needed to train those behaviors. Further, as seen in Figure 2, the process is iterative from inception through its life cycle. That is, as changes are induced in the system for whatever reason, resulting changes in the design of the training system are iterated based on a set of criteria for system effectiveness. As decisions are made relative to training system design, such as selection of training system media, another loop is initiated through the process much the same way as if a training requirement changes. An ISD-defined training system requirement analysis (TSRA), as these detailed analyses are called, is probably inappropriate at early stages of training system concept development because of its inherent detail. We suggest the overall training system concept should be definitized before a TSRA is accomplished to avoid needless detail generation.

The approach used in SUPT development is to retain the ISD process in concept, but perform the initial analyses at a top-level. The stage is then set for a top-down total system definition, including only the level of detail needed at each step to define a particular training concept. In most cases, we can stay at a high enough level in the S+K hierarchy to not get mired in aircraft-specific S+K (such as operation of aircraft-specific equipment). This approach allows us, for example, to overlay different media, particularly aircraft, on the entire training system and observe training system response relative to, say, aircraft performance (in terms of our effectiveness criteria) without engaging needless detail during the tradeoff analyses. We can also vary the phase boundaries between PATS and BFTS, considered the most critical in terms of defining life-cycle costs (LCC), to observe the effects on the total SUPT system. By using this approach, we are finding that we already know enough about training system design to make intelligent decisions relative to training media, given a particular skill or task hierarchy (defined at a top-level) that needs to be trained, and that we can save the detailed enumeration of tasks, skills, and objectives until we begin the task of writing system specifications. This important element of system acquisition can begin after critical tradeoffs have been quantified and we have some idea of what the system should look like.

The Recce-Attack-Fighter Training System (RAFTS) concept studies were the first to be completed. These studies address the BFTS phase of training, with some consideration given to the PATS and required output S+K for integration tradeoffs. Three prime airframe manufacturers worked from the same statement of work to define three training system concepts each, one of which had to be based on a newly developed aircraft optimized for that particular training mission. The foundation for these studies was a Phase I effort completed by Battelle, Columbus Division, in 1986. This preliminary look at the advanced phase of training supported the idea of specialized training through a broad look at

1. Future training needs,
2. Current system deficiencies, and
3. Preliminary design concepts for SUPT.

For example, some of the major deficiencies uncovered in the Battelle study were

1. Instrument flying training was limited and not tailored to operational needs,
2. Formation flying was not tailored to operational needs, and
3. The T-38 was limited in terms of performance, cockpit instrumentation and symbology relative to today's front-line fighter aircraft, and was becoming increasingly difficult and expensive to maintain.

The follow-on RAFTS studies focused on these and other deficiencies, including a best-guess of what technologies the SUPT graduate will face through the year 2030 and beyond. The RAFTS studies followed the basic ISD methodology:

1. Define the skills essential to BF pilot training,
2. Determine the phasing for the training of these skills,
3. Determine the mix of training devices, and
4. Perform life-cycle cost and logistics support analyses on each concept.

792
What is missing here from the total ISD process is the process engine - the system performance feedback loop. However, the methodology does allow us to establish training system concepts using only the level of detail needed, and if an iteration is needed, needless detail is not iterated.

The RAFTS studies provided us some baseline concepts for one track of the advanced phase of training. Meanwhile, the TTTS TSR was completed, leading to the current acquisition program. To complete the system-level look at SUPT, the Primary Aircraft Training System (PATS) program was initiated in June 1989. The exact same methodology is being used in PATS concept development except for two major differences:

1. The U. S. Navy has joined the effort to make the Joint PATS (JPATS) a potential joint USAF/USN program from inception. The USN is considering the JPATS aircraft as a replacement for the T-34C, the current goal being to maximize commonality of the USAF/USN training system in terms of hardware/software. The study will initially focus on separate definition of USAF and USN concepts and follow-up with the required tradeoffs to define two systems with maximum commonality. The Navy JPATS acquisition will follow the Air Force program.

2. Central to the JPATS program is a non-developmental aircraft buy. This means our study effort must account for aircraft that will exist in the 1994 timeframe. Since the aircraft is central to the training system, we will define notional categories of aircraft, each potential JPATS aircraft candidate being represented by a category in terms of performance, and overlay our training system concepts with these categories. We can then quantify such criteria as LCC for JPATS, as well as SUPT, based on differing aircraft performance capabilities. This will allow us to make intelligent decisions relative to aircraft performance and its effect on the entire SUPT system.

SYSTEMS APPROACH TO SUPT REVISITED

Our goal is to maintain an overall awareness of SUPT system-level issues, addressing them as they emerge as the various components are acquired. A particular set of systems engineering methodologies (SEMs) have been developed that will discipline and document our system description, showing interrelationships between functions and information flows within the complex SUPT system. The methodologies allow us to define and understand how our systematic approach to

![Diagram](figure3.png)

**Figure 3 -- The SUPT Pipeline - Another Viewpoint**

SUPT planning and development should proceed. They also evolve top-down, matching our conceptual approach to SUPT development. Most importantly, the SEMs are well documented and dynamic, allowing the model to evolve along with our system and decisions to be documented as they are made.

A first step is to abandon our mindset that UPT is a phased training system - it is a total training system that is really a subsystem within the overall USAF training system. Artificial boundaries between phases are broken down and redefined according to our training system effectiveness criteria. Refer to Figure 3, where we show primary training within SUPT described as such and not relative to the type of aircraft used. We then begin to realize that the phase boundaries are defined by the “footprint” of the media used and not by some arbitrary criterion, or “that's the way it is now and it works (or, it ain't broke...).” The boundaries can then be optimized relative to the many options for training media mix. Our SEMs help us keep track of system-level effects of decisions made during the ISD process.

Collateral benefits of a structured SEM are inherent in the process engine - the system performance feedback loop - function of the ISD. Our system model permits us to depict top-level information flows between
macro-functions, then decompose them down into identifiable pieces of information needs at the lower levels. Our planning then incorporates information needs into the design of the training management system - functions and information or data - which runs the training system. Its model also evolves with the training system. The model also guides us in implementing the training system, defining criteria used to select or classify the best pilot trainees, and future research needs (in the proper context) that will support development and operation of the SUPT system. Other uses include:

1. Definition of what information is needed to perform specific analyses. That is, we only show what is necessary.

2. Statement of Work definition - top-down description of an integrated work breakdown structure.

3. Data gathering - what data is needed, who has it, and how and where it is used.

4. Assignment of responsibilities, especially during implementation.

Figure 4 shows an example of an SEM depiction using the Integrated Computer-Aided Manufacturing Definition (IDEF-0) language. The boxes represent, in this case, top-level functions involved in developing SUPT. Arrows from the left and right are inputs and outputs, and arrows from the top and bottom are controls or constraints and mechanisms. More detailed descriptions are found in related papers in this session.

**SUMMARY**

Our case is simple relative to training system design:

1. We need to conceptually define before we define in detail,

2. We need to model interfaces, integration, information flows/needs, and functions to guide our system development.

This paper shows how we combine these methodologies to design a real training system. A much more powerful message, however, is apparent: The methodologies are applicable to any large system or enterprise. We will further develop this idea relative to defining goals and objectives, conceptual and pragmatic planning, development, implementation, and operation of large,
complex systems. We also consider this method essential to understanding Total Quality Management within the enterprise, and understanding is essential prior to implementation. Finally, as the ISD process is expanded to encompass higher-level cognitive learning objectives, we consider how the ISD process fits into the SEM framework.

REFERENCES

