Training Interventions to Reduce Predator Crew Errors

Gregg A. Montijo, David Kaiser and Jeff Eberhart
Crew Training International
Memphis, TN
gmontijo@cti-crm.com
dkaiser@cti-crm.com
jeberhart@cti-crm.com

V. Alan Spiker
Anacapa Sciences
Santa Barbara, CA
vaspiker@anacapasciences.com

Robert Nullmeyer
Air Force Research Laboratory
Mesa, AZ
robert.nullmeyer@af.mil

ABSTRACT

As the USAF dramatically expands Remotely Piloted Aircraft (RPA) usage, the explosive growth in flying hours is accompanied by an equally rapid growth in the need to train aircrews and by initiatives to use less experienced personnel as operators. Earlier research revealed that most MQ-1 Predator accidents involved causal human factors, often in four specific aircrew behavioral areas: inadequate crew coordination, channelized attention, task misprioritization, and wrong course of action.

Working with the Predator community, four specific training interventions were developed for pilots and sensor operators in initial qualification training: (1) enhanced academics; (2) web-based interactive mishap case histories; (3) a game-based multi-task skills trainer; and (4) GemaSim, a laptop-based team trainer. The four training interventions were introduced cumulatively over the course of 18 months for 27 different training classes (540 aircrew) using baseline, control and experimental classes. Training effectiveness assessment was structured around Kirkpatrick's Level I (student reaction), Level II (evidence of learning), and Level III (transfer of learning). Level III impacts were evaluated during two specific sorties in training.

Student reactions (Level I) regarding all four treatments were positive, but highest for the GemaSim team trainer and enhanced academics. Student reactions for interactive case studies and multi-task skills training were higher for sensor operators than experienced pilots. Evidence of learning (Level II) was present for all interventions and was statistically significant with the GemaSim intervention and enhanced academics. Positive transfer of learning (Level III) was observed for enhanced academics and the full complement of interventions. As the Air Force moves towards more inexperienced RPA aircrews, these interventions may be useful to not only reduce mishap rates, but also to increase mission effectiveness.

ABOUT THE AUTHORS

Gregg A. Montijo is the Combat Air Forces Crew/Cockpit Resource Management Program Manager for Crew Training International, Inc. He is a retired U.S. Air Force (USAF) command pilot with over 4,000 hours in the A-10, F-16, A-320 aircraft and various gliders. He earned a Bachelor’s degree from the U.S. Air Force Academy in 1981, specializing in Human Factors Engineering. He also earned a Master’s degree in Procurement and Acquisition Management from Webster University in 1995. He holds an Airline Transport Pilot’s license with a type rating in the B-737 and has over 11 years program management experience at the Pentagon and in the civilian sector. He has been with Crew Training International since 2001.

David Kaiser is the Managing Director of Corporate Learning for Crew Training International and is responsible for all courseware development for both Crew Resource Management and Contract Aircrew Training. He earned his Master’s degree from Embry Riddle Aeronautical University with a dual specialization in Aviation Education and Aviation Safety. He is a Navy aviator with combat experience and is currently active in the Navy Reserve. He has managed various experimental projects and has been personally awarded two U.S. patents. He has been with Crew Training International since 2006.

Jeff Eberhart is an Instructor/Subject Matter Expert for fighter, bomber and remotely piloted aircraft for Crew Training International and the on-site manager for the Real Time Cockpit Resource Management Research project at

Creech Air Force Base. He is a combat-experienced veteran and military aviator with over 4,300 flying hours, holding various command positions culminating as a numbered USAF vice commander. He earned a Master's degree from Auburn University and has been with Crew Training International since 2007.

Alan Spiker is a principal scientist at Anacapa Sciences where he has worked since 1982. He received his PhD in experimental psychology from the University of New Mexico in 1978. At Anacapa, he is responsible for managing human factors research projects in advanced technology, and has specialized in aviation training and human performance for all branches of service and the airline industry. During the past 11 years, he has conducted research on the cognitive underpinnings of effective, safe aircraft operation, including crew resource management, multi-tasking, planning, and decision-making.

Robert Nullmeyer is a research psychologist with the Air Force Research Laboratory at Mesa, AZ, where he has been since 1981. He has conducted research on training system evaluation, simulator training effectiveness, and crew resource management training needs analysis. He earned a PhD in Experimental Psychology from the University of New Mexico in 1979.

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INTRODUCTION

When Orville and Wilbur Wright made their series of initial flights in December 1903, they introduced the modern aviation world to human error as a mishap cause. Early aviators did not have an appreciation of the complexity of flight or the impact of many factors to include human performance (Anderson, 2004). A tremendous amount of progress has occurred since then; aircraft are considerably larger, faster, are more reliable and easier to operate and now, fly without humans on board. The development and operational use of unmanned or Remotely Piloted Aircraft (RPA) has expanded exponentially within the last two decades. The 2006 Quadrennial Defense Review set in motion the acquisition of large numbers of these systems (Office of the Secretary of Defense, 2006). Future aircraft design is following current trends towards unmanned aircraft for a variety of missions, both military and civilian.

The USAF has dramatically increased RPA use over the last 10 years starting with the use of the General Atomics MQ-1 Predator in mid-1995. Surveillance demands in Iraq and Afghanistan have dramatically increased the requirement for RPAs and have grown from several orbits to over sixty 24-hour-a-day orbits.

The explosion in the aircrew requirements needed to operate the expanding fleet of Predator aircraft has been met by a rapidly expanding training system and the quadrupling of aircrews trained over the past five years (CTI, 2010). According to Air Force Safety Center data, the corresponding annual flight hours increased dramatically between fiscal year 2001 and 2009, from 5,751 to 187,393.

The Predator is operated by a crew consisting of a pilot and sensor operator with assistance from an intelligence specialist and often operated via satellite communication links by crews located halfway around the world. Pilots come from a variety of backgrounds within the U.S. Air Force (USAF). Recently, pilot training graduates with no prior operational flying experience and officers with no prior flying experience whatsoever have entered the Predator pilot force. Sensor operators come from various operational Air Force backgrounds including many who just recently entered the service with no prior military experience. The intelligence specialists are not officially considered part of the flight crew and their participation is not addressed as part of this study.

Despite advances in technology, equipment, training, and the maturation of the Predator weapons system, the absence of a human-on-board has not translated into the elimination of human error. RPA mishaps have been well documented by a variety of sources and studies, where four recent military mishap studies are particularly relevant. Tvaryanas, Thompson, and Constable (2005) reviewed UAV mishaps across the U.S. military services. They reported that, since the inception of the systems through the end of FY 2003, 32 Class A mishaps per 100,000 flying hours occurred with the USAF Predator system. Typically USAF Class A mishap rates ($1 million damage or fatality) were in the low single digit (1 to 2) range per 100,000 flying hours during that period (O'Toole, Hughes, & Musselman, 2006). Nullmeyer, Herz, Montijo, and Leonik (2007) specifically analyzed Predator mishaps through 2006 and found major changes over time. Class A mishap rates dropped to under 10 per 100,000 flying hours by 2006. Mishap causal factors also changed, shifting from equipment failures to human factors, particularly crew skill and knowledge. While early studies theorized that RPAs experience a higher than normal mishap rate, updated USAF Class A mishap information (Nullmeyer, et al., 2007) showed that mishap rates for the Predator were improving and following a trend line similar to that seen following the introduction of the F-16, a single-engine manned aircraft two decades earlier.

Missing in almost all of the studies to date are concrete recommendations regarding how to best fix deficiencies documented in mishap trends. While many recommendations have been made regarding hardware fixes, few have addressed the human performance part of the effectiveness equation. The effectiveness of human factors skills training has been often debated in the past with few definitive, data-based transfer of training studies published to date (Helmreich, Merritt, & Wilhelm, 1999; Salas, Wilson, Burke, & Wightman, 2006).

Our goal was to determine if mishap-related errors could be reduced through training, and more specifically, explore the effects of both academic and hands-on training media. Our approach was to begin with as complete a picture of Predator aircrew performance as possible. To determine which human factors skills needed improvement, we used multiple sources of information, starting with detailed analyses of USAF Predator mishap reports. While many studies relied solely on mishap reports, this data only tells part of the story – there were thousands of Predator sorties where human factors skills were equally contributory to a successful mission and we also used this data, obtained from a panel of Predator experts. Additionally, we also wanted to capture typical student human factor errors that occur daily in training. This combined data would give a comprehensive human factors performance picture from training through operational use for successful as well as unsuccessful missions. This foundation would help identify promising training interventions and also help define measures of performance for these interventions.

From an analytic standpoint, we wanted a measurement plan that would give us a comprehensive picture of the effectiveness of the training interventions we would introduce to the RPA squadron. Kirkpatrick's (1976) four-level framework offers such an approach, in which training impact is assessed in terms of student reaction to the training (Level I), amount of learning exhibited (Level II), degree of transfer to the operational environment (Level III), and change within the organization (Level IV). Salas, et al. (2006) reported in their meta-analysis of the crew resource management (CRM) literature that very few studies achieve measurement at either the third or fourth level, with the vast majority focused on student reaction and learning. A primary goal of the present effort was to push the measurement boundaries further, by including Level III and IV measures in our study design.

METHODS

To develop a more complete picture of Predator crew performance and which human factors skills needed improvement, we analyzed three sources of data: Class A mishaps, a Delphi panel of warfighter experts, and Predator training records. A detailed explanation of the mishap analysis process was previously described by Nullmeyer et al. (2005) and Nullmeyer et al. (2007). The top ten Predator human factors mishaps causes are listed below.

1. Channelized Attention
2. No Training for Task Attempted
3. Crew Coordination
4. Selected Wrong Course of Action (COA)
5. Task Misprioritization
6. Checklist Error
7. Inattention
8. Inadvertent Operation
9. Risk Assessment
10. Confusion

We also used findings from a Delphi Panel of RPA experts with operational combat and instructional experience. The methodology was previously described in Nullmeyer, Spiker, Montijo and Kaiser (2008). The top 10 operational challenges identified by the Delphi Panel are summarized below.

1. Inadvertent Operation
2. Task Misprioritization
3. Crew Coordination Breakdown
4. Channelized Attention
5. Distraction
6. Select Wrong COA
7. Inadequate Inflight Analysis
8. Misperception of Speed, Distance, Altitude
9. Complacency
10. Cognitive Task Oversaturation

The third source of data was 305 student gradesheets from 70 pilots and 75 sensor operators formally enrolled in Predator training. The methodology and results were also reported in detail in Nullmeyer et al. (2008). The top human factors identified in the gradesheet analysis are as follows.

1. Channelized Attention
2. Inadequate Flight Planning Analysis
3. Crew Coordination
4. Course of Action Selection
5. Lack of Task Training
6. Checklist Error
7. Task Misprioritization
8. Limited Total Experience
9. Risk Assessment
10. Inattention

We selected a subset of these human factors skills to be addressed through training interventions; criteria for inclusion were: (1) they were among the leaders in each source of data; (2) they represented a skill that could be most appropriately addressed through training; and (3) they posed a particular problem for the Predator community. Applying these criteria, the most prominent four human factors skills are listed in Table 1.

Table 1: Identified Predator Human Factors Skills

1	Task Prioritization
2	Channelized Attention
3	Selecting an Appropriate Course of Action
4	Crew Coordination

TRAINING INTERVENTIONS

With the pertinent human factors skills identified, we refined four training interventions previously described in detail in Nullmeyer et al. (2008). The training interventions were:

1. Enhanced Academics (EA)
2. Web-Based Interactive Case Histories (ICH)
3. Game-Based Multi-task Trainer (MTT)
4. Computer-Based Team Trainer (TT)

Enhanced Academics (EA)

Every Predator aircrew member receives four hours of Crew Resource Management (CRM) classroom instruction as part of their formal syllabus training. At best, this academic class can be described as fourth generation CRM training. EA training exposed Predator crewmembers to sixth generation CRM principles of Threat and Error Management. The two-hour facilitated course immerses the student in interactive Predator mishap case studies focusing on task prioritization, situational awareness, crew coordination and decision making plus mission planning and communication. Unknown to the researchers was if additional immersive multimedia CRM classroom training potentially affected aircrew performance.

Web-Based Interactive Case Histories (ICH)

With many of the Predator crews being Generation "Y" familiar with computer-based training (CBT), we designed an interactive CBT module to further enhance human factors skills. This approach was similar to one developed by Spiker, Hunt, and Walls, (2005). Written case histories with interactive hyperlinks included detailed explanations, graphics and where applicable, video or computer recreations. A visual checklist kept the student on task to ensure that learning was standardized and complete. Each case study concluded with a set of fairly difficult questions, written so that the student had to understand the lesson's main points. Answers were electronically tracked, collected and analyzed for training effectiveness. Would the effectiveness of this method of training (CBT), using essentially the same information as enhanced academics, be more effective than the present methods of training?

Game-Based Multi-Task Trainer (MTT)

The two previous training interventions focused on human factors knowledge, while this third intervention focused on practicing individual skills in an interactive and competitive environment. This intervention allowed each student to improve their task management skills, actively see and learn to avoid channelized attention, practice task prioritization and decision making. The four-quadrant multitasking screen with audio, visual, memory, and calculation tasks, was an adaptation of SYNWIN (Elsmore, 1994). It replicated similar tasks needed to operate the Predator weapons system. Students not only received individual scores, but also competed within their student class for top scores. Scores were provided at the end of each session, as well as collected for later analysis. Figure 1 shows a sample MTT screen. Would exposing students to game-based skill exercises improve the identified individual human factors skills performance later in training?

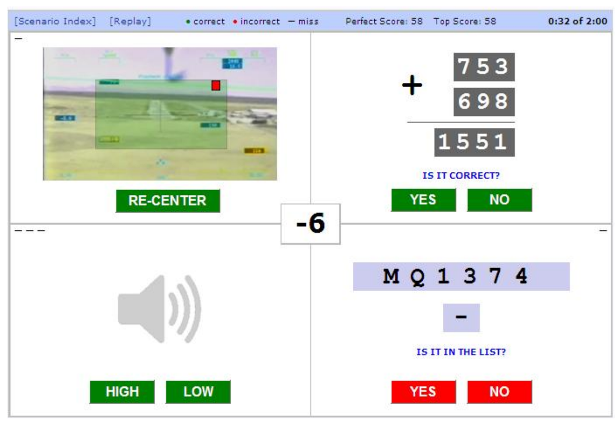

Figure 1: Representative MTT Screen

Computer-Based Team Trainer (CBTT)

This training intervention exercised previously taught and practiced individual human factors skills in a crew environment (crew coordination) under stressful conditions. GemaSim, a proprietary commercial software package, was modified to practice personal and team behavior in a stressful crew flying-type environment. Would practicing individual and crew human factors skills under stress in a non-Predator environment help improve their performance on Predator simulator and flying missions? Figure 2 shows Predator crews using the GemaSim Team Trainer.

Figure 2: GemaSim Team Trainer

TRAINING INTERVENTION FLOW

Table 2 shows the class flow, their treatment and the number of students. In order to establish a typical student performance baseline, we gathered student grades from three classes before introducing the first training intervention. Training interventions were introduced in four spirals. Spiral 1 (classes 09-1, 09-3, 09-5, 09-7, and 09-09) added EA to the initial qualification course syllabus. Spiral 2 (classes 09-11 and 09-13) added EA and ICH. Spiral 3 (classes 09-15 and 10-01) added EA, ICH, and MTT instruction to the syllabus. Finally, Spiral 4 (classes 10-3, 10-5, and 10-6) added all four interventions (EA, ICH, MTT, and Gemasim). Due to late approval to proceed beyond the first intervention, three extra classes received EA before ICH was introduced.

The delay also compressed collecting data for the last class; hence class 10-06 received Spiral 4 instead of class 10-07. To prevent student classes from interacting with one another, treatments were given to every other student class with the non-participating class acting as a control group (no treatments, performance evaluated). We introduced our interventions as progressively building spirals rather than as individual treatments since our ultimate focus was on assessing the impact of an integrated curriculum of enhanced knowledge, hands-on practice, and team-building training. Only a spiral methodology would allow us to make this determination with a between-class experimental design.

Instructors/evaluators did not know which classes received treatment(s). Logistically for the USAF, it proved easier to alternate student classes rather than measure select individuals within a class. Dividing classes would have created "compensatory spillover" effects in which members of the control group seek and receive some or all aspects of the treatment once word gets out (Cook & Campbell, 1979). Since Predator students in a given class train together for three months, there would have been no secrets among them

Table 2: Class Treatment Assignment

Class #	Treatment	Size		Class #	Treatment	Size
08-13	Baseline	19		09-10	Control	21
08-14	Baseline	21		09-11	EA + ICH (Spiral 2)	21
08-15	Baseline	19		09-12	Control	19
08-16	EA (Spiral 1)	20		09-13	EA + ICH (Spiral 2)	20
08-17	Control	18		09-14	Control	18
09-01	EA (Spiral 1)	20		09-15	EA+ICH+MTT (Spiral 3)	22
09-02	Control	22		09-16	Control	24
09-03	EA (Spiral 1)	20		10-01	EA+ICH+MTT (Spiral 3)	19
09-04	Control	19		10-02	Control	22
09-05	EA (Spiral 1)	21		10-03	EA+ICH+MTT+TT (Spiral 4)	21
09-06	Control	21		10-04	Control	16
09-07	EA (Spiral 1)	20		10-05	EA+ICH+MTT+TT (Spiral 4)	18
09-08	Control	22		10-06	EA+ICH+MTT+TT (Spiral 4)	18
09-09	EA (Spiral 1)	19		**TOTAL SUBJECTS**		**540**

once training interventions were introduced. By alternating student classes, all classes were separated by approximately six weeks and rarely, if ever, interacted with one another.

Alternating treatment/control assignments across classes introduced its own effect, namely a "cohort" effect (Cook & Campbell, 1979) in which certain classes might be unusually strong or weak in terms of CRM skills. Depending on the pattern, this variation could mask a significant treatment effect, artificially inflate a no-effect situation, or add random variability to the data, thereby reducing statistical power (Harris, 1994). Due to the large amount of subjects over a long period of time with a great variety of student background, the effect was negligible as a confounding factor (Campbell & Stanley, 1996) although it did add to error variance.

DATA COLLECTION AND MEASUREMENT

Training effectiveness was addressed for the first three levels of Kirkpatrick's training effectiveness evaluation model (Kirkpatrick, 1976). An initial small sample size Level IV (organizational impact) assessment was also recently completed and additional surveys are still being collected. The analyses reported here represents a "first look" at the large amounts of data collected. In the coming months, we conduct a more detailed analyses that will compare the results of the spirals with one another so that the impact of the individual interventions may be discerned, as well as perform content analyses on the instructor comments of the training records to extract qualitative themes associated with the four human factors skills.

The nature of our experimental design allows for intervention-specific assessments at Levels I and II, whereas the Level III transfer effects are examined at the spiral level. Level I involved completing student critiques customized for each specific training intervention. Level II looked for evidence of learning within each training intervention. Level III addressed transfer of training to subsequent environments. We collected baseline student data (Level I and III) to see how an average student performed without any training interventions. During EA, we collected Level I and Level II data from a course critique and a 7-question pre- and post-test quiz. ICH quiz results provided Level II data. Gaming scores for the MTT for the various exercises provided Level II data. For all students (control and experimental groups), we collected Level III student performance data in the four targeted skill areas (avoiding channelized attention, task prioritization, selecting an appropriate course of action, and crew coordination) during two sorties, the simulator emergency procedures evaluation (EPE) and the final flying mission before course graduation (C03).

Data collection instruments included the standard Air Combat Command Form 206 and a specific supplemental human factors form where instructors used a traditional five-point scale (0-4) in the emergency procedures evaluation (EPE) simulator session and the final flight before graduation (CO-3). In addition, strengths and weaknesses were identified for 25 specific behaviors distributed across the four targeted skill areas. Additionally, we collected all student gradesheets (approximately 21 gradesheets for all 540 students; 11,340 gradesheets) for later data analysis. As an additional task, we are presently conducting a Level IV analysis of student performance and organization effects with their gaining units.

RESULTS

Enhanced Academics (EA)

Our Level I findings for EA (Spiral 1) were based on student responses to 15 statements using a 5-point Likert scale, plus answers to three open-ended questions – good things about the lesson, things that need improvement, and skills needing more training. Level II results came from a 7-question pre- and post-class test given to students. Level III data came from instructor ratings of student performance and observations of concrete behaviors in the two selected simulator and flight missions.

Overall student reactions to EA were quite positive. The mean of all student ratings on a 5-point Likert scale with "5" always representing "strongly agree" to a series of 15 positive statements was 4.4, which is significantly higher ($p < .05$) for the mandatory initial CRM class (4.1). Student critiques suggested that some "fine-tuning" might be helpful prior to incorporating this type of information into future Predator initial qualification training. Students also were asked via an optional question, to indicate if additional training was needed in any of the seven areas. Of the approximately 100 students responding, frequency of responses to the need for additional training in the seven areas is indicated in parentheses below.

Situation Awareness (17)
Flight Integrity/Crew Coordination (14)
Task Management (12)
Risk Management/Decision Making (10)
Debriefing (6)
Communications (4)
Mission Planning (4)

With regard to Level II learning effects, pre-test and post-test mean scores (within subjects) are shown below in Figure 3 for pilots and for sensor operators. The maximum score was 7. A statistically significant increase in post-test class mean scores was found, F(1, 8) =17.922, p<.03). Pilot scores tended to be higher than sensor scores, F(1,8) = 5.092, p<.054. The higher scores for pilots may be accountable from pilots having received training in the target areas earlier in their flying training. The learning gains for pilots and sensor operators were comparable.

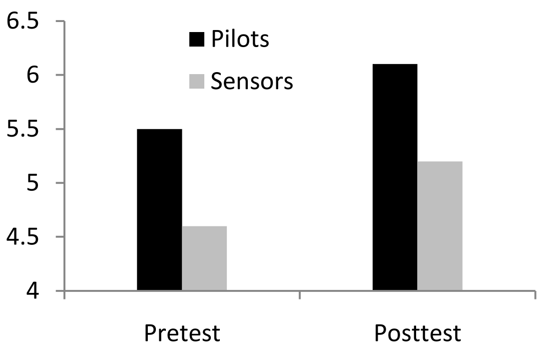

Figure 3: EA Student Pretest and Posttest Scores (Spiral 1; n=120)

Level III Results

Student performance in four targeted skill areas was documented by instructors in two subsequent training events, EPE and CO-3. Instructor ratings using a five-point scale tended to be higher for students receiving EA instruction versus control classes, but differences were small, usually less than a tenth of one scale point. However, there was encouraging evidence that that the percent of negative remarks/notations in the 25 specific behaviors were lower for the EA group (Spiral 1) than the control group in both the EPE (Figure 4) and C0-3 (Figure 5). A Wilcoxon sign test across these combined data revealed that this Spiral 1 reduction was statistically significant, (T(8) = 3.0, p<.035). . This translates into fewer errors or problems by students who received the additional training (EA) compared to those who did not.

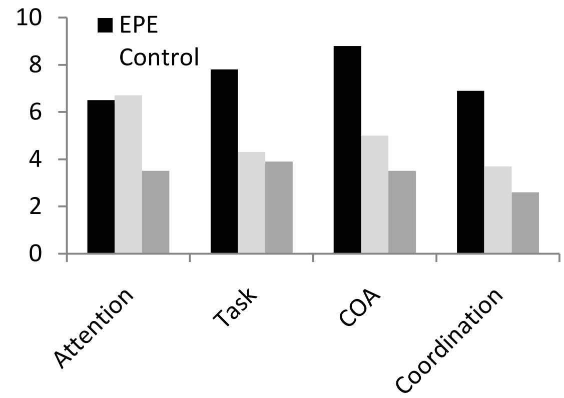

Figure 4: Percent of Negative Comments during the Simulator Emergency Procedures Evaluation (EPE)

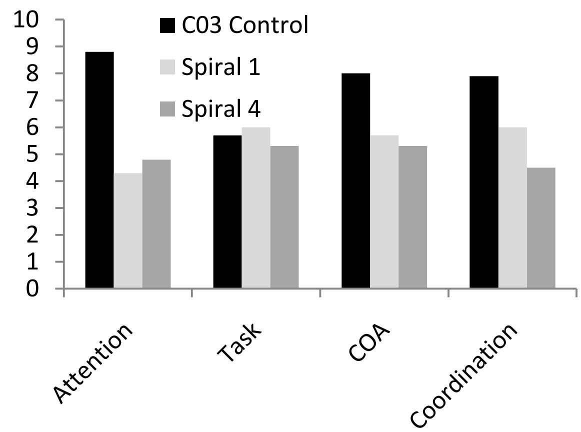

Figure 5: Percent of Students Receiving Negative Comments During the Final Training Flight

The remaining three training interventions were added to EA cumulatively, one intervention at a time (EA + ICH, then EA + ICH + MTT, and finally, EA + ICH + MTT + GemaSim). As a result, isolating the contributions of ICS, MTT, and GemaSim as stand-alone interventions requires comparing the performance of the spirals with one another in successive fashion; this detailed analysis is presently being conducted and will be reported later. For each of the new training interventions, student feedback was solicited. As new interventions were introduced, learning in the added intervention was assessed. Transfer to subsequent simulator and flight events was assessed for each spiral as a package. The remainder of this section highlights findings that may be generalized to other training applications.

Interactive Case Histories (ICH)

A 41-question survey was completed by student pilots and sensor operators. Reactions were generally positive. Many of the questions pertained to details of ICH system implementation. These results are not reported here. One question pertained to the usefulness of reviewing computer-delivered case histories. Reactions by crew position are shown in Table 3. Pilots were evenly split between whether interactive case studies were helpful or not. Sensor operators, however, overwhelmingly supported the utility of this training approach. All student pilots in these studies were highly experienced USAF pilots who graduated from undergraduate pilot training and flew at least one operational weapons system. As such, they had been exposed to many case studies earlier in their flying careers. Sensor operators, however, are usually much less experienced, with the Predator being the first operational assignment for many of them and having this additional detailed insight to mishaps and their root causes was viewed as beneficial to them.

Table 3: Frequency of Student Reaction to Usefulness of Interactive Case Histories

Survey Response Item	Pilot	Sensor	Total
Not Enough Information to Answer	1	1	2
Not Useful	4	0	4
Moderately Useful	4	4	8
Very Useful	1	5	6

A Level III analysis compared the performance of students who received EA and ICH to the performance of control group students not receiving the additional training. There was a generally positive advantage for this intervention that cut across targeted training areas and crew position, but there were no statistical differences between Spiral 2 students and control groups. When coupled with the fairly positive student reaction data (Level I) to the training, there appeared to be a slightly positive impact of our CRM training interventions, but more so for sensor operators than experienced pilots.

Multi-Task Trainer (MTT)

Student assessments of usefulness for this training intervention are provided in Table 4. The MTT tended to generate "moderately useful" responses from these students, especially pilots. The results in our Level III analysis for parametric and non-parametric testing showed a slight positive advantage for these classes (EA + ICH + MTT) that appears to reside with Sensors operators for the EPE simulator evaluation. For the flying mission (CO-3), there was no clear evidence of a positive impact for this treatment compared to EA training alone. We did notice a consistent problem of distraction by radios for both sensor operators and pilots for both control and treatment groups.

Table 4: Frequency of Student Reaction to Overall Usefulness of MTT Training

Survey Response Item	Pilot	Sensor	Total
Not Enough Information to Answer	1	3	4
Not Useful	6	2	8
Moderately Useful	12	5	17
Very Useful	3	1	4

Computer-Based Team Trainer

Student critiques of the CBTT are summarized in Table 5. This approach received the highest ratings by students of all interventions considered in this project. In most cases, the average ratings were not statistically different than the maximum scale value of 5. Level II statistical analyses were performed on team scores, instructor ratings of student performance and evaluation comments. There was statistically significant evidence of learning based on improved team scores between first and second session; t-test results showed improvement in all four individual human factors skills areas (all $p < .05$ with some $p < .001$) and evaluation comments noted a marked improvement in CRM skills between missions. Level III effectiveness assessments were based on instructor ratings during the EPE simulator scenario (Spiral 4 in Figure 4) and the C-03 flight (Spiral 4 in Figure 5). Wilcoxin sign tests revealed statistically significant reductions in negative notations regarding specific behaviors from instructors compared to either EA training alone (Spiral 1) students ($p<.02$) or no added instruction (control) students ($p<.01$).

In summary, the CBTT gaming environment created multiple opportunities for students to experience the consequences of poor teamwork as well as the benefits that accrue when members work effectively as a team that translated into better performance in the simulator and actual Predator flight missions. It was indeed a powerful intervention, as evidenced by unusually positive student critiques, rapid learning, and significant transfer effects.

Table 5: Average Likert-Ratings for the Team Trainer Critique Questions (5-point scale)

Critique Item	**Class**			**Item Average**
	10-03	**10-05**	**10-06**	
1. I used CRM skills in this training	4.9	4.8	4.9	4.9
2. I felt I was challenged in this training	4.9	4.6	4.8	4.8
3. I learned from this experience	4.9	4.6	4.6	4.7
4. The training helped develop my CRM skills	4.9	4.7	4.6	4.7
5. I see benefit in this type of training	4.9	4.7	4.5	4.7
6. I enjoyed this type of training	4.9	4.7	4.1	4.6
7. I prefer this type of training over others	4.7	4.7	4.3	4.6
OVERALL CLASS AVERAGE	**4.9**	**4.7**	**4.5**	**4.7**

CONCLUSIONS

In the bigger picture looking across all levels of analysis, there was consistently positive student reaction (Level I) to the new types of training as well as consistent evidence of learning (Level II). Students preferred the team trainer the most followed by enhanced academics.

Preference for ICH and MTT varied by crew position with pilots preferring the MTT and sensor operators preferring ICH. Sensor operators, generally lacking in aviation-related knowledge and experience, but thrust in a critical crew position, found the ICH an easy method to look at all the factors involved in a mishap and how it relates to doing their job. Pilots with operational flying experience have this knowledge from safety briefings and presentations and would naturally find this method repetitive to what they previously have accomplished. MTT training was more useful for the pilots as it practiced those skills that they would need to directly operate the Predator, more so than the sensor operators who can only operate Predator mission systems.

While there were sometimes inconsistent results for Level III effects for specific interventions, overall, there was a fairly solid set of data to support a positive impact of both enhanced academics and the full combination of all four interventions. Overall, across 540 students, those that had the training interventions had fewer negative evaluation comments during the evaluated missions. They showed an improvement in documented human factors skills. This should translate into fewer errors, better teamwork, reduced mishaps and more effective missions over time. We anticipate seeing marked Level IV effects at the unit level as trained Predator crewmembers would arrive at their unit better prepared to fly more effective combat missions than their predecessors. Over a longer period of time, this could translate into a reduction of the Predator mishap rate, although it will take several years before the data is available for such a comparison. Training effects on mishap data in a growing weapons system often takes years before any noticeable trend is evident and was not possible given this short-term investigation.

Another observation from the study was the effectiveness of the training for pilots and sensor operators. A top-level look at the data across all training interventions shows that there were more positive training effects for sensor operators compared to pilots. This would correlate directly with the general aviation experience level of each aircrew member. The current USAF approach is a one-size-fits-all approach for Cockpit Resource Management training when the results clearly show that sensor operators would benefit more from a unique training program than pilots. Level I feedback comments from pilots attending mandatory initial CRM training indicate that the training is generally repetitive from what they have already received and that they would prefer shorter, more Predator-specific training.

Our results raise several new questions: Which training intervention provided the most *bang-for-the-buck*? Should existing CRM training be changed to provide better trained Predator crewmembers? The data showed that the most effective intervention was the culmination of all four training interventions. Can team training work as well when implemented as a stand-alone intervention? We think that it could provide some significant benefits to improve CRM training and ultimately aircrew performance.

Should existing USAF CRM training be modified? Based on feedback from EA, consideration should be made for the USAF to modify the initial CRM academics to include elements of enhanced academics and introduce sixth generation CRM training as part of the initial CRM training in the Predator. Early positive feedback from EA was incorporated in the 2010/2011 Predator CRM Continuation Training course given to operational aircrews. Given the positive response for interactive case histories, there could be some benefit for use as continuation training or continuing education programs similar to those in other professional fields (legal, medical, etc.). There appears to be some merit in using the MTT to enhance aircrew skill, although its value may be limited, perhaps as part of a "spin-up session," prior to receiving team training.

If additional training time is available, the USAF should explore the use of some type of team trainer for small crew-based weapons systems as part of initial training. The opportunity for pilots and sensor operators to interact directly with one another early in training was viewed favorably by virtually all students. Use of the a team trainer for larger crew or fighter aircraft would need an effectiveness validation before implementation.

Ultimately, did this training have an impact for operational combat Predator units? An initial response to an on-line survey for gaining unit supervisors indicates that there are slightly positive effects for students that received spiral training versus those that did not receive the training. While the overall sample size is too small at this time to draw conclusions about Level IV effects, the initial results are encouraging and should become clearer as students become integrated into their squadrons and more data is returned for analysis.

As the USAF moves to increasingly larger amounts of RPA and crews with significantly less or no aviation experience, relying on traditional training methods may not be the optimal path to produce the most capable Predator or RPA aircrew members. Aircrew manning has often lagged the ability and desire to operate more RPA orbits and non-traditional sources of aircrews are now part of the process to fill RPA requirements. Will this type of training allow Mission Coordinators, non-aviator members of the crew, to be able to perform more effectively? With validated Level III results of new training interventions that improved human performance, we know how to better prepare our Predator aircrews to maximize their effectiveness and do it safer than was possible in the past. A new training paradigm is ready for the challenges of the future.

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