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A benefit analysis of using a low-cost flight simulator for the MH-60R

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THESIS

A BENEFIT ANALYSIS OF USING A LOW-COST FLIGHT SIMULATOR FOR THE MH-60R

by

J. Gregory Zilai

September 2016

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This thesis examines eight different configurations of a low-cost trainer, and analyzes the impact of each configuration on the utilization rates of the existing simulators. It uses the throughput data from the MH-60R Fleet Replacement Squadron to compare the configurations, as the Fleet Replacement Squadron is the single largest user of the devices. This thesis does not aim to determine an optimal configuration. It provides analytical evidence that the introduction of a low-cost trainer has the ability to make the existing devices significantly more available for events that require a high level of fidelity.

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A BENEFIT ANALYSIS OF USING A LOW-COST FLIGHT SIMULATOR FOR THE MH-60R

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ABSTRACT

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LIST OF ACRONYMS AND ABBREVIATIONS

AIS	automated identification system
ALFS	airborne low-frequency sonar
API	aviation preflight indoctrination
ASW	antisubmarine warfare
ATO	airborne tactical officer
CAI	computer aided instruction
CAT I	category one
CAT III	category three
CDF	cumulative distribution function
CIS	contract instructor support
CNATRA	Chief of Naval Education and Training
CO	commanding officer
COA	courses of action
CRM	crew resource management
DH	department head
EP	emergency procedure
ESM	electronic support measures
FLIR	forward looking infrared
FRAC	Fleet Replacement Aircrewman
FRP	Fleet Replacement Pilot
FRS	Fleet Replacement Squadron
FST	fleet synthetic trainer
FY	fiscal year
HSM	Helicopter Maritime Strike
HSMWSP	Helicopter Maritime Strike Weapons School Pacific
IAC	instructor aircrewman
ICW	interactive courseware
IFS	introductory flight screening
IGR	instructor guided review
IP	instructor pilot

LCT	low-cost trainer
MD	mission display
MOE	measure of effectiveness
NAPP	Naval Aviator Production Process
NAS	naval air station
NATOPS	Naval Aviation Training and Operations Procedures Standardization
NAVPERS	Navy Personnel Command
NVD	night vision device
OFT	operational flight trainer
SACT	surface to air counter tactics
SAR	search and rescue
SNA	student naval aviator
SO	sensor operator
SUW	antisurface warfare
TACAIR	tactical aircraft
TACEVAL	tactical evaluation
TMS	type, model, series
TOFT	tactical operational flight trainer
TRL	training requirements letter
TRP	technology refresh process
TYCOM	type commander
WTT	weapons and tactics trainer
XO	executive officer

EXECUTIVE SUMMARY

Constricting fiscal environments coupled with rapidly improving technologies have created a shift in aviation training mentalities. High-fidelity flight trainers provide novice and professional aviators alike the ability to conduct tactical operations in a simulated environment that is on par with the real world. While these high-fidelity devices can be operated at a lower cost per hour of operation than an actual aircraft, they are not free. As the devices become more capable, there is more demand for usage.

The Helicopter Maritime Strike (HSM) community utilizes a fully capable tactical operational flight trainer (TOFT) for training in the MH-60R. At Naval Air Station North Island in San Diego, California, there are four TOFT available, which are contracted to run from 0600–2359, Monday through Friday. Even while running such long schedules, the utilization rate is roughly 90%, and projections are that usage requirements will only continue to grow. The largest user of the TOFT is HSM-41, the MH-60R Fleet Replacement Squadron (FRS), as they are responsible for training all pilots and aircrew preparing to join every HSM squadron on the West Coast, Hawaii and Japan. While the TOFT are capable of completing every possible event, questions arise as to whether or not the full capabilities of the TOFT are required for all events: Could a lesser capable trainer could be utilized to complete some events, therefore leaving the TOFT available for events that require the full complement of capabilities? This thesis addresses this question.

The first step in trying to answer the aforementioned question was to scope the project. Since the largest user was determined to be the FRS, and the largest population at the FRS to use the TOFT was determined to be the Fleet Replacement Pilots (FRPs), it seemed like a logical population to investigate. The two primary FRP syllabi were analyzed, and individual event requirements were determined in order to create various alternative configurations for a low-cost trainer (LCT). Eight separate configurations were developed, labeled A through H. Configuration A most closely resembles the TOFT, and subsequent configurations were of decreasing capabilities. The specific capabilities and respective alternative configurations can be seen in Table 1.

	Cockpit	Full Visuals	Dual LCD Displays	Single LCD Display	Dual Functioning Controls	Single Functioning Controls	Single Keyset/Displays	Dual Keysets/Displays	Aircrew Interface	Acoustics	MTS	Mission Systems
Configuration A	X		X		X			X	X	X	X	X
Configuration B	X		X		X			X	X		X	X
Configuration C	X			X		X	X		X	X	X	X
Configuration D	X	X			X			X			X	X
Configuration E	X	X			X			X				X
Configuration F							X		X	X	X	X
Configuration G							X				X	X
Configuration H							X					X

Table 1. LCT Configuration Matrix.

Once the configurations were determined, the next step was to decide which events were compatible with each different configuration. Using an Excel spreadsheet, the syllabus flow was mapped in conjunction with student throughput projections to determine a distribution of number of events of each device type on any given training day. The TOFT itself is can be broken up into two separate devices and used independently: The operational flight trainer (OFT), which is used primarily for pilot, non-tactical events, and the weapons tactics trainer (WTT), which is a tactical module with no functional controls. Some events require an OFT, some a WTT, and some require a full TOFT. As such, the number of OFT, WTT, TOFT and LCT compatible events were determined for each training day, for each configuration. These distributions, as well as one for the existing system without a LCT to act as a control, were utilized as the input for the system.

Computer experimentation and simulation was determined to be the best method to analyze the different configurations. It provided the ability to run multiple replications as well as to introduce randomness while controlling random error. ExtendSim was the primary software selected, and the system comprised of a source, a processor, a feedback loop (to capture the statistically proven 10% of events that did not complete due to a student or device failure) and an output data gathering mechanism for each device type. It included four OFT, four WTT and two LCT as resources to be utilized, and ran for 16 hours per day, five days per week, which is the intended run time for the actual system.

The system utilized the individual input distributions for each device type and each configuration, and was run with 50 replications, each the length of one training year. The desired and collected output was the overall utilization of the OFT, WTT and LCT. Table 2 is a summary of that data.

Table 2. Output Data.

	WTT USE	OFT USE	LCT USE
Control	39.05%	73.05%	0.00%
A	11.93%	39.25%	84.04%
B	27.72%	44.81%	59.77%
C	20.37%	51.63%	66.66%
D	38.81%	32.58%	78.91%
E	38.11%	43.38%	66.41%
F	28.56%	59.62%	47.97%
G	37.88%	59.27%	36.48%
H	37.96%	65.11%	24.77%

From this data, it can be concluded that introducing a LCT into the MH-60R simulator system can have an impact on the utilization availability of the existing TOFT. Configurations A and B resemble the existing TOFT, with the exception of utilizing LCD displays instead of full visuals (and Configuration B also does not utilize acoustic systems required for antisubmarine warfare). The introduction of up to two devices of Configuration A, or one of Configuration B, however, would be on the level of installing new, fully functional TOFT device in terms of how they affect OFT and WTT utilization.

This study provided an initial look into the procurement of a LCT for the MH-60R. Additional research into optimization or a cost-benefit analysis of different capabilities versus utilization savings could provide grounds for procurement of some variation of LCT. The utility is apparent, and as more events are projected to move into simulators, the LCT option may prove necessary and viable in the future of the HSM community.

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I wish the best to all of my classmates, professors and staff of the PD-21 Program. It has been an adventure and one of the more challenging things I have undertaken in my career. I have learned a lot, and I hope that perhaps someone may use the information included in this thesis for something productive in the future.

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I. INTRODUCTION

A. PURPOSE

This chapter provides the reader with a baseline of information about MH-60R flight training to help understand the problem that will be introduced in Chapter II. It briefly describes the general training pipeline for Navy helicopter pilots, as well as the various training events that they complete throughout their training program. It describes the current flight simulators and how they are used throughout the program.

B. NAVAL AVIATION TRAINING PIPELINE

1. General Information

All student naval aviators (SNAs) follow the same general training pipeline, regardless of platform. Whether at their commissioning source or shortly thereafter, SNAs participate in an introductory flight screening (IFS) program, which consists of 15 hours of flight training in a civilian aircraft. This is simply to determine whether the SNA has an aptitude for flying prior to beginning the rigorous flight training pipeline (Chief of Naval Air Training 2012). Following commissioning as an officer in the United States Navy, all SNAs report to aviation preflight indoctrination (API) in Pensacola, Florida. API consists of four weeks of instruction in basic aerodynamic principles, meteorology, flight planning and survival. Upon completion, SNAs are sent to Primary Flight Training in either Corpus Christi, Texas, or Milton, Florida, to learn how to fly the T-6 fixed wing training aircraft. SNAs learn how to perform basic flight maneuvers, aerobatic maneuvers, emergency procedures (EPs), and instrument procedures. They are also introduced to formation flying. Upon successful completion of Primary, students select an aviation pipeline based primarily on their performance in the training program, as well as individual student preference. Each SNA selects tailhook (Tactical Aircraft [TACAIR] or E-2/C-2), Maritime Patrol (P-3/P-8), or rotary wing.

2. Helicopter Training

All SNAs who select rotary wing aircraft complete Advanced Flight Training in Milton, Florida. There they learn the basics of helicopter flight in the TH-57 to include how to hover, how to perform helicopter EPs, advanced instrument flying, night vision device (NVD) training and helicopter formation flight. At the conclusion of this training program, SNAs are no longer considered students: They are awarded their wings and are designated as Naval Aviators. Currently, the only available platforms for Navy rotary wing pilots are MH-60S, MH-60R, and CH-53. The newly winged aviators next complete a course of instruction at a Fleet Replacement Squadron (FRS) to learn to fly their fleet aircraft. This thesis will focus specifically on the MH-60R FRS.

C. MH-60R FLEET REPLACEMENT SQUADRON

1. Fleet Replacement Pilot Categories

The FRS controls various Chief of Naval Education and Training (CNATRA) with approved syllabi for Fleet Replacement Pilots (FRPs) and Fleet Replacement Aircrew (FRACs) (Chief of Naval Air Training 2014). This thesis will focus specifically on the FRP syllabi or training program.

a. Category One

Category one (CAT I) FRPs are those who are completing their initial course of instruction in a fleet aircraft. An aircraft is described by type, model, and series (TMS); The MH-60R, for example, is type MH (Helicopter, Medium Lift), model 60, series R. CAT I FRPs in the MH-60R have never flown an H-60 model of aircraft. Occasionally, pilots change from one platform to another, and pilots who have flown a similar series of aircraft will complete one of the other category syllabi described below. In general CAT I FRPs are recently winged Navy pilots (Commander, Naval Air Forces 2007). The full, CNATRA approved CAT I syllabus is maintained by HSM-41, and can be made available upon request.

b. *Category III*

Category III (CAT III) FRPs have already been given instruction in the same series of aircraft at an early stage of their career, but have been out of the aircraft for longer than 18 months (Commander, Naval Air Forces 2007). These pilots are often returning from non-flying orders and are on their way to a fleet squadron to be a department head (DH), executive officer (XO), or commanding officer (CO). The CAT III syllabus covers the same topics as the CAT I syllabus, but it has fewer events as it is assumed that CAT III FRPs are just reviewing previously learned topics. The full, CNATRA approved CAT III syllabus is maintained by HSM-41, and can be made available upon request.

c. *Other FRP Syllabi*

There are other FRP syllabi at the FRS. However, the vast majority of FRPs complete either a CAT I or CAT III syllabus. The author acknowledges the syllabi described below, but recognizes that they are not within the scope of this thesis. They are better addressed in a follow-on study.

- CAT IIC syllabus: This syllabus was primarily used for pilots who were Naval Aviation Training and Standardization Operating Procedures (NATOPS) current in a similar series of aircraft. For the MH-60R, this meant SH-60B pilots who were transitioning to the MH-60R as the SH-60B was being replaced.

- CAT IINC syllabus: This syllabus was similar to the CAT IIC Syllabus; however, the FRP would not be NATOPS current at the time of instruction. Similar to the CAT III syllabus, these FRPs were typically returning from non-flying orders to be a fleet DH, XO or CO.

- CAT IV syllabus: This syllabus is for previously qualified MH-60R pilots who have been out of the aircraft for less than 18 months (Commander, Naval Air Forces 2007). These FRP are extremely rare due to the structure of the helicopter pilot career path.

- CAT V syllabus: This syllabus is a provisionary one utilized by the FRS CO for any pilot who needs a special syllabus to meet specific requirements. Each student has a specially tailored syllabus based on his/her follow-on assignment. One example would be Test Pilots of HX-21 getting a baseline of instruction in the MH-60R.

2. FRAC Syllabus

The MH-60R FRS is also responsible for training FRACs. The MH-60R consists of two pilots and at least one aircrewman on each sortie. The FRS gives FRPs and FRACs the opportunity to work on crew resource management (CRM) principles at the very beginning of flying their fleet aircraft. They are referenced here for the reader to fully understand the requirements of the FRS.

D. MH-60R SIMULATORS

1. General Description

Unlike most other Naval Aviation communities, the MH-60R and MH-60S platforms have only one type of simulator in use. This means that regardless of the individual event objectives, a fully functional simulator is utilized. For a large number of events, the full functionality of the simulator is not required and many of its capabilities are left unused. While there are events that require the full capabilities of the device, there are also events that can be completed with far fewer functions.

This thesis will focus specifically on the West Coast MH-60R simulator configurations at Helicopter Maritime Strike Squadron FOUR ONE (HSM-41), the west coast MH-60R FRS located at Naval Air Station (NAS) North Island in San Diego, California. While there is only one *type* of simulator for the MH-60R, other *configurations* of the device will be described. Specific capabilities and details about the function of the devices is proprietary information found in the design and procurement contract, and may be made available upon request. This thesis will describe these capabilities in general terms.

2. Tactical Operational Flight Trainer

Each simulator is referred to as a tactical operational flight trainer (TOFT). When in TOFT mode, the simulator provides a realistic tactical environment for the pilots and aircrewman. It includes

- full visual displays for the two pilots,
- fully functional flight controls,

- full functionality in all cockpit switches and circuit breakers,
- interface between the cockpit and aircrew station,
- fully functional aircrew station,
- accurate aerodynamic flight modeling,
- fully functional mission systems for all sensors,
- tactical environment simulation, and
- the ability to model all EP.

These capabilities are available on each of the four TOFT present at North Island. There is also a capability to configure each TOFT into two separate devices for individual use.

3. Operational Flight Trainer

An operational flight trainer (OFT) is simply the cockpit section of the TOFT without the aircrew interface. It still has all of the same simulator capabilities with the exception of the airborne fow frequency SONAR (ALFS) sensor. FRP are able to simulate all missions with the exception of antisubmarine warfare (ASW). Additionally, since there is no aircrewman in the trainer, they do not have the opportunity to exercise CRM. A picture of the OFT can be seen in Figure 1.

Figure 1. OFT Cockpit. Source: Alcock (2014).

4. Weapons and Tactics Trainer

The weapons and tactics trainer (WTT) has a fully functional aircrew console, and airborne tactical officer (ATO) mission display and keyset only. It provides the ability for a FRAC to conduct an event without being linked to an OFT, or provides a FRP the ability to perform an event that does not require any sort of actual piloting (for example, a mission system procedural trainer). There are no visuals, no functioning controls and no working cockpit switches or circuit breakers. However, this configuration is responsible for all FRAC events (besides those that are completed in conjunction with a FRP TOFT event), as well as the majority of FRP ASW events.

5. Configuration implications

As previously mentioned, there are four TOFT simulators available at NAS North Island. When the simulators are not running in TOFT mode, each can be viewed as two independent trainers, as each TOFT has the ability to run simultaneously in OFT and WTT mode. The civilian contractor simulator maintenance personnel can link or de-link OFT and WTT on an event-by-event basis, typically in less than 15 minutes. On any given training day, a TOFT can be reconfigured multiple times depending on the event requirement for that day. This means that there can be up to eight separate events occurring simultaneously in the four TOFT, assuming that the event breakdown is four WTT events and four OFT events.

E. FRS RESOURCES AND REQUIREMENTS

This section describes the magnitude of operations required for HSM-41 to complete the mission of training Fleet Replacement Pilots and Aircrew to fly and tactically employ the MH-60R. Currently, HSM-41 has the following resources available:

- 48 instructor pilots (IP)
- 32 instructor aircrew (IAC)
- 16 contract instructor support (CIS)
- 29 MH-60R aircraft
- 4 TOFT

The number of FRP and FRAC for Fiscal Year 2016 (FY16) follows:

- 83 CAT I FRP
- 35 CAT III FRP
- 44 CAT I FRAC
- 8 CAT III FRAC

In order to meet this demand the following resources are required:

- 8,893 flight hours
- 22,365 simulator hours (Total OFT and WTT)
- 38,015 instructor classroom hours

Resource coordination at HSM-41 to accomplish the mission is a tremendous undertaking. Each day, there are two IP and two IAC who build the flight schedule for the following day. Planners must consider student requirements, IP qualifications, aircraft and simulator availability, as well as flight-hour restrictions.

F. FRP TRAINING PROGRAM FLOW

CNATRA has approved a specific syllabus for all categories of FRP (with the exception of CAT V that is at the discretion of the CO of HSM-41). The syllabus consists of flight events, simulator events, IP led computer aided instruction (CAI) and instructor guided reviews (IGRs), self-paced interactive courseware (ICW), and various fleet required schools. Each event must be completed prior to FRS graduation, but not necessarily in the order described in the syllabus. Some events are prerequisite for other events; however, there are also events that may be completed out of order. This is important to understand as a basis for resource scheduling. If one of the scheduling officers is unable to schedule an FRP for the next event in his/her syllabus due to a resource constraint, the scheduling officers could possible schedule a classroom event out of order. The FRP would then complete the previously required event at a time when resources become available. Each CAT I FRP is given 39.6 weeks to complete the 167 events in the syllabus. There are roughly 25 slack days to account for weather or maintenance cancellations, illness, or student event failures. The scheduling officer's manipulation of the syllabus is imperative for on-time FRP graduation.

G. ADDITIONAL SIMULATOR USAGE ENTITIES

HSM-41, while the largest user of the MH-60R simulators, is not the only entity that has simulator requirements: There are also eight other HSM Squadrons stationed at NAS North Island that have currency requirements that must be met in the simulator. Additionally, the HSM Weapons School Pacific (HSMWSP) is responsible for providing advanced tactical training for units preparing for deployment, as well as conducting eactical evaluations (TACEVALs) for all HSM pilots and aircrew. Finally, growing simulator capabilities have afforded coordinated training opportunities between aircrew and shipboard units. Fleet synthetic trainers (FST) are events which allow surface warfare personnel as well as other aviation platforms to link with aircrew in a TOFT to provide realistic training in a simulated tactical environment. These requirements are outside of the scope of this thesis; however, it is important for the reader to understand that the FRS is not the only user of the TOFT.

H. SUMMARY

This provides the reader with a look into the structure of the simulator usage requirements for HSM-41. It provides background information on the various syllabus types as well as the general simulator requirements for each of those syllabi. It also describes the simulator devices themselves, as well as the different configuration modes in which they can be run. Finally, it illustrates the immense usage requirements imposed upon the MH-60R TOFT.

II. PROBLEM DEFINITION

A. PURPOSE

This chapter outlines the challenge, with regards to simulator availability that the HSM community believes it will encounter in the future. It explains the research questions that the author intends to address in this thesis. The discussion provides the rationale for selecting this problem as a thesis topic and the benefits of the study.

B. SIMULATOR SHORTFALLS

To date, HSM-41 is able to complete all requirements for FRP and FRAC in the simulator. However, the HSM community has identified a number of circumstances that have the potential of increasing simulator requirements beyond its current and planned capacity.

1. Obsolescence Upgrades

The four TOFT at North Island were constructed as early as 2006. Since that time, they have not had any major hardware upgrades. Simulator configuration, in fact, has not even been able to keep pace with upgrades in aircraft technology. There are hardware components of the TOFT that are in limited supply, some of which are manufactured by companies that are no longer in business. The technology refresh process (TRP) was planned for in 2010 and was scheduled to begin in FY14, but ended up significantly behind schedule. Contract disputes pushed this timeline back to mid FY16. Once the TRP begins, each TOFT must be taken offline for a period of 6 to 18 months in order to complete the hardware upgrade. In the total, the TRP may be ongoing for a period of 2 to 6 years. During that time the FRS's simulator capacity will be at 75%, assuming that there are no failures of the functioning TOFT as a result of delayed upgrades. Plans are in process to construct two more TOFT to augment the four in service, but it is unknown whether or not the construction will be before or after the TRP.

2. Increased Fleet Requirements

Because of the expense associated with aircraft operations, flight hours are in shorter supply as a result of tighter budgets. The total cost for each hour flown in a MH-60R is $3,284 when considering fuel and maintenance requirements (Randy Menn, personal correspondence 2016). Type commanders (TYCOM), or leaders of each aviation community, are looking for ways to conduct more quality training out of the aircraft, including an expansion of the number of events conducted in the simulator. Even without moving events from the aircraft to the simulator, there is the added projection of performing more tactical sorties in the simulator to increase tactical proficiency. All of these projections produce an increased strain on current simulator capacity.

3. Expanding FST Requirements

The technology improvements in linked simulators are only projected to improve over time. FST events have proven an extremely cost effective way of conducting group exercises with coordination between multiple different air and surface assets. Live exercises are extremely expensive to conduct, and working out communication and coordination in a simulated tactical environment before conducting a live exercise has a great deal of merit. Consequently, FST requirements are expected to grow. These projections are not provided in an appendix in an effort to keep this thesis unclassified and not FOUO; however, they can be provided by the author upon reader request.

C. RESEARCH QUESTIONS

The motivation behind this thesis was to determine whether or not a configuration of low-cost trainer (LCT), when introduced into the current simulator system to be utilized for FRS syllabus events, could provide a significant increase in TOFT availability for other entities. In order to investigate this issue, the following questions were used to drive the research process:

1. What are specific capability requirements for individual syllabus simulator events at the MH-60R FRS?
2. Are individual requirements driven by the simulator capabilities as they existed, or were the simulators designed to meet those requirements?
3. Are there suitable options for using a trainer with a lower fidelity to accomplish training on all or some of the syllabus simulator events?
4. What are the effects of introducing different configurations of LCT on the utilization of the existing OFT and WTT?
5. What capabilities have the greatest impact on OFT and WTT usage?
6. What areas of study can further investigate this problem?

D. BENEFITS OF STUDY

FRP syllabus events have a wide range of requirements: Some events require the full depth and breadth of the TOFT capabilities while some require nothing more than a functioning mission display (MD) to practice pushing buttons. In the current mode of operation, each of those events consume generally the same resources due to the fact that an entire simulator (either an OFT, WTT or a full TOFT) is required for all events, regardless of complexity. If a trainer was in existence that could accomplish some of the less requirement-intensive events, it would make additional simulator capacity available for events that require the full complement of capabilities. The identification of such a system would not only be useful in meeting the foreseeable potential for a capacity shortcoming, but also in the mitigation of currently un-identified future capacity gaps.

E. MEASURES OF EFFECTIVENESS

1. OFT and WTT Usage Rate

The primary measure to determine the effectiveness of each LCT as it is introduced into the system will be the effect of utilization on the existing simulators. The premise is that if FRS utilization can be offloaded onto a LCT, it will leave the high-fidelity TOFT, OFT or WTT available for use in external events that require the full TOFT functionality. The model will be developed to capture this utilization in terms of time utilized versus time available. Specifically, the total time that the OFT and WTT were utilized for events of each device type is divided by the total available time for each respective trainer type.

A decrease in utilization in the existing devices will be an indication of a successful LCT. An ideal LCT would be one that is able to be utilized at a high rate while allowing the OFT and WTT to operate at a low rate for FRS requirements. This translates to additional availability of these high-fidelity devices to be utilized by external entities that may require the full range of simulator capabilities. Since a TOFT is simply an event that requires both the use of an OFT and WTT, it does not have its own separate utilization parameter. To capture this measure, therefore, only the OFT and WTT utilization rates will be analyzed for the alternative solutions.

2. LCT Utilization

The premise of the study is to investigate the introduction of a LCT into the system. One can make a baseline assumption that the more capable the LCT, the more it will have the ability to be utilized, and the lower the utilization rate will be for the OFT and WTT. One way to gauge the effectiveness of an LCT can therefore be having a low utilization itself compared to the positive utilization impact on the OFT and WTT. In other words, it is beneficial for the LCT to provide for a decrease in utilization in the OFT and WTT while not having excessive utilization of its own. Another consideration is that introducing a LCT with capabilities that are essentially the same as a TOFT may become higher in cost, and defeat the purpose of being a LCT. Therefore, a lesser capable LCT that still significantly reduces the utilization of the OFT and/or WTT is preferable. This topic will be discussed further in the analysis chapter.

F. SCOPE

Due to the size and complexity of this problem, the scope of this thesis has been reduced to a manageable level. The focus will be to analyze the impact of introducing a LCT on the FRP syllabus at HSM-41. It will first determine the throughput of the FRP, based on previous data as well as projected numbers. Next, it will analyze the requirements of individual simulator events to determine various configurations of a LCT that may provide utility. It will then model and simulate the throughput of FRP scheduled events in the present and altered simulator configurations. Finally, it will examine the impact of introducing each LCT into the existing system to determine the effect of such a trainer on existing simulator utilization.

G. SUMMARY

This chapter explains the projected shortfalls in simulator capacity in the HSM community, which led the author to select this analysis as a thesis topic. It then presents the research questions that charted the course for the development of this topic. Finally, it presents the scope, measures of effectiveness, as well as the assumptions that shape the thesis.

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III. MODEL DEVELOPMENT AND EXPERIMENTATION

A. PURPOSE

This chapter explains the process for examining the impact of different LCT configurations on the total utilization rate for each of the existing simulators. It describes experimentation in general, as well as why experimentation was selected as the method for investigating the effectiveness of different LCT configurations. After describing this method of evaluation, it outlines how the simulation model was developed, as well as simplifying the assumptions that make it a useful representation of the current system. This discussion includes study of the individual simulator events for CAT I and CAT III FRP that are required for syllabus completion. Next, it maps those requirements onto capabilities that a simulator must possess in order to complete each event. This leads to grouping of certain capabilities, which determine the various configurations of LCT. Finally, it will describe the simulation model that was used to determine the effect of each LCT configuration on the simulator system as a whole.

B. EXPERIMENTATION

1. Computer Models and Experimentation

Experimentation on a computer model for the simulator system was selected as an effective approach to conduct this study. For this analysis, the goal is to take a known input (the number of events required over the course of a given training year), examine the output (the utilization rates of existing devices) and determine the factors that cause significant changes in the output. While desirable, attempting to solve this function analytically would be virtually impossible. The data in existence is one possible combination of events that might take place over the course of the training year, but the randomness inherent in the system is not captured. Multiple replications depict the variations in usage and the scenarios in which they occur.

2. Why Do We Use Experiments? What Are the Advantages?

The advantages to using a computer experiment are abundant: Although not the intent of this study, regression analysis can help to determine a mathematical function to represent the relationship between the factors and response variable. Secondly, a randomization of the input takes into account variations in the data. This is a critical element when using a computer experiment. The simulation is an estimate of what exists in the real world; therefore, it is essential to introduce some form of randomness to accurately compare output parameters (Koehler 1996). Computer experiments also allow for a side-by-side comparison of different functions using the same input data, even if that data is randomly created. Most importantly, computer experimentation enables researchers to show causality between independent factors and outputs of interest.

3. Why was Computer Experimentation Chosen for This Thesis?

Principally, the introduction of randomness in the input data was the largest advantage that led to the selection of computer experimentation for this study. Instead of developing an analytical model to precisely capture previous event occurrences, simulation based on assumptions and Bayesian distributions was determined the best method for predicting future outcomes. This simulation allows for a study of the problem without requiring unrealistic assumptions to obtain an analytically tractable model (Lucas et al. 2015). Through numerical analysis, a reasonable prediction of future outcomes as a result of changes to the system is possible. Consequently, computer experimentation was an ideal approach to address the research questions in this thesis.

C. DEFINING REQUIRED SIMULATOR CAPABILITIES

1. General Event Description

While each event tests specific skills and knowledge, all of the events can be grouped into one of five general categories for which specific capability requirements can be identified. While there may be some differences between specific events within each category, these generalizations serve as a basis for determining groupings of capabilities to be used as alternative configurations of LCT.

a. EP Event

EP training is arguably the most critical component to flight training. FRP ability to correctly diagnose, react and perform the correct actions could save his or her life, as well as the lives of the crew and passengers on board the aircraft. At every level of student development, from the first few OFT events, to the Naval Aviation Training and Operating Procedures Standardization NATOPS evaluation, to the final EP event at the conclusion of the syllabus, it is imperative that the simulator act and react as close to identical to the aircraft as possible.

b. Pilot Procedural Event

A procedural trainer is one where the FRP is learning to perform basic and advanced procedures centered on maneuvering the aircraft in specific flight regimes. These events include search and rescue (SAR), ALFS employment (from a non-tactical perspective), surface-to-air counter-tactics (SACT) and an introduction to formation flight. Similar to the EP events, pilot procedural trainer events require high-fidelity visuals and a functional set of cockpit controls. If the simulator does not mirror aircraft performance, it has the possibility of developing negative habits in the FRP.

c. Mission Systems Procedural Event

These events are currently conducted in a WTT without any pilot controls or visuals. The basic requirement for these events is that the FRP get a chance to learn how to utilize the various mission systems. There is a heavy emphasis on pushing buttons and manipulating displays in order to get the FRP accustomed to the various settings, menus and operational modes of all of the systems. Each event has specific requirements for which system is required to be operational, but generally speaking, they do not require any cockpit controls, switches or visuals to successfully complete.

d. Tactical Scenario Event

Once the FRP learns how to utilize the mission systems, they are expected to be able to employ those systems in various tactical scenarios. The ATO syllabus is divided into antisurface warfare (SUW) and antisubmarine warfare (ASW), with different events have different capability requirements. There is a requirement for some form of visuals to give the pilot flying the simulator at least some reference to the environment, but does not a require the fidelity of visuals needed for the EP or Procedural Trainers. The situation is the same for the cockpit controls in the device: Although the controls need to be present, they do not necessarily need to be identical to the aircraft.

e. Checkrides

There are a few points in the syllabus that are conducted under the instruction of an evaluator: these events are known as checkrides. The FRP is expected to be able to apply certain levels of knowledge commensurate with his or her progress in the syllabus. These checkrides require high fidelity as they are designed to demonstrate to the evaluator that the FRP is capable of conducting a particular evolution successfully in a simulator the same as they would be able to in an aircraft. Without a simulator that accurately models the real world environment, this requirement cannot be met.

2. General Capabilities

To meet the requirements outlined above, there are certain general capabilities that come to the surface. Within each capability, more specific simulator features would be required; however, the scope of this thesis is to look at the broad capabilities while designing configurations of LCT.

a. Visuals

It may be assumed that a simulator requires some form of visual display for the pilot, but this is not the case. Instrument training as well as mission systems procedural trainers do not require that the FRP have any reference to what is happening outside of the aircraft besides what is displayed internally. Because of the wide range of event requirements, there are four possible configurations for visuals:

- no visuals
- a single LCD type display for the pilot

- dual LCD type displays for both pilots
- full fidelity visuals comparable to the existing OFT

b. Cockpit Controls

Some events require the cockpit controls and switches to function identically to how they function in the aircraft. Some on the other hand may only need to provide the pilot the ability to maneuver the aircraft in the tactical environment while the ATO conducts a sortie. Still others may not need any controls, simply an input method to tell the simulated aircraft where to move.

c. Keysets and Displays

The pilot and ATO interface with the aircraft and simulator is conducted via an input keyset and pointing device. Some events require that this input device be identical to what will be encountered in the aircraft in order to develop positive behavioral patterns. Other events may be directed at a more broad approach to tactics, and therefore not require precise representation of the input devices to be effective. Similarly, the information that the aircraft presents to the pilot and ATO has a required range of fidelity based on the specific event being conducted. There are some events that require that both the pilot and ATO have complete and accurate mission and flight displays, while others may not.

d. Aircrew Interface

Very few actual missions are conducted without an aircrewman sensor operator (SO) as part of the crew. There are, however, some events conducted in the simulator that focus on skills that do not require the SO to meet the event requirements. With the addition of an aircrew interface, there is also a requirement that the SO station have a certain level of fidelity so that he or she can be a performing member of the crew.

e. Mission Systems

The final capability to be discussed is certainly the broadest. Different events require very different configurations of mission systems. To keep within the scope of this thesis, three specific mission systems groupings are examined:

- surface mission systems include RADAR, electronic support measures (ESM), automated identification system (AIS), Link 16 and a communications suite
- forward looking infrared (FLIR) system and associated armament systems
- ALFS and acoustic systems as well as associated armament systems

3. Pairing Events to Capabilities

Appendices A and B contain the tables for general device requirements for each simulator event in the CAT I and CAT III syllabus, respectively. They provide a basic description of the items required on every simulator syllabus event, and also show the simulator capabilities that are therefore required to complete each event. Each of the general capabilities can be broken into more specific requirements. However, for the scope of this thesis, the general capabilities adequately serve for modeling purposes.

D. DETERMINING LCT CONFIGURATIONS

Using the data in Appendices A and B, multiple configurations of a LCT were developed to provide alternatives for analysis. Each configuration was selected to provide certain capabilities, and thus compatible with different groupings of events. Selection of each configuration was done by first assuming that the simulator was a TOFT, and then gradually removing capabilities for each configuration until reaching the lowest practical function for a trainer. The thought behind this was that each capability will have some monetary value, and future analysis of this information could provide a method of determining an optimum cost vs. capability solution. This, however, was outside of the scope of this thesis. Table 1 shows the eight configurations (labeled A–H) that were developed and used in the study.

Table 1. LCT Configuration Matrix.

	Cockpit	Full Visuals	Dual LCD Displays	Single LCD Display	Dual Functioning Controls	Single Functioning Controls	Single Keyset/Displays	Dual Keysets/Displays	Aircrew Interface	Acoustics	MTS	Mission Systems
Configuration A	X		X		X			X	X	X	X	X
Configuration B	X		X		X			X	X		X	X
Configuration C	X			X		X	X		X	X	X	X
Configuration D	X	X			X			X			X	X
Configuration E	X	X			X			X				X
Configuration F							X		X	X	X	X
Configuration G							X				X	X
Configuration H							X					X

E. DETERMINING INPUT PARAMETERS

1. Initial Assumptions

Determining how to model the daily events that a scheduling officer would schedule is based on analysis of historic FRS student throughput. The annual throughput of students is a set value that is determined by fleet requirements. Current projections are that approximately 85 CAT I and 42 CAT III FRPs will attend the MH-60R FRS training program in FY17. This number of FRPs is projected to remain roughly constant in follow-on years. In general, CAT I students arrive in a group (or class), once per month, and stay together for the majority of the syllabus. However, it is not uncommon for a student to be one or two events ahead or behind his/her class. For the purposes of this thesis, the assumption is that the students remain together as a class throughout training. CAT III FRP, on the other hand, tend to arrive more sporadically. Again to keep the modeling possible, it was assumed that these students arrived evenly distributed throughout the 12 months and remained together until completion. These two assumptions led to the determination that 7.08 CAT I FRP and 3.5 CAT III FRP arrive each month to begin training.

2. Training Year Structure

Appendices C and D illustrate which event is conducted on which training day in the CAT I and CAT III syllabus, respectively. This data, coupled with the throughput assumptions, was used to develop a spreadsheet to determine the number and type of events to be conducted on any given day. Due to the size of the spreadsheet, it is not included in the appendices but can be made available by contacting the author. Figure 2 is a simplified version of the spreadsheet, which shows how each class of FRPs progresses through the syllabus over the course of a training year. It was used to determine the events to be conducted on each individual training day by tracking each individual class's progression through the syllabus. Assuming a continuous throughput, each month in Figure 2 (August, for example) may include classes of FRPs from two different years. This continuity allows for an analysis of each training day, independent of the specific year that the FRPs begin the syllabus.

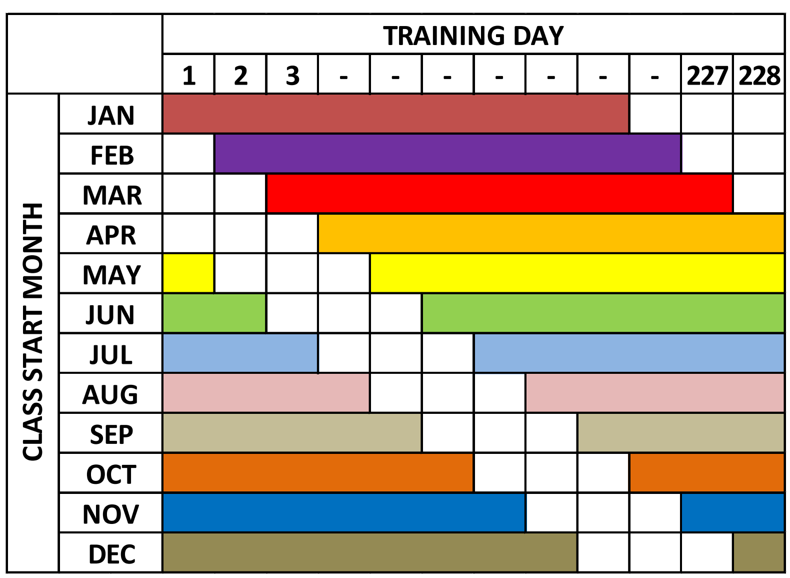

Figure 2. Training Year Class Progression.

For clarity, only a portion of the training year is illustrated in Figure 2. The basic premise is that at any given point in the year, there are different classes of students conducting different events based on their place in the syllabus. This is important because it shows how the different levels of progress for each of the classes of students leads to a randomly distributed number of events, and therefore also device types, that are required on any given day.

Moving toward each specific training day over the course of the year, Table 2 focuses in on how the distribution for the number of events of each simulator type on each training day was calculated. It should be noted that the section depicted in Table 2 is not an actual section that was used in the formulation of the input distributions, but rather created to illustrate the method in a clearer form for this thesis.

Table 2. Training Day Tally Matrix.

Jan	**TRN DAY**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**	**51**	**52**
	Event	WTT 6	Day 45	WTT 7	Day 47	OFT TAC 2	TAC 2	TAC 3	Day 51	Day 52	OFT TAC 4
	Comp						Y		N	N	
	Dev						O		O	O	
	Rem						XO				
Feb	**TRN DAY**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**
	Event	FAM 6N	INST 2N	TOFT 1	DIP 1	NVD 1	SAR 2N	OFT INST X	EXAMS	TOFT 2X	FAM 9X
	Comp			Y				Y		N	
	Dev			T				O		T	
	Rem			XT				XO			
Mar	**TRN DAY**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	Event	Day 1	Day 2	Day 3	Day 4	NITE LAB	OFT 2	Day 7	OFT 4	OFT 5	Day 10
	Comp	Y		N		N					N
	Dev	W		W		O					O
	Rem	XW									
Totals	**LCT**	**1**		**1**			**1**	**1**			
	WTT			**1**							
	OFT					**1**			**1**	**1**	**1**
	TOFT									**1**	

Each class start month has the entire syllabus represented in a row, with each class starting on the corresponding day of the training year. Events that do not require a simulator (flights and classroom events, for example) serve only as placeholders for each class's progression through the syllabus. For each configuration, it was determined whether or not each syllabus event to be conducted was compatible with that particular configuration of LCT. If an event *was* deemed compatible based on the data in Table 1, it has a “Y” in the “Comp” row, signifying that it is an event compatible with the particular configuration of LCT. The next row down in each class labeled “Dev” signifies the particular device that is required to complete the event, regardless of whether or not there is an LCT in use. The third row for each class is the method used for removing tallied events for the TOFT, OFT and WTT if they are deemed compatible with the configuration of LCT. Finally, the total number of events for each simulator is tallied at the bottom of the spreadsheet. The actual spreadsheet (which contains over 250,000 cells and is therefore not included as an appendix) encompasses all 228 training days as well as all of the projected start classes for the CAT I and CAT III FRP. This was completed for all eight configurations of LCT. A control case was also developed and similarly analyzed in order to be able to provide a baseline to determine the impact of the different LCT configurations.

The results of this spreadsheet is the actual number of events for each device (WTT, OFT, LCT and TOFT) over the course of each training day, for all eight configurations of LCT. This data was then used to determine input distributions for the number of devices required to complete the events to be scheduled each day.

3. Determining Distributions for the Number of Event Types

Using the data described in the previous section allows the computation of the number of events of each type, on each training day, for all configurations of LCT. Using a histogram plot for each alternative configuration, a data-fitting analysis using Microsoft Excel yields the most compatible distribution type. For instance, Figure 3 shows the histogram data as well as the cumulative distribution function (CDF) for the OFT events in the control configuration.

OFT		
Bin	Freq	Cumulat %
0.00	37	16.23%
1.88	0	16.23%
3.77	14	22.37%
5.65	0	22.37%
7.53	62	49.56%
9.41	0	49.56%
11.30	38	66.23%
13.18	0	66.23%
15.06	39	83.33%
16.94	0	83.33%
18.83	20	92.11%
20.71	0	92.11%
22.59	11	96.93%
24.47	0	96.93%
26.36	6	99.56%
More	1	100.00%

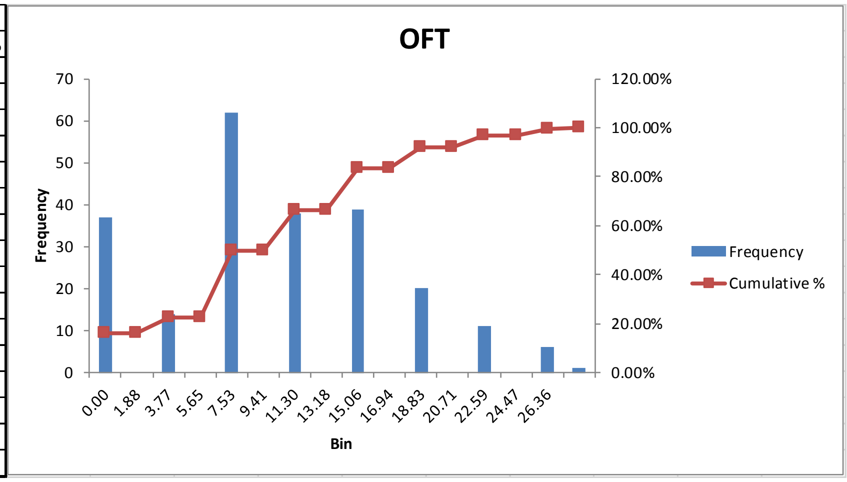

Figure 3. Histogram Data for Configuration C OFT Events.

Data analysis using Risk Simulator in Microsoft Excel yields that a triangular distribution was the best fit for all of the configurations. For this particular data, the minimum, most likely, and maximum values were determined to be -1.17, 3.37 and 28.86, respectively. To ensure the distribution data correctly represents the actual data, Risk Simulator was used for each scenario in order to compare the CDF of the distribution data to that of the empirical data used to create the histogram. The depiction of this relationship can be seen as a triangular distribution in Figure 4, and as a CDF function in Figure 5.

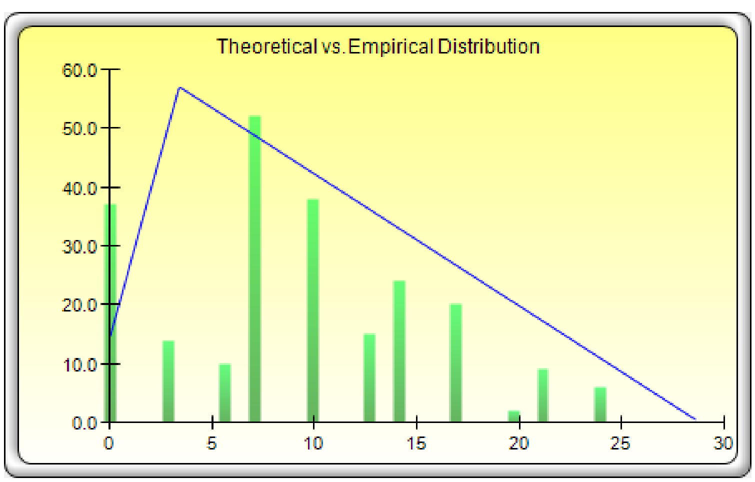

Figure 4. Triangular Distribution Plot for Configuration C OFT Events.

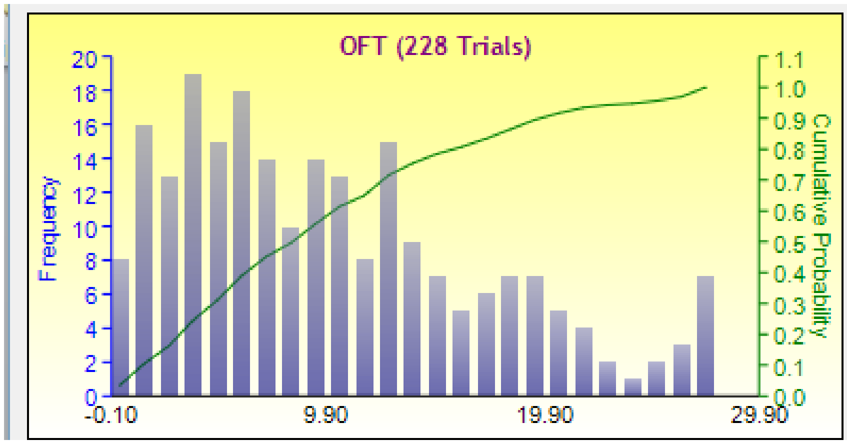

Figure 5. Risk Simulator CDF Plot for Configuration C OFT Events.

This same analysis was conducted for each event type across all LCT configurations, as well as the control configuration. Each case contains separate input distributions for the WTT, OFT, TOFT and LCT events. This led to 36 different input distributions to be used for subsequent modeling and simulation. The reason for different event distributions is due to the fact that each configuration of LCT has different capabilities. A LCT with a greater number of capabilities would have a larger number of compatible events, and a subsequent lower number of events required in the OFT, WTT and TOFT. Table 3 compiles all of the different distributions.

4. Utilizing the Input Data

The distributions in Table 3 represent the number of events corresponding to each device type on any given training day. This determination is completed for each configuration, including the control. It should be noted that a large amount of the data used for determining the distributions resulted in zero events on some of the devices on certain days. Because of this, some of the distributions resulted in the possibility of negative numbers for the number of events. While having a day with negative events is not a possibility, the negative numbers still had to be left in place to avoid changing the shape of the distribution. The simulation was designed to treat all negative numbers as zero events of that type.

Table 3. Triangular Distribution Input Data.

	Device	Min	ML	Max		Device	Min	ML	Max
CONTROL	LCT	-0.50	0.00	0.50	CONFIG E	LCT	0.74	6.26	28.32
	TOFT	-1.61	2.46	27.36		TOFT	-1.61	2.46	27.36
	WTT	-5.89	0.00	14.16		WTT	-5.89	0.00	14.16
	OFT	2.24	5.15	38.90		OFT	-8.11	0.00	21.24
CONFIG A	LCT	0.81	11.53	35.32	CONFIG F	LCT	-3.51	0.00	28.24
	TOFT	-8.40	0.00	17.66		TOFT	-1.61	2.46	27.36
	WTT	-0.50	0.00	0.50		WTT	-0.50	0.00	0.50
	OFT	-1.86	2.96	25.36		OFT	-0.35	2.79	29.32
CONFIG B	LCT	0.21	2.47	28.24	CONFIG G	LCT	-7.51	0.00	24.74
	TOFT	-3.83	0.00	21.24		TOFT	-1.61	2.46	27.36
	WTT	-5.89	0.00	14.16		WTT	-5.96	0.00	14.16
	OFT	-1.86	2.96	25.36		OFT	-0.35	2.79	29.32
CONFIG C	LCT	1.64	2.73	31.82	CONFIG H	LCT	-6.89	0.00	17.66
	TOFT	-5.56	0.00	24.74		TOFT	-1.61	2.46	27.36
	WTT	-0.50	0.00	0.50		WTT	-6.21	0.00	14.16
	OFT	-1.17	3.37	28.86		OFT	0.00	3.35	35.32
CONFIG D	LCT	-0.01	10.56	31.82					
	TOFT	-1.61	2.46	27.36					
	WTT	-5.89	0.00	14.16					
	OFT	-5.73	0.00	7.08					

F. SIMULATION MODEL STRUCTURE AND CONSTRUCTION

1. Software Selection

The principle software used in the experimentation for this analysis was ExtendSim. From a model processing standpoint, ExtendSim has the capability to effectively capture the system processes. It can create events corresponding to different device types, process the events in a device trade space utilizing the simulators as resources, and keep track of the events as they move through the system. It can also be used to model the 10% of events that do not pass through the system on the first attempt as a result of an equipment or student failure, and ensure that those failed events are passed back into the system for completion. Finally, it can run different LCT configurations within one experiment to provide a side-by-side analysis of the measures of effectiveness (MOEs).

2. Assumptions

a. Student Throughput

CAT I FRP production requirements are set by Navy Personnel Command (NAVPERS) and are based on the projected needs of the fleet. The Naval Aviator Production Process (NAPP) program is one which is used to accurately forecast these requirements; it uses a "pull" method of projection, which means that instead of basing the number of aviators selected through the commissioning source on the number of aviators who are required at that time, it anticipates the requirement for those potential aviators at the time that they will enter the fleet following flight training (Chief of Naval Operations 2001b).

This method of prediction has proven to be incredibly accurate. The HSM community uses the training requirements letter (TRL) in conjunction to the NAPP process to determine student throughput for the upcoming fiscal year, as well as the subsequent seven years. Once the total number has been determined, students are loaded on a monthly basis to start instruction at HSM-41. Generally speaking, the total loading is evenly spaced over the course of the year with one class of FRP starting each month. For example, if the FY requirement for CAT I FRP is 85, a class of seven would start each month, with one class of eight at some point over the year. This generalization will serve as an assumption for this thesis.

b. Simulator Configuration

A second assumption is that the current system of simulators in use is the one which will be used for analysis. There are plans in progress to construct new TOFT in order to increase capacity; however, this thesis will be analyzing the current TOFT in use only. It is assumed that by adding new TOFT the resultant utilization to be analyzed in this thesis could be extrapolated to future configurations, but this assumption will be left for future research projects and not analyzed within this thesis.

c. Event and Device Pairing

HSM-41 has been dealing with a thin margin of error in simulator capacity for a long time. As such, there have been a number of controls put into place to attempt to mitigate this shortfall. Due to the fact that FRACs only utilize the WTT, and FRPs utilize both OFT and WTT, the WTT is often the limiting factor when scheduling events. Because of this, Schedule Officers schedule some FRP WTT events in the OFT, provided they are compatible. Generally speaking, every WTT prior to WTT 11 is regularly scheduled in the OFT, and the model was designed to continue to incorporate this control measure.

d. Event Requirements

A final assumption is that the number of events that are required for completion of individual syllabi are going to remain constant. There are projections for future technologies to be introduced into the aircraft and thus the simulator as well, but without a detailed description of the requirements of these new systems, it was determined not to speculate and rather use the current requirements.

3. Model Flow

a. Step 1: Event Generation

Using the distribution data from Table 3, each training day a randomly distributed number of events are created. Over the course of the 16 hour work-day, each one of these events is expected to be completed by a device for which the event is compatible. Event generation occurs for OFT, WTT, TOFT and LCT events separately, and upon generation are queued into the system.

b. Step 2: Event Processing

Once an event is introduced into the system, it is sent for processing in the particular device required for that event. For example, an event that requires a WTT moves to an execution block where it utilizes a WTT device for completion. Each event uses a device for exactly two hours before being considered complete. The existing system has four OFT and four WTT devices, and represents the available resources. As an event comes to the front of a respective queue, if there is a device available, it uses the device and passes through after completion. If one is not available, the event will wait in the queue until one becomes available. For the TOFT events, a OFT and WTT are required for completion, and the event will not be processed until one of each is available.

Scheduling officers at HSM-41 use a computer based method for scheduling. While the squadron does not necessarily put the student events in a queue, the scheduling officers view the events required for the next day and place them in two-hour blocks for completion.

c. Step 3: Event Completion

Once an event is processed, it is determined whether it was a success or a failure. From historical data collection, 10% of events are not completed as a result of student failure or simulator malfunction. This 10% failure rate is introduced into the simulation as well. If an event is *not* completed, it is recycled to the queue for the following day for completion.

d. Model run Parameters

To correctly simulate the training year, the model was run for 16 hours per day, over the course of the 228 training days. Fifty iterations of this simulation were run for each configuration in order to gather output data that could show statistical significance upon which to base conclusions.

e. Output Data Collection

Two different categories of output data were collected for analysis of the simulation. The first was the utilization rates of the actual devices. Since the TOFT consists of an OFT and a WTT device, TOFT utilization was not collected as a separate parameter; rather, the usage is captured in the usage of the OFT and WTT. As the primary MOE for this project, this data is critical for basing conclusions. The second collection category was the total number of events of each type completed. This data provides the basis for comparing the total number of completed events across the different configurations. The total number of events should be reasonably the same for each configuration, and any large deviation would indicate possible errors in the input distributions. This number was also used to develop a correction factor to be discussed in Chapter IV. A flow diagram for each of the event and device types can be seen in Figure 6.

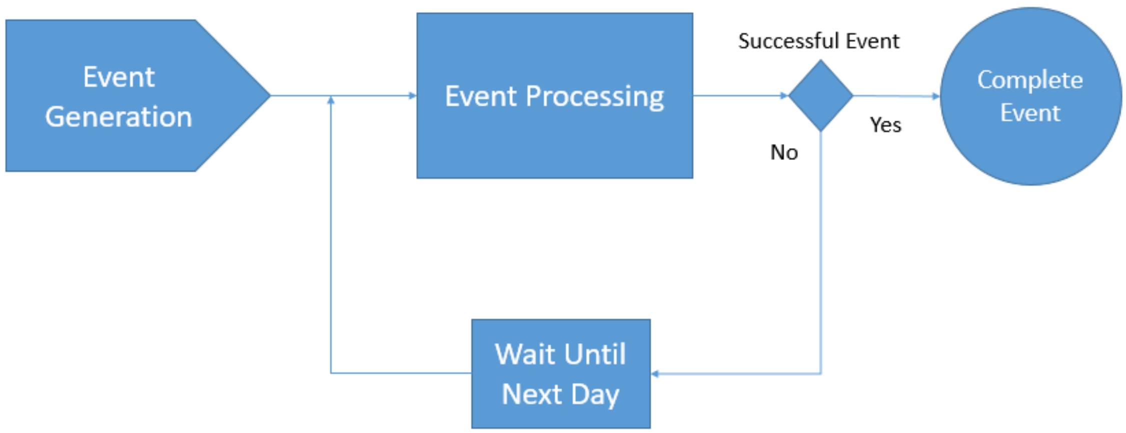

Figure 6. Event Flow Diagram.

G. SUMMARY

This chapter served as a background into the formulation of the model. First, it set out the requirements for the completion of FRS syllabus events, both generally and specifically as they related to individual sorties. Next, it looked at ways to group those capability requirements into alternative configurations of LCT. Once the LCT configurations were determined, the student throughput itself was analyzed, estimated and modeled as to how those events would flow through a model of the simulator system. Finally, it described the outputs of the system and how they relate to the measures of effectiveness.

IV. EXPERIMENTATION RESULTS AND FINDINGS

A. PURPOSE

This chapter presents the analysis and findings that result from the computer experiments in this study. First, it explains the design of the experiment as a means to efficiently explore the decision space of the problem. It then describes the summary statistics as they pertain to the measures of effectiveness, as well as a comparison of those results for the different LCT. Finally, it amplifies the significance in the differences between LCT configurations.

B. EXPERIMENTS AND DATA

Once the input distributions were determined for each LCT configuration and event type, the computer simulation parameters were prepared for the experiment. The experiment runs 50 replications of each LCT configuration and the control system, with each replication representing a training year. The replications controlled the random error that is present in the experiment. Each set of replications for each of the configurations was independent of one another. It allowed for a valid comparative analysis of the configurations.

Another decision was made to run the model with two operational LCTs for each case. The rationale for this decision was that there were some cases that could utilize more than one LCT. In the actual environment, the LCT would be scheduled by the scheduling officers to the maximum extent possible. The events would only be scheduled in the device for which they would have originally been intended if there were not an LCT available. This human component was not possible to simulate without more data. Instead, the addition of a second LCT was used as the solution, and post analysis is used to interpret the utilization rates.

C. DATA ANALYSIS

1. Summary Statistics

Table 4 presents the average value of utilization percentages for each device type based on the introduction of a LCT configuration. An important item of note is a discussion on events that must be rescheduled. While the total number of events of each type is summed to equal the total number of events *completed,* some of these events required at least two attempts to be considered complete. The simulator utilization percentages in Table 4 portray the actual usage of the devices, including those that require multiple attempts.

Table 4. Simulator Usage Rates.

	WTT USE	OFT USE	LCT USE
Control	39.05%	73.05%	0.00%
A	11.99%	39.49%	84.57%
B	28.29%	45.86%	61.10%
C	20.91%	53.04%	68.31%
D	39.10%	32.91%	79.60%
E	39.29%	44.91%	68.73%
F	29.10%	60.67%	48.87%
G	39.17%	61.54%	37.91%
H	39.20%	67.33%	25.66%

2. Calibrating Usage Rates

The fact that each configuration applies a different distribution for event creation results in a different total number of events that must be processed. They in turn affect the usage rates. It is necessary to adjust the utilization percentages. The total events created by each configuration was compared to that of the control case, and a proportion was used to recalibrate the usages. This recalibration of utilization rates are shown in Table 5.

Table 5. Adjusted Utilization Rates.

	WTT USE	OFT USE	LCT USE
Control	39.05%	73.05%	0.00%
A	11.93%	39.25%	84.04%
B	27.72%	44.81%	59.77%
C	20.37%	51.63%	66.66%
D	38.81%	32.58%	78.91%
E	38.11%	43.38%	66.41%
F	28.56%	59.62%	47.97%
G	37.88%	59.27%	36.48%
H	37.96%	65.11%	24.77%

3. Utilization Comparison

Figure 7 is the average utilization percentages for the OFT, WTT and LCT for each case. We see for the baseline system (control) that without a LCT of any type, the percent use of WTT and OFT is nearly 40% and 75%, respectively. Configuration A shows the most LCT usage with 84%, which results in much lower usage of WTT (~12%) and OFT (~40%). However, there are other configurations such as B and C that, while less utilized, still manage to reduce the use of WTT and OFT usage significantly.

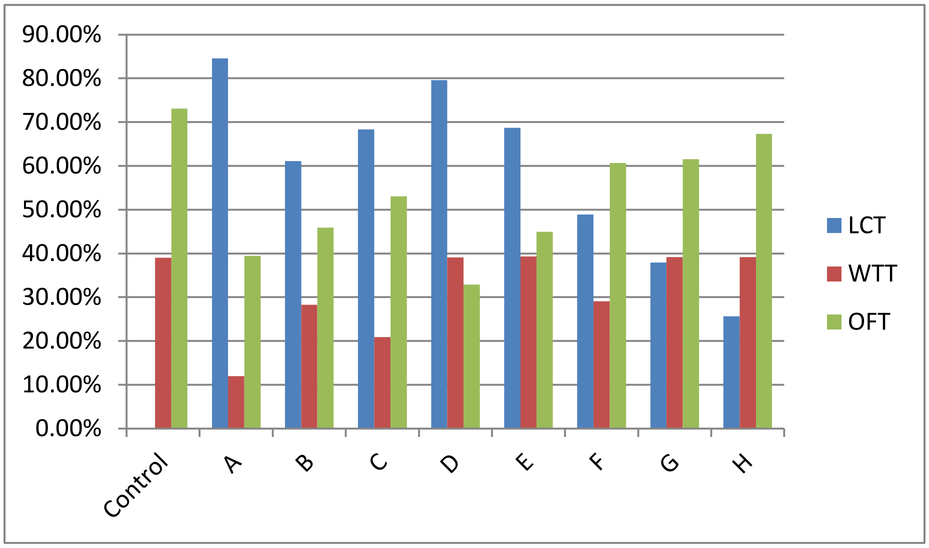

Figure 7. Average Utilization Comparison.

For a slightly different view of the data, Figure 8 shows the comparison of device *availability* between the different configurations. The availability is simply the percentage of time the devices are *not* utilized (or 100% - [usage %]). The control case is represented as a horizontal line to illustrate the impact of each LCT configuration. This data clearly demonstrates that while some configurations may be more effective at increasing device availability than others, all of the configurations of LCT have an impact. The specifics of these impacts will be made clear in the following sections.

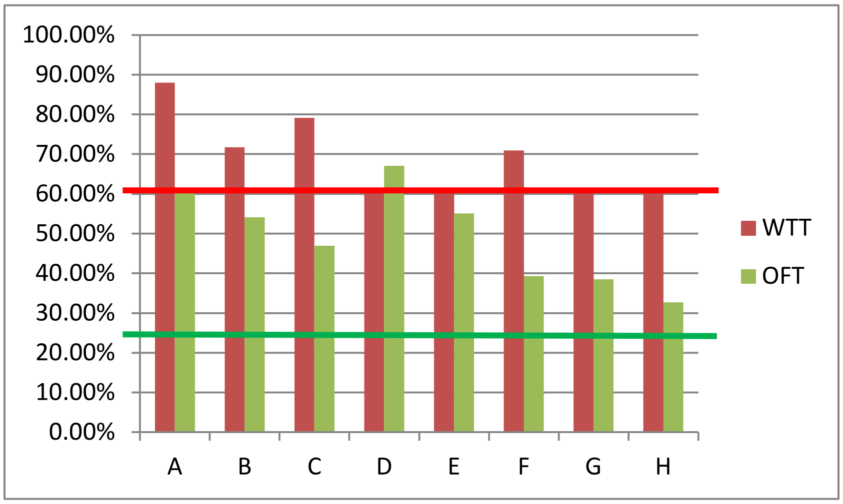

Figure 8. OFT and WTT Availability.

D. COMPARATIVE DISCUSSION OF LCT ALTERNATIVES

1. Analysis of Variances

An analysis of variances (ANOVA) tests the hypothesis that different configurations of LCT will not make any changes in the utilization percentages of WTT and OFT devices. The alternative hypothesis is that a LCT does make a difference. The ANOVA table developed for the usage rates of the WTT and OFT as a result of introducing a LCT can be seen in Tables 6 and 7. The p-value of zero in each case states that there is enough evidence to reject the null hypothesis in favor of its alternative.

Table 6. ANOVA for WTT Usage.

Single Factor: LCT Configuration	**WTT Use%**					
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Control	50	19.36865	0.387373	0.000266		
A	50	5.96458	0.119292	7.02E-05		
B	50	13.86121	0.277224	0.000143		
C	50	10.18696	0.203739	0.000159		
D	50	19.40414	0.388083	0.000182		
E	50	19.05295	0.381059	0.000167		
F	50	14.28228	0.285646	0.000163		
G	50	18.93826	0.378765	0.000182		
H	50	18.98212	0.379642	0.000193		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	***P-value***	*F crit*
Between Groups	3.80135	8	0.475169	2805.09	**0**	1.959398
Within Groups	0.074703	441	0.000169			
Total	3.876054	449				

Table 7. ANOVA for OFT Usage.

Single Factor: LCT Configuration	**OFT Use%**					
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Control	50	36.16657	0.723331	0.000251		
A	50	19.62416	0.392483	0.000158		
B	50	22.40487	0.448097	0.000102		
C	50	25.81518	0.516304	0.000269		
D	50	16.29018	0.325804	0.00019		
E	50	21.69075	0.433815	0.000244		
F	50	29.80901	0.59618	0.000228		
G	50	29.63336	0.592667	0.000219		
H	50	32.55523	0.651105	0.000134		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	***P-value***	*F crit*
Between Groups	6.810016	8	0.851252	4272.124	**0**	1.959398
Within Groups	0.087872	441	0.000199			
Total	6.897889	449				

Table 8 is an ANOVA that considers just the different LCT configurations without the control configuration of the set of simulators. It indicates that there are significant differences among the LCT configurations. Later in this chapter a discussion of the different capabilities of each LCT option and how they impact the percentage of use of OFT and WTT devices is presented. This set of ANOVA tables supports the conjecture that a LCT can adequately explain a large part of the variances in the use rates of OFT and WTT simulators in the model.

Table 8. ANOVA for LCT Usage.

Single Factor: LCT Configuration	**OFT Use%**					
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
A	50	42.01775	0.840355	0.000198		
B	50	29.88295	0.597659	0.000432		
C	50	33.3309	0.666618	0.000596		
D	50	39.45597	0.789119	0.000293		
E	50	33.20558	0.664112	0.000277		
F	50	23.98577	0.479715	0.000557		
G	50	18.24059	0.364812	0.000679		
H	50	12.38667	0.247733	0.000314		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	***P-value***	*F crit*
Between Groups	14.65781	7	2.093973	5006.652	**0**	2.032949
Within Groups	0.163949	392	0.000418			
Total	14.82176	399				

2. Comparative Outputs

Figure 9 compares the box plots of WTT and LCT usage. The comparison illustrates how an increase in the usage of the LCT corresponds to a decrease in the usage in the WTT. For instance, LCT A has a nearly 84% use rate as shown on the right hand side of the chart. Associated with this result on the left hand side of the chart is a drop in the WTT use rate from nearly 40% in the control case to less than 15% when LCT configuration A is introduced into the set of simulators.

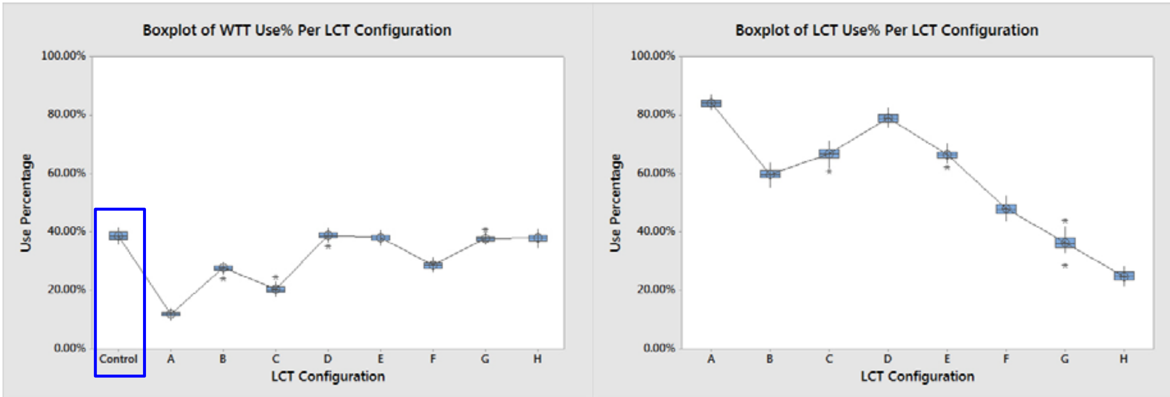

Figure 9. Box Plot of WTT Usage versus LCT Usage.

Similar to Figure 9, Figure 10 presents a comparison of OFT and LCT usage. Again, using LCT A as an example, there is a significant drop in the control case's use rate for the OFT devices when this configuration is introduced. These results will be further analyzed in detail later in this chapter.

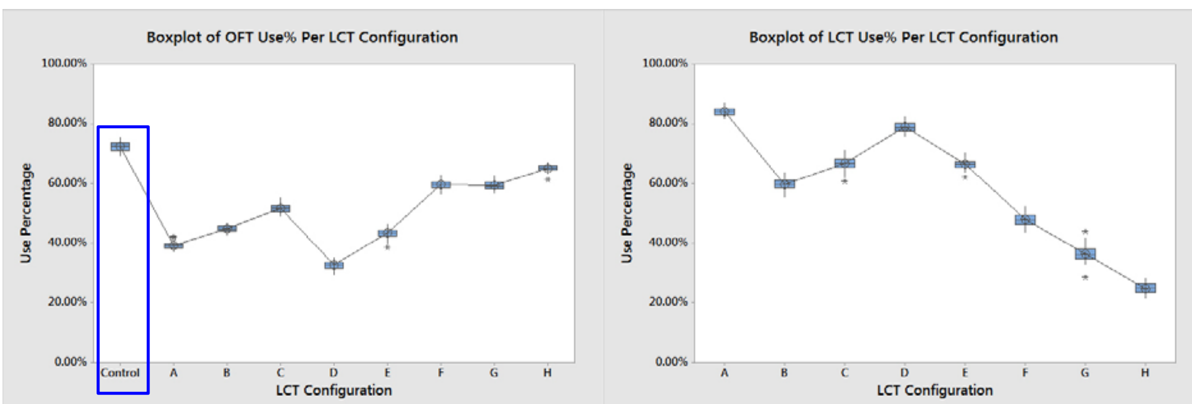

Figure 10. Box Plot of OFT Usage versus LCT Usage.

It should be noted that since no configuration was designed to be *exactly* a WTT or OFT, that there is not an *exact* correlation of usage for any one device type. This means that just because the usage in the LCT went up by a certain percentage, it cannot be assumed that the usage in either the OFT or WTT went down by the same. The impact of the LCT must be viewed on the system as a whole.

3. OFT Utilization

A number of LCT configurations (Table 1) provided an increase in OFT availability. Configuration A is the closest resemblance to a TOFT in capabilities, and is therefore most capable of decreasing the utilization in the OFT and WTT. Likewise, Configuration D most closely resembles an OFT, and therefore has the capability to lower the OFT utilization with greater effectiveness than the other configurations.

Configurations B and E have OFT utilization near 40%, and therefore provide just slightly less utility than A and D. The capabilities of Configurations B and E, on the other hand, are very different (see Table 1): Configuration B is essentially a tactical trainer for pilot events only (with no aircrew interface and LCD visuals) and Configuration E does not have much tactical utility but can be used as a pilot procedural trainer. The fact that these two very different configurations similarly ease OFT utilization illustrates the need for further investigation of alternative configurations, with a careful analysis of individual capabilities.

Configurations F, G and H each do not have visuals, and therefore are only capable of completing WTT events. It may look as though the data is incorrect, as each configuration is incapable of completing any OFT events so should have the same OFT utilization rate as the control. Recall that the OFT device is used to complete some of the WTT events; it is still capable of decreasing OFT utilization.

4. WTT Utilization

While the WTT utilization percentages do not change as drastically as the OFT with the introduction of the different configurations of LCT, there are some significant differences worth noting. With Configuration A most closely resembling the capabilities of the existing TOFT, it has the most significant reduction in capacity requirements for the WTT. This is only true if there is more than one LCT in the system. If the desired system is only able to have one LCT, further analysis would be required to determine the specific impact that this would have on the individual utilization of each device type.

Configuration C is the outlier among the remaining configurations with a utilization percentage of just under 20%. A major reason for this result is that it has functioning controls and displays for the pilots, as well as acoustics and an aircrew interface. This combination of capabilities makes it useful for a wide range of events. Configurations B, D, E, F, G, and H each provide a utilization break of roughly less than 10% over the existing system. The scheduling officer's strategy of scheduling WTTs 1 through 10 in the OFT dampens the effect of LCT capabilities on the WTT utilization percentages. The overall result is that the LCT does not affect OFT use rate as much.

5. LCT Utilization

Study of the LCT utilization confirms that a more capable LCT can complete more events and therefore decrease the utilization of the OFT and WTT. Initial observation of the numbers in Tables 4 and 5 might drive the conclusion that adding a LCT of Configuration A would be the "best" solution to improve OFT and WTT utilization. Recall, however, that a second LCT was added into the system to accurately model the degree that an LCT could be used. All LCT configurations with the exception of F, G and H have utilization percentages above 50%. This means that while the rest of the configurations may provide for a greater decrease in OFT and WTT utilization, this effect can only be reached with more than one LCT.

One way to use post-processing analysis to understand the effect of only having one LCT in the system is to translate the usage percentage into hours, and compare the total number of hours utilized in the LCT to the total number of hours *saved* in the other devices. For example, configuration D was highly utilized, and had a corresponding high availability of OFT and WTT time. The total number of hours that the LCT was utilized in this configuration was 5805, and at the same time, it provided 5850 more hours of availability in the OFT and WTT than was available in the control case. Configuration B, on the other hand, was only utilized for 4458 hours, and provided an extra 5540 hours of availability in the OFT and WTT. This means that Configuration B provided more utility than adding either a whole OFT or WTT to the system. This is only one example of how to look at this data. More in-depth analysis is a subject for future studies.

E. SUMMARY

This chapter provides statistical support for incorporating a LCT into FRS system of simulators. It describes how simulation experiments are used to understand the impact of a LCT and to develop insights about the FRS capability to achieve its mission when future increases in required student throughput will stress the overall system. The assumptions and limitations of the experiment are explained, as well as the strategies used to mitigate them. Findings from the experiments show that the introduction of any number of alternative LCT into the simulator system at NAS North Island will have an impact on the utilization of the existing devices.

V. CONCLUSIONS

A. PURPOSE

This chapter revisits the research questions for this thesis. It recommends how the study can be applied to this and similar problems for managing the training cycles of students. Finally, it presents some ideas for future research into the topic that may lead to additional theses or capstone projects.

B. STUDY OVERVIEW

1. Factors Driving Problem Selection

Flight simulators make up a critical component of pilot and aircrew mission readiness. Increasing requirements to conduct more events in simulators instead of in aircraft has, and will continue to place a strain on the availability of the devices. For the MH-60R, construction of fully capable simulators is extremely expensive. As some training events do not require the full capability of the devices, it may be possible to conduct some events in a less capable device. This study was able to provide meaningful data that support this conjecture.

2. Process Used for Analysis

Computer simulation proved to be a very effective tool for analyzing the questions proposed in this thesis. After determining what groupings of capabilities would make for effective configurations of LCT, input distributions were developed to simulate a standard training day at HSM-41. Those distributions, when run through the computer model, each led to significant changes in the output parameters, which could be linked to individual configuration capabilities. Using statistical analysis, as well as qualitative insights from the model, the resulting data lends credibility to the claim that introducing a LCT could provide utility in the simulator system.

C. SUMMARY AND RECOMMENDATIONS

1. Design Parameters of the TOFT

The existing TOFT used in the MH-60R was designed to replicate the actual aircraft in every way possible: The aerodynamic modeling is the same, the input devices are the same, the mission systems operate in a simulated tactical environment, and the warning and diagnostics provide realistic EP simulation. The devices, therefore, were not designed with a specific event requirement in mind. They were designed to do everything that the aircraft can do, and provide a space for pilots and aircrew to practice procedures and tactics.

The syllabus was designed to best meet the needs of the students. Syllabus events were not developed with simulator capabilities in mind. While some events are designed to take place in an OFT or WTT, it is often the case that such events are conducted in the TOFT with its full capabilities available. As a result, the availability of the FRS simulators is strained and will likely be more so in future years as student throughput continues to increase.

2. Utility of an Alternative Training Device

The experiment contained within this thesis provided sound evidence that a LCT with certain specific capabilities could be designed to accomplish syllabus events at HSM-41. Eight different alternatives, spanning a wide range of capabilities were examined. Each case demonstrated that the use of LCTs provided an increase in availability of the OFT and WTT. These configurations were not exhaustive. The point was to determine if a LCT with less capability than the full TOFT would have value to the FRS. There is much room for further investigation into alternatives.

3. Impact of Individual Capabilities

Determining the impact of individual device capabilities, while outside of the scope of this thesis, can be done with some comparisons of configurations with similar configurations. Look at Table 1 for example: The only capability difference between Configuration A and B is the incorporation of the acoustics mission system into

Configuration A. The corresponding decrease in WTT and OFT utilization was approximately 16% and 5%, respectively. The difference between Configuration A and C is simply having both the pilot and co-pilot be provided with visuals and controls, which leads to a decrease in WTT and OFT utilization of 9% and 14%, respectively. However, the subset of building blocks of capabilities in each alternative is intertwined with other variables in the system, including the activities and strategies of the scheduling officers. Analytically determining the precise impact of each capability requires more experimentation and further analysis.

4. Analysis of Capability Groupings

Each configuration provided differing effects on OFT and WTT utilization. Configuration A, with capabilities similar to the existing TOFT, was able to be used at a very high rate, and provided the system with a large increase in OFT and WTT availability. While Configurations G and H may not have alleviated a large percentage of utilization on the OFT, the low capability levels of these configurations may lead to the assumption that they would also not be as large of an investment. Finally, Configuration B, while not providing the greatest *increase* in availability for the WTT and OFT, was able to provide the availability at a higher rate than its own individual usage: In other words, it could produce at a higher level of efficiency than other configurations. With all of these realizations, more research would be required to make any conclusions as to ideal configurations.

5. Recommendations

There are a few recommendations that could be made as a result of this analysis. First, while the capability of the TOFT devices in use is outstanding, and the training opportunity provided by the system is exceptionally close to the actual tactical environment, there are events that could be completed with a less capable device. This concept is nothing groundbreaking, as not every capability of the simulator is utilized on every event. What is unique about the outcome of this analysis is the *number* of events that could be completed in a LCT, as well as how much of an impact one would have on simulator availability. Previous suppositions were that a LCT could only be used for "button pushing." Other opinions surmise that it would only be useful for non-tactical EP training. This analysis shows that there is a wide range of utility for a LCT.

Secondly, there is a great deal of possible configurations that could be designed to complete a wide range of events at the FRS. This thesis, using the personal experiences of the author, analyzed eight possible configurations. It is highly likely that there many more possible alternatives that could be designed, modeled and analyzed in the same way. Optimization could even be used to pair different capabilities to create a configuration that could complete the most events at the least cost. What is evident is that a subset of capabilities as described in Table 1 is the foundation of a LCT that can be developed for the FRS requirements.

Finally, while more fully capable TOFT devices are in the construction phase at the time of the writing of this thesis, there is a utility in the investigation of the cost of the design and procurement of an LCT. The capacity requirements for the MH-60R are only projected to increase as more events are moved to the simulator, and this study shows that having a lower cost device capable of completing events that do not require the full capability of the TOFT could very well prove to be a worthwhile endeavor.

D. AREAS FOR FURTHER RESEARCH

1. Cost vs. Capacity Optimization

Due to the scope of this thesis, cost was not a consideration in the analysis. If it is ever decided that this would be something for the HSM community to pursue, a cost analysis and optimization would be the next logical step to considering the optimal configuration. If a project is considered for further analysis, the author can be reached as a resource to the modeling and spreadsheet data in raw form as a baseline of data. All resources could be made available to an interested scholar.

2. Syllabus Update or Augmentation

This thesis was designed around an analysis of the MH-60R syllabus in current form. There is nothing that says that the current syllabus is the best possible, only that it has worked thus far. If new capabilities become available, or if new requirements arise in training, there might be a utility in a re-structure or augmentation of the syllabus. If this possibility is considered, there may also be a utility in designing a LCT in conjunction with such a change. This way, a device could be designed to meet the new requirements without impacting the capacity of the simulator system.

3. Deployable Proficiency

Another possible topic of further research would be the design of a LCT that has the capability of being deployed with units. In the current deployment model, all of the training requirements while deployed must be met in the aircraft. There are some not widely utilized devices that allow for aircrew to conduct tactical missions on deck, but if a LCT could be designed to meet the needs of some FRS syllabus events, as well as fleet events, such a trainer might have some utility as a deployable trainer. An analysis of this would be an area of further research into this topic.

4. Other LCT Utilities

Finally, the scope of this thesis was on the MH-60R FRS. There are other aviation communities, as well as other sources of utilization within the HSM community that were not analyzed. The same principles applied to this thesis could easily be applied to other entities in order to better understand the utility of a LCT. All of the models and data can be made available by the author if another interested party is looking to conduct such research.

E. FINAL THOUGHTS

There have been many debates of whether or not a LCT would be of value to the HSM community. Such discussions were often conducted within short time periods and with limited analysis outside of the subject matter expert opinions of the involved parties. Opposition to the idea of a LCT emanated from limited experience with less capable simulators. Gathering analytic evidence to help groups such as MH-60R FRS instructors recognize the value of a device less capable than the TOFT is a major objective for this thesis. The careful compilation and analysis of data within this thesis provides grounds for further investigation into the matter.

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APPENDIX A. CAT I EVENT REQUIREMENT TABLE

	CAT I	Cockpit switches/circuit breakers	Full Visuals	Dual LCD Displays	Single LCD Display	Dual Functioning Controls	Single Functioning Controls	Single Keyset/Displays	Dual Keysets/Displays	Aircrew Interface	Acoustics	MTS	Mission Systems
OFT 1	Engine Starts, T/O, Landing, Running Landing	X	X			X			X				
OFT 2	Course Rules, Review Previous FAM	X	X			X			X				
OFT 3	Fuel Dump, Fire, FAM	X	X			X			X				
OFT 4	Engine EPs, FAM	X	X			X			X				
OFT 5	Oil Eps, Engine Air Restart, FAM	X	X			X			X				
OFT 6	Utility Mode, Autos, T/R EPs, FAM	X	X			X			X				
OFT 7	Quick Stop, Hyd EPs, Boost Off, FAM	X	X			X			X				
OFT 8	AFCS EPs, Stab, FAM	X	X			X			X				
OFT 9	Electrical EPs, FAM	X	X			X			X				
OFT 10	All Review	X	X			X			X				
WTT 1	Plan Bezel Key							X					
OFT 11	Instrument Procedures (BI, Approaches, Inst T/O)	X				X			X				
OFT 12	SAR Procedures	X	X			X			X				
TOFT 1	Dipping Procedures	X	X			X			X	X			X
TOFT 2X	Pre-NATOPS	X	X			X			X	X			X
O-NATOPS	NATOPS	X	X			X			X				
OFT DLQ 1	Air Capable Ship Procedures, RA, ELVA, Shipboard EPs	X	X			X			X				
OFT DLQ 1	Aviation Ship Procedures, T/R Shipboard EPs	X	X			X			X				
WTT 2	IFF, MMR, TAID CTRL							X					X
WTT 3	MMR, Mission/Weapons Checks	X						X					X
WTT 4	Hawklink, ISAR							X					X
WTT 5	ARPDD							X					X
WTT 6	ESM, Data Fusion							X					X
WTT 7	L16							X					X
OFT TAC 1	Sensor Review in OFT	X		X		X			X			X	X
OFT TAC 2	TACFORM, all systems are review items	X	X			X			X			X	X
WTT 8	MTS operations							X				X	X
OFT TAC 4	MTS operations	X		X		X		X				X	X
TOFT 3	Search, Detect, Classify and ID	X		X			X		X	X		X	X
OFT TAC 5	ISD, SACT	X	X			X			X			X	X
WTT 9	Hellfire, Ordnance CTRL	X						X				X	X
TOFT 4	Hellfire Autonomous	X		X			X		X	X		X	X
WTT 10	Hellfire Remote	X						X				X	X
TOFT 5	SSC, Hellfire	X		X			X		X	X		X	X
TOFT 6	Section Attack	X		X			X		X	X		X	X
TOFT 7	SCAR	X		X			X		X	X		X	X
TOFT 8	Surface Engagements	X		X			X		X	X		X	X
TOFT 9	Surface Engagements	X		X			X		X	X		X	X
TOFT 10X	SUW Chekride	X	X			X			X	X		X	X
WTT 11	Dipping Sonar Functions							X		X	X		X
WTT 12	Sonobuoy Procedures							X		X	X		X
WTT 13	Sonobuoy Processing (1)							X		X	X		X
WTT 14	Sonobuoy Processing (2)							X		X	X		X
WTT 15	Dipping/Sonobuoy Combined Processing							X		X	X		X
TOFT 11	ASW Search	X			X		X		X	X	X	X	X
WTT 16	Torpedo Procedures	X						X		X	X		X
TOFT 12	Passive Attack	X			X		X		X	X	X	X	X
TOFT 13	Active Attack	X			X		X		X	X	X	X	X
TOFT 14	ASW Search and Attack	X			X		X		X	X	X	X	X
TOFT 15	ASW Screen Tactics	X			X		X		X	X	X	X	X
TOFT 16	Dual-Dipper Operations	X			X		X		X	X	X	X	X
TOFT 17	ASW Review	X			X		X		X	X	X	X	X
TOFT 18X	ASW Checkride	X	X			X			X	X	X	X	X
OFT 13	EP Review	X	X			X			X				

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APPENDIX B. CAT III EVENT REQUIREMENT TABLE

	CAT III	Cockpit switches/circuit breakers	Full Visuals	Dual LCD Displays	Single LCD Display	Dual Functioning Controls	Single Functioning Controls	Single Keyset/Displays	Dual Keysets/Displays	Aircrew Interface	Acoustics	MTS	Mission Systems
OFT 2	Course Rules, Vertical T/O, Running Landing, Start Checks	X	X			X			X				
OFT 4	Fuel, Fire, Engine EPs, FAM	X	X			X			X				
OFT 5	Max GW T/O, Oil EPs, FAM	X	X			X			X				
OFT 6	T/R EPs, FAM	X	X			X			X				
OFT 8	Electrical Eps, FAM	X	X			X			X				
WTT 1	Plan Bezel Key							X					
OFT 11	Instrument Procedures (BI, Approaches, Inst T/O), SAR	X	X			X			X				
TOFT 1	Dipping Procedures	X	X			X			X	X			X
TOFT 2X	Pre-NATOPS	X	X			X			X	X			X
O-NATOPS	NATOPS	X	X			X			X				
OFT DLQ 1&2	Air Capable/Aviation Ship Procedures, RA, ELVA, Shipboard EPs	X	X			X			X				
WTT 5	MMR, IFF, ARPD, ISAR Hawklink (51 Introduce Items)							X					X
WTT 6	ESM, Data Fusion, MMR Review (23 Introduce Items)							X					X
WTT 7	L16 (22 Introduce Items)							X					X
OFT TAC 2	TACFORM	X	X			X			X			X	X
OFT TAC 4	ISD, SACT	X		X		X		X				X	X
WTT 9	MTS, Hellfire (11 Introduce Items)	X						X				X	X
TOFT 5	Hellfire Employment	X		X			X		X	X		X	X
TOFT 7	SCAR, Section Attack	X		X			X		X	X		X	X
TOFT 9	SUW Review	X		X			X		X	X		X	X
TOFT 10X	SUW Checkride	X	X			X			X	X		X	X
WTT 11	Dipping Sonar Procedures (21 Introduce Items)							X		X	X		X
WTT 13	Sonobuoy Procedures (39 Introduce Items)							X		X	X		X
WTT 16	Torpedo Procedures	X						X		X	X		X
TOFT 12	Passsive Attack	X			X		X		X	X	X	X	X
TOFT 13	Active Attack	X			X		X		X	X	X	X	X
TOFT 15	Screen Tactics	X			X		X		X	X	X	X	X
TOFT 16	Dual Dipper, ASW Review	X			X		X		X	X	X	X	X
TOFT 18X	ASW Checkride	X	X			X			X	X	X	X	X
OFT 13	EP Review	X	X			X			X				

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APPENDIX C. CAT I TRAINING DAYS

TRN DAY	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Event	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	OFT 1	Day 12	Day 13	Day 14	OFT 2	OFT 3	Day 17	FAM A	OFT 4	NITE LAB	OFT 5
TRN DAY	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
Event	Day 22	OFT 6	Day 24	FAM B	OFT 7	Day 27	Day 28	OFT 8	FAM C	OFT 9	Day 32	Day 33	FAM 0	OFT 10	FAM 1	FAM 2	FAM 3	FAM 4	FAM 5	Day 41	HITS
TRN DAY	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63
Event	HITS	WTT 1	OFT 11	FAM 6N	INST 1	INST 2N	OFT INST X	Day 50	Day 51	Day 52	Day 53	OFT 12	SAR 1	Day 56	Day 57	TOFT 1	DIP 1	NVD 1	SAR 2N	EXAMS	FAM 7
TRN DAY	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84
Event	FAM 8	TOFT 2X	FAM 9X	OFT NATOPS X	NATOPS X	Day 69	Day 70	FAM 10	Day 72	Day 73	Day 74	OFT DLQ 1	OFT DLQ 2	FDLPs	DLQ 1	DLQ 2	INTEL G/S	Day 81	Day 82	Day 83	ISAR SCHOOL
TRN DAY	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105
Event	ISAR SCHOOL	ISAR SCHOOL		WTT 2	WTT 3	Day 89	WTT 4	WTT 5	Day 92	Day 93	WTT 6	Day 95	Day 96	WTT 7	OFT TAC 1	TAC 1	Day 100	OFT TAC 2	TAC 2	NVD 2	NVD 3
TRN DAY	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126
Event	TAC 3	Day 106	Day 107	Day 108	Day 109	OFT TAC 4	TAC 4	Day 112	Day 113	TOFT 3	Day 115	Day 116	Day 117	DTTT 1	WTT 8	WTT 9	TOFT 4	WTT 10	OFT TAC 5	TOFT 5	TAC 5
TRN DAY	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147
Event	TOFT 6	TOFT 7	TOFT 8	Day 134	TOFT 9	TOFT 10X	TAC 6	OCEANOGRAPHY DAY 1	OCEANOGRAPHY DAY 2	OCEANOGRAPHY DAY 3	DAY 135	Day 136 ASW GS	Day 137	Day 138	Day 139	Day 140	WTT 11	WTT 12	WTT 13	WTT 14	WTT 15
TRN DAY	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168
Event	TOFT 11	Day 147	Day 148	Day 149	WTT 16	TOFT 12	TOFT 13	Day 159	TOFT 14	TAC 7	Day 162	Day 163	TOFT 15	TOFT 16	Day 166	Day 167	TOFT 17	TOFT 18X	TAC 8	OFT 13	FIREFIGHTING

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APPENDIX D. CAT III TRAINING DAYS

TRN DAY	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Event	Day 1	Day 2	Day 3	Day 4	NITE LAB	OFT 2	Day 7	OFT 4	OFT 5	Day 10	Day 11	OFT 6	OFT 8	WTT 1	FAM 0-2	FAM 4	FAM 5	HITS	HITS	Day 20	OFT 11
TRN DAY	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
Event	FAM 6N	INST 2N	TOFT 1	DIP 1	NVD 1	SAR 2N	OFT INST X	EXAMS	TOFT 2X	FAM 9X	OFT NATOPS X	NATOPS X	Day 33	OFT DLQ 1 & 2	FDLP's	DLQ 1	DLQ 2	INTEL G/S	Day 41	Day 42	WTT 5
TRN DAY	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63
Event	WTT 6	Day 45	WTT 7	Day 47	OFT TAC 2	TAC 2	TAC 3	Day 51	Day 52	OFT TAC 4	TAC 4	Day 55	WTT 9	TOFT 5	TOFT 7	TOFT 9	TAC 6	TOFT 10X	OCEANO I	OCEANO II	OCEANO III
TRN DAY	64	65	66	67	68	69	70	71	72	73	74	75	76	77							
Event	Day 65 ASW GS	Day 66	Day 67	WTT 11	WTT 13	DAY 70	WTT 16	TOFT 12	TOFT 13	TAC 7	TOFT 15	TOFT 16	TOFT 18X	OFT 13							

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