Dynamics of Combat Aviator Training

James R. Enos, Major, U.S. Army
Department of Systems Engineering
Mahan Hall, West Point, NY 10996
(845) 938-3114
james.enos@usma.edu

Abstract
This paper presents an application of system dynamics to understand the behavior of the AH-64 Advanced Aircraft Course at the U.S. Army Aviation Center of Excellence. This course trains Army lieutenants and warrant officers as combat aviators. In the last several years, a large "bubble" of students awaiting the different phases of training has developed because of organizational and process problems within the course. This paper presents a system dynamics model of the course and recommends policy changes to eliminate the backlog of students awaiting training. The model incorporates both the organizational aspects of the course, including personnel and equipment; as well as the processes within the course. Base on output from the system dynamics model, the best course of action for the U.S. Army Aviation Center of Excellence is to add additional days to the course to account for weather and increase the number of hours available for training on a daily basis. This policy enables the center to eliminate the "bubble" of students and stabilize the process of training combat aviators.

Key Words: System Dynamics, Aviator Training, Army Aviation

Introduction

This paper presents an application of system dynamics to understand the behavior of the AH-64 Advanced Aircraft Course as one process in the FS XXI Enterprise. The intent of the model is to simulate the observed behavior of the system, in which, the actual course length varies greatly from class to class, to determine the causes of this oscillation. The model incorporates several aspects of the different views of enterprise architecting to gain a holistic view of the process and show how the interactions between the views affect the process. Again, because system dynamics examines components of the system in an aggregate, the model will not examine individual students as they flow through the system or individual courses. These variables are aggregates, so the model's course length variable represents the average course length of the individual courses in session. The intent for the model is to gain a better understanding of the dynamics of the system and to determine policies that can help correct the behavior of the system.

Background

The Flight School XXI (FS XXI) Enterprise is a training process that consists of several different individual courses that Army lieutenants and warrant officers attend to become combat aviators. In the last several years, a large "bubble" of students awaiting the different phases of training has developed. On any given day, over 700 students do not participate in any training at Ft. Rucker because they are awaiting a slot in a training course. With the current requirement to train 1200 students annually, Ft. Rucker has over six months of inventory they are not processing. Because of this, junior officers and warrant officers spend between 1 and 2 years at Ft. Rucker during training, which should only take approximately one year (Dinges 2009).

There are several impacts of this wait time on training at Ft. Rucker. First, aviator skills degrade between completing basic flying course and beginning the combat aircraft course. In addition, these young officers and warrant officers lose valuable time becoming certified aviators when they should be gaining experience in a combat unit. The bubble of students is a large concern for the leadership of the U.S. Army Aviation Center of Excellence (USAACE) and the Army and several efforts have begun to address this problem.

The AH-64 Advanced Aircraft Course trains new aviators on the operation and tactical employment of the AH-64 Apache attack helicopter. The course consists of several phases: transition, instruments, day systems, night and night vision goggles, gunnery, and advanced combat skills. The total course length is 107 days, with 20 simulator days (46.8 Flight Hours), 53 daytime flight days (59.6 Flight Hours), 26 night flight days (29.8 Flight Hours), and the remaining 8 days spent in the classroom (110th AB 2006). Each course consists of a planned student load of 22 students and the course starts every four weeks (USAACE 2009). The course appears straight forward and the FS XXI Enterprise should be able to schedule courses to maximize throughput and efficiently utilize the enterprise's resources utilizing traditional project management tools. However, several feedback loops influence the course that demonstrates how the organization, policy/external influences, strategy, knowledge, and product views influence the process. The next sections describe the casual loops identified in the AH-64 course, which drive the dynamics of the system.

Literature Review

System Dynamics is an approach to understand the dynamic complexity that exists within systems, simulate the behavior of systems over time, adjust individuals' mental models of the system, and implement policies to improve the system. Forrester described the potential for system dynamics as an approach that should help in the important high-level management problems (1961). He noted that solutions to small problems will only yield small results and that people get mediocre results by setting improvement goals too low. He suggests that the change must be at the enterprise level to achieve major improvement and that the goal should be to determine policies that lead to greater success (Forrester 1961). In his book World Dynamics, he developed a model of the world to understand the dynamic complexity and limits to growth of the world and the interrelations between population, capital investment, geographical space, natural resources, pollution, and food production (Forrester 1971).

Forrester describes a system as "a grouping of parts that operate together for a common purpose" (1968). He further classifies two types of systems: open systems, in which exogenous, or external, variables affect the system, or closed systems, in which all variables are endogenous, or internal to the system (Forrester 1961). The distinction between open and closed systems relies heavily on where the system boundary is drawn; however, a model of a system will provide a better understanding of the dynamics the closer it is to a closed system. Dynamics are the behavior of a system over time, which are generally complex and non-linear in nature (Forrester 1961). System Dynamics attempts to understand the dynamic complexity that is inherent in any natural or human system. Even the simplest of systems, with apparently low levels of structural complexity, can exhibit high levels of dynamic complexity. This complexity comes from feedback within the system, time delays between decisions and effects, and the learning process of the system (Sterman 2000).

Causal loops are one of the key elements of the system dynamics approach and are closed loop processes. System Dynamics uses signed diagrams to represent these loops and designates them as reinforcing or balancing loops. Casual loops are different from discrete, event-oriented perspective of individual causes and effects in that they acknowledge that in a closed system any cause is an effect and any effect is a cause (Richardson 1991). In System Dynamics, the feedback loop diagrams indicate that one variable influences another through physical or information flows. One is able to describe the behavior of the system by talking through the loop to tell the story of the interactions within the system (Meadows, Randers and Meadows 2004). However, in natural or human systems there are often delays in information or material which increase the dynamic complexity of these systems. These delays can have dramatic effects on a system's behavior over time. Delays can cause a system to overshoot is limits when the feedback signal is delayed which prevents the system from establishing an orderly balance within its limits (Meadows, Randers and Meadows 2004).

The other major components of system dynamics models are stocks and flows. A stock is a measurable accumulation of material or information in a system. Where as a flow is an instantaneous rate of change of material or information between stocks in a model (Forrester 1961). Mathematically, the value of the stock is equal to the integral of the combined inflows and outflows into and out of the stock.

Applications of System Dynamics have provided insights into the dynamics of several different areas including corporate policy, the dynamics of infectious disease and diabetes, drug addiction in a community, and the dynamics of commodity markets (Forrester 1971). Companies and consultants have extensively used System Dynamics for managing large, complex projects with a great deal of success. One area in which businesses utilize System Dynamics is in the development of their corporate strategy and analysis of business decisions. Generally, a crisis or complex problem triggers these shifts in business strategy and System Dynamics can provide insights into how the problem arose and help to determine the root cause of the crisis. Additionally, System Dynamics can assist in determining the consequences of alternative courses of action the business could take and the impact of the leadership's decisions. Lyneis presents a four phase framework for working with clients to solve these complex problems using System Dynamics (1999). Lyneis's framework includes: Business Structure Analysis; Development of a Small, Insight-Based Model; Development of a Detailed, Calibrated Model; and Continuation of the Relationship, which provides a guide for evaluating the problem faced by the FS XXI Enterprise utilizing System Dynamics. The application portion of this paper generally follows the first three phases of Lyneis's framework to determine the underlying dynamics of the AH-64 Advanced Aircraft, development of a model to simulate observed behavior, and evaluate alternative courses of action to correct the problems identified.

System Structure

The most evident casual loop in the AH-64 course is the effect that spending excess time in the bubble has on new aviators. As new aviators spend weeks, even months in the bubble, between the IERW common course and the advanced aircraft course, this time degrades their knowledge and they lose their basic aviator skills. Ninety-two percent of instructor pilots surveyed agreed or strongly agreed that the bubble degrades new pilot skills between these courses and eighty-eight percent agreed that they dedicate a significant amount of time to re-teaching these skills (Pilots 2010). This increases the amount of time that instructor pilots in the advanced aircraft course have to spend with the new aviators to train all of the required tasks for that aircraft.

Figure 1 presents "The Bubble is Bad" reinforcing casual loop which depicts the effect of time spent in the bubble on new aviators and the course length. As the number of *Students in Bubble* increases, the amount of *Time Spent in Bubble* also increases. The degradation of basic aviator skills because of the time spent between course increases the actual *Flight Hours Required* which in-turn increases the number of *Flight Days* in a course. As more flight days are required for a course, this increases the *Course Length*. Because of fixed resources, if student ability, aircraft maintenance, or weather significantly delays a course, beyond about 2 weeks, the enterprise either cancels or delays subsequent courses. The loop represented this as in increase in *Class Schedule*, which is the time between course start dates. This increase causes the *Class Start Rate* to decrease, because students are entering the course less frequently. Finally, if the courses are not starting as often, this delay increases the number of *Students in Bubble* because students continue to flow into the stock from the common course; however, the delay has decreased the outflow of students beginning the AH-64 course.

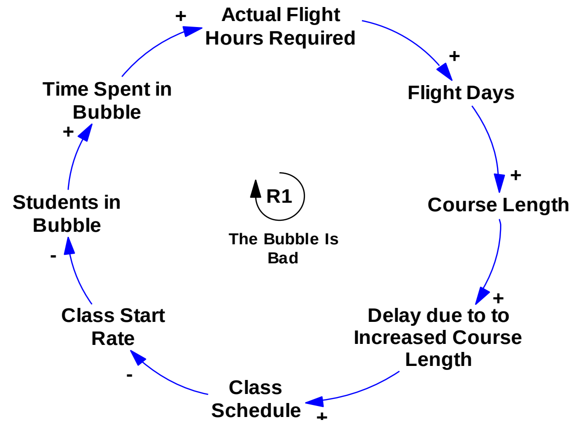

Figure 1: "The Bubble is Bad"

Much like a civilian enterprise's hiring process, the process for getting new instructor pilots requires the enterprise to request additional instructor pilots from outside the organization. However, there are significant delays from the time the enterprise requests an instructor pilot to the time an instructor pilot arrives at Ft. Rucker. Additionally, a delay exists between the time the instructor pilot arrives, when the Army clasifies the position as filled, and the time the instructor pilot actually begins training students. The new instructor pilots must become certified as instructor pilots and could possibly have to attend additional professional development courses.

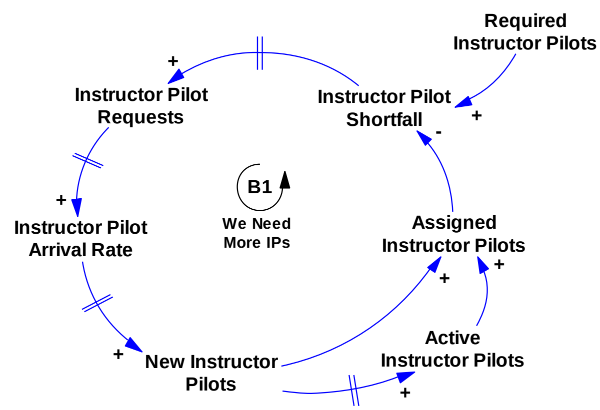

Figure 2: "We Need More IPs"

Figure 2 presents the balancing loop, "We Need More IPs" which describes the process for requesting additional instructor pilots. First, the difference between the *Required Instructor Pilots* and the *Assigned Instructor Pilots* determines the *Instructor Pilot Shortfall*. As this is a balancing loop, the system will attempt to achieve equilibrium at the level of *Required Instructor Pilots*. As this shortfall increases, the enterprise increases the *Instructor Pilot Requests* after a short delay to realize there will be a shortfall and process the requests through the Army's Human Resources Command. After the requests increase, the *Instructor Pilot Arrival Rate* increases, again after a delay for Human Resources Command (HRC) to identify a potential candidate and process the aviator's Permanent Change of Station (PCS) orders. After a delay, for the instructor pilot to move from their current post to Ft. Rucker, this increases the stock of *New Instructor Pilots*. The arrival of a new instructor pilot at Ft. Rucker immediately increases the number of *Assigned Instructor Pilots*, so HRC considers the instructor pilot position as filled. However, there is a delay between a new instructor pilot arriving and becoming an *Active Instructor Pilot*. The delays that exist in this feedback loop will cause instability in the system and the FS XXI Enterprise should address them to create a stable stock of *Active Instructor Pilots.*

One of the options the enterprise has to get a delayed course back on schedule is to fly on Saturdays. If a course is significantly behind schedule, the enterprise can elect to add an additional flight day to the week. This puts increased stress on the aircraft which require maintenance every 750 hours (AFS 2009). Also, regulations limit the number of flight hours that instructor pilots can fly during a 30 day period (1-14 Avaition Regiment 2008). So by adding additional days, an instructor pilot could reach this limit and have to rest when they could be flying students.

Figure 3 presents the “Fly More Often” balancing loop. When the *Course Length* increases past the Program of Instruction (*POI) Specified Course Length*, this creates *Pressure to Complete Course on Time.* As this pressure increases to a certain point, where the enterprise can no longer complete the course by flying a little extra every day, the enterprise increases the *Change to Training Days*. This increases the *Planned Training Days per Week* from 5 days to 6 days, which represents flying on Saturday. By flying an additional day per week, the enterprise is able to decrease the *Course Length* and the balancing loop returns the course length to the scheduled course length.

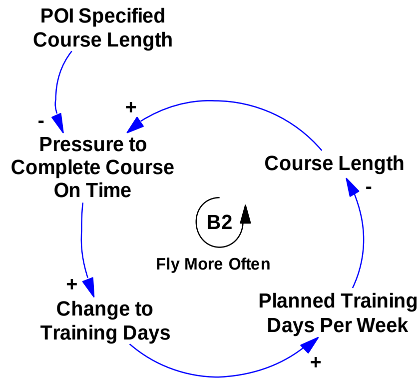

Figure 3: “Fly More Often”

Another issue that affects the FS XXI Enterprise is the student to instructor pilot ratio. Ideally, there is one instructor pilot for every two students; however, the situation might dictate that as many as three students per instructor pilot. The fixed flight window of three hours per day causes the course length to increase when the student to instructor pilot ratio is greater than two. This causes delays in training and affects the ability of instructor pilots to graduate students on time.

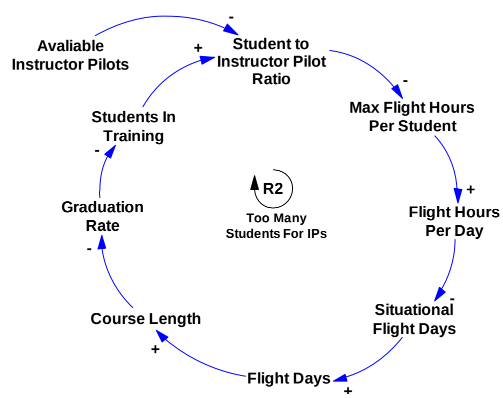

Figure 4: “Too Many Students for IPs”

Figure 4 presents this reinforcing feedback loop that explains how an increase the student to instructor pilot ratio affects the course length. As the number of *Students in Training* increases, the *Student to Instructor Pilot Ratio* increases, assuming that the *Available Instructor Pilots* remain the same. This decreases the *Max Flight Hours per Student* from 1.5 hours per day which also decreases the number of *Flight Hours per Day* actually flown. Because the students are flying less per day, the *Situational Flight Days*, days flown in addition to the scheduled flight days, and the *Flight Days* increase. The increase in the *Flight Days* causes the *Course Length* to increase which decreases the *Graduation Rate*. The fewer students graduating increase the number of *Students in Training* which then increases the *Student to Instructor Pilot Ratio*. So, this feedback loop shows how not having enough Instructor Pilots for the number of students can create a snowball effect and cause even greater delays.

The “Fly the Wings Off” reinforcing feedback loop is the largest loop affecting the FS XXI Enterprise and is difficult to identify because of the length of time between cause and effect in this loop. In addition to daily preventative maintenance, helicopters require extensive phase maintenance every 750 flight hours, during which maintainers spend about three weeks repairing the helicopter. The current maintainers are able to process six helicopters at a time with a completion rate of about two helicopters per week (AFS 2009). This means that the enterprise can only fly 1500 flight hours per week without exceeding the current capabilities of their maintainers. However, the "Fly More Often" feedback loop causes the instructor pilots to want to fly more often, which could trigger this feedback loop. Also, this limits the number of planned flight hours per day to a certain level.

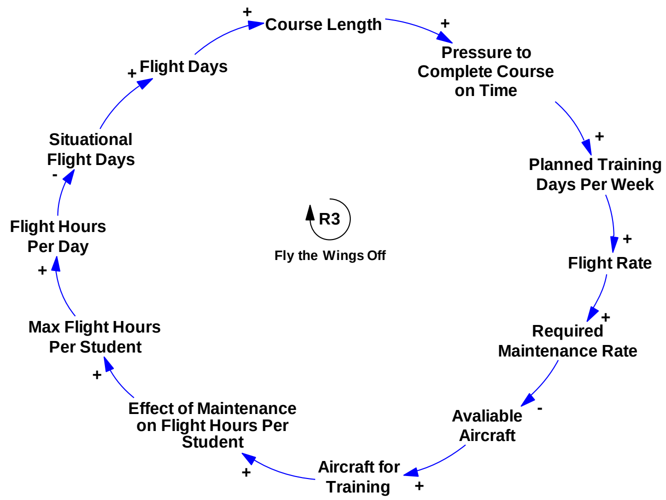

Figure 5: "Fly the Wings Off"

Figure 5 presents the reinforcing feedback loop that explains this systemic problem of flying in excess of what maintenance can provide. Beginning at the top of the figure, an increase in the *Course Length* increases the *Pressure to Complete Training on Time* which in-turn increases the *Planned Training Days per Week* and the *Flight Rate*. As the *Flight Rate* increase, the additional flight hours increase the *Required Maintenance Rate*. Because these helicopters now require maintenance, this decreases the number of *Available Aircraft* and *Aircraft for Training*, which is a percentage of available aircraft to account for unscheduled maintenance. This causes an *Effect of Maintenance on Flight Hours per Student* which also decreases the *Max Flight Hours per Student.* This decrease also causes the *Flight Hours per Day* to decrease, which increases the number of *Situational Flight Days.* Like the previous loop, this increases the number of *Flight Days* required and extends the *Course Length*. A major concern of this loop is that the cause and effect of the feedback loop occur over a very long period. Because aircraft are on different maintenance schedules, it would take several months of flying in excess of 1500 hours to cause a noticeable effect on the number of aircraft available for training. It is likely that the symptoms of this feedback loop would begin presenting as a few aircraft awaiting phase maintenance. This could cause exponential growth of aircraft awaiting phase maintenance and would eventually create a complete breakdown of the system.

System Dynamics Model

The model of the AH-64 advanced aircraft course simulates the AH-64 course for 3 years (156 months) to determine how a bubble developed and what causes the course delays. To calibrate the model, the initial simulation of the model extends the course length to about 25 weeks, which is consistent with the available data. The model uses the five feedback loops from above as a base for the structure of the stocks and flows. Figure 6 presents the basic structure of the model as a two-stage growth model in which the students progress from the IERW Common Course, to the AH-64 Bubble, then to training, and finally they graduate from the AH-64 advanced aircraft course. The *Whitebook Specified Class Schedule, POI Specified Course Length, POI Required Flight Hours, and Class Capacity* variables are FS XXI's goals and objectives. The model also accounts for the *Effect of bubble on Flight Hours,* which is the variable that increases the required flight hours per student and is a part of "The Bubble is Bad" feedback loop. This simulates the degradation of aviator skills as students spend time awaiting training in the bubble, similar to inventory becoming obsolescent.

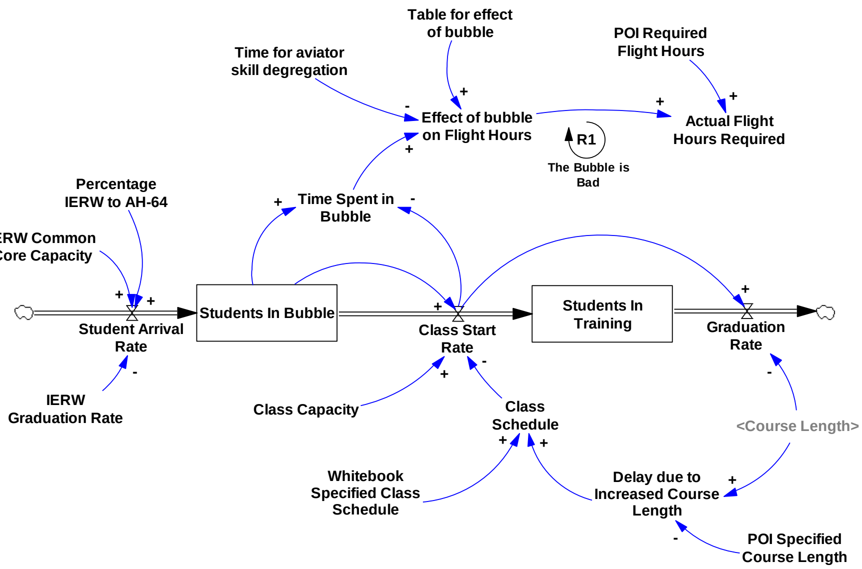

Figure 6: AH-64 Model – Student Sub-Model

Two organizational aspects of the FS XXI Enterprise affect the process of training aviators. First, the instructor pilots are an essential component of the organization that directly impact training. Although the USAACE designed the organization to support training for the number of students dictated by the enterprise's strategy, the Army cannot always fully staff the organization, which impacts the training process. Additionally, there is a knowledge aspect to the instructor pilots which affects the number of instructor pilots available to train students. As new instructor pilots arrive at Ft. Rucker, there is a delay until they can train students because they have to gain knowledge as instructors for FS XXI.

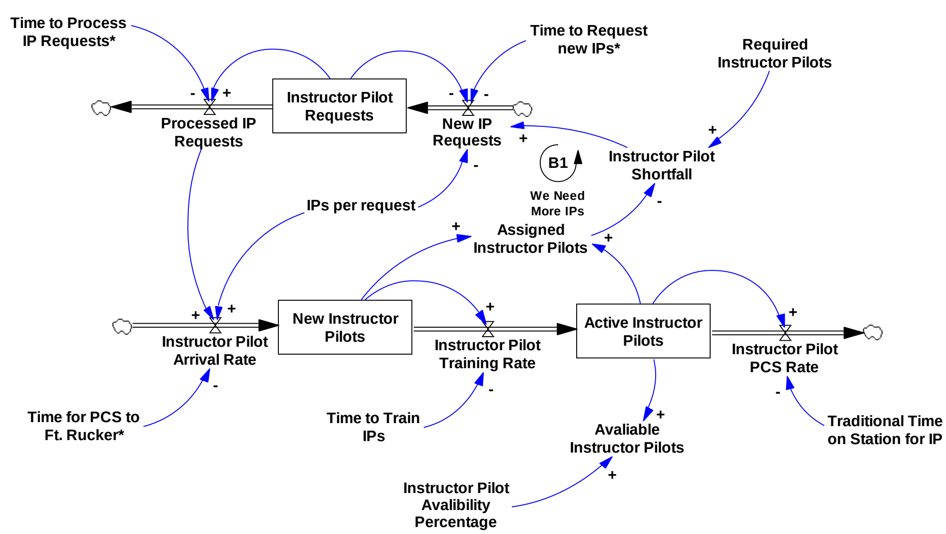

Figure 7: AH-64 Model – Instructor Pilot Sub-Model

The other organizational aspect that directly impacts the training process is the number of aircraft in the enterprise and the maintenance of these aircraft. Figure 8 presents this portion of the model which represents the "Fly the Wings Off" feedback loop. This impacts the training process through the *Effect of Maintenance on Flight Hours per Student* which accounts for when aircraft are not available because of maintenance. The *Flying Hour Program* variable is a common term in the aviation community which describes the total amount of time the fleet of aircraft can fly. The enterprise decreases this stock as aircraft are flown and can increase the stock by completing maintenance on aircraft. A problem arises if the flight rate or outflow is greater than the inflow of hours from maintenance. Additionally, aspects of the Policy View directly affect this portion of the model in that Army policies regulate the number of flight hours an aircraft can fly between scheduled phase maintenance. Also, the FS XXI Enterprise's strategy affects this portion of the model through the *Flight Hours per Day* and *Planned Training Days per Week* which also directly impacts the training process.

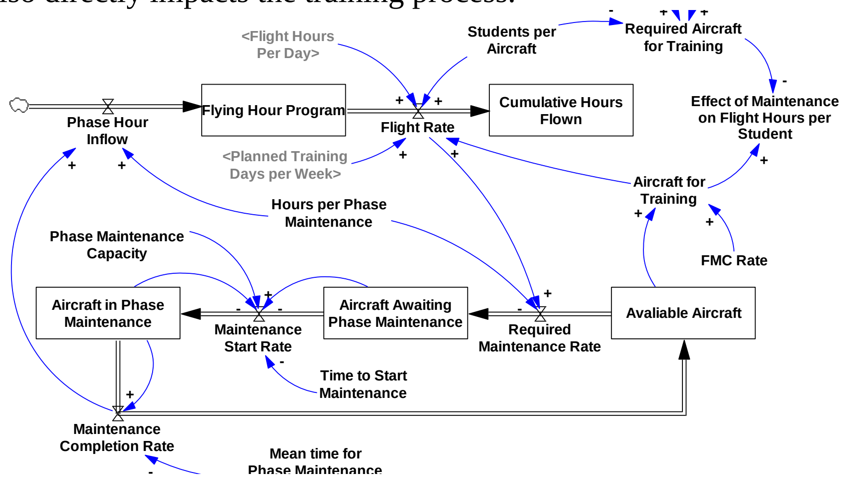

Figure 8: AH-64 Model – Maintenance Sub-Model

Weather is the main external factor that directly impacts the training process in the FS XXI Enterprise. The nature of the training requires good weather for the days that the POI specifies as *Flight Days*, which comprise a majority of the course. In the model, the *Weather Day* variable is a random normally distributed variable with a mean of 0.962 and a standard deviation of 0.929, derived from two years of historical data (ACLC 2009). When the model determines that weather would affect training for the day, it adds an additional flight day to the course length. However, the model allows instructor pilots to make up these weather days by flying additional hours, up to the maximum flight hours for the day. The *Change to Flight Days* flow from the stock of *Flight Days* accounts for instructor pilots flying additional hours to make up weather days.

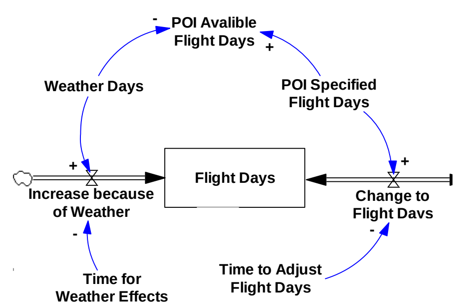

Figure 9: AH-64 Model – Course Length Sub-Model

Simulation

The intent of the initial simulation was to simulate an increase in course length, similar to the increase in course length found in historical data from the Status of Flight Line Reports, and generate a bubble of students awaiting the course. Although a precise calibration to the historical data would be ideal, the behavior of the system provides valuable insights into the dynamics of the AH-64 Advanced Aircraft Course. The initial simulation utilizes current values from the FS XXI Enterprise as initial conditions for the model to represent the actual performance of the course.

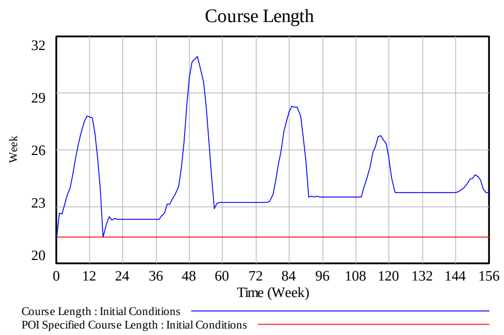

Figure 10: AH-64 Initial Simulation

Figure 11: AH-64 Course Length - APR 09 to OCT 09 (110th Aviation Brigade 2009)

Figure 10 presents the *Course Length* variable from the AH-64 Model with the initial conditions. The model generates an increase in course length, which aligns with the actual data from the enterprise. Also, the course length, shown in blue in the figure, is constantly above the POI specified course length, shown in red. This behavior is very similar to the actual course length recorded by the enterprise. Figure 11 presents the actual course length of the AH-64 Advanced Aircraft Course from April to October 2009. Although this data is only from a few months, whereas the model is for three years, the behavior is similar. The actual data shows a spike in course length, followed by a brief period of stability at a longer course length than specified by the POI.

Additionally, the model generated a bubble of students awaiting training which reaches current levels of students awaiting the AH-64 Advanced Aircraft Course. This is an important aspect of the model because it demonstrates that a bubble could occur as a result of the feedback looks in the system and not a result of some external factor that is uncontrollable by the FS XXI Enterprise. Also, Figure 13 presents the number of students in training at any time, again this stock shows an oscillating behavior, which demonstrates that increased course length is delaying course starts and impacting throughput. This aspect of the model is very important because it impacts the throughput of the course, which means the enterprise will fail to meet their objective of producing 1200 aviators per year.

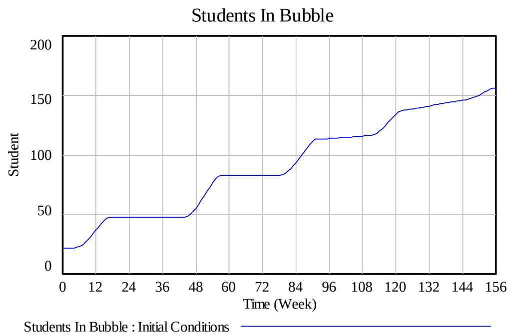

Figure 12: AH-64 Initial Simulation Results

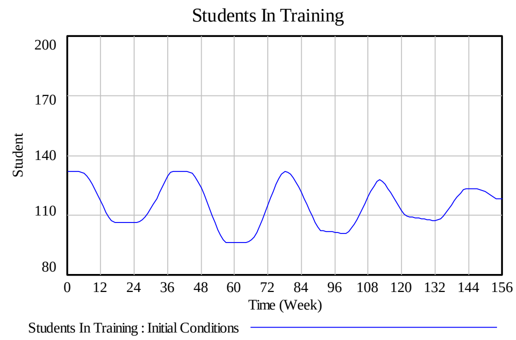

Figure 13: AH-64 Initial Simulation Results

Overall, the initial simulation of the model appears to successfully represent the actual behavior of the AH-64 Advanced Aircraft Course. The actual course length varies and is consistently greater than the POI specified course length. The model generates a bubble of students awaiting training, the main problem facing the FS XXI Enterprise. Finally, the model affects the throughput of the process to the point that the enterprise is unable to meet their goals of training 1200 aviators per year. The model is a good starting point for evaluating potential courses of action to stabilize the course length and correct the problems of the course.

The main insight from the model is the impact that the *Student to IP Ratio* variable has on the course length (Figure 14). When the ratio is greater than two to one, the course length begins to increase. Further analysis identified that this is because instructor pilots are unable to make up weather days with the internal buffer because they cannot fly the maximum of 1.5 hours per day per student.

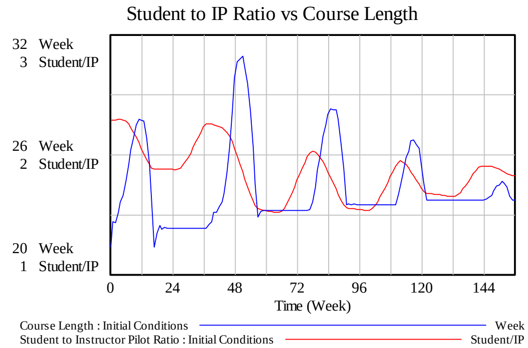

Figure 14: AH-64 Initial Simulation Results

Policy Recommendations

The FS XXI Enterprise could take several possible courses of action to improve the performance of the AH-64 training process. These courses of action could include modifications to the process, organization, or strategy view of the enterprise. The purpose of these modifications is to stabilize the course length and create a constant flow of students through the system. In order to create a constant flow of students through the entire FS XXI Enterprise, all of the courses of action reduce the batch size of students to 11 and begin every 2 weeks to align with the output of the IERW Common Course. FS XXI would have to actually increase the batch size to 12, because students train in teams of two, but for the simulation, it remains at 11 to ensure consistency with the initial run of the simulation. The three courses of action are: 1) to increase the number of aircraft; 2) increase the daily flight period; and 3) add weather days to the Program of Instruction (POI).

The first course of action evaluates increasing the number of aircraft available for the enterprise. In this course of action, the model simulates a 10% increase in aircraft by increasing the *Available Aircraft* variable from 50 to 56 aircraft. This should reduce the *Effect of Maintenance on Flight Hours per Student* by increasing the number of aircraft and reducing the effect of unscheduled maintenance on training. With a constant fully mission capable (FMC) rate, more aircraft that are available will lead to more aircraft for training. The enterprise requires approximately 50 A*ircraft for Training* per day and the current *FMC Rate* is approximately 79%, this creates a deficit of *Aircraft for Training* which impacts the *Maximum Flight Hours per Day* (ACLC 2009). If the enterprise increases the number of *Aircraft Available*, they will reduce the impact of unscheduled maintenance on training.

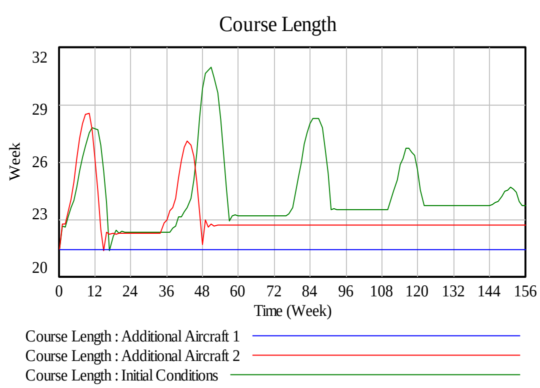

Figure 15: Increase in Aircraft – Course Length

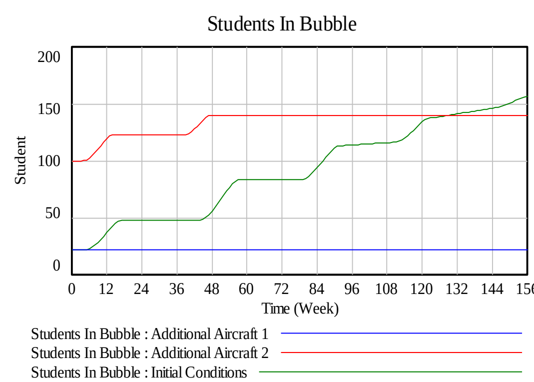

Figure 16: Increase in Aircraft – Bubble

Initially this course of action appeared to be successful at stabilizing the *Course Length* and maintaining a steady stock of *Students in Bubble.* Figure 15 and Figure 16 present the output from this simulation. In each of the figures, the blue lines represent the initial simulation with the increased number of *Aircraft Available*. The Initial Conditions and the Additional Aircraft 1 simulations assumed that the initial value for the bubble was only 22 students. However, the current bubble is approximately 100 students and any simulated policy change would have to consider this bubble (1st Aviation Brigade 2009). So, the Additional Aircraft 2 simulation sets the *Students in Bubble* variable to 100. In this case, this course of action does not succeed in stabilizing the *Course Length* or maintaining a constant stock of *Students in Bubble*. .

For the second course of action, the model evaluates increasing the daily flight period to provide the instructor pilots with a longer window to train students per day. This increases the *Flight Hour Window per Day* from 3 hours to 3.5 hours per day. This enables instructor pilots to fly a maximum of 1.75 hours per student per day and should mitigate the effects of weather, maintenance, and a lack of instructor pilots. At the current maintenance level, the maintainers complete maintenance on two aircraft per week, which constrains the instructor pilots to 1500 flight hours per week; otherwise, the maintenance system will develop a backlog of aircraft (AFS 2009). Additionally, the current contract states that Army Fleet Support will provide the USAACE with 85 sorties per day based on the current number of aircraft assigned (AFS 2009). If instructor pilots are able to fly all sorties, five days a week, there will be 425 sorties per week. Additionally, instructor pilots are constrained to fly a maximum of 85 hours in a 30 day period. (1-14 Avaition Regiment 2008) Assuming pilots only fly during the regular work week, an instructor pilot will fly approximately 22 days per 30 day period. So, given the maintenance and instructor pilot limits, the maximum flight time is 3.5 hours per sortie.

Again, this course of action demonstrated positive results when the initial bubble included only 22 students. In this simulation, the course length stabilized at 21.4 weeks for the duration of the simulation and the stock of *Students in Bubble* remained constant at 22 students. However, when the initial value of *Students in Bubble* is 100 students the course length increased to about 26 weeks and the bubble increased slightly during this time as the red line represents in Figure 17 and Figure 18. Additionally, the course length reaches equilibrium at about 22 weeks, which is greater than the planned course length of 21.4 weeks. So, this course of action appears to be promising and the FS XXI Enterprise could implement this course of action because it only requires changes internal to the enterprise.

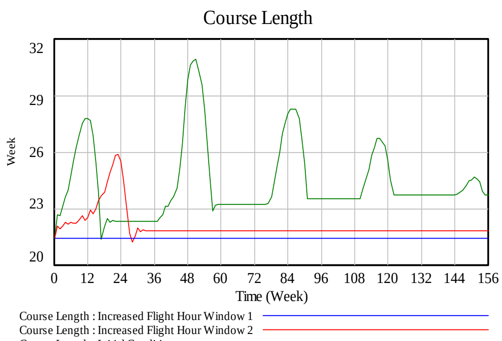

Figure 17: Increase Flight Hours – Course Length

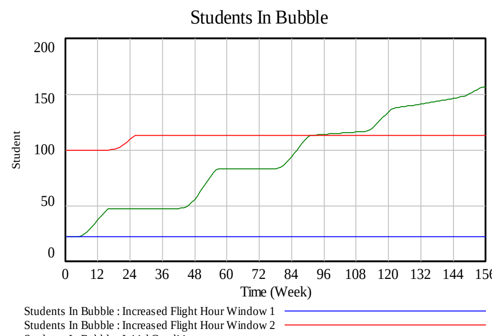

Figure 18: Increase Flight Hours –Bubble

In the final course of action, the model evaluates the addition of 5 weather days to the POI and adding a one week buffer at the end of the course to account for weather days. This increases the *Course Length* to 22.4 week and the number of *POI Specified Flight Days* to 84; however, the *POI Required Flight Hours* remain the same as the initial conditions. Also, the buffer at the end of the course requires the enterprise to schedule three weeks in between the end of one course and the beginning of the next course for each team of instructor pilots. This provides each team of instructor pilots with an additional 5 days of possible training if the weather is extremely bad and maintains two weeks to complete additional tasks before beginning a new course. Although the POI currently accounts for weather days by only requiring an average of 1.2 flight hours per day out of 1.5 flight hours available, this is not adequate if weather affects more than one day per week. On average, weather affects one day per week, so given the current POI, which has 15.8 weeks of flight training, weather could affect between 0 and 31.6 days, with an average of 15.8 days per course. So, if the weather is average during a course, the instructor pilots are able to make up the training missed due to weather, and have an additional 5.4 flight hours for a buffer. However, the worst case scenario, in which two days per week are lost to weather, only allows instructor pilots to fly 71.1 hours, which leaves them with an 18.3 hour deficit to complete the required 89.4 hours specified by the POI. Instructor pilots would require an additional 12.2 days of good weather to complete the course.

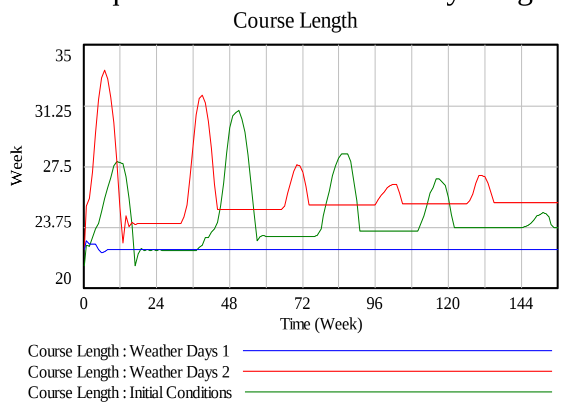

Figure 19: Add Weather Days – Course Length

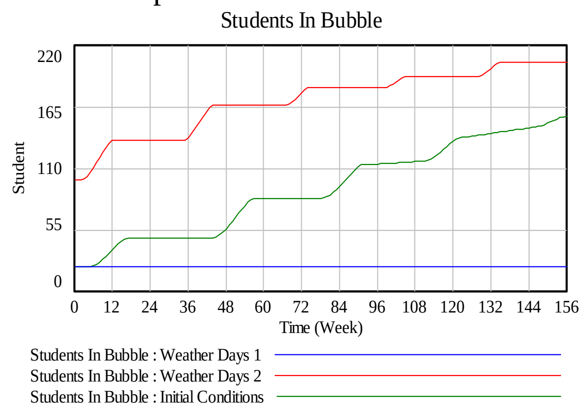

Figure 20: Add Weather Days – Bubble

Again, this course of action initially appeared to have promising results. Figure 19 presents the course length for this course of action vs. the initial conditions and Figure 20 presents the students in the bubble for the simulation. In the Weather Days 1 simulation, identified by the blue line in the figures, there appears to be a slight variation in course length in first weeks of this simulation then, the system quickly reaches equilibrium and maintains a constant course length of 22.4 weeks, which is the planned length with the addition of weather days. Additionally, even with the slight variation to the course length, the number of students in the bubble remains constant at 22, which is the buffer required to ensure that all classes begin with enough students. However, the red line presents the outcome of the simulation when the initial value of the bubble is set at 100 and the course of action does not perform well. So, this course of action alone does not present a very good option for improving the enterprise.

Recommendations

Although none of the initial courses of action provided increased performance when the initial conditions represented current bubble levels, the process provided valuable insights to develop a combined course of action for implementation. The recommended course of action is for the enterprise to add weather days and increase the daily flight hour window. In this simulation, the model simulates an additional five days for weather within the course, a five day buffer between courses, and increases the daily flight hour window to 3.5 hours. A benefit of this course of action is that if the USAACE can implement the course of action through internal policy changes. An addition of aircraft or instructor pilots would require organizations external to the enterprise to provide the USAACE with additional resources which are being used by operational units preparing for a deployed to Iraq and Afghanistan. So, the best course of action would be for the USAACE to stabilize the course length and maintain a steady stock of students in the bubble with internal policies.

The results of this combined course of action were very positive as the course length remained constant at 22.4 weeks throughout the simulation and the number of students in the bubble did not change. Similar to the other course of action, the model used an initial bubble of 100 students to simulate the current state of the AH-64 bubble. Figure 21 presents the results for the course length for this simulation, blue line, as well as adding weather days, red line, and increasing the flight hour window, green line. As shown, the recommended course of action provides the enterprise with a stable course length which is essential for maintaining a continuous flow of students through the process. This is evident in Figure 22, which shows a constant bubble of students and demonstrates how the system will operate in equilibrium.

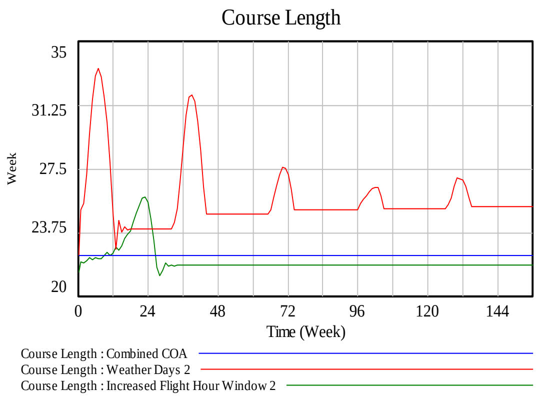

Figure 21: Recommended COA – Course Length

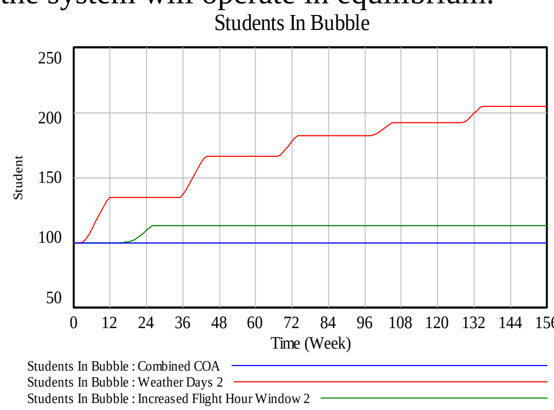

Figure 22: Recommended COA –Bubble

With a stable process of training students, the enterprise has the ability to attack the problem of the bubble before the AH-64 course. The bubble of students between the common course and the advanced aircraft courses is nothing more than a bathtub, so to lower the level of the bathtub one can either decrease the water flowing into the tub or increase the water flowing out of the tub. The FS XXI Enterprise can decrease the inflows into the AH-64 Advanced Aircraft Course Bubble by reducing the number of students that graduate from the common course. This would be similar to turning off the faucet in the bathtub example to prevent water from spilling out of the bathtub. Alternatively, they could increase the outflow of the course by increasing the number of students per class. This would be like increasing the size of the bathtub's drain to increase water flow. So, because the addition of weather days and increasing the flight hour period stabilized the training process, the FS XXI Enterprise can now address the problem of reducing the bubble.

Conclusion

This paper presents an application of system dynamics to evaluate policy recommendations for improving the process of training combat aviators at the U.S. Army Aviation Center of Excellence. Initial simulations of the model output data that aligned with historical data from the course. The policy recommendations included increasing the number of aircraft available, increasing the number of flight hours per day, and increasing the course length to account for weather. However, after running the simulations, none of these policy recommendations improved the performance of the enterprise. So, the final recommendation combines aspects of the initial recommendations to increase the number of flight hours per day and add additional weather days to the program of instruction.

References

110th AB. "AH-64D Longbow POI." Ft. Rucker, AL: U.S. Army Aviation Center of Excellence, September 2006.

110th Aviation Brigade. "Status of Flight Line Report." Ft. Rucker, AL: U.S. Army Aviation Center of Excellence, 2009.

1-14 Avaition Regiment. "1-14th Crew Endurance Policy." *1-14th Aviation Regiment SOP*, April 2008: 37-39.

1st Aviation Brigade. "Awating Training Report." Ft. Rucker, AL: U.S. Army Aviation Center of Excellence, September 25, 2009.

ACLC. "Annual Aircraft Utilization." Ft. Rucker, AL: U.S. Army Aviation Center of Excellence, 2009.

AFS, interview by James Enos. "Coordinator, Army Fleet Support." *ACLC / AFS Survey.* Ft. Rucker, AL, (October 20, 2009).

Dinges, John LTC. "Army Aviation Training Program: Interim Analysis Review Board." Washington DC: Center For Army Analysis, May 21, 2009.

Forrester, Jay W. *Industrial Dynamics.* Waltham, MA: Pegasus Communications Inc, 1961.

—. *Principles of Systems.* Cambridge, MA: Wright-Allen Press, Inc., 1968.

—. *World Dynamics.* Cambridge, MA: Wright-Allen Press, INC, 1971.

Lyneis, James. "System Dynamics for Business Strategy: A Phased Approach." *System Dynamics Review* 15, no. 1 (Spring 1999): 37-70.

Lyneis, James, and David Ford. "System Dynamics Applied to Project Management: A Survey, Assessment, and Directions for Future Research." *System Dynamics Review* 23, no. 2/3 (Summer/Fall 2007): 157-189.

Lyneis, James, Kenneth Cooper, and Sharon Els. "Strategic Management of Complex Projects: A Case Study Using System Dynamics." *System Dynamics Review* 17, no. 3 (Fall 2001): 237-260.

Meadows, Donella, Jorgen Randers, and Dennis Meadows. *Limits to Growth: The 30-year Update.* White River Junction, VT: Chelsea Green Publishing Company, 2004.

Nightingale, Deborah. "Principles of Enterprise Systems." *Second International Symposium on Engineering Systems.* Cambridge, MA: MIT, 2009.

Nightingale, Deborah, and Donna Rhodes. "ESD.38J Enterprise Architecture." *Course Notes.* Cambridge, MA: Massachuessetts Institute of Technology, 2007.

Pilots, Instructor, interview by James Enos. *Flight School XXI Instructor Pilot Survey* 27 Surveys Completed, (January 20, 2010).

Richardson, George P. *Feedback Thought in Social Sciences and Systems Theory.* Pennsylvania , PA: University of Pennsylvania Press, 1991.

Sterman, John. *Business Dynamics: Systems Thinking and Modeling for a Complex World.* Boston, MA: Irwin McGraw-Hill, 2000.

USAACE. "Flight School XXI Increase." Ft. Rucker, AL: U.S. Army, March 1, 2008.

—. "Whitebook FY10." Ft. Rucker, AL: U.S. Army Aviation Center of Excellence, 2009.

About the Author

Major James Enos is currently an instructor in the Department of Systems Engineering at the United States Military Academy, West Point, NY. Throughout his military service, he has held numerous leadership positions as an infantry officer, including Rifle Company Commander, Ranger Instructor, and Platoon Leader. He graduated from the US Military Academy at West Point in 2000 with a Bachelor of Science degree in Engineering Management. He earned his Master's of Science in Engineering and Management in 2009 from the Systems Design and Management program at MIT. He teaches classes in modeling and simulation, systems engineering, and system dynamics.