SORTIE GENERATION SIMULATION OF A FIGHTER SQUADRON

THESIS

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Abstract

The Turkish Air Force utilizes several fighter squadrons to enhance its military capabilities. One of the most critical challenges for these squadrons is generating sorties to meet the currency and demand during both peacetime and wartime. This sortie generation process directly affects the success of both training and operations. In this study, this process is assessed using a discrete event simulation.

Air Force decision makers require a simulation tool to conduct "what-if" analysis on how potential changes in the environment affect an F-16 fighter squadron's sortie generation process. Creating a usable simulation provides decision makers with a flexible tool to analyze and evaluate the possible scenarios. The model assists in determining new concepts to provide benefits over current systems. These benefits may include increased operational availability and better system performance.

To my wife and son for their loving support, patience, and for understanding of the long hours I spent working and to Family for their encouragement and love – Thank you all.

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Abdurrahman Sevimli

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SORTIE GENERATION SIMULATION OF A FIGHTER SQUADRON

I. Introduction

1.1. General Issue

Turkey is a strong member of NATO with its significant military superiority. Aviation is the leading factor to keep this current military presence strong. Aviation technology is the pioneer of the advanced technologies. Rapidly advancing aircraft technologies both increase mission effectiveness and require advanced planning. To support the technological advancement, planning tools must also be considered. The Air Force needs tools allowing analysis and evaluation of the sortie generation process.

Turkish Air Forces have several fighter squadrons including F-16s. During peace and war all the squadrons need to generate sorties to meet the currency and requirements. The sortie generation process directly affects the success of both training and operations. To better assess the sortie generation process requires a model and a simulation program. A simulation provides decision makers with a flexible tool to analyze and evaluate the sortie generation process. This thesis builds a discrete event simulation tool of the current sortie generation process. This tool allows decision makers to perform what-if analyses to determine new concepts to provide benefits over current systems. These benefits may include increased operational availability and better system performance.

1.2. Problem Statement

Air Force decision makers need a simulation tool to study the effects of what-if analyses emerging with the change of the current sortie generation process on an F-16 fighter squadron. The simulation model developed in this research provides the capability to analyze and evaluate changes in operating policy, available aircraft, available pilots, and other factors affecting the sortie generation process for a typical F-16 squadron.

1.3. Research Objectives

Our model is built in Simio which is an object oriented simulation tool. We start with 100% availability of modeled resources to see the maximum sortie generation. Then we modify our baseline model to evaluate different scenarios and check the change in the number of generated sorties and other performance metrics. Simio simulation software enables better decisions by providing decision makers the impact of proposed changes before they are implemented.

1.4. Research Focus

This study focuses on the sortie generation process modeled in Simio. After getting the results, Simio allows us to analyze and remove risk from our sortie generation process. Our simulation provides insight to improve process performance by maximizing sortie generation for our scenarios by intelligent use of critical resources and risk reduction associated with operational decisions.

1.5. Investigative Questions

All countries make operational plans with taking the threats' targets into account. Missions planned for killing and defending the targets must be executed with the needed resources. Therefore, the resources must be determined and the flight schedules must be generated. In this study we generate fixed flight schedules using a Decision Support

Software (DSS) and random flight schedules in terms of the resources. We used these flight schedules in our sortie generation process model created in Simio. In this study we look for answers to the following questions:

- **Question 1:** Given a baseline sortie generation process in Simio with fixed flight schedules and defined resources, how do ground, air, and weather abort rates affect sortie generation?

- **Question 2:** Given a sortie generation process in Simio with random flight schedules and defined resources, how do ground, air, and weather abort rates affect sortie generation? How does removal of the mission planning affect sortie generation process?

- **Question 3:** How does a reduction in pilots at different ratings affect the sortie generation process?

1.6. Thesis Organization

This thesis is organized in five chapters. In this chapter we describe the problem statement along with our research objectives and scope. Three different questions were formed to analyze the change in sortie generation using our simulation created in Simio. Chapter two reviews the previous research regarding the sortie generation process with a focus on flight scheduling and simulation. Chapter three defines the structure of the model, how it is built in Simio, and gives some detailed information of the model. In chapter four, model results and conclusions are presented. The last chapter pulls together highlights from all chapters and makes some conclusions and recommendations for future research.

II. Literature Review

2.1 Chapter Overview

The sortie generation process is driven by the sortie schedule. The process of scheduling aircraft is an iterative process which includes annual, quarterly, monthly, and weekly scheduling meetings. This chapter summarizes the literature on flight scheduling and sortie generation to learn how to implement similar applications to the sortie generation process. The literature review includes the following areas: the sortie generation process, recent research on flight scheduling, and other simulation projects in the area of sortie generation.

2.2 Sortie generation process

The complexity of computing sortie rates is more than a mere spreadsheet task, and to collect an abundance of data for large models reduces the commander's flexibility, responsiveness, and ability to create alternative options. Thus, a requirement for a generic sortie model with simple operational input and quick turnaround will help the entire Air Force and contribute significant operational insights that add realism to the planning process. This was the motivation for developing a generic sortie generation rate model (Harris, 2002). The process is cyclical in nature; Figure 1 shows the typical process.

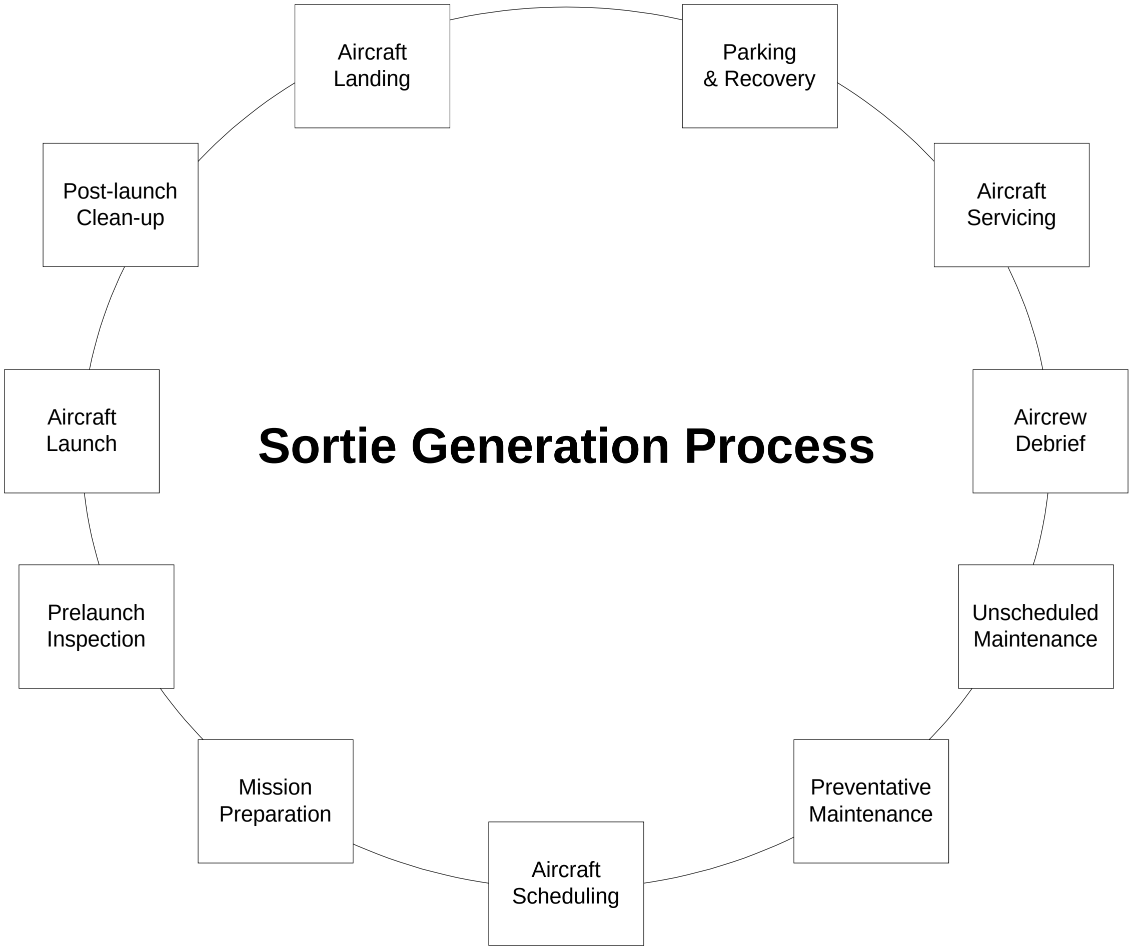


Figure 1. Sortie Generation Process (Faas, 2003)

The starting point is generally considered to be the aircraft landing. After moving to the parking location and engine shutdown, post flight servicing is conducted, while the aircrew conducts their debriefings to the maintenance crew. Numerous routine maintenance functions are required to ready the jet for the next mission, followed by any unscheduled maintenance derived from the recorded faults collected during the flight. The aircraft are prepared for flight by the ground crews; the pilots then load the assigned mission, take-off, perform the mission, and land to the complete the cycle (Faas, 2003).

2.3 Recent Research on Flight Scheduling

Multiple studies on squadron flight schedules have been done by past researchers. Most of the research observed in this literature review focuses on training squadrons instead of fighter squadrons. It is important to understand the differences in personnel and requirements between the two different types of squadrons. Overall, the complexity and difficulty of scheduling issues for training squadrons is less than fighter squadrons. In order to properly understand the flight scheduling problem, it is crucial to understand these differences and how they change the problem. This section presents a thorough overview on past research efforts to improve flight scheduling.

2.3.1 Nguyen's research

Nguyen's (2002) research attempts to solve the flight scheduling problem by creating a Microsoft Excel VBA tool to maximize the number of sorties while meeting training requirements for a training squadron. His Squadron Scheduling Decision Tool (SSDT) utilizes previous work by Belton and Elder (1996) by implementing a heuristic engine to influence search, preference, and performance criteria. Nguyen's tool gives the scheduler the ability to interact with generated schedules until a satisfactory schedule is built. In addition, the tool was an updated version of previous scheduling tools which removed the need for new training. Finally, the tool allows the scheduler to manually prioritize specific flights over other flights depending on training requirements (Nguyen, 2002).

2.3.2 Aslan's research

Another interesting study on flight scheduling is Aslan's (2003) research focusing on an F-16 training squadron. Similar to Nguyen's (2002) study, Aslan also developed a tool to improve daily training schedules. Moreover, the tool is based on a bottleneck heuristic and also allows the user to edit the schedule based on their preferences. The main disadvantage of this method is that the scheduler is not allowed to make any arrangements after the schedule is built (Aslan, 2003).

2.3.3 Boyd, Cunningham, Gray, and Parker's Research

These authors (Boyd et al., 2006) attempted to solve the flight scheduling problem using a network flow model to set up the weekly flight schedule for a fighter squadron in Germany. The main strategy was to split each workday as morning scheduled flight windows (AM GOs) and afternoon scheduled flight windows (PM GOs). The researchers found that splitting into these additional sections increases the number of variables dramatically, pushing the Premium Solver Platform software past its limit. The main finding from this study understands the complexity and constraints in flight scheduling for fighter squadrons (Boyd et al., 2006).

2.3.4 Newlon 's Research

Newlon's (2007) research attempts to go where Boyd et al. (2006) left off in creating a mathematical model of the scheduling process for fighter squadrons. While Boyd et al. (2006) aimed to split the workday into two sections, Newlon (2007) partitions the workday into hourly sections by taking these constraints as sub problems of the overall problem. Due to having a less complex problem and relatively lower number of variables, an optimal solution can be found using standard optimization software. However, there are many occurrences where the tool presents an infeasible solution and does not take into account pilot availability and unavailability. Finally, unlike the other tools discussed in this literature review, Newlon's (2007) research does not consider manual inputs from the scheduler because of the fighter squadron's nature and need for operational flexibility.

2.3.5 Gokcen 's Research

Gokcen's (2008) research is another study on scheduling which generates robust flight schedules for fighter squadrons. Gokcen tries to develop a weekly schedule by producing multiple schedules and comparing these generated schedules according to the expected number of real-time updates to capture the potential daily changes. Following the comparison phase, candidate schedules are sorted with respect to the number of updates and the schedule with the minimum number of updates is accepted as the best schedule (Gokcen, 2008).

Gokcen's (2008) primary objective is developing a schedule that has the smallest probability of being re-arranged or the smallest probability of assigning alternate pilots. To achieve this goal, he introduces some simplifying assumptions to reduce the scope of the problem that have practical implications. For instance, the number of flown sorties is limited to six flights. Since Gokcen (2007) divides workday into morning (AM), afternoon (PM), and Night GO sections, assuming a maximum of six flights is not realistic for a fighter squadron. Furthermore, all of the flight leads are assumed to be four-ship leaders and two-ship leaders are not included in his model. In most of the fighter squadrons the number of four-ship leaders is almost the same as the number of two-ship leaders. As a result, the number of scheduled two-ship missions is high in the flight schedule. Moreover, Gokcen (2008) assumes that the squadron does not have any D model (two-seated) aircraft. However, as he stated in this study, every squadron has two-seated aircraft to keep the training level as high as possible and scheduling two-seated aircraft is the most difficult part of the schedule. If a scheduler can decide two-seated aircraft assignments, the remaining sections of the schedule do not take much time (Gokcen, 2008).

2.3.6 Yavuz 's Research

Yavuz (2010) worked on automating weekly flight schedules for fighter squadrons, focusing on the Turkish Air Force. His research answers the question of which pilots to assign to predetermined missions. Data of predetermined missions include take-off time, landing time, and pilots in which category to assign to each mission. With this approach the flight scheduler selects pilots by name to fill mission slots. Therefore, Yavuz focuses on the pilot assignment portion of flight schedule (Yavuz, 2010).

2.3.7 Durkan 's Research

Following Yavuz's (2010) research on establishing a decision analysis model to evaluate pilot-mission matches, Durkan (2011) looks for a way to save additional time on building a flight schedule. He applies a Value Focused Thinking approach to his model to speed up the flight scheduling process with the support of experienced schedulers and decision makers. Durkan (2011) uses his value model to rank order pilot-mission matches at the end of his evaluation phase. His approach considers the evaluation of pilot-mission matches as a multi-objective assignment problem and claims that the decision analysis model in his research presents a relatively new solution technique (Durkan, 2011).

Durkan's (2011) model helps the scheduler to manually build flight schedules with the focus on a specific time frame like a block or a day. He summarizes the process of the model in three steps and sets his goal to achieve the first two steps. These three steps are:

i. Building an evaluation model using VFT (Defining objectives and values).

ii. Using the evaluation model structure to aid the scheduler in manually building schedules (Decision Support System).

iii. Automating the process of pilot-mission assignment with the help of defined values and objectives.

Durkan (2011) asks the question of "What is the value of a pilot-mission match in a specific block of time?" to start his methodology. The value of a particular pilot-mission match comes from the four major measures shown in Figure 2 (Durkan, 2011).

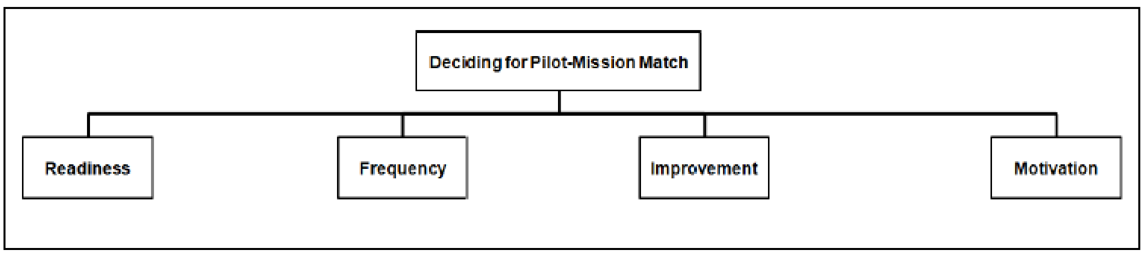


Figure 2. Four Major Values for Pilot-Mission Match (Durkan, 2011)

He cites measures for each major value branch and their value functions for evaluation. Preferences of decision makers and subject matter experts are considered to construct value functions to get results close to real life. In the construction phase of his value functions, Durkan uses a software tool (Hierarchy Builder 2.0, Weir, J. 2008) to build the value hierarchy (Durkan, 2011).

2.3.8 Erdemir 's Research

In Erdemir's (2014) research, the main objective is to build a Decision Support System (DSS) to assist the schedulers in fighter squadrons. Scheduling in fighter squadrons is complex and time consuming due to the combination of the large number of constraints and limited number of schedulers. Also, the dynamic environment of the operations area increases the uncertainty of the problem. For this reason, building flight schedules without any supplementary tools takes a large amount of time. Thus, air forces are in need of an automated decision support system for flight scheduling (Erdemir, 2014).

In his thesis, Erdemir (2014) develops the required DSS using Microsoft Excel Visual Basic to produce flight schedules which are now made manually. To generate feasible schedules, Greedy Randomized Adaptive Search Procedures are implemented and generated schedules are scored to attain the best solution. Resulting solutions are then analyzed to evaluate performance of the DSS and scoring method (Erdemir, 2014).

In our modeling of the sortie generation process, the needed flight schedules are created via Erdemir's (2014) DSS. His tool generates the monthly schedules which are then transferred into our simulation program. More details on this process are discussed in Chapter 3.

2.4 Other simulation studies of the sortie generation process

This section highlights other simulation studies that have been conducted in the area of sortie generation. These simulation projects come from academia, small businesses, larger companies, and the government. The purpose of this section is to identify different simulation and programming techniques in order to enrich the simulation model built for this research with the most useful techniques.

2.4.1 Simulation of Autonomic Logistics System (ALS) Sortie Generation

Faas (2003) modeled a sortie generation system in Arena, focusing on the impact of an Autonomic Logistics System (ALS) with various measures of effectiveness (MOE).

As MOEs he used the Mission Capable Rate, Not-mission Capable for Maintenance and Supply, and Flying Scheduling Effectiveness. He felt that these rates would offer the best way to observe the differences between the baseline system and the ALS, and also the differences between the various ALS levels that were set-up. He analyzed the impact of ALS to the MOEs by performing a full factorial design of experiments.

2.4.2 SIMFORCE

SIMFORCE (Scalable Integration Model for Objective Resource Capability Evaluations) is a desktop decision support tool that predicts resource utilization using simulation and modeling technology (Kelley Logistics Support Systems, 2002). It calculates probable maintenance resource (people, equipment, vehicles, facilities, and parts) needs based on an Air Force Wing's operational tasking. SIMFORCE also determines the effects of reduced or increased levels of resources on sortie capability. The user can adjust operations tempo, tasking, resources and failure rates. The model captures the information on the logistics and maintenance operation and provides the output as spreadsheets and charts via Microsoft Excel. Users familiar with Excel can use the raw data to create their own unique graphs to examine different views or answer different questions.

2.4.3 LogSAM

The Logistics Simulation and Analysis Model (LogSAM) (Smiley, 1997) is built by Synergy Inc. LogSAM also simulates the aircraft sortie generation process. The model is broken down into several modules: aircraft generation, sortie generation, preflight and launch, and post flight evaluation. Added features include its ability to schedule sorties based on the Air Tasking Orders (ATOs). These ATOs describe what targets to attack along with numbers and types of aircraft to use. Synergy has also expanded LogSAM to include a module called LogBase, which simulates enemy attacks and the effect of those attacks on sortie generation capability. Both LogSAM and LogBase are interesting applications but are more applicable for a wartime scenario.

2.4.4 Simulation Model for Military Aircraft Maintenance and Availability

The Helsinki University of Technology constructed a simulation model for the use of a fleet of Bae Hawk MK51 aircraft during their normal operational use (Raivio et al., 2001). The model describes the flight policy and the main factors of the maintenance, failure, and repair processes. The model aims at a better understanding of the critical paths in the normal service activity, and thus helps to determine ways to shorten the turnaround times in the maintenance process. Model implementation with graphical simulation software allows rapid what-if analysis for maintenance designers. The authors then conducted sensitivity analysis with respect to the most important model parameters, like the average duration of the maintenance operations and the manpower capacities of the repair facilities (Raivio et al., 2001). The model was also built in Arena®.

2.4.5 Useful Approaches and Techniques

Based on the information provided above regarding other simulation studies of the sortie generation process, the following approaches and techniques were included in the development of our simulation. The first is that most of the simulation studies of the sortie generation process were built using a commercial Discrete Event Simulation (DES) tool such as Arena. This demonstrates that a tool such as Arena (Simio in our case) provides a flexible simulation environment for modeling the sortie generation process. Secondly the graphical process flow for model construction and animation features of such a tool were highlighted for ease of use and key in verification and validation efforts. Many studies also used some type of Graphical User Interface (GUI) or other feature for ease of changing model parameters for different system configurations such as setting levels of factors for a Design of Experiment. In addition, a number of studies took advantage of features for importing or exporting data to external tools such as Microsoft Excel for analysis. The Simio DES tool we are using has import and export capabilities as well as powerful analysis tools included within Simio, for ease of performing a variety of different types of output analysis.

2.5 Summary

In building a model to study the sortie generation process we begin by reviewing previous research regarding the sortie generation process with a focus on flight scheduling and simulation. The literature review in this chapter covers material on the sortie generation process, a number of recent research efforts in flight scheduling, and a closer look at previous simulation studies of this process, highlighting approaches and techniques incorporated with our research described in detail in Chapter 3.

III. Methodology

3.1. Chapter Overview

Understanding the sortie generation process significantly aids decision makers in properly executing a flight schedule to meet mission requirements. Once information is gathered for a typical fighter squadron regarding system entities and resources, we can create a model of the sortie generation process to assess and improve the execution of a flight schedule. In this study we create a simulation for the sortie generation process and use a DSS for generating flight schedules. This chapter discusses details of the sortie generation process and assumptions made in developing our simulation in Simio.

3.2. Sortie Generation Process Model

Our model simulates all of the processes a pilot is required to perform before and after a scheduled flight. Before processing a flight in our model, the resources (aircraft and pilots) and the entities (scheduled missions) must be determined. The sortie generation process consists of scheduling, mission planning, briefing, flight and debriefing phases. With the needed data gathered we built our simulation in SIMIO. The model logic is presented in Figure 3 and each of the processes and data are described in further detail below.

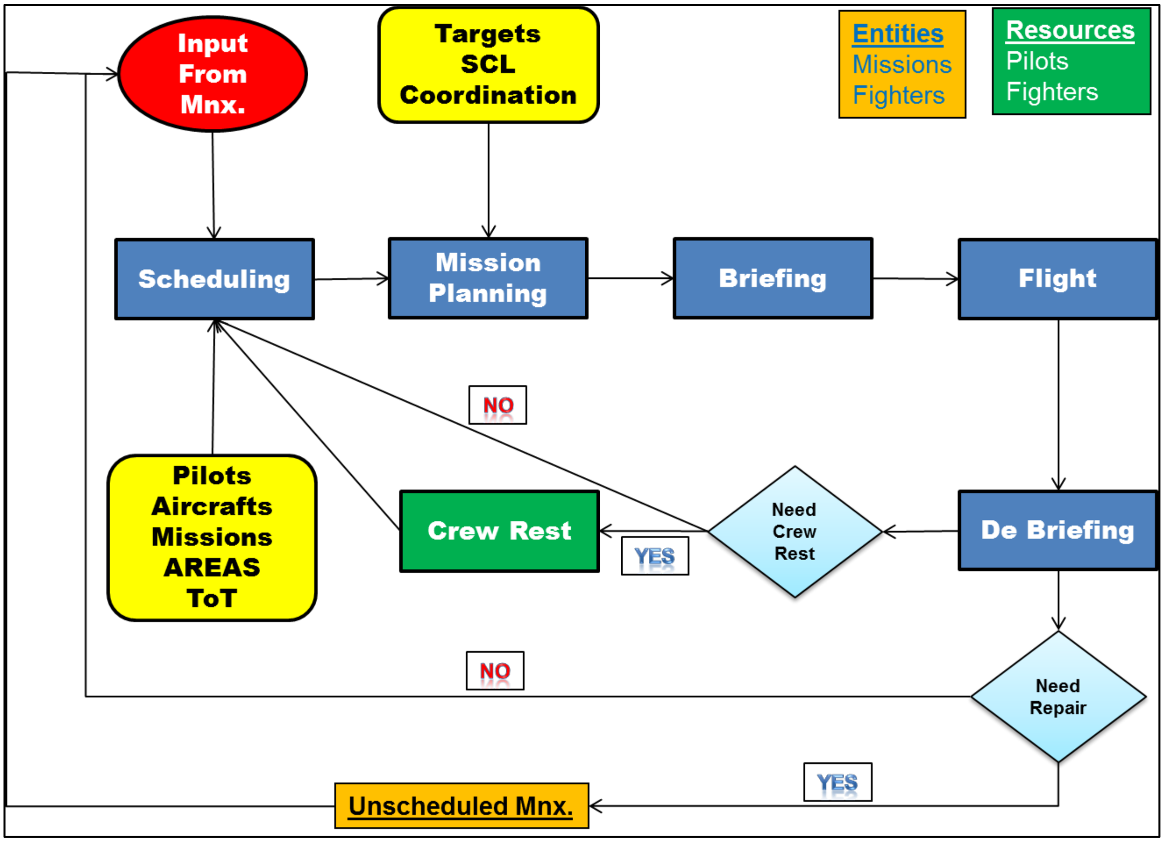


Figure 3. The Sortie Generation Process

3.2.1. Scheduling

The first requirement is generating the flight schedules. In this model we generate flight schedules both randomly and with the use of a DSS. This DSS was created in Erdemir's (2014) research. We generate monthly schedules and transfer them into Simio for creating the mission entities. The DSS includes the information that the schedulers need before generating the schedules. To illustrate what a scheduler does in producing a flight schedule, we first present some definitions regarding fighter squadron schedules. These definitions help in providing a better understanding of the DSS.

3.2.1.1. Erdemir's (2014) DSS Definitions

The definitions highlighted in Figure 4 are explained in the following sections.

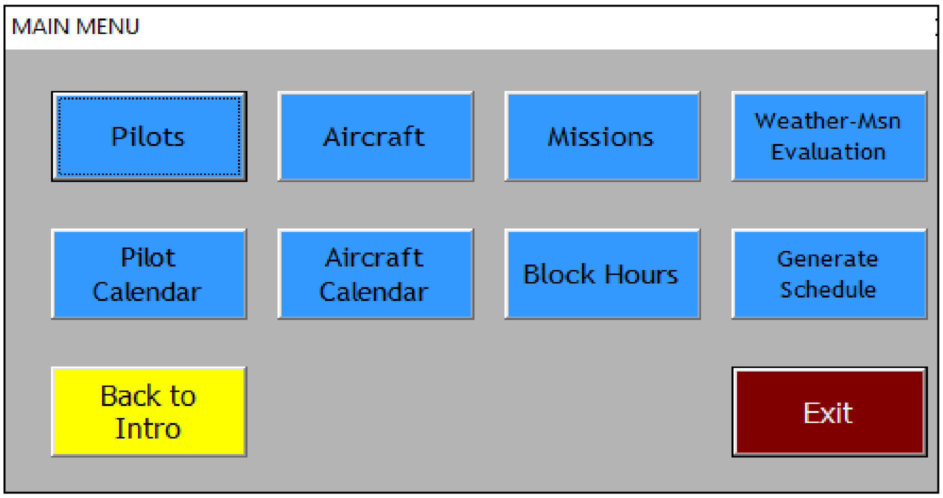


Figure 4. The Main Menu of Erdemir's DSS

3.2.1.2 Pilots

This research focuses on a typical fighter squadron. The number of pilots assigned to a squadron is determined according to the crew ratio (AFI 65-503, 2015), which is 1.25 for F-16 C/D. In fighter squadrons the total number of aircraft typically falls in the range of 15-25. For this study, we assume that the squadron has 20 aircraft for executing the missions along with 25 pilots based on the given crew ratio.

In fighter squadrons, there are four main pilot ratings determined according to flight hours and pilot skills. From the lowest to highest qualifications, these are Wingman, Two-Ship Leader, Four-Ship Leader, and Instructor Pilot. The number of pilots according to their ratings varies for each year. The menu coming from the initial DSS's window when we hit the pilots' button is shown in Table 1.

Table 1. Pilot List with Ratings

INSTRUCTOR	4-SHIP LEADER	2-SHIP LEADER	WINGMAN
LUNDAY	BRADSHAW	DAVIS	BOARDMAN
MILLER	LUCAS	KIM	CLISBY
SHALLCROSS	YILDIZ	PARK	GUNDUZ
	SEVIMLI	MCDONALD	TETRAUT
		MCLEAN	PALKO
			SALGADO
			KEVIN
			ERHAN
			AYKIRI
			YASIN
			DWYER
			AMIE
			GUZMAN

The pilots, categorized by their ratings, are shown in Table 1 which includes three Instructor Pilots, four Four-Ship Leaders, five Two-Ship Leaders and thirteen Wingmen.

Each pilot rating has a list of suitable cockpits in which that pilot can be assigned. The list of the suitable cockpits for each pilot rating is shown in Table 2 which depicts that only instructor pilots are allowed to fly D Model back cockpits.

Table 2. Pilot Ratings and Suitable Cockpits

PILOT STATUS		INSTRUCTOR	4-SHIP LEADER	2-SHIP LEADER	WINGMAN
4-SHIP MISSIONS	NUMBER 1	YES	YES	NO	NO
	NUMBER 2	YES	YES	YES	YES
	NUMBER 3	YES	YES	YES	NO
	NUMBER 4	YES	YES	YES	YES
3-SHIP MISSIONS	NUMBER 1	YES	YES	NO	NO
	NUMBER 2	YES	YES	YES	YES
	NUMBER 3	YES	YES	YES	NO
2-SHIP MISSIONS	NUMBER 1	YES	YES	YES	NO
	NUMBER 2	YES	YES	YES	YES
1-SHIP MISSIONS	FRONT SEAT	YES	YES	YES	YES
ALL MISSIONS	BACK SEAT	YES	NO	NO	NO

3.2.1.3 Aircraft

Most of the fighter squadrons (except special role squadrons) consist of one type of fighter aircraft, such as the F-16, F-22, or any other jet. These squadrons usually have two different aircraft models such as one-seated and two-seated models. In this research, one-seated and two-seated aircraft are called C and D Model aircraft, respectively. To significantly simplify our aircraft scheduling logic, we restrict our model to only one-seated aircraft and therefore have 20 F-16C fighters assigned as listed by tail number in the aircraft DSS window shown in Table 3.

Table 3. Aircraft List

AIRCRAFT LIST				
F-16C				
0001	0005	0009	0013	0017
0002	0006	0010	0014	0018
0003	0007	0011	0015	0019
0004	0008	0012	0016	0020

3.2.1.4 Missions

In general, there are two types of missions, day-time and night-time, with two sub-categories; each includes Air to Air (AA) and Air to Ground (AG) missions. The mission button on the initial DSS window leads to the menu of the missions determined for this research as shown in Table 4. Mission acronyms are defined in Table 5.

Table 4. Mission List

DAY MISSIONS		NIGHT MISSIONS	
A-A Missions	**A-G Missions**	**A-A Missions**	**A-G Missions**
1V1 INT	SA	1V1 NI	NSA
2V2 INT	SAT	2V2 NI	
AAR	CAS	NAAR	
ACM		NCAP	
ACT		NESC	
BFM			
CAP			
ESC			
HVAAP			

Table 5. Mission Acronyms

Acronyms	Description
AAR	Air to Air Refueling
ACM	Air Combat Maneuver
ACT	Air Combat Training
BFM	Basic Flight Maneuver
CAP	Combat Air Patrol
CAS	Close Air Support
ESC	Escort
HVAAP	High Value Airborne Asset Protection
INT	Intercept
IF	Instrument Flight
NAAR	Night Air to Air Refueling
NCAP	Night Combat Air Patrol
NESC	Night Escort
NI	Night Intercept
NSA	Night Surface Attack
SA	Surface Attack
SAT	Surface Attack Tactics

While some missions require four aircraft, some missions need three, two, or one aircraft to be able to be flown. Missions and the required number of aircrafts are depicted in Table 6.

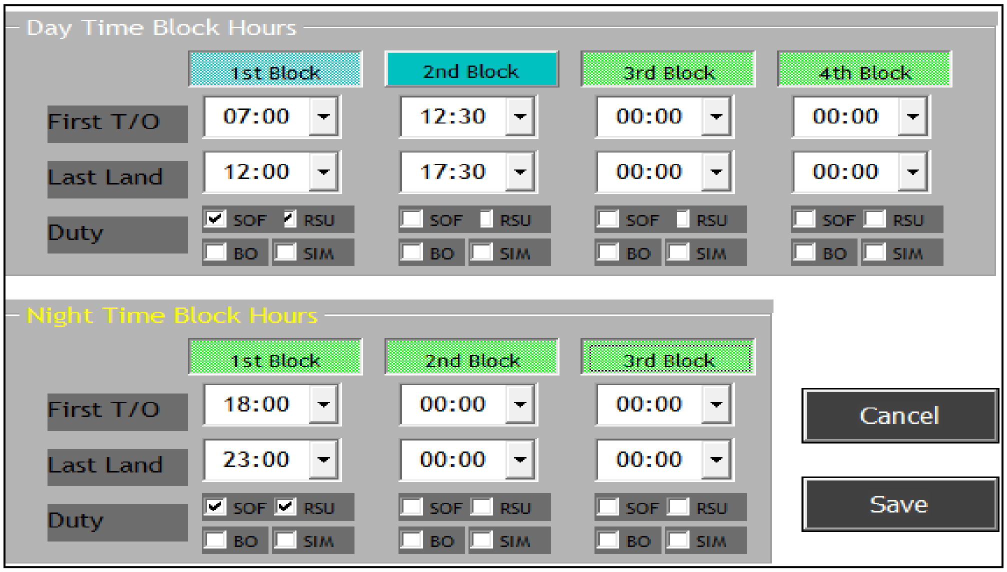
Table 6. Mission-Aircraft Requirements

MISSION	AIRCRAFT REQUIREMENT			
	4-SHIP	3-SHIP	2-SHIP	1-SHIP
ACT	YES	NO	NO	NO
INT	YES	NO	YES	NO
CAP	YES	NO	YES	NO
ESC	YES	NO	YES	NO
HVAA	YES	NO	YES	NO
CAS	YES	NO	YES	NO
AREC	YES	NO	YES	NO
AAR	YES	NO	YES	NO
NI	YES	NO	YES	NO
NCAP	YES	NO	YES	NO
NESC	YES	NO	YES	NO
NAAR	YES	NO	YES	NO
ACM	NO	YES	NO	NO
BFM	NO	NO	YES	NO
IF	NO	NO	NO	YES

3.2.1.5 Blocks

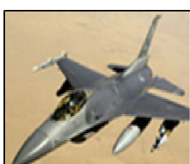
Block time period is used to partition a day into segments in which several flights are executed. Blocks are preferred to be four or five hour time intervals. In Erdemir's DSS, there are four potential different day-blocks and three night-blocks. Hitting the blocks menu on the initial window shows us the blocks as depicted in Table 7.

Table 7. Flight Block Hours



We classify the five flying days per week into two different categories labeled even and odd, with three even days and two odd days in a week. Even days have only two day blocks, on the other hand odd days have three blocks including one night block. The weekly flight schedule is shown in Table 8.

Table 8. Weekly Flight Schedule



Weekly Flight Schedule Fighter Squadron				
WEEK # 1				
Day	AM GOs	PM GOs	NIGHT GOs	DAY TYPE
Monday	√	√	X	EVEN
Tuesday	√	√	√	ODD
Wednesday	√	√	X	EVEN
Thursday	√	√	√	ODD
Friday	√	√	X	EVEN

All the flight blocks necessitate five hours for our study. The crew rest is twelve hours. So, a pilot can only fly two consecutive flight blocks under these circumstances, otherwise they would violate the crew rest time. The scheduled AM/PM/NIGHT GOs Time Table is depicted in Table 9 below.

Table 9. AM/PM/NIGHT GOs Time Table

AM/PM/NIGHT GOs TIME TABLE
Fighter Squadron

TIME	AM GOs	PM GOs	NIGHT GOs
0700-0800	Mission Planning		
0800-1000	Briefing		
1000-1130	Flight		
1130-1200	De Briefing		
1230-1330		Mission Planning	
1330-1530		Briefing	
1530-1700		Flight	
1700-1730		De Briefing	
1800-1900			Mission Planning
1900-2100			Briefing
2100-2230			Flight
2230-2300			De Briefing

3.2.1.6 Ground Duties

Ground duties are additional responsibilities requiring an assigned pilot to check activities which may violate flight and/or ground safety. The pilot on duty must assure that all activities inside his/her responsibility area are performed without any unsafe practices. The main duties are Supervisory of Flight (SOF), Runway Supervisory Unit (RSU), Base Operation (BO), and Simulator (SIM). Since there is no need for RSU or BO duty in certain bases, SOF is the only mandatory ground duty slot in flight schedule for some squadrons (Erdemir, 2014). We only model RSU and SOF duties in our simulations however; we have included BO and SIM duties in the duty-pilot rating table shown in Table 10.

Table 10. Ground Duty-Pilot Rating

PILOT STATUS	INSTRUCTOR	4-SHIP LEADER	2-SHIP LEADER	WINGMAN
SOF	YES	YES	NO	NO
RSU	YES*	YES*	YES	YES
BO	YES*	YES*	YES	YES
SIM	YES*	YES*	YES	YES
YES* : Pilot can be assigned to duty but not preferable				

3.2.1.7 Flight Schedule

By using the definitions above, we generate the flight schedule. During this phase, all the pilots and aircraft are available. The availability of resources change dynamically as the simulation is run. We also change initial resource numbers in Simio for some of our analysis in the next chapter. The flight schedule generated from the initial window is shown in Table 11.

Table 11. The Flight Schedule

192TH SQUADRON WEEKLY FLIGHT SCHEDULE

MONDAY					1/11/2015	
NUMBER	BLOCK	MISSION	ACFT	PILOTS	TAKE OFF	LAND
1	1	ACT	4XF-16C/D	SEVIMLI	1000	1130
				AYKIRI		
				PARK		
				YASIN		
2	1	BFM	2XF16C/D	LUNDAY	1000	1130
				ERHAN		
3	1	1X1 INT	2XF16C/D	MILLER	1000	1130
				CLISBY		
4	1	AAR	4XF-16C/D	BRASDSHAW	1000	1130
				GUNDUZ		
				DAVIS		
				TETRAUT		
5	1	1X1 INT	2XF16C/D	MCLEAN	1000	1130
				PALKO		
6	1	CAP	2XF16C/D	MCDONALD	1000	1130
				SALGADO		
7	1	ESC	2XF16C/D	LUCAS	1000	1130
				KEVIN		
8	1	BFM	2XF16C/D	SHALLCROSS	1000	1130
				DWYER		
9	2	2X2 INT	4XF-16C/D	SEVIMLI	1530	1700
				AYKIRI		
				PARK		
				YASIN		
10	2	ACT	4XF-16C/D	BRASDSHAW	1530	1700
				GUNDUZ		
				DAVIS		
				TETRAUT		
11	2	CAP	2XF16C/D	LUNDAY	1530	1700
				ERHAN		
12	2	1X1 INT	2XF16C/D	MILLER	1530	1700
				CLISBY		
13	2	BFM	2XF16C/D	MCDONALD	1530	1700
				SALGADO		
14	2	BFM	2XF16C/D	LUCAS	1530	1700
				KEVIN		
15	2	ESC	2XF16C/D	SHALLCROSS	1530	1700
				DWYER		
16	2	ESC	2XF16C/D	MCLEAN	1530	1700
				PALKO		
SIM 0900 - 1000 KIM						
SIM 1000 - 1100 AMIE						
RSU- 1				SOF - 1		
GUZMAN				YILDIZ		
SIM 1500 - 1600 KIM						
SIM 1600 - 1700 AMIE						
RSU- 2				SOF - 2		
GUZMAN				YILDIZ		

TUESDAY					2/11/2015	
NUMBER	BLOCK	MISSION	ACFT	PILOTS	TAKE OFF	LAND
1	1	SA	4XF-16C/D	YILDIZ	1000	1130
				AYKIRI		
				KIM		
				AMIE		
2	1	AAR	4XF-16C/D	BRASDSHAW	1000	1130
				GUNDUZ		
				DAVIS		
				GUZMAN		
3	2	STA	4XF-16C/D	MILLER	1530	1700
				CLISBY		
				MCDONALD		
				SALGADO		
4	2	CAS	2XF16C/D	LUNDAY	1530	1700
				ERHAN		
5	2	HVAAP	4XF-16C/D	LUCAS	1530	1700
				KEVIN		
				SHALLCROSS		
				DWYER		
6	2	ESC	2XF16C/D	MCLEAN	1530	1700
				PALKO		
7	2	SA	4XF-16C/D	BRASDSHAW	1530	1700
				GUNDUZ		
				DAVIS		
				GUZMAN		
8	2	AAR	4XF-16C/D	YILDIZ	1530	1700
				AYKIRI		
				KIM		
				AMIE		
9	3	NCAP	4XF-16C/D	MILLER	2100	2230
				CLISBY		
				MCDONALD		
				SALGADO		
10	3	1X1 NI	2XF16C/D	LUNDAY	2100	2230
				ERHAN		
11	3	2X2 NI	4XF-16C/D	LUCAS	2100	2230
				KEVIN		
				PARK		
				DWYER		
12	3	NESC	2XF16C/D	MCLEAN	2100	2230
				PALKO		
SIM 0900 - 1000 YASIN						
SIM 1000 - 1100 BOARDMAN						
RSU- 1				SOF - 1		
TETRAUT				SEVIMLI		
SIM 1500 - 1600 YASIN						
SIM 1600 - 1700 BOARDMAN						
RSU- 2				SOF - 2		
TETRAUT				SEVIMLI		
SIM 2000 - 2100 YASIN						
SIM 2100 - 2200 PARK						
RSU- 3				SOF - 3		
BOARDMAN				SHALLCROSS		

WEDNESDAY					3/11/2015	
NUMBER	BLOCK	MISSION	ACFT	PILOTS	TAKE OFF	LAND
1	1	ACT	4XF-16C/D	SEVIMLI	1000	1130
				AYKIRI		
				PARK		
				YASIN		
2	1	BFM	2XF16C/D	LUNDAY	1000	1130
				ERHAN		
3	1	1X1 INT	2XF16C/D	MILLER	1000	1130
				CLISBY		
4	1	AAR	4XF-16C/D	BRASDSHAW	1000	1130
				GUNDUZ		
				DAVIS		
				TETRAUT		
5	1	1X1 INT	2XF16C/D	MCLEAN	1000	1130
				PALKO		
6	1	CAP	2XF16C/D	MCDONALD	1000	1130
				SALGADO		
7	1	ESC	2XF16C/D	LUCAS	1000	1130
				KEVIN		
8	1	BFM	2XF16C/D	SHALLCROSS	1000	1130
				DWYER		
9	2	2X2 INT	4XF-16C/D	SEVIMLI	1530	1700
				AYKIRI		
				PARK		
				YASIN		
10	2	ACT	4XF-16C/D	BRASDSHAW	1530	1700
				GUNDUZ		
				DAVIS		
				TETRAUT		
11	2	CAP	2XF16C/D	LUNDAY	1530	1700
				ERHAN		
12	2	1X1 INT	2XF16C/D	MILLER	1530	1700
				CLISBY		
13	2	BFM	2XF16C/D	MCDONALD	1530	1700
				SALGADO		
14	2	BFM	2XF16C/D	LUCAS	1530	1700
				KEVIN		
15	2	ESC	2XF16C/D	SHALLCROSS	1530	1700
				DWYER		
16	2	ESC	2XF16C/D	MCLEAN	1530	1700
				PALKO		
SIM 0900 - 1000 KIM						
SIM 1000 - 1100 AMIE						
RSU- 1				SOF - 1		
GUZMAN				YILDIZ		
SIM 1500 - 1600 KIM						
SIM 1600 - 1700 AMIE						
RSU- 2				SOF - 2		
GUZMAN				YILDIZ		

THURSDAY					4/11/2015	
NUMBER	BLOCK	MISSION	ACFT	PILOTS	TAKE OFF	LAND
1	1	SA	4XF-16C/D	YILDIZ	1000	1130
				AYKIRI		
				KIM		
				AMIE		
2	1	AAR	4XF-16C/D	BRASDSHAW	1000	1130
				GUNDUZ		
				DAVIS		
				GUZMAN		
3	2	STA	4XF-16C/D	MILLER	1530	1700
				CLISBY		
				MCDONALD		
				SALGADO		
4	2	CAS	2XF16C/D	LUNDAY	1530	1700
				ERHAN		
5	2	HVAAP	4XF-16C/D	LUCAS	1530	1700
				KEVIN		
				SHALLCROSS		
				DWYER		
6	2	ESC	2XF16C/D	MCLEAN	1530	1700
				PALKO		
7	2	SA	4XF-16C/D	BRASDSHAW	1530	1700
				GUNDUZ		
				DAVIS		
				GUZMAN		
8	2	AAR	4XF-16C/D	YILDIZ	1530	1700
				AYKIRI		
				KIM		
				AMIE		
9	3	NCAP	4XF-16C/D	MILLER	2100	2230
				CLISBY		
				MCDONALD		
				SALGADO		
10	3	1X1 NI	2XF16C/D	LUNDAY	2100	2230
				ERHAN		
11	3	2X2 NI	4XF-16C/D	LUCAS	2100	2230
				KEVIN		
				PARK		
				DWYER		
12	3	NESC	2XF16C/D	MCLEAN	2100	2230
				PALKO		
SIM 0900 - 1000 YASIN						
SIM 1000 - 1100 BOARDMAN						
RSU- 1				SOF - 1		
TETRAUT				SEVIMLI		
SIM 1500 - 1600 YASIN						
SIM 1600 - 1700 BOARDMAN						
RSU- 2				SOF - 2		
TETRAUT				SEVIMLI		
SIM 2000 - 2100 YASIN						
SIM 2100 - 2200 PARK						
RSU- 3				SOF - 3		
BOARDMAN				SHALLCROSS		

FRIDAY					5/11/2015	
NUMBER	BLOCK	MISSION	ACFT	PILOTS	TAKE OFF	LAND
1	1	ACT	4XF-16C/D	SEVIMLI	1000	1130
				AYKIRI		
				PARK		
				YASIN		
2	1	BFM	2XF16C/D	LUNDAY	1000	1130
				ERHAN		
3	1	1X1 INT	2XF16C/D	MILLER	1000	1130
				CLISBY		
4	1	AAR	4XF-16C/D	BRASDSHAW	1000	1130
				GUNDUZ		
				DAVIS		
				TETRAUT		
5	1	1X1 INT	2XF16C/D	MCLEAN	1000	1130
				PALKO		
6	1	CAP	2XF16C/D	MCDONALD	1000	1130
				SALGADO		
7	1	ESC	2XF16C/D	LUCAS	1000	1130
				KEVIN		
8	1	BFM	2XF16C/D	SHALLCROSS	1000	1130
				DWYER		
9	2	2X2 INT	4XF-16C/D	SEVIMLI	1530	1700
				AYKIRI		
				PARK		
				YASIN		
10	2	ACT	4XF-16C/D	BRASDSHAW	1530	1700
				GUNDUZ		
				DAVIS		
				TETRAUT		
11	2	CAP	2XF16C/D	LUNDAY	1530	1700
				ERHAN		
12	2	1X1 INT	2XF16C/D	MILLER	1530	1700
				CLISBY		
13	2	BFM	2XF16C/D	MCDONALD	1530	1700
				SALGADO		
14	2	BFM	2XF16C/D	LUCAS	1530	1700
				KEVIN		
15	2	ESC	2XF16C/D	SHALLCROSS	1530	1700
				DWYER		
16	2	ESC	2XF16C/D	MCLEAN	1530	1700
				PALKO		
SIM 0900 - 1000 KIM						
SIM 1000 - 1100 AMIE						
RSU- 1				SOF - 1		
GUZMAN				YILDIZ		
SIM 1500 - 1600 KIM						
SIM 1600 - 1700 AMIE						
RSU- 2				SOF - 2		
GUZMAN				YILDIZ		

3.2.2. Mission Planning

Mission planning phase starts after scheduling. When the flight schedule is generated, pilots start to plan their missions. Mission planning requires the pilots to get the needed information about the missions, weapons, and coordination. In fighter squadrons the mission planning is done by the pilots. We use the pilots in our baseline model to perform mission planning. As an alternative approach, we consider an operation cell with a route planner, target expert, weapon expert, and intelligence personnel. This operation cell is not explicitly modeled, but allows us to remove the mission planning task from the pilots executing the flying schedule. At most the mission planning phase needs one or two hours. In our study we use one hour for each mission.

3.2.3. Briefing

In this phase, the pilots brief the mission requirements in respect with the route, target information, coordination, weapon planning, and intelligence. In flight operations, the briefing typically starts two hours prior to the take-off time, which is how we model it for this study.

3.2.4. Flight

We conduct different missions of a Multi Role F-16 Fighter Squadron in this study. The average time of these missions is modeled deterministically as one and a half hours. The flight starts with the take-off time and ends with the landing time. Our simulation model checks the availability of the required resources according to the fixed schedules and flys all supportable sorties. The number of completed sorties over a selected time period produces a sortie rate.

3.2.5. Debriefing

The sortie generation process finishes with the debriefing phase which we model as thirty minutes for an F-16 squadron. We expect this phase to be removed with the use of advanced technology in fifth generation aircraft such as F-35 and F-22. Removal of the debriefing phase may affect the sortie generation rate and must be checked with our simulation. After the debriefing phase, the pilots are released for the next mission, ground duty, or crew rest, and the maintenance division releases the aircraft if it does not need a repair. If the aircraft needs unscheduled maintenance, the release occurs at the end of the maintenance.

3.3. Description of Models

In our study, we investigated ten different model configurations with different features in order to answer the research questions presented in this study. The first model represents a baseline scenario where a fixed flight schedule is generated and abort rates are not considered. From here, the baseline scenario is modified to capture various situations of interest proposed by the researcher. These configurations allow thorough analysis on the behavior and impact of certain features on sortie generation of a fighter squadron. Each model's unique features can be referenced in Table 12.

Table 12. Model Features

Model Number	Fixed Flight Schedule	Abort Rates Considered	Set Abort Rates	Set Pilot Numbers	Mission Planning Present
1	YES	NO	NO	NO	YES
2	YES	YES	NO	NO	YES
3	NO	YES	NO	NO	YES
4	NO	YES	NO	NO	NO
5a	YES	YES	YES	NO	YES
5p	YES	YES	NO	YES	YES
6a	NO	YES	YES	NO	YES
6p	NO	YES	NO	YES	YES
7a	NO	YES	YES	NO	NO
7p	NO	YES	NO	YES	NO

The baseline model utilizes a fixed flight schedule with zero abort rates. Whenever a fixed flight schedule is not used, the models use random flight schedules generated by Simio. Fixed flight schedules represent times of peace whereas random schedules model times of conflict where there is a higher level of operational variability. Excluding the baseline model, all other models incorporate abort rates. In addition, some models go step further and apply a stochastic element to the abort rates. For example, model 5a includes abort rates in its experiments but it also implements multiple combinations of abort rates to represent dynamic aspect of abort rates. Lastly, in models 4, 7a and 7p, the mission planning function was removed to observe the impact on the number of sorties generated.

In models 5-7, ground, air, and weather abort rates are varied by increments to represent real life changes in the sortie generation process. In addition, models 5-7 also utilize mixed combination of pilot numbers for the instructor and four ship leader to capture potential personnel shortages and manning constraint. The Abort Rates and Pilot Numbers are depicted in Table 13 and 14. Pilot numbers are the instructors and four ship leaders available in a squadron to carry out missions in each respective scenario. Increments show the level of deviation from the baseline.

Table 13. Abort Rates

Abort Rates (%)				
Scenario	**Ground**	**Air**	**Weather**	**Increments**
1	3	2	3	0
2	2	1	2	-1
3	1	0	1	-2
4	0	0	0	-3
5	4	3	4	+1
6	5	4	5	+2
7	6	5	6	+3

Table 14. Pilot Numbers

Pilot Numbers				
Scenario	**Instructors**	**Inst. Incr.**	**Four Ship Leaders**	**FShipLdr Incr.**
1	3	0	4	0
2	2	-1	4	0
3	1	-2	4	0
4	3	0	3	-1
5	3	0	2	-2
6	3	0	1	-3
7	2	-1	3	-1
8	1	-2	2	-2

3.4. Model Development

The sortie generation process is modeled using Simio Simulation Software. In this section we provide a brief discussion of some key Simio features and how they were used in building our simulation.

3.4.1. Standard Library

We used the standard library included with Simio to provide a set of modeling features. Model construction began with dragging an object into the facility view and connecting it to other objects. Each object has a comprehensive set of properties to allow

Table 15. Simio Standard Library Objects

Object	Description
Source	Generates entity objects of a specified type and arrival pattern.
Sink	Destroys entities that have completed processing in the model.
Server	Represents a capacitated process such as a machine or service operation.
Workstation	Includes setup, processing, and teardown and secondary resource and material requirements.
Combiner	Combines multiple entities together with a parent entity (e.g. a pallet).
Separator	Splits a batched group of entities or makes copies of a single entity.
Resource	A generic object that can be seized and released by other objects.
Worker	A moveable resource that may be seized for tasks as well as used to transport entities.
Vehicle	A transporter that can follow a fixed route or perform on demand pickups/drop offs.
BasicNode	Models a simple intersection between multiple links
TransferNode	Models a complex intersection for changing destination and travel mode.
Connector	A simple zero-time travel link between two nodes. Path
Path	A link over which entities may independently move at their own speeds.
TimePath	A link that has a specified travel time for all entities.
Conveyor	A link that models both accumulating and non-accumulating conveyor devices.

customizing its behavior. In addition, the behavior of each object can be extended by taking advantage of add-on processes to define extra logic specific to our application. Finally, all of the objects in the standard library have been defined using processes. The standard library objects are illustrated in Table 15 (Sturrock & Pegden, 2010).

3.4.2. Processes

Object-based tools such as Simio are very good for rapidly building models. We simply drag objects into the workspace, set the properties for those objects, and our model is ready to run. However, the traditional problem with this approach is modeling flexibility. It's extremely difficult to design a set of objects that work in all situations across multiple and disparate application areas without making the objects overly complicated and difficult to learn and use. The Simio Standard Library addresses this problem through the concept of add-on processes (Sturrock & Pegden, 2010). In our sortie generation process we created different processes to represent ground duties, four ship flight, three ship flight, and two ship flight.

3.4.2.1. Ground Duties Process

We transfer the flight schedules generated with the use of DSS or randomly into Simio. Our sortie generation process scheduling starts with assigning the pilots for SOF and RSU duties.

This process respectively checks the availability of the four ship leader and instructor for the SOF and assigns the first available. If there are no pilots of appropriate skill available, the flight block is canceled.

After assigning the SOF it assigns the RSU with the similar logic across all pilot ratings. It respectively checks the availability of pilots starting at lowest skill level (wingman) up to instructor pilot. If no pilot is available the flight block is canceled. After the ground duties are assigned, the generation of the flights in the schedule starts. The ground duties process is shown in Figure 5.

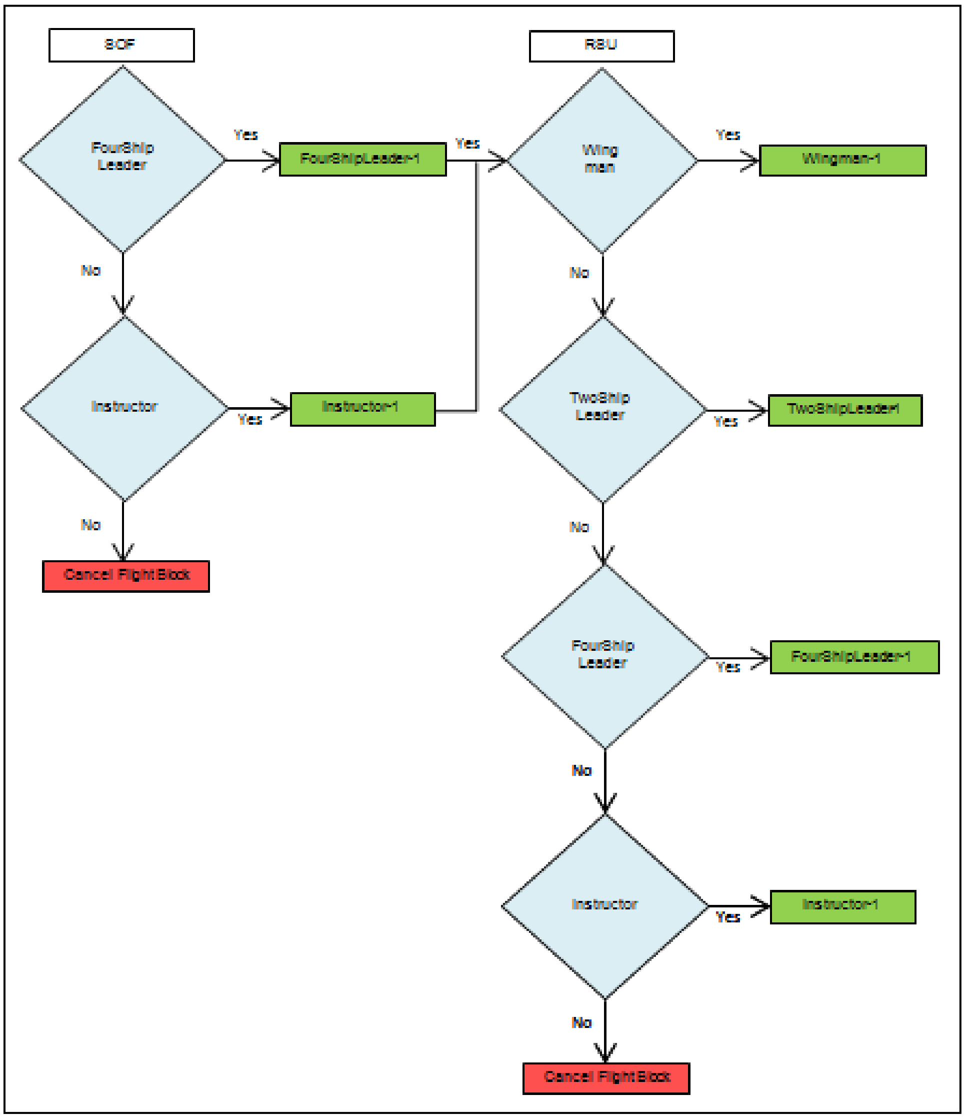


Figure 5. The Ground Duties Process

3.4.2.2. Four Ship Flight Process

This process starts when a scheduled mission requires four aircraft. It respectively checks the availability of the four ship leader and instructor, then assigns the first available to the first aircraft. For all other aircraft, available pilots are checked starting at the lowest skill level qualified up to instructor pilot. If qualified pilots are not available for all four aircraft, the mission is canceled. The four ship flight process is shown in Figure 6.

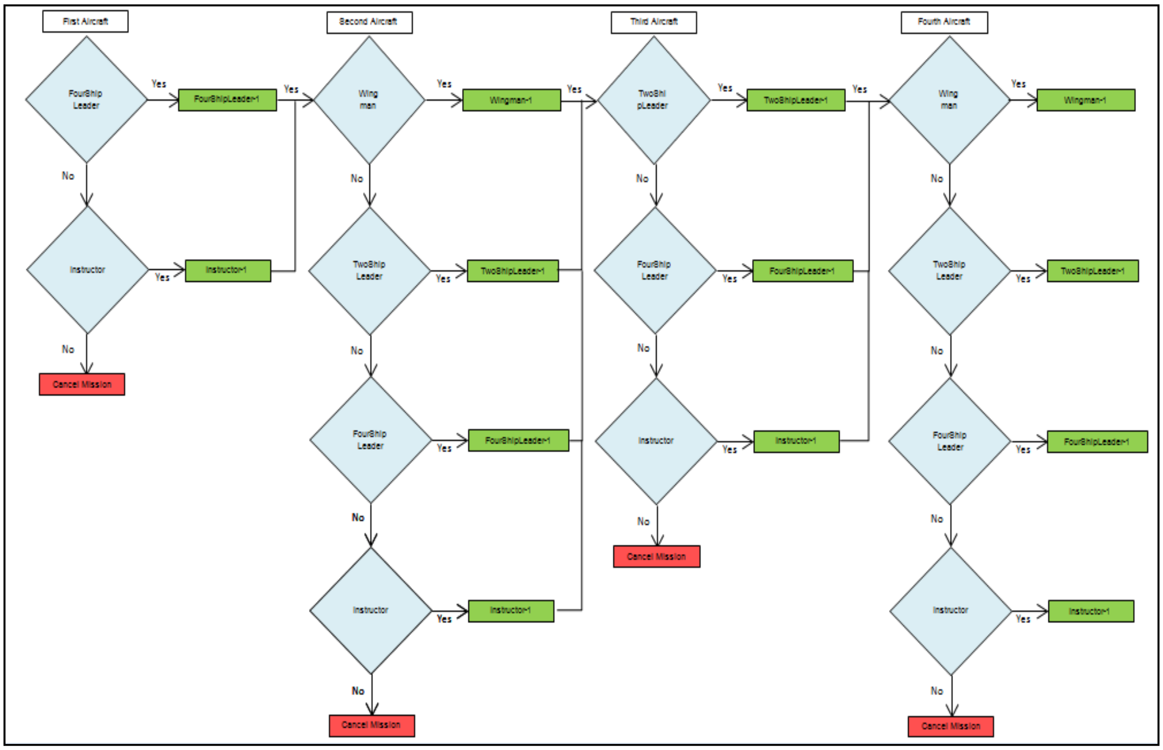


Figure 6. The Four Ship Process

3.4.2.3. Three Ship Flight Process

This process starts when a scheduled mission requires three aircraft. It respectively checks the availability of the four ship leader and instructor, then assigns the first available to the first aircraft. For all other aircraft, available pilots are checked starting at the lowest skill level qualified up to instructor pilot. If qualified pilots are not available for all three aircraft, the mission is canceled. The three ship flight process is shown in Figure 7.

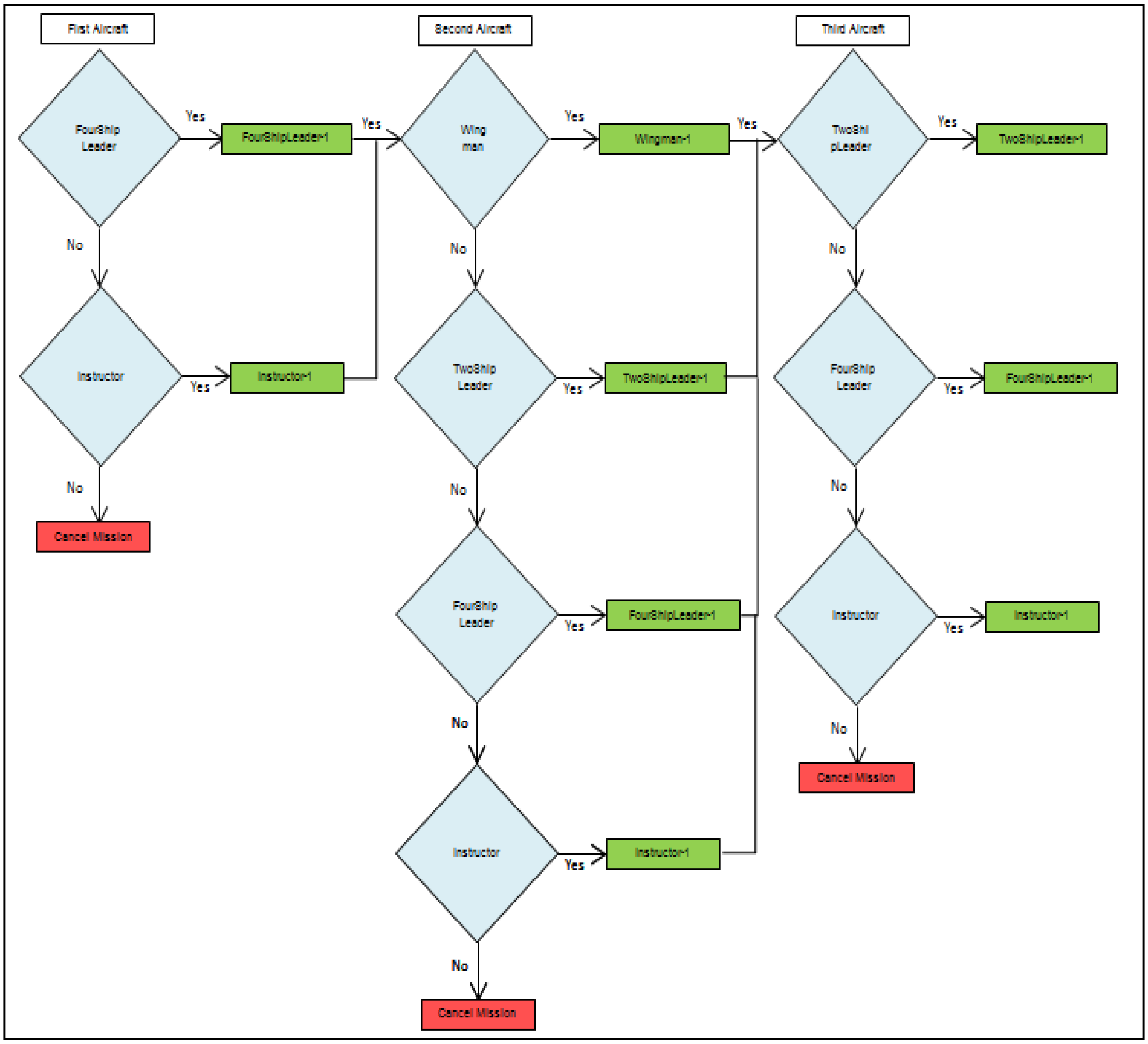


Figure 7. The Three Ship Flight

3.4.2.4. Two Ship Flight Process

This process starts when a scheduled mission requires two aircraft. It respectively checks the availability of the two ship leader, four ship leader and instructor, then assigns the first available to the first aircraft. For all other aircraft, available pilots are checked starting at the lowest skill level qualified up to instructor pilot. If qualified pilots are not available for both aircraft, the mission is canceled. The two ship flight process is shown in Figure 8.

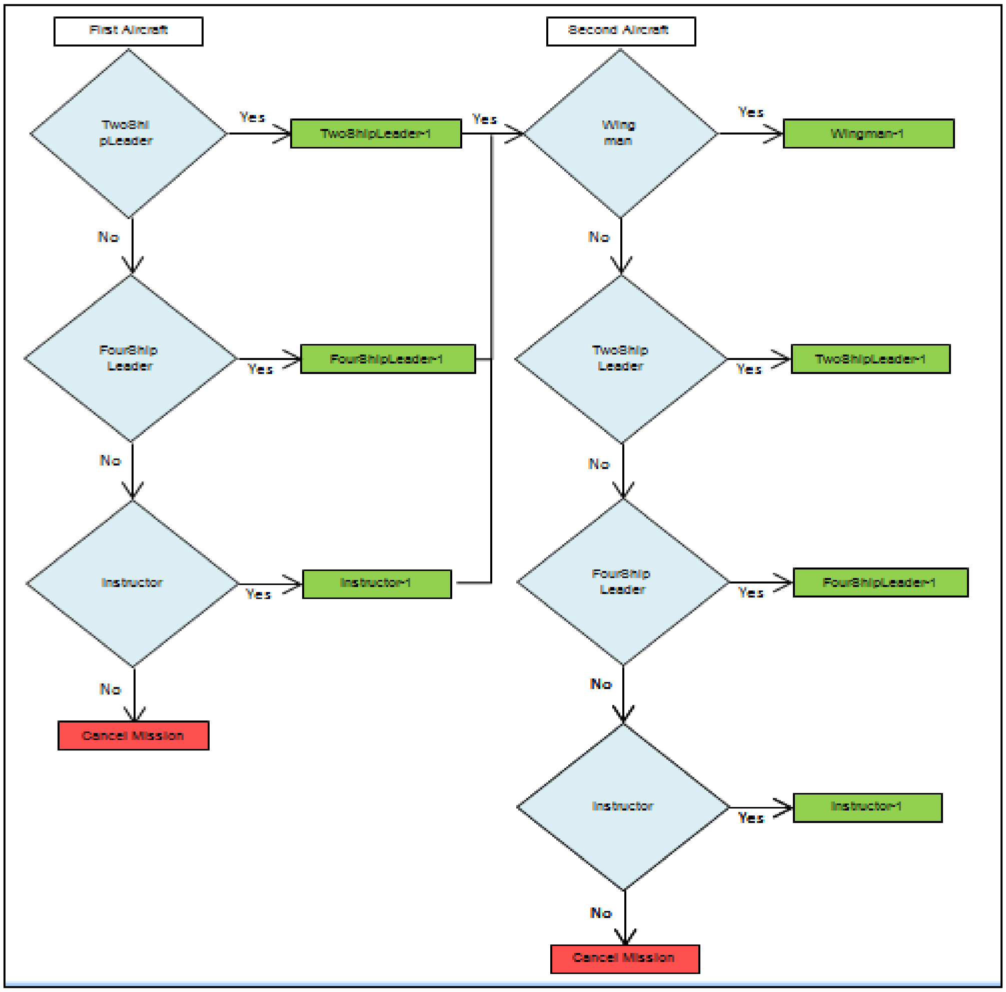
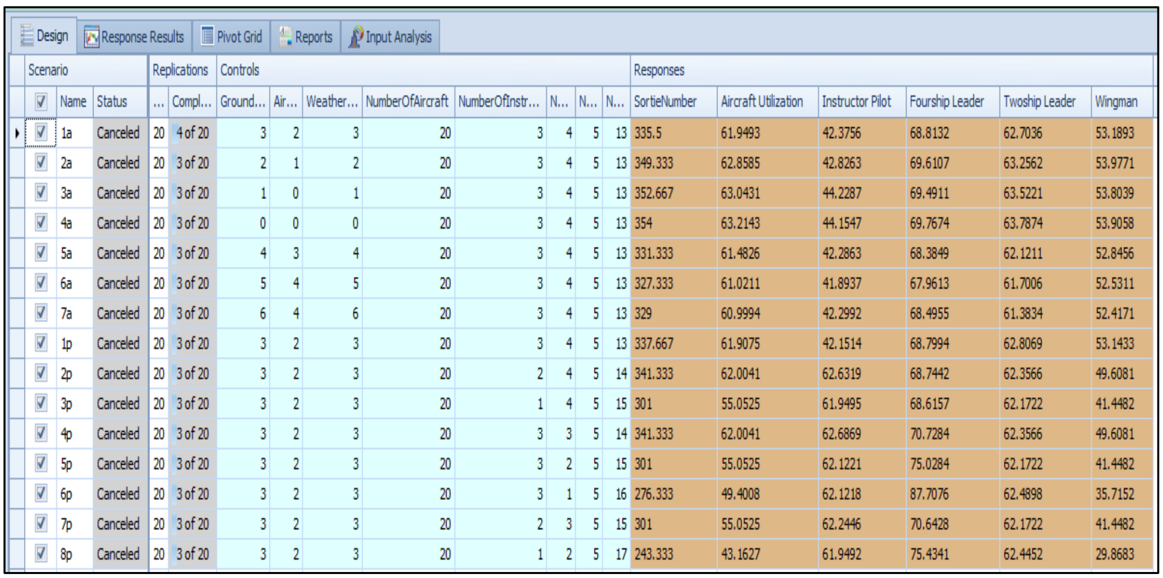


Figure 8. The Two Ship Flight

3.4.3. Experiment Windows

In the experimentation mode we define one or more properties on the model that we can change to see the impact on the system performance. These properties, exposed in the experiment as Controls, might be used to vary things like the number of pilots, the number of aircraft, or the abort percentage. These model properties are then referenced by one or more objects in the model. You may also add Responses; these would generally be your Key Performance Indicators (KPIs) on which you make the primary decision on "goodness" of the scenario. You may dynamically sort on any column, for example to display the highest daily sorties scenarios first. You can also add Constraints that will automatically be applied before or after a run to prevent running, or to later discard a scenario that violates an input or output constraint. When you run an experiment, it takes full advantage of all processors available (Sturrock & Pegden, 2010). In our model we created an experiment to see the results of our responses for a number of different scenarios defined by varying the values of our parameters. An example of our model's experiment window is shown in Figure 9.


Design | Response Results | Pivot Grid | Reports | Input Analysis

Scenario			Replications		Controls								Responses					
✓	Name	Status	...	Compl...	Ground...	Air...	Weather...	NumberOfAircraft	NumberOfInstr...	N...	N...	N...	SortieNumber	Aircraft Utilization	Instructor Pilot	Fourship Leader	Twoship Leader	Wingman
✓	1a	Canceled	20	4 of 20	3	2	3	20	3	4	5	13	335.5	61.9493	42.3756	68.8132	62.7036	53.1893
✓	2a	Canceled	20	3 of 20	2	1	2	20	3	4	5	13	349.333	62.8585	42.8263	69.6107	63.2562	53.9771
✓	3a	Canceled	20	3 of 20	1	0	1	20	3	4	5	13	352.667	63.0431	44.2287	69.4911	63.5221	53.8039
✓	4a	Canceled	20	3 of 20	0	0	0	20	3	4	5	13	354	63.2143	44.1547	69.7674	63.7874	53.9058
✓	5a	Canceled	20	3 of 20	4	3	4	20	3	4	5	13	331.333	61.4826	42.2863	68.3849	62.1211	52.8456
✓	6a	Canceled	20	3 of 20	5	4	5	20	3	4	5	13	327.333	61.0211	41.8937	67.9613	61.7006	52.5311
✓	7a	Canceled	20	3 of 20	6	4	6	20	3	4	5	13	329	60.9994	42.2992	68.4955	61.3834	52.4171
✓	1p	Canceled	20	3 of 20	3	2	3	20	3	4	5	13	337.667	61.9075	42.1514	68.7994	62.8069	53.1433
✓	2p	Canceled	20	3 of 20	3	2	3	20	2	4	5	14	341.333	62.0041	62.6319	68.7442	62.3566	49.6081
✓	3p	Canceled	20	3 of 20	3	2	3	20	1	4	5	15	301	55.0525	61.9495	68.6157	62.1722	41.4482
✓	4p	Canceled	20	3 of 20	3	2	3	20	3	3	5	14	341.333	62.0041	62.6869	70.7284	62.3566	49.6081
✓	5p	Canceled	20	3 of 20	3	2	3	20	3	2	5	15	301	55.0525	62.1221	75.0284	62.1722	41.4482
✓	6p	Canceled	20	3 of 20	3	2	3	20	3	1	5	16	276.333	49.4008	62.1218	87.7076	62.4898	35.7152
✓	7p	Canceled	20	3 of 20	3	2	3	20	2	3	5	15	301	55.0525	62.2446	70.6428	62.1722	41.4482
✓	8p	Canceled	20	3 of 20	3	2	3	20	1	2	5	17	243.333	43.1627	61.9492	75.4341	62.4452	29.8683

Figure 9. The Experiment Window

3.4.4. Simio Measure of Risk and Error (SMORE) Plots

Simio Pivot Tables and Reports provide an estimate of the population mean and confidence interval based on multiple replications. While this is exactly what is needed in some situations, in others it provides an inadequate amount of information required to make a decision while accounting for risk.

The Response Results window of an Experiment creates a SMORE plot using the Response value that is selected in the Response pull down menu. A SMORE plot displays both the estimated expected value of a scenario and multiple levels of variability behind the expected value. The plot displays results across replications, for each scenario.

A SMORE plot consists of a Mean, Confidence Interval for the Mean, Upper Percentile Value, Confidence Interval for the Upper Percentile Value, Lower Percentile Value, Confidence Interval for the Lower Percentile Value, Median, Maximum Value, and Minimum Value (Sturrock & Pegden, 2010). An example of a SMORE plot is depicted in Figure 10.

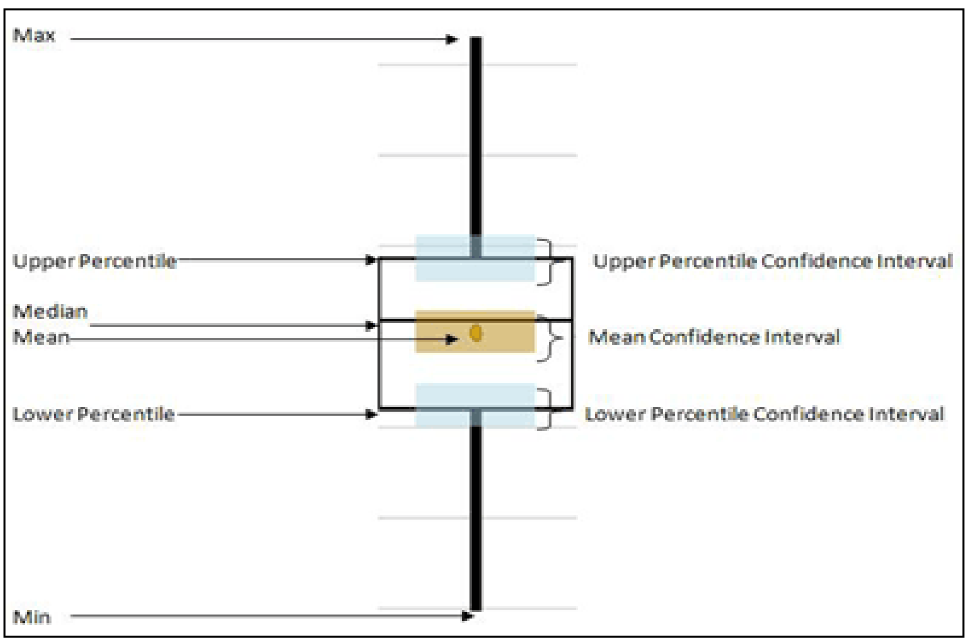


Figure 10. SMORE Plot (Sturrock & Pegden, 2010)

3.5. Verification and Validation of the Model

Verification is the step to check the model and logic to ensure they are implementing what is intended. In this section, our focus is on the application of verification methods for the model. First it is appropriate to mention again that verification should not be considered as a step which is applied once while building a model. It is an ongoing process where a modeler uses various techniques throughout construction of the model. The animation feature in Simio is one of the major techniques used to verify the model. Whenever additional logic or a new sub model is inserted, the simulation is run with animation enabled to check for the proper flow of entities and use of resources. Simio has other useful features such as dynamic variables to count entities at specific points. These counters are embedded into the model to check the results and verify them numerically. For instance, a dynamic variable is inserted for every flight sub phases to collect and check the number of simulator missions accomplished. The numbers from the simulation are compared with numbers obtained analytically or from the actual system. This technique is used in a number of places throughout our model.

Another verification technique is to have someone familiar with the actual system review the model. Our model and sub models were reviewed by pilots who flew more than 1000 hours with F-16 to see whether the sortie generation flow logic is correctly represented. In addition, the sub process created for four ship, three ship, two ship flight and ground duties representing the actual procedures was also reviewed. Based upon feedback from these reviews, the model was modified accordingly.

Face validity is used among the validation techniques. A graduate student in the ENS department simulation track reviewed most of the model's modification as a face validity technique.

3.6. Summary

The model for this research was built to replicate the sortie generation process. This chapter focused on description of the sortie generation system, concepts of building a simulation model and application of steps for building a simulation model. Details of our final model are discussed to include numerous figures depicting the Simio logic. In the following chapter, we discuss the analysis of our simulation output using a variety of techniques.

IV. Analysis and Results

4.1. Chapter Overview

The previous chapter defined the simulation model that was used for this research. This chapter defines the requirements in setting up and performing our analysis. These requirements start by determining the number of replications to produce sufficiently normal output data while meeting a specified confidence interval half width. We discuss the organization of our analysis and the results from our simulation runs.

4.2. Model Results

After models described in the methodology are executed, initial results are presented with their significant explanations.

4.2.1. Model 1 (Baseline)

In this model, we created the baseline model including the fixed scheduled generated in a DSS with no resource failures. Our DSS created 288 different missions while utilizing all the resources. As expected, with deterministic processing times, a single Simio replication produced 288 sorties with baseline utilizations for all resources. Results for model 1 are shown in Table 16.

Table 16. Initial Results for Model 1

Model	Replication	SortieNumber	AircraftUtilization	InstructorPilot	FourshipLeader	TwoshipLeader	Wingman
1	1	288	51.1	16.6	57.9	57.6	43.8

Aircraft utilization is around 50 % because the aircraft are assigned for 12 hours in a whole day. However, instructor pilots only have a utilization percentage of around 16 %. This can be explained by the way the models' process logic is set up. As a reminder, the sortie generation process assigns instructor pilots last after selecting all other pilots for suitable cockpits. In addition, this model does not take into account back seat flights which require instructor pilots.

The use of this baseline model provides the squadron commander with the needed plan for the next month beforehand. That way he can assess at the end of the month as to how well the squadron did in meeting the planned sorties. This simulation also provides a nice tool to effectively share results of flight line operations with the base commander or headquarters.

Another important aspect of such tools is facilitation in standardization of reporting operations at the Air Force level. This kind of simulation, when used by all squadrons, would make it much easier to collect and present standard operational performance data across appropriate units, providing personnel more time to improve other job requirements.

4.2.2. Model 2

Model 2 is created by adjusting the baseline model to include abort rates. The model is replicated 20 times and there are significant differences between model 2 and model 1 (baseline). Twenty replications were selected since output from all metrics was approximately normal and all standard deviations were reasonable. Averaged results for Model 2 along with the standard deviations are shown in Table 17.

Table 17. Averaged Results for Model 2

Model	Replication	SortieNumber	AircraftUtilization	InstructorPilot	FourshipLeader	TwoshipLeader	Wingman
1	1	288	51.1	16.6	57.9	57.6	43.8
2	20	266±5.35	55.6±0.65	19.3±0.46	63.1±0.71	66.2±0.75	49.3±0.47

First, the results show that the sortie number decreases significantly, both statistically and practically, when compared to the baseline. Also, aircraft and pilots utilization show a statistically significant rise, with little practical difference. These results are confirmed by both a paired student's t test and also a Tukey-Kramer HSD test executed in JMP at the 95% confidence level. In depth analysis can be found in Appendix A. All statistical comparison tests and analysis for the models from this point can be found in the Appendix.

Understanding the impact of various factors on the flying schedule is an important aspect of planning for a squadron commander. The squadron commanders can compare past variations with potential future ones given by the tool. Moreover, it would become very easy for the scheduling officer or squadron commander to make adjustments based on the anticipated impacts from the simulation. In this model the abort rates are given monthly. For future studies, we may want to model using daily aborts instead of monthly aborts. One reason for this is that the forecast for weather is much more accurate for the next day as compared to that of 28 days ahead.

4.2.3. Model 3

Model 3 is almost identical to Model 2 but uses a random flight schedule instead of a fixed flight schedule. Our use of a random flight schedule represents increased operational tempo in time of a conflict. In this model, the results show that the sortie number and instructor utilization increase clearly much larger, both statistically and practically, when compared to the baseline. Also, aircraft and other pilots utilization show a statistically significant rise, but not nearly as much practically. Averaged results for Model 3 along with the standard deviations are shown in Table 18.

Table 18. Averaged Results for Model 3

Model	SortieNumber	AircraftUtilization	InstructorPilot	FourshipLeader	TwoshipLeader	Wingman
2	266±5.35	55.6±0.65	19.3±0.46	63.1±0.71	66.2±0.75	49.3±0.47
3	337.2±6.97	61.8±0.45	42.7±0.91	68.6±0.47	62.4±0.35	53.0±0.45

The Squadron Commander can get a fair idea about the maximum utilization of his assets in this case. This is especially important for wartime scenarios not only for operational planning but also for associated logistics planning at base and headquarter levels. The base commander and headquarter now have better insight into the other resources needed to complete the missions such as weapons and fuel.

4.2.4. Model 4

Model 4 makes further adjustments to Model 3 by removing the mission planning function in the simulation. As mentioned in Chapter 3, we remove the mission planning phase to leave more time for the pilots to actually fly. When we remove it, it provides another block to fly each day. So the sortie number and utilizations increase significantly, both statistically and practically, compared to Model 3. Averaged results for Model 4 along with the standard deviations are shown in Table 19.

Table 19. Averaged Results for Model 4

Model	SortieNumber	AircraftUtilization	InstructorPilot	FourshipLeader	TwoshipLeader	Wingman
3	337.2±6.97	61.8±0.45	42.7±0.91	68.6±0.47	62.4±0.35	53.0±0.45
4	422.9±6.93	77.3±0.44	53.7±1.05	85.8±0.44	77.9±0.50	66.3±0.46

This is a good model to show how many additional sorties we can generate with a minor change to the sortie generation process during a conflict. In this model we deactivated the mission planning for the pilots. In future studies, the briefing or flight section can be shortened and analyzed.

4.2.5. Model 5a and 5p

In Model 5a, seven different scenarios are created using the abort rates shown in Table 13. Averaged results for Model 5a along with the standard deviations are depicted in Table 20. In Abort column the first number represents the ground abort percentage, the second number air abort percentage, and the third number weather abort percentage.

Table 20. Averaged Results for Model 5a

Model	Scenario	Abort Rates	SortieNumber	AircraftUtilization	InstructorPilot	FourshipLeader	TwoshipLeader	Wingman
5a	1	3/2/3	266.5±5.36	55.6±0.65	19.3±0.46	63.1±0.71	66.2±0.75	49.3±0.47
5a	2	2/1/2	275.2±3.76	56.6±0.55	19.4±0.38	64±0.51	67.4±0.70	50.1±0.41
5a	3	1/0/1	283.1±2.06	57.5±0.30	19.8±0.18	64.7±0.39	68.4±0.41	50.8±0.22
5a	4	0/0/0	288	58.1	19.9	65.1	69.1	51.2
5a	5	4/3/4	257.7±6.91	54.7±0.81	18.9±0.59	62.7±1.01	65±0.90	48.7±0.60
5a	6	5/4/5	250.7±6.80	54.2±0.72	18.7±0.82	62.4±0.90	64.4±0.84	48.3±0.55
5a	7	6/5/6	246.6±5.68	53.6±0.66	18.5±0.67	61.7±0.95	63.7±0.83	47.8±0.53

From the analysis of these results, a slight decrease in abort rates lead to a significant rise in the number of sorties generated and utilizations. In contrast, decreases in abort rates result in significant drops in both the number of sorties generated and utilizations. The SMORE plot in Figure 11 illustrates these differences with our baseline scenario as the single point in middle of the plot (Scenario 4). Scenarios to the left of the baseline show a statistically significant increase (non-overlapping confidence intervals-brown rectangles) as the abort rates decrease. On the right side of the baseline scenario, scenarios 5, 6, and 7 show a significant decrease (not statistically significant between scenario 6 and 7 as the abort rates increase).

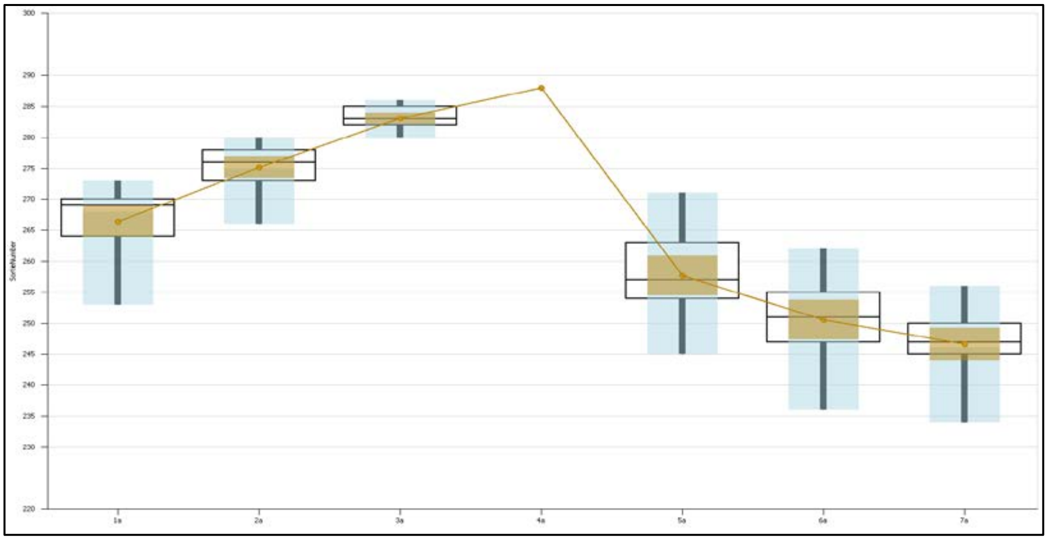


Figure 11. Model 5a Scenarios Comparison Analyses

In Model 5p, eight different scenarios are created using the pilot numbers mentioned in Table 14. Here, instead of manipulating abort rates, pilot numbers are emphasized. Averaged results for Model 5p along with the standard deviations are shown in Table 21 and Figure 12. In Pilots column the first number represents change in instructor pilots and the second number change in four ship leaders.

Table 21. Averaged Results for Model 5p

Model	Scenario	Pilots	SortieNumber	AircraftUtilization	InstructorPilot	FourshipLeader	TwoshipLeader	Wingman
5p	1	3/4	266.5±5.36	55.6±0.65	19.3±0.46	63.1±0.71	66.2±0.75	49.3±0.47
5p	2	2/4	266.3±5.32	55.6±0.64	28.9±0.73	63.1±0.71	66.2±0.73	45.8±0.43
5p	3	1/4	255.5±4.65	53.8±0.57	38.1±1.35	63.4±0.72	66.3±0.66	41.6±0.38
5p	4	3/3	266.5±5.92	55.6±0.65	36.2±0.65	67.2±0.67	66.2±0.84	45.8±0.75
5p	5	3/2	255.5±4.65	53.8±0.57	46.6±0.94	76±0.73	66.3±0.66	41.6±0.38
5p	6	3/1	232.7±3.10	50±0.41	55.5±0.78	87.7±0	66.2±0.54	36.6±0.24
5p	7	2/3	255.5±4.65	53.8±0.57	44.5±1.05	67.6±0.68	66.3±0.66	41.6±0.38
5p	8	1/2	203.4±4.46	44.8±0.55	51.2±1.06	75.8±0.67	66.3±0.79	31.4±0.31

First, we changed the number of instructors while keeping the number of four ship leaders the same. The result was a significant increase in utilizations. However, there was no obvious change in the number of sorties generated. Second, we changed the number of four ship leaders while keeping the number of instructors constant. Again, there was a significant rise in utilizations but, sortie numbers saw a drop. Lastly, we degraded both the number of instructors and four ship leaders. This led to another significant drop in sortie numbers and a jump in utilizations at a fluctuation greater than seen previously. The SMORE plot in Figure 12 illustrates the influence of instructors and four ship leaders can have on sortie numbers. In Scenarios 2p and 3p the number of instructors is decreased by increments of one. Once again, because of the process logic implemented in our simulation and the exclusion of back seat flights, the SMORE plots show no significant changes from scenario 2p. However, a notable drop is observed when a second instructor is absent in scenario 3p. Starting from scenarios 4p to 6p, the SMORE plots represent a constant number of instructors and incremental drop in four ship leaders. Here, there is an immediate significant drop of sorties generated in all three scenarios as the number of four ship leaders go down. Next, in scenario 7p both a single instructor and a single four ship leader are removed from the fighter squadron. Compared to scenario 1p where no personnel are missing, there is a significant drop in sortie numbers. Finally, the SMORE plot from scenario 7p to 8p presents a dramatic drop in sortie numbers. Here, an additional instructor and four ship leader are removed leading to even greater statistical and practical consequences.

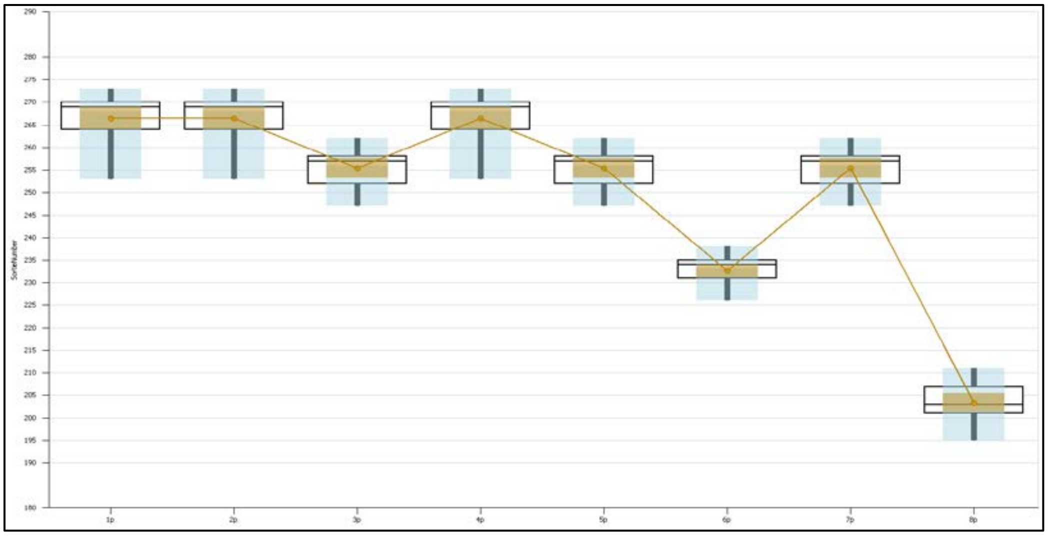


Figure 12. Model 5p Scenarios Comparison Analyses

4.2.6. Model 6a and 6p

In Model 6a, seven different scenarios are created using the abort rates mentioned in Table 13. Averaged results for Model 6a along with the standard deviations are shown in Table 22. In Abort column the first number represents the ground abort percentage, the second number air abort percentage, and the third number weather abort percentage.

Table 22. Averaged Results for Model 6a

Model	Scenario	Abort Rates	SortieNumber	AircraftUtilization	InstructorPilot	FourshipLeader	TwoshipLeader	Wingman
6a	1	3/2/3	337.2±6.97	61.8±0.45	42.7±0.91	68.6±0.47	62.4±0.35	53.0±0.45
6a	2	2/1/2	344.3±6.51	62.4±0.38	43.2±0.60	69.1±0.37	62.8±0.34	53.5±0.41
6a	3	1/0/1	353.7±6.28	63.0±0.32	43.6±0.73	69.5±0.22	63.4±0.18	53.9±0.34
6a	4	0/0/0	357.3±7.65	63.4±0.28	43.9±0.77	69.8±0	63.8±0	54.2±0.38
6a	5	4/3/4	327.8±5.33	61.0±0.41	42.4±0.70	68.0±0.52	61.6±0.44	52.4±0.46
6a	6	5/4/5	327.0±9.04	60.9±0.66	42.2±0.92	68.0±0.54	61.5±0.64	52.4±0.58
6a	7	6/5/6	326.0±9.91	60.7±0.56	42.1±0.96	68.0±0.60	61.2±0.51	52.2±0.47

The big change in this model is adjusting the abort rates but with a random schedule. Similar to Model 5a, a decrease in abort rates causes a rise in both sortie numbers and utilizations. The opposite is true for raising abort rates. The SMORE plot in Figure 13 illustrates these differences with our baseline scenario 4a. Scenarios to the left of the baseline show a statistically significant increase (non-overlapping confidence intervals-brown rectangles) as the abort rates decrease. On the right side of the baseline scenario, scenarios 5, 6, and 7 show a significant decrease (not statistically significant between scenarios 5, 6, and 7 as the abort rates increase). Also, range increases in the responses as the abort rate increases.

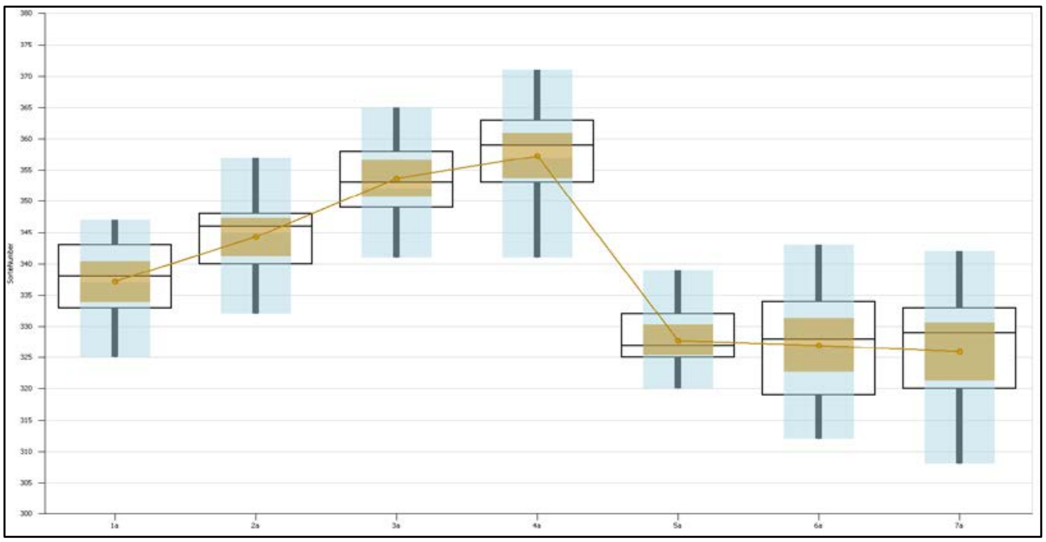


Figure 13. Model 6a Scenarios Comparison Analyses

In Model 6p, eight unique scenarios are generated using the pilot numbers mentioned in Table 14. Here, instead of manipulating abort rates, pilot numbers are altered. Averaged results for Model 6p along with the standard deviations are shown in Table 23. In Pilots column the first number represents change in instructor pilots and the second number change in four ship leaders. We use a random schedule here as in Model 6a.

Table 23. Averaged Results for Model 6p

Model	Scenario	Pilots	SortieNumber	AircraftUtilization	InstructorPilot	FourshipLeader	TwoshipLeader	Wingman
6p	1	3/4	337.2±6.97	61.8±0.45	42.7±0.91	68.6±0.47	62.4±0.35	53.0±0.45
6p	2	2/4	327.4±7.81	59.5±0.63	62.2±0.94	69.3±0.49	62.2±0.51	46.7±0.61
6p	3	1/4	304.8±7.22	55.4±0.47	62.3±0.86	68.7±0.37	62.3±0.43	41.8±0.47
6p	4	3/3	338.7±18.73	61.5±3.13	62.3±0.67	70.7±2.30	62.2±0.47	49.1±3.74
6p	5	3/2	304.8±7.22	55.4±0.47	62.3±0.62	75.1±0.42	62.3±0.43	41.8±0.47
6p	6	3/1	272.6±7.07	49.2±0.52	62.3±0.67	87.7±0	62.3±0.42	35.5±0.44
6p	7	2/3	304.8±7.22	55.4±0.47	62.4±0.67	70.8±0.43	62.3±0.43	41.8±0.47
6p	8	1/2	246.0±5.38	43.2±0.34	62.2±0.69	75.0±0.53	62.4±0.42	30.0±0.27

The logic in these results follows that from Model 5p. First, we changed the number of instructors while keeping the number of four ship leaders the same. As expected, the result was a significant increase in utilizations. However, there was no obvious change in the number of sorties generated. Second, we changed the number of four ship leaders while keeping the number of instructors constant. Again, there was a significant rise in utilizations but, sortie numbers saw a drop. Lastly, we degraded both the number of instructors and four ship leaders. This led to another significant drop in sortie numbers and a jump in utilizations at a fluctuation greater than seen previously. The SMORE plot in Figure 14 illustrates the influence instructors and four ship leaders can have on sortie numbers. In Scenarios 2p and 3p the number of instructors is decreased by increments of one. Once again, because of the process logic implemented in our simulation and the exclusion of back seat flights, the SMORE plots show no significant changes from scenario 2p. However, a notable drop is observed when a second instructor is absent in scenario 3p. Starting from scenarios 4p to 6p, the SMORE plots represent a constant number of instructors and incremental drop in four ship leaders.

Here, there is an immediate significant drop of sorties generated in all three scenarios as the number of four ship leaders go down. Next, in scenario 7p both a single instructor and a single four ship leader are removed from the fighter squadron. Compared to scenario 1p where no personnel are missing, there is a significant drop in sortie numbers. Finally, the SMORE plot from scenario 7p to 8p presents a dramatic drop in sortie numbers. Here, an additional instructor and four ship leader are removed leading to even greater statistical and practical consequences.

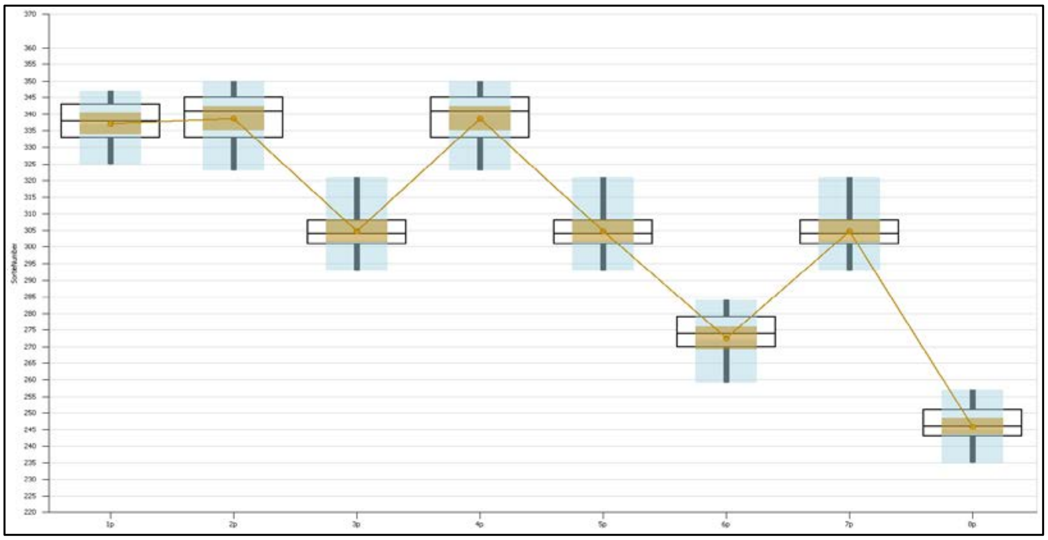


Figure 14. Model 6p Scenarios Comparison Analyses

4.2.7. Model 7a and 7p

Model 7a and 7p are similar to Model 6a and 6p, but the mission planning function has been removed. However, the effects on the results follow trends seen in Model 6a and 6p as expected. The results for these models are summarized in Tables 24 and 25 and the SMORE plots belonging to this analysis are shown in Figure 15 and 16. In Abort column the first number represents the ground abort percentage, the second number air abort percentage, and the third number weather abort percentage. In Pilots column the first number represents change in instructor pilots and the second number change in four ship leaders.

Table 24. Averaged Results for Model 7a

Model	Scenario	Abort Rates	SortieNumber	AircraftUtilization	InstructorPilot	FourshipLeader	TwoshipLeader	Wingman
7a	1	3/2/3	422.4±8.98	77.3±0.57	53.4±1.01	85.8±0.45	77.9±0.46	66.3±0.54
7a	2	2/1/2	431.5±6.66	78.0±0.39	53.9±0.76	86.3±0.35	78.6±0.36	66.9±0.46
7a	3	1/0/1	442.7±6.38	78.7±0.31	54.3±0.65	86.9±0.21	79.3±0.19	67.4±0.33
7a	4	0/0/0	446.5±7.19	79.2±0.32	54.7±0.78	87.2±0	79.7±0	67.8±0.38
7a	5	4/3/4	411.4±7.71	76.3±0.54	53.0±0.82	85.1±0.56	77.0±0.59	65.5±0.58
7a	6	5/4/5	408.7±11.10	76.2±0.68	52.9±1.07	84.9±0.56	76.8±0.64	65.5±0.59
7a	7	6/5/6	408.6±10.76	75.9±0.60	52.5±1.16	85.0±0.58	76.6±0.50	65.2±0.49

Table 25. Averaged Results for Model 7p

Model	Scenario	Pilots	SortieNumber	AircraftUtilization	InstructorPilot	FourshipLeader	TwoshipLeader	Wingman
7p	1	3/4	422.4±8.98	77.3±0.57	53.4±1.01	85.8±0.45	77.9±0.46	66.3±0.54
7p	2	2/4	421.7±7.88	76.8±0.64	77.9±1.00	85.8±0.47	77.6±0.46	61.4±0.61
7p	3	1/4	380.5±7.73	69.2±0.58	77.9±1.02	85.9±0.42	77.8±0.47	52.2±0.60
7p	4	3/3	421.7±7.88	76.8±0.64	78.0±0.81	88.3±0.52	77.6±0.46	61.4±0.61
7p	5	3/2	380.5±7.73	69.2±0.58	77.9±0.71	93.9±0.49	77.8±0.47	52.2±0.60
7p	6	3/1	341.5±7.32	61.6±0.52	77.9±0.73	93.8±0.51	77.9±0.44	44.4±0.44
7p	7	2/3	380.5±7.73	69.2±0.58	78.0±0.86	88.4±0.44	77.8±0.47	52.2±0.60
7p	8	1/2	307.0±5.49	53.9±0.39	77.5±0.95	93.8±0.58	78.0±0.43	37.4±0.30

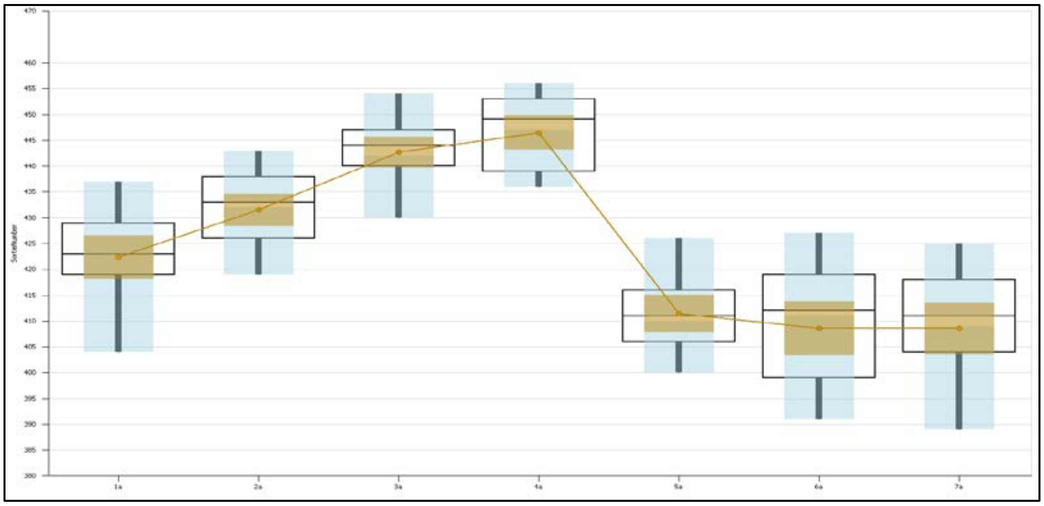


Figure 15. Model 7a Scenarios Comparison Analyses

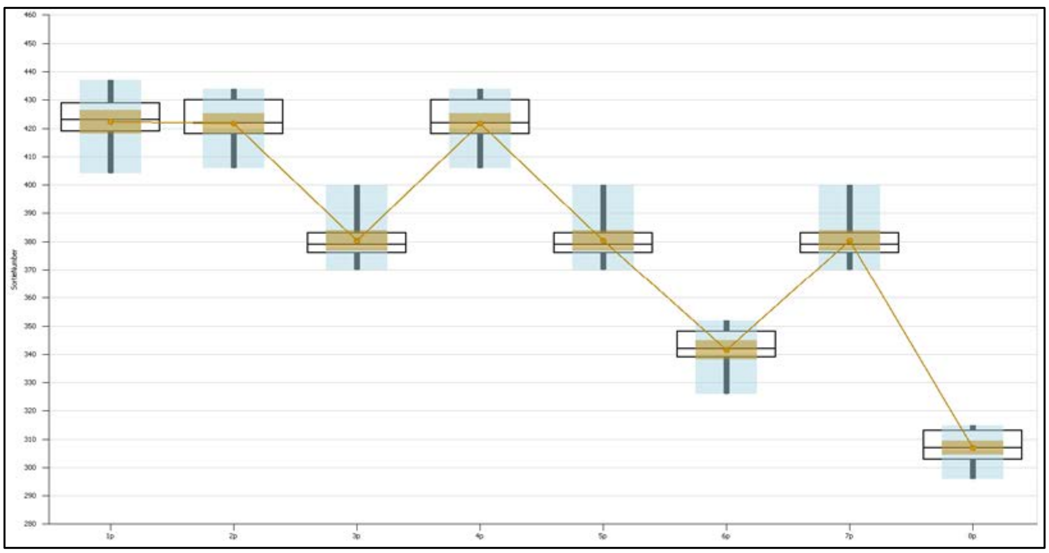


Figure 16. Model 7p Scenarios Comparison Analyses

Models 5a, 6a, and 7a follow similar trends and observations seen in the previous models that explore abort rate effects. Likewise, results from models 5p, 6p, and 7p closely resemble responses found in the previous models that examine the influence of personnel availability. Key insights from this analysis are discussed further in the next summary section of this chapter. Changes in abort rates, personnel availability, and the usage of mission planning have been explored in these results. As explained in the methodology, each model slightly modifies a specific area of the sortie generation process and investigates the impact. For example, in model 6p1, the mission planning cell is removed for model 7p1 resulting in an increase of around 85 missions. These impacts are further explained in Chapter 5.

4.3. Summary

These models allow decision makers to assess the impact certain situations have on fighter squadrons. By utilizing all of these models which cover various variables in different scenarios, a commander can gain valuable insight on the impact of changes in these factors. They give a basis for planners and schedulers to see how changes in circumstances affect the sortie generation process. For example, a randomized schedule seen in war time scenario forces squadrons to generate more missions. In addition, when the mission planning function is removed in the sortie generation process, pilots are able to have more flexibility in their roles allowing an increase in sorties. These results presented many key insights into the overall sortie generation process. As expected, when abort rates are increased, fewer sorties are flown. Additionally, when the number of instructors and four ship leaders are altered, the squadron must adjust to these personnel changes. An overall comparison between all models is presented in Appendix A.

Having this level of quantitative analysis through simulation gives fighter squadrons major insights on how to properly conduct sortie operations both in peacetime and wartime situations. This study puts numbers with logical patterns in results. The impact and significance of this analysis is further explored in Chapter 5.

V. Conclusions and Recommendations

5.1. Chapter Overview

This chapter concludes major points discussed in this research. In the first chapter, the main problem is defined with critical investigative questions. Then, studies concerning the sortie generation process, scheduling and simulation are discussed in the second chapter. Next, a description of produced models is explained and model improvements. Finally, the previous chapter defines results from the performed analysis. After forming the problem, determining the methodology, and analyzing the results, conclusion and recommendations are made. This section now summarizes the impact and significance of these findings. In addition, suggestions and recommendations for future research are included.

5.2. Conclusions of Research

The main purpose of this study was to create reasonable simulation models representing the sortie generation process for a fighter squadron. The models are run through Simio and could provide value as a tool for Air Force planners and operators. Important investigative questions are answered by altering and adjusting various model parameters and running comparisons. For example, the effects of abort rates have been considered by adding them to a baseline model. It's noted that sortie numbers drop significantly as abort rate rise. Furthermore, various "What-If" scenarios are run in these analyses. Final findings on the effects of certain features are summarized in Table 26 below.

Table 26. Model Feature Modifications and Effects

	Abort Rates	InstNum	FourShipNum	SortieNum	AcftUtil	InstPilot	FourshipLdr	TwoshipLdr	Wingman
Change	↑	↔	↔	↓	↓	↓	↓	↓	↓
	↓	↔	↔	↑	↑	↑	↑	↑	↑
	↔	↓	↔	↓	↓	↑	↑	↔	↓
	↔	↔	↓	↓	↓	↑	↑	↔	↓
	↔	↓	↓	↓	↓	↑	↑	↔	↓
	↔	↓	↓	↓	↓	↑	↑	↔	↓

The features highlighted in green are modified in the various models and scenarios. The effects examined from the output of the simulation are highlighted in blue. Also, we observed that removal of mission planning function provided the ability to generate more sorties. The significance and impact of these findings are now explained.

5.3. Significance and Recommendations

A proper method for efficient sortie generation is critical for a high performing fighter squadron. The research conducted in this study explores many insights that can assist key decision makers towards this goal. This simulation gives planners a basis to make calculations on required missions, aircraft, and personnel according to their pilot ratings. These findings give personnel the confidence to make improved decisions with quantitative support.

This tool is not only useful at the tactical level, but can be used in other fields as well. Some of the diverse areas where this research can be applied are listed:

- Providing improved estimates of aircraft and pilot requirements when creating new squadrons,
- Serving as a baseline for personnel and aircraft estimates before deployments,

- Informing policy-makers on modifying specific functions in the sortie generation process to improve sortie numbers/utilizations,

- Giving supporting numerical information during modernization efforts where abort rates are guaranteed to be affected,

- Observing the effect on the sortie numbers during times of conflict where there are dynamic changes in personnel and aircraft,

- Assisting in the analysis of the effects that pilot ratings and crew rest have on sortie numbers and the overall squadron status.

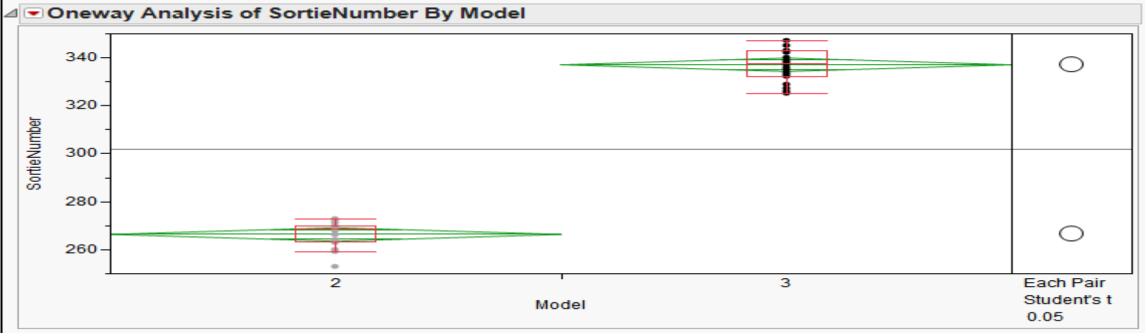
5.4. Recommendations for Future Research

The model can be enhanced by increasing the scope of this simulation. A simplified baseline sortie generation process was modeled. The number of missions, pilots, aircraft and blocks are limited. By increasing these numbers with minor logic changes in the model, more representative system performance could be captured. Scheduling is created using a DSS or randomly. In future studies, the schedules can be created automatically.

In this study, the sortie generation model was generated and ran in Simio for a fighter squadron. It can be transformed for transportation squadrons. Furthermore, this simulation model can be used for the simulators to see the effect of these centers in sortie generation during training phases. Future research can include generating models based on deploying to unique geographical locations that are much different than your current climate such as dessert. The crew rest may change during the conflicts and this change can be plugged into a different model and see the results compared to the baseline model. This study modeled the SOF and RSU for the ground duties. Future studies may focus on the BO and SIM as well.

Appendix. In Depth Analysis of Models

Oneway Analysis of SortieNumber By Model



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
2	253	259	263.25	268.5	270	272	273
3	325	326.1	332.25	337.5	343	346.8	347

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
2.02439	0.05

LSD Threshold Matrix

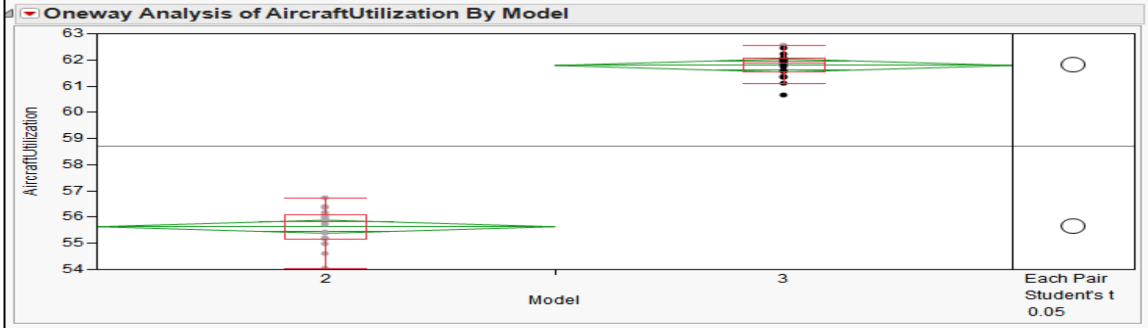
Abs(Dif)-LSD

	3	2
3	-3.978	66.722
2	66.722	-3.978

Positive values show pairs of means that are significantly different.

Figure 17. Model 1 and Model 2 Comparison Analyses of Sortie Number

Oneway Analysis of AircraftUtilization By Model



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
2	54.05568	54.63994	55.16451	55.8283	56.0749	56.39365	56.71751
3	60.64264	61.12439	61.54183	61.89309	62.05377	62.42622	62.53751

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
2.02439	0.05

LSD Threshold Matrix

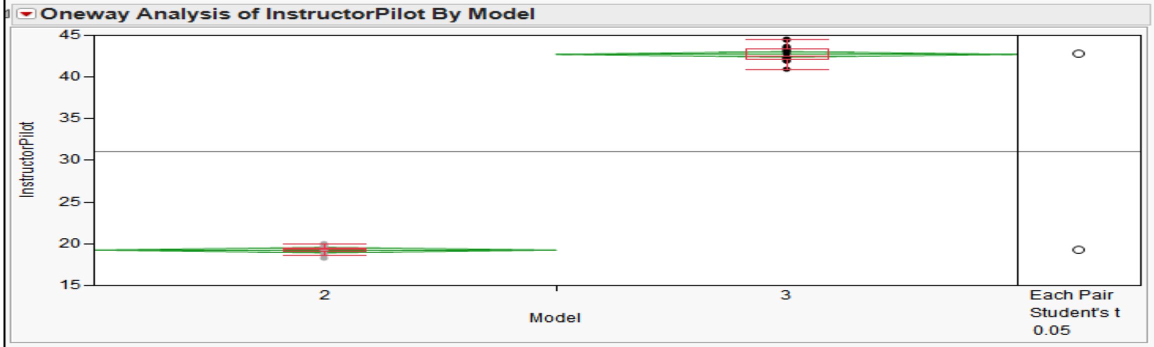
Abs(Dif)-LSD

	3	2
3	-0.3567	5.7953
2	5.7953	-0.3567

Positive values show pairs of means that are significantly different.

Figure 18. Model 1 and Model 2 Comparison Analyses of Aircraft Utilization

Oneway Analysis of InstructorPilot By Model



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
2	18.20434	18.24504	19.07249	19.31155	19.52455	19.75086	19.93909
3	40.87235	41.87251	42.12546	42.55082	43.38071	44.27344	44.52421

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
2.02439	0.05

LSD Threshold Matrix

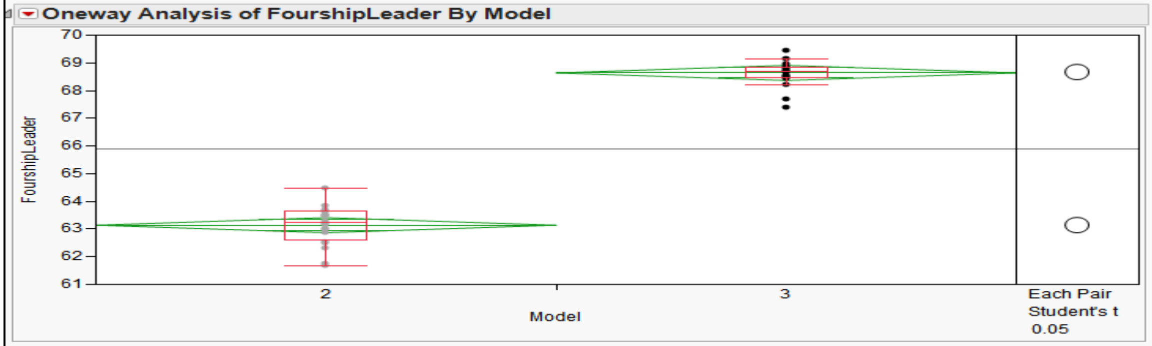
Abs(Dif)-LSD

	3	2
3	-0.463	23.015
2	23.015	-0.463

Positive values show pairs of means that are significantly different.

Figure 19. Model 1 and Model 2 Comparison Analyses of Instructor Pilot

Oneway Analysis of FourshipLeader By Model



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
2	61.68413	61.79757	62.6054	63.2485	63.64329	63.84275	64.47978
3	67.38964	67.74528	68.48251	68.70281	68.84792	69.15912	69.43577

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
2.02439	0.05

LSD Threshold Matrix

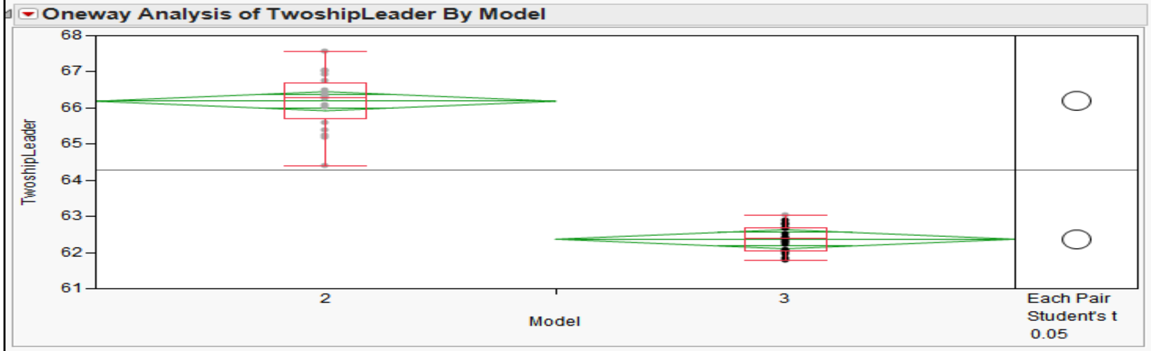
Abs(Dif)-LSD

	3	2
3	-0.3862	5.1140
2	5.1140	-0.3862

Positive values show pairs of means that are significantly different.

Figure 20. Model 1 and Model 2 Comparison Analyses of Four Ship Leader

Oneway Analysis of TwoshipLeader By Model



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
2	64.41093	65.18874	65.69378	66.2801	66.69043	67.04267	67.55343
3	61.79628	61.8538	62.05106	62.38286	62.67552	62.87159	63.03529

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
2.02439	0.05

LSD Threshold Matrix

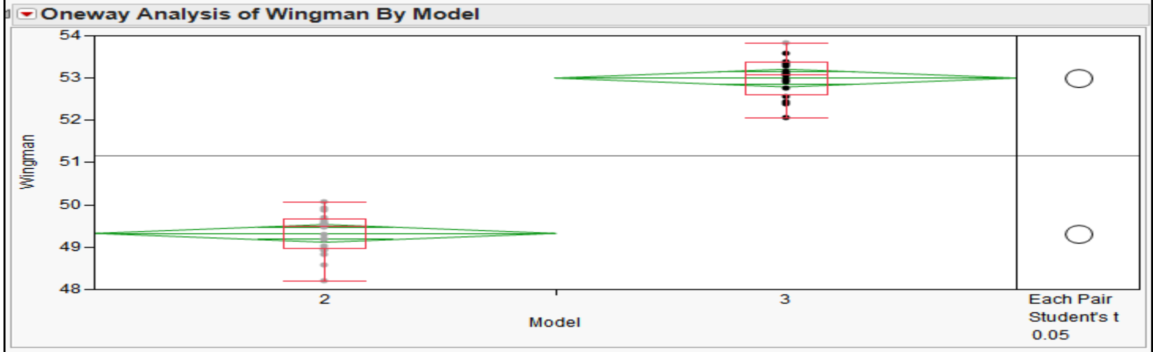
Abs(Dif)-LSD

	2	3
2	-0.3733	3.4457
3	3.4457	-0.3733

Positive values show pairs of means that are significantly different.

Figure 21. Model 1 and Model 2 Comparison Analyses of Two Ship Leader

Oneway Analysis of Wingman By Model



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
2	48.20025	48.60624	48.97054	49.49353	49.65781	49.90797	50.05615
3	52.06807	52.39568	52.61229	53.07678	53.37219	53.56368	53.83029

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
2.02439	0.05

LSD Threshold Matrix

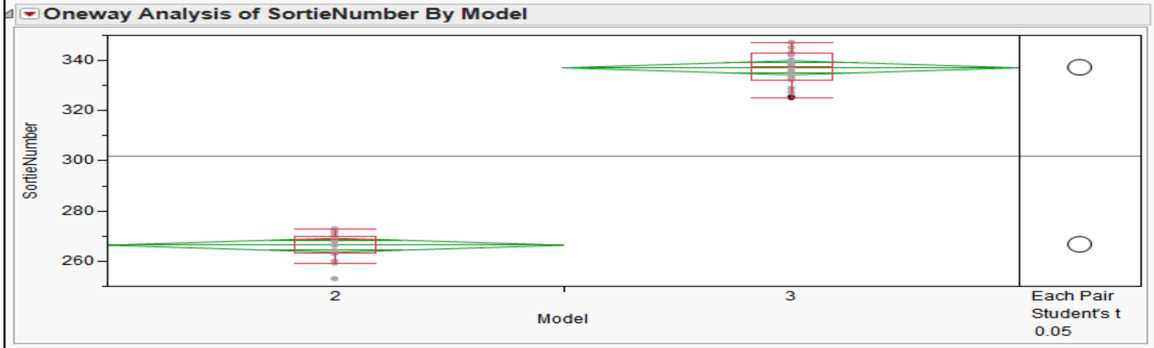
Abs(Dif)-LSD

	3	2
3	-0.2955	3.3774
2	3.3774	-0.2955

Positive values show pairs of means that are significantly different.

Figure 22. Model 1 and Model 2 Comparison Analyses of Wingman

Oneway Analysis of SortieNumber By Model



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
2	253	259	263.25	268.5	270	272	273
3	325	326.1	332.25	337.5	343	346.8	347

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
2.02439	0.05

LSD Threshold Matrix

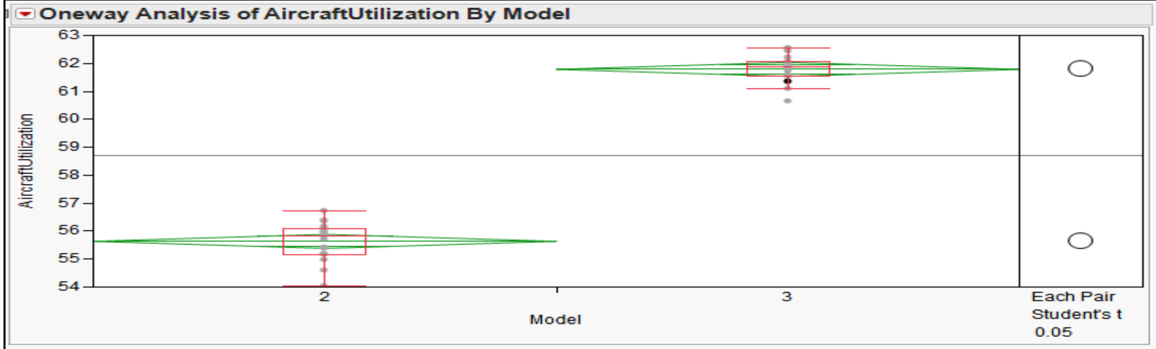
Abs(Dif)-LSD

	3	2
3	-3.978	66.722
2	66.722	-3.978

Positive values show pairs of means that are significantly different.

Figure 23. Model 2 and Model 3 Comparison Analyses of Sortie Number

Oneway Analysis of AircraftUtilization By Model



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
2	54.05568	54.63994	55.16451	55.8283	56.0749	56.39365	56.71751
3	60.64264	61.12439	61.54183	61.89309	62.05377	62.42622	62.53751

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
2.02439	0.05

LSD Threshold Matrix

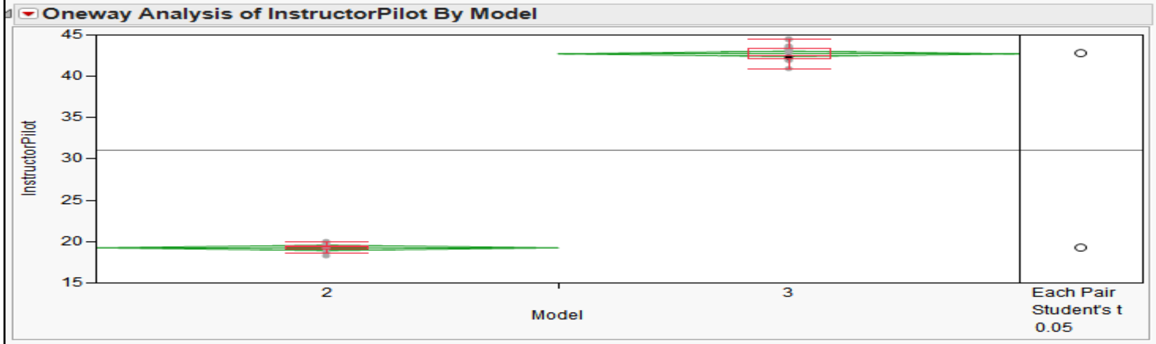
Abs(Dif)-LSD

	3	2
3	-0.3567	5.7953
2	5.7953	-0.3567

Positive values show pairs of means that are significantly different.

Figure 24. Model 2 and Model 3 Comparison Analyses of Aircraft Utilization

Oneway Analysis of InstructorPilot By Model



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
2	18.20434	18.24504	19.07249	19.31155	19.52455	19.75086	19.93909
3	40.87235	41.87251	42.12546	42.55082	43.38071	44.27344	44.52421

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
2.02439	0.05

LSD Threshold Matrix

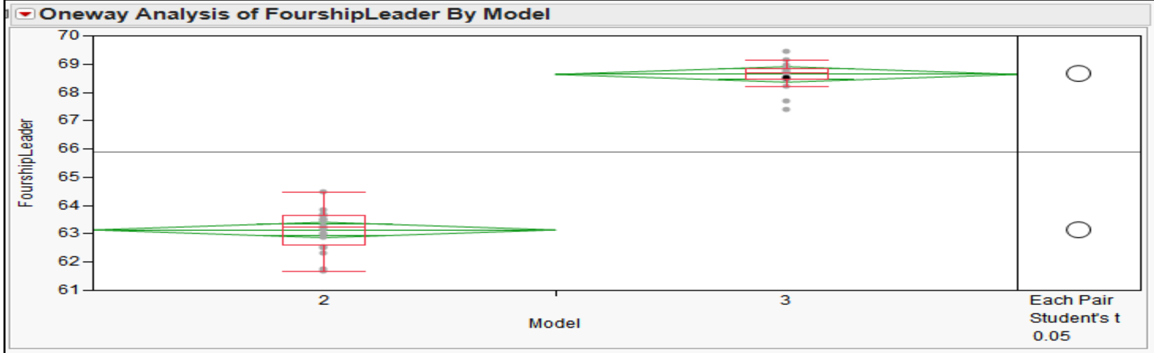
Abs(Dif)-LSD

	3	2
3	-0.463	23.015
2	23.015	-0.463

Positive values show pairs of means that are significantly different.

Figure 25. Model 2 and Model 3 Comparison Analyses of Instructor Pilot

Oneway Analysis of FourshipLeader By Model



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
2	61.68413	61.79757	62.6054	63.2485	63.64329	63.84275	64.47978
3	67.38964	67.74528	68.48251	68.70281	68.84792	69.15912	69.43577

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
2.02439	0.05

LSD Threshold Matrix

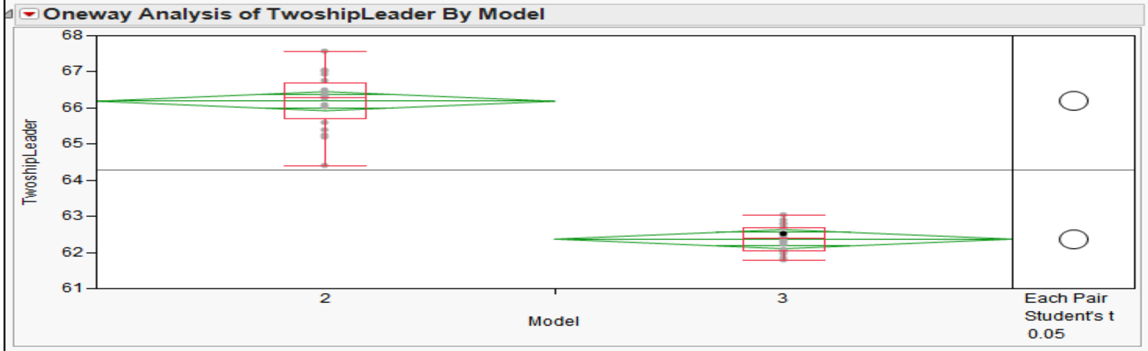
Abs(Dif)-LSD

	3	2
3	-0.3862	5.1140
2	5.1140	-0.3862

Positive values show pairs of means that are significantly different.

Figure 26. Model 2 and Model 3 Comparison Analyses of Four Ship Leader

Oneway Analysis of TwoshipLeader By Model



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
2	64.41093	65.18874	65.69378	66.2801	66.69043	67.04267	67.55343
3	61.79628	61.8538	62.05106	62.38286	62.67552	62.87159	63.03529

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
2.02439	0.05

LSD Threshold Matrix

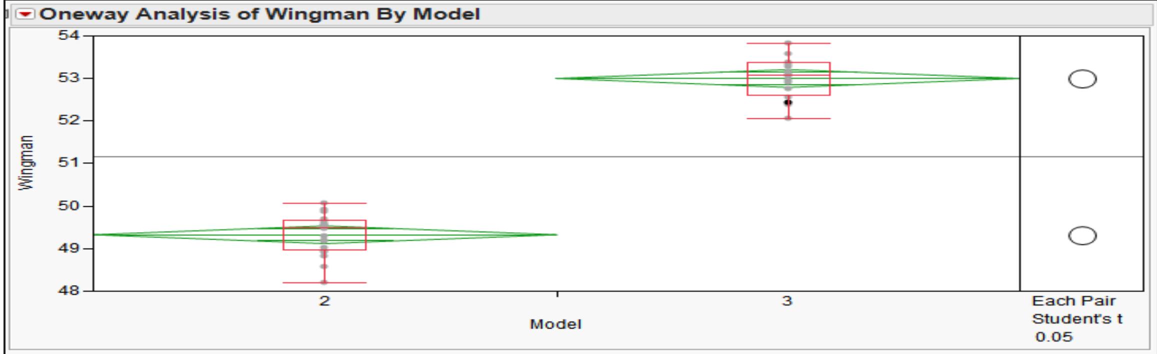
Abs(Dif)-LSD

	2	3
2	-0.3733	3.4457
3	3.4457	-0.3733

Positive values show pairs of means that are significantly different.

Figure 27. Model 2 and Model 3 Comparison Analyses of Two Ship Leader

Oneway Analysis of Wingman By Model



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
2	48.20025	48.60624	48.97054	49.49353	49.65781	49.90797	50.05615
3	52.06807	52.39568	52.61229	53.07678	53.37219	53.56368	53.83029

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
2.02439	0.05

LSD Threshold Matrix

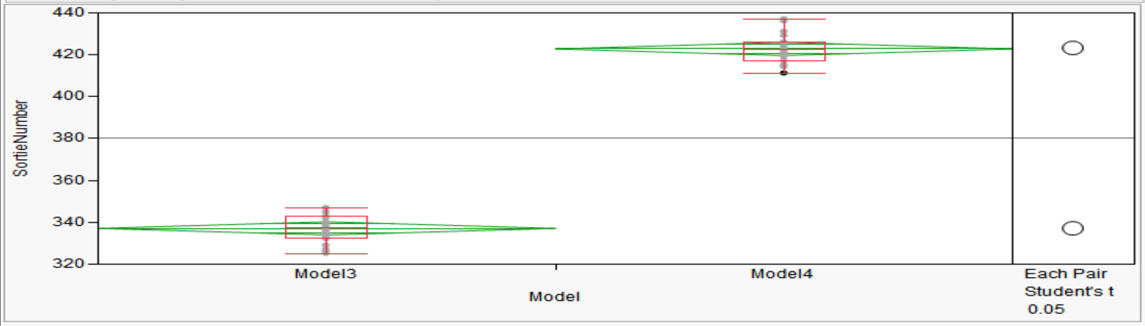
Abs(Dif)-LSD

	3	2
3	-0.2955	3.3774
2	3.3774	-0.2955

Positive values show pairs of means that are significantly different.

Figure 28. Model 2 and Model 3 Comparison Analyses of Wingman

Oneway Analysis of SortieNumber By Model



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
Model3	325	326.1	332.25	337.5	343	346.8	347
Model4	411	414.1	417	422.5	426	435.5	437

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
2.02439	0.05

LSD Threshold Matrix

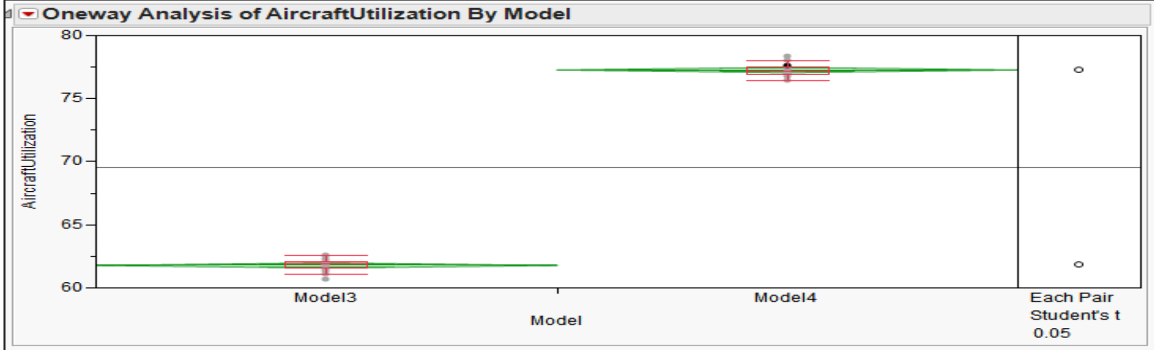
Abs(Dif)-LSD

	Model4	Model3
Model4	-4.449	81.251
Model3	81.251	-4.449

Positive values show pairs of means that are significantly different.

Figure 29. Model 3 and Model 4 Comparison Analyses of Sortie Number

Oneway Analysis of AircraftUtilization By Model



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
Model3	60.64264	61.12439	61.54183	61.89309	62.05377	62.42622	62.53751
Model4	76.42974	76.80928	76.96525	77.19772	77.51732	77.97613	78.35406

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
2.02439	0.05

LSD Threshold Matrix

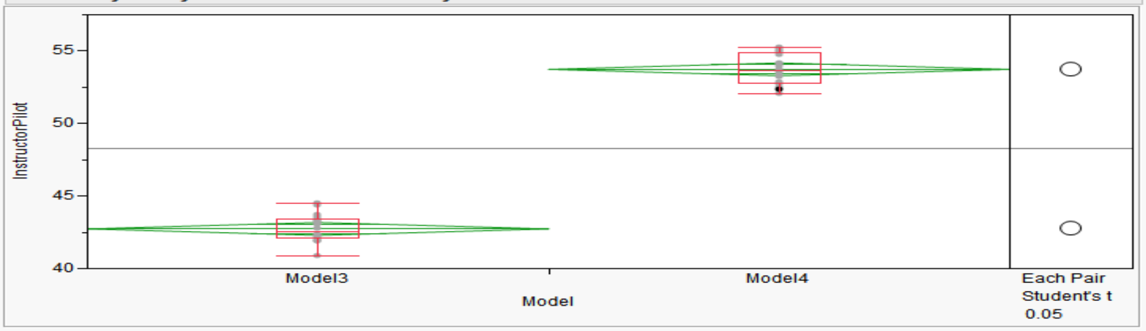
Abs(Dif)-LSD

	Model4	Model3
Model4	-0.284	15.209
Model3	15.209	-0.284

Positive values show pairs of means that are significantly different.

Figure 30. Model 3 and Model 4 Comparison Analyses of Aircraft Utilization

Oneway Analysis of InstructorPilot By Model



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
Model3	40.87235	41.87251	42.12546	42.55082	43.38071	44.27344	44.52421
Model4	52.02008	52.33214	52.80516	53.66142	54.87922	55.2255	55.23024

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
2.02439	0.05

LSD Threshold Matrix

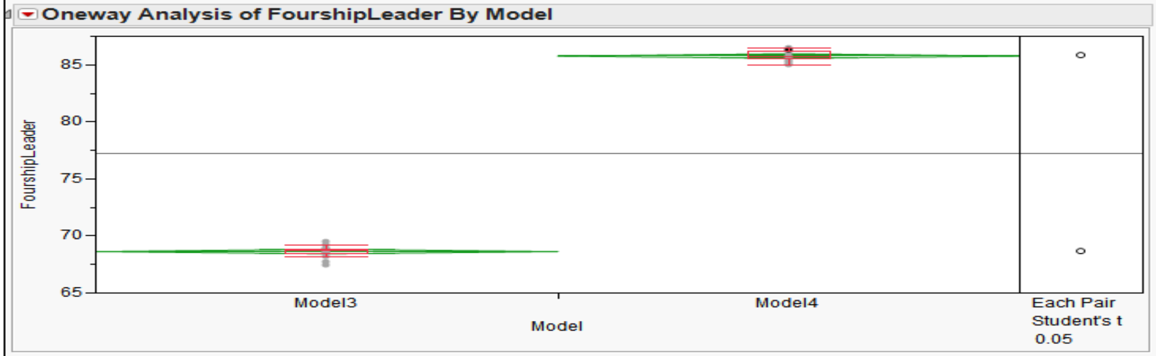
Abs(Dif)-LSD

	Model4	Model3
Model4	-0.628	10.376
Model3	10.376	-0.628

Positive values show pairs of means that are significantly different.

Figure 31. Model 3 and Model 4 Comparison Analyses of Instructor Pilot

Oneway Analysis of FourshipLeader By Model



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
Model3	67.38964	67.74528	68.48251	68.70281	68.84792	69.15912	69.43577
Model4	84.9408	85.06998	85.49525	85.74347	86.1724	86.42114	86.4624

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
2.02439	0.05

LSD Threshold Matrix

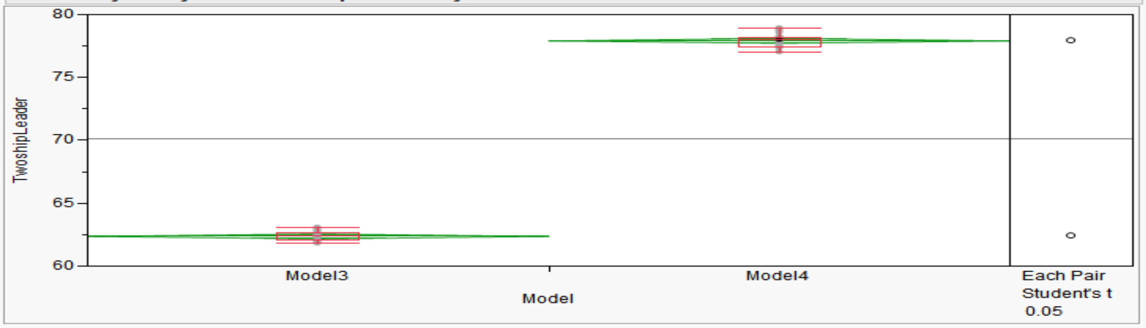
Abs(Dif)-LSD

	Model4	Model3
Model4	-0.291	16.845
Model3	16.845	-0.291

Positive values show pairs of means that are significantly different.

Figure 32. Model 3 and Model 4 Comparison Analyses of Four Ship Leader

Oneway Analysis of TwoshipLeader By Model



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
Model3	61.79628	61.8538	62.05106	62.38286	62.67552	62.87159	63.03529
Model4	76.99108	77.35439	77.45085	78.01952	78.14169	78.70543	78.96033

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
2.02439	0.05

LSD Threshold Matrix

Abs(Dif)-LSD

	Model4	Model3
Model4	-0.277	15.269
Model3	15.269	-0.277

Positive values show pairs of means that are significantly different.

Figure 33. Model 3 and Model 4 Comparison Analyses of Two Ship Leader

Oneway Analysis of Wingman By Model

Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
Model3	52.06807	52.39568	52.61229	53.07678	53.37219	53.56368	53.83029
Model4	65.45154	65.75726	65.95313	66.29782	66.69546	66.91941	67.22993

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
2.02439	0.05

LSD Threshold Matrix

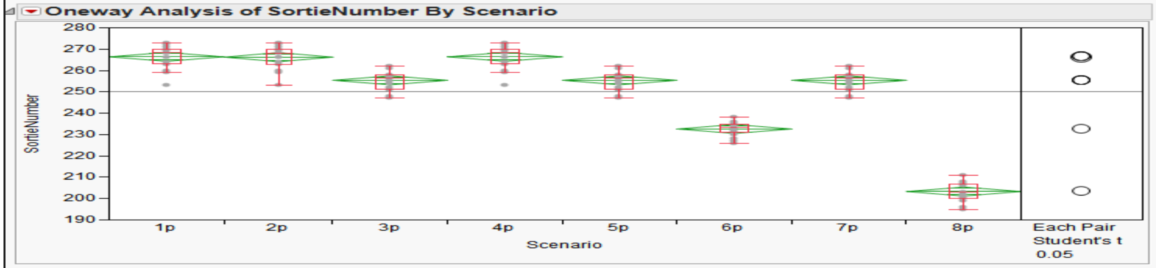
Abs(Dif)-LSD

	Model4	Model3
Model4	-0.291	13.033
Model3	13.033	-0.291

Positive values show pairs of means that are significantly different.

Figure 34. Model 3 and Model 4 Comparison Analyses of Wingman

Oneway Analysis of SortieNumber By Scenario



Excluded Rows 1

Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
1p	253	259	263.25	268.5	270	272	273
2p	253	259	263	268	270	272	273
3p	247	248	251.25	256.5	258	261.9	262
4p	253	259	263.25	268.5	270	272	273
5p	247	248	251.25	256.5	258	261.9	262
6p	226	227.1	231	233.5	234.75	236	238
7p	247	248	251.25	256.5	258	261.9	262
8p	195	196.3	200.25	203	206.75	210.7	211

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
1.97580	0.05

LSD Threshold Matrix

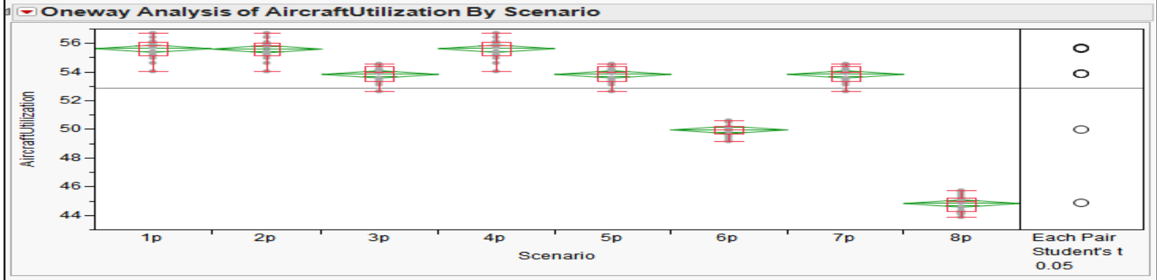
Abs(Dif)-LSD

	1p	4p	2p	3p	5p	7p	6p	8p
1p	-2.974	-2.974	-2.879	8.026	8.026	8.026	30.826	60.126
4p	-2.974	-2.974	-2.879	8.026	8.026	8.026	30.826	60.126
2p	-2.879	-2.879	-3.052	7.853	7.853	7.853	30.653	59.953
3p	8.026	8.026	7.853	-2.974	-2.974	-2.974	19.826	49.126
5p	8.026	8.026	7.853	-2.974	-2.974	-2.974	19.826	49.126
7p	8.026	8.026	7.853	-2.974	-2.974	-2.974	19.826	49.126
6p	30.826	30.826	30.653	19.826	19.826	19.826	-2.974	26.326
8p	60.126	60.126	59.953	49.126	49.126	49.126	26.326	-2.974

Positive values show pairs of means that are significantly different.

Figure 35. Model 5a Scenarios Comparison Analyses of Sortie Number

Oneway Analysis of AircraftUtilization By Scenario



Excluded Rows 1

Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
1p	54.05568	54.63994	55.16451	55.8283	56.0749	56.39365	56.71751
2p	54.05568	54.60213	55.15597	55.8201	56.00832	56.3964	56.71751
3p	52.63639	53.10262	53.31384	54.00419	54.39722	54.4968	54.57446
4p	54.05568	54.63994	55.16451	55.8283	56.0749	56.39365	56.71751
5p	52.63639	53.10262	53.31384	54.00419	54.39722	54.4968	54.57446
6p	49.182	49.28548	49.68442	49.99248	50.18086	50.56087	50.60429
7p	52.63639	53.10262	53.31384	54.00419	54.39722	54.4968	54.57446
8p	43.8938	44.08063	44.26706	44.97051	45.21936	45.58307	45.74834

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
1.97580	0.05

LSD Threshold Matrix

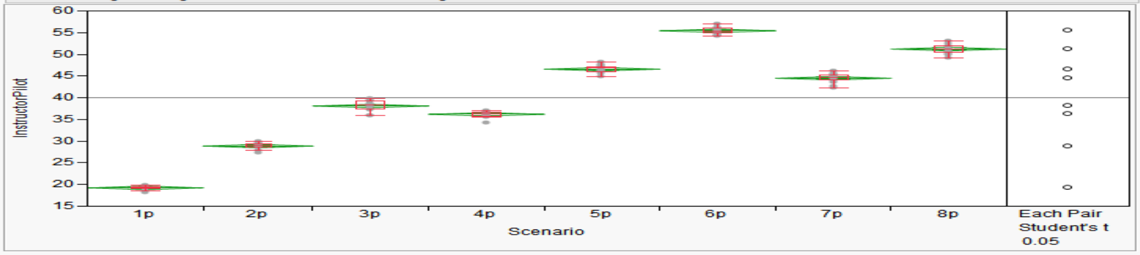
Abs(Dif)-LSD

	1p	4p	2p	3p	5p	7p	6p	8p
1p	-0.364	-0.364	-0.342	1.430	1.430	1.430	5.300	10.433
4p	-0.364	-0.364	-0.342	1.430	1.430	1.430	5.300	10.433
2p	-0.342	-0.342	-0.373	1.398	1.398	1.398	5.268	10.401
3p	1.430	1.430	1.398	-0.364	-0.364	-0.364	3.506	8.639
5p	1.430	1.430	1.398	-0.364	-0.364	-0.364	3.506	8.639
7p	1.430	1.430	1.398	-0.364	-0.364	-0.364	3.506	8.639
6p	5.300	5.300	5.268	3.506	3.506	3.506	-0.364	4.769
8p	10.433	10.433	10.401	8.639	8.639	8.639	4.769	-0.364

Positive values show pairs of means that are significantly different.

Figure 36. Model 5a Scenarios Comparison Analyses of Aircraft Utilization

Oneway Analysis of InstructorPilot By Scenario



Excluded Rows 1

Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
1p	18.20434	18.24504	19.07249	19.31155	19.52455	19.75086	19.93909
2p	27.30374	27.30384	28.57872	28.96456	29.29772	29.62901	29.90587
3p	35.88787	35.88843	37.38125	38.26689	39.20939	39.87265	39.87265
4p	34.18866	35.49955	35.76597	36.32915	36.61562	37.0783	37.10441
5p	44.78329	44.85432	45.99214	46.84996	47.18272	47.64734	48.28982
6p	54.15967	54.3562	54.96241	55.39582	56.0046	56.89808	57.00101
7p	42.31031	42.53852	44.03973	44.69055	45.28585	45.57136	46.18539
8p	49.17497	49.86309	50.50432	51.16934	51.99947	53.09538	53.16168

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
1.97580	0.05

LSD Threshold Matrix

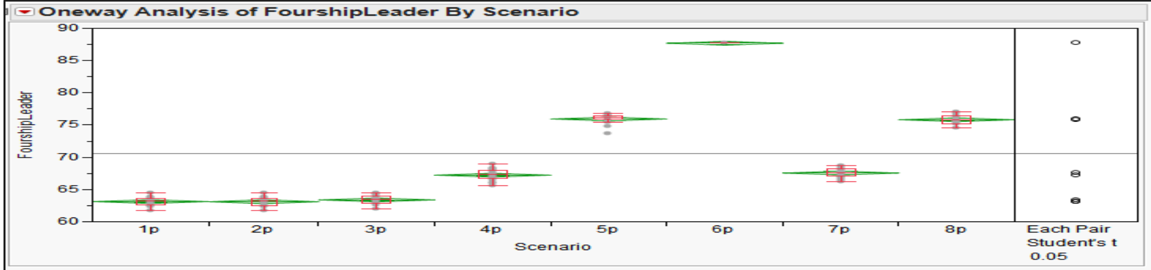
Abs(Dif)-LSD

	6p	8p	5p	7p	3p	4p	2p	1p
6p	-0.573	3.647	8.268	10.363	16.764	18.674	25.985	35.618
8p	3.647	-0.573	4.048	6.143	12.544	14.455	21.765	31.398
5p	8.268	4.048	-0.573	1.522	7.923	9.833	17.144	26.777
7p	10.363	6.143	1.522	-0.573	5.828	7.738	15.049	24.682
3p	16.764	12.544	7.923	5.828	-0.573	1.337	8.648	18.281
4p	18.674	14.455	9.833	7.738	1.337	-0.573	6.738	16.371
2p	25.985	21.765	17.144	15.049	8.648	6.738	-0.588	9.045
1p	35.618	31.398	26.777	24.682	18.281	16.371	9.045	-0.573

Positive values show pairs of means that are significantly different.

Figure 37. Model 5a Scenarios Comparison Analyses of Instructor Pilot

Oneway Analysis of FourshipLeader By Scenario



Excluded Rows 1

Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
1p	61.68413	61.79757	62.6054	63.2485	63.64329	63.84275	64.47978
2p	61.68413	61.73937	62.51574	63.20643	63.65042	63.84275	64.47978
3p	61.98834	62.07435	62.90213	63.4281	63.9952	64.38878	64.47967
4p	65.59729	65.94048	66.76019	67.33274	67.94981	68.28356	68.91842
5p	73.75519	74.8063	75.87258	76.13511	76.41196	76.51723	76.74481
6p	87.70764	87.70764	87.70764	87.70764	87.70764	87.70764	87.70764
7p	66.26061	66.47171	67.08289	67.553	68.18963	68.47545	68.69738
8p	74.58589	75.08971	75.20823	75.74865	76.41303	76.79407	77.07641

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
1.97580	0.05

LSD Threshold Matrix

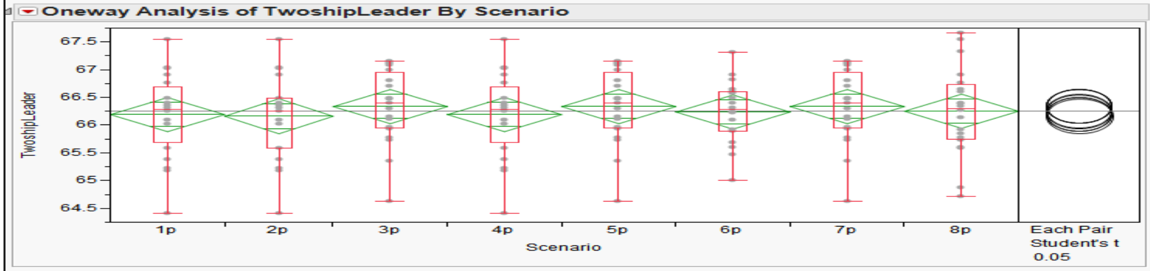
Abs(Dif)-LSD

	6p	5p	8p	7p	4p	3p	1p	2p
6p	-0.426	11.324	11.440	19.710	20.035	23.875	24.139	24.152
5p	11.324	-0.426	-0.310	7.961	8.286	12.125	12.389	12.403
8p	11.440	-0.310	-0.426	7.845	8.169	12.009	12.273	12.287
7p	19.710	7.961	7.845	-0.426	-0.101	3.738	4.003	4.016
4p	20.035	8.286	8.169	-0.101	-0.426	3.414	3.678	3.692
3p	23.875	12.125	12.009	3.738	3.414	-0.426	-0.162	-0.148
1p	24.139	12.389	12.273	4.003	3.678	-0.162	-0.426	-0.412
2p	24.152	12.403	12.287	4.016	3.692	-0.148	-0.412	-0.437

Positive values show pairs of means that are significantly different.

Figure 38. Model 5a Scenarios Comparison Analyses of Four Ship Leader

Oneway Analysis of TwoshipLeader By Scenario



Excluded Rows 1

Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
1p	64.41093	65.18874	65.69378	66.2801	66.69043	67.04267	67.55343
2p	64.41093	65.18419	65.5832	66.24714	66.49093	67.04495	67.55343
3p	64.63065	65.39842	65.94278	66.40193	66.94948	67.13051	67.15458
4p	64.41093	65.18874	65.69378	66.2801	66.69043	67.04267	67.55343
5p	64.63065	65.39842	65.94278	66.40193	66.94948	67.13051	67.15458
6p	65.00767	65.48474	65.89788	66.27962	66.59602	66.90268	67.31008
7p	64.63065	65.39842	65.94278	66.40193	66.94948	67.13051	67.15458
8p	64.71975	64.94505	65.7484	66.30302	66.72847	67.53142	67.66431

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
1.97580	0.05

LSD Threshold Matrix

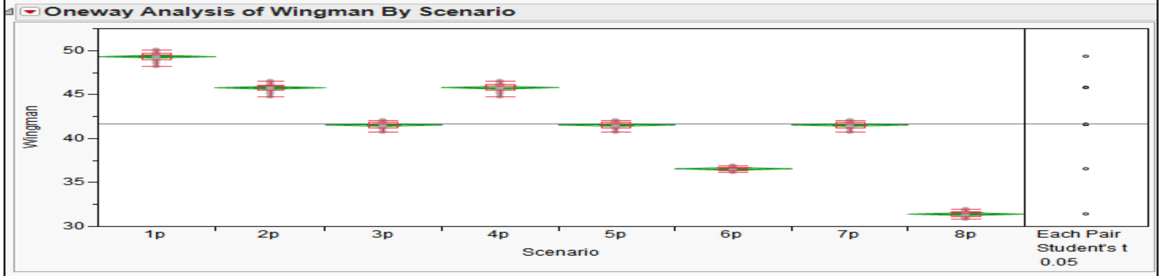
Abs(Dif)-LSD

	3p	5p	7p	8p	6p	1p	4p	2p
3p	-0.43530	-0.43530	-0.43530	-0.35151	-0.33700	-0.29051	-0.29051	-0.26646
5p	-0.43530	-0.43530	-0.43530	-0.35151	-0.33700	-0.29051	-0.29051	-0.26646
7p	-0.43530	-0.43530	-0.43530	-0.35151	-0.33700	-0.29051	-0.29051	-0.26646
8p	-0.35151	-0.35151	-0.35151	-0.43530	-0.42079	-0.37430	-0.37430	-0.35025
6p	-0.33700	-0.33700	-0.33700	-0.42079	-0.43530	-0.38881	-0.38881	-0.36475
1p	-0.29051	-0.29051	-0.29051	-0.37430	-0.38881	-0.43530	-0.43530	-0.41124
4p	-0.29051	-0.29051	-0.29051	-0.37430	-0.38881	-0.43530	-0.43530	-0.41124
2p	-0.26646	-0.26646	-0.26646	-0.35025	-0.36475	-0.41124	-0.41124	-0.44661

Positive values show pairs of means that are significantly different.

Figure 39. Model 5a Scenarios Comparison Analyses of Two Ship Leader

Oneway Analysis of Wingman By Scenario



Excluded Rows 1

Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
1p	48.20025	48.60624	48.97054	49.49353	49.65781	49.90797	50.05615
2p	44.75738	45.1121	45.46073	45.93462	46.06909	46.34627	46.48071
3p	40.71662	41.08675	41.24843	41.66171	41.87369	42.0057	42.08242
4p	44.75738	45.13437	45.47264	45.95827	46.11083	46.34312	46.48071
5p	40.71662	41.08675	41.24843	41.66171	41.87369	42.0057	42.08242
6p	36.17199	36.18448	36.37616	36.60779	36.71506	36.9094	36.91889
7p	40.71662	41.08675	41.24843	41.66171	41.87369	42.0057	42.08242
8p	30.81304	30.96008	31.12543	31.47097	31.658	31.82825	31.95281

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
1.97580	0.05

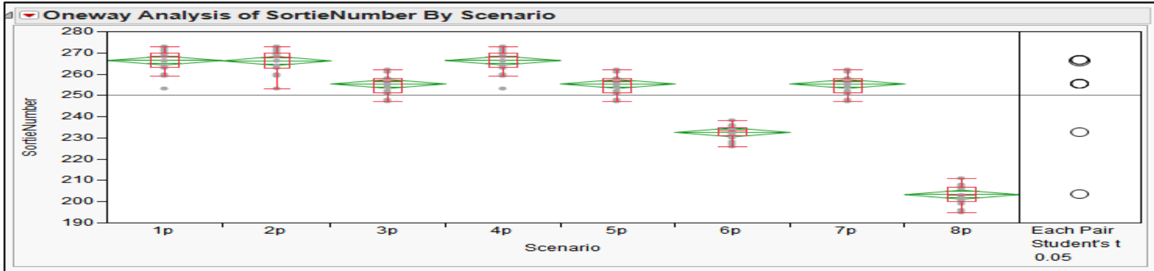
LSD Threshold Matrix

Abs(Dif)-LSD

	1p	4p	2p	3p	5p	7p	6p	8p
1p	-0.241	3.282	3.296	7.528	7.528	7.528	12.512	17.668
4p	3.282	-0.241	-0.228	4.004	4.004	4.004	8.988	14.144
2p	3.296	-0.228	-0.248	3.985	3.985	3.985	8.968	14.124
3p	7.528	4.004	3.985	-0.241	-0.241	-0.241	4.742	9.898
5p	7.528	4.004	3.985	-0.241	-0.241	-0.241	4.742	9.898
7p	7.528	4.004	3.985	-0.241	-0.241	-0.241	4.742	9.898
6p	12.512	8.988	8.968	4.742	4.742	4.742	-0.241	4.914
8p	17.668	14.144	14.124	9.898	9.898	9.898	4.914	-0.241

Positive values show pairs of means that are significantly different.

Figure 40. Model 5a Scenarios Comparison Analyses of Wingman



Excluded Rows 1

Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
1p	253	259	263.25	268.5	270	272	273
2p	253	259	263	268	270	272	273
3p	247	248	251.25	256.5	258	261.9	262
4p	253	259	263.25	268.5	270	272	273
5p	247	248	251.25	256.5	258	261.9	262
6p	226	227.1	231	233.5	234.75	236	238
7p	247	248	251.25	256.5	258	261.9	262
8p	195	196.3	200.25	203	206.75	210.7	211

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
1.97580	0.05

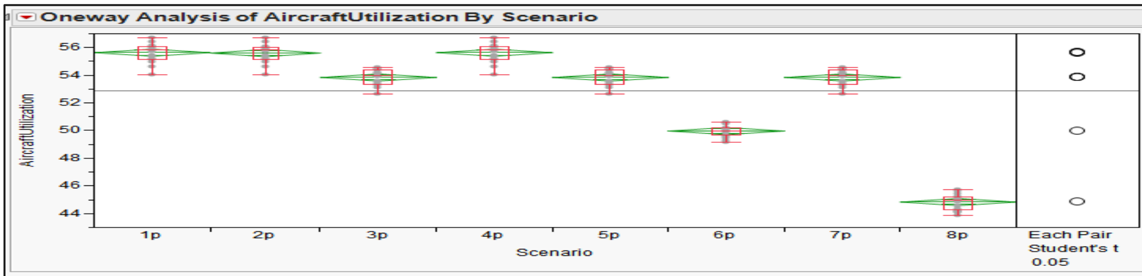
LSD Threshold Matrix

Abs(Dif)-LSD

	1p	4p	2p	3p	5p	7p	6p	8p
1p	-2.974	-2.974	-2.879	8.026	8.026	8.026	30.826	60.126
4p	-2.974	-2.974	-2.879	8.026	8.026	8.026	30.826	60.126
2p	-2.879	-2.879	-3.052	7.853	7.853	7.853	30.653	59.953
3p	8.026	8.026	7.853	-2.974	-2.974	-2.974	19.826	49.126
5p	8.026	8.026	7.853	-2.974	-2.974	-2.974	19.826	49.126
7p	8.026	8.026	7.853	-2.974	-2.974	-2.974	19.826	49.126
6p	30.826	30.826	30.653	19.826	19.826	19.826	-2.974	26.326
8p	60.126	60.126	59.953	49.126	49.126	49.126	26.326	-2.974

Positive values show pairs of means that are significantly different.

Figure 41. Model 5p Scenarios Comparison Analyses of Sortie Number



Excluded Rows 1

Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
1p	54.05568	54.63994	55.16451	55.8283	56.0749	56.39365	56.71751
2p	54.05568	54.60213	55.15597	55.8201	56.00832	56.3964	56.71751
3p	52.63639	53.10262	53.31384	54.00419	54.39722	54.4968	54.57446
4p	54.05568	54.63994	55.16451	55.8283	56.0749	56.39365	56.71751
5p	52.63639	53.10262	53.31384	54.00419	54.39722	54.4968	54.57446
6p	49.182	49.28548	49.68442	49.99248	50.18086	50.56087	50.60429
7p	52.63639	53.10262	53.31384	54.00419	54.39722	54.4968	54.57446
8p	43.8938	44.08063	44.26706	44.97051	45.21936	45.58307	45.74834

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
1.97580	0.05

LSD Threshold Matrix

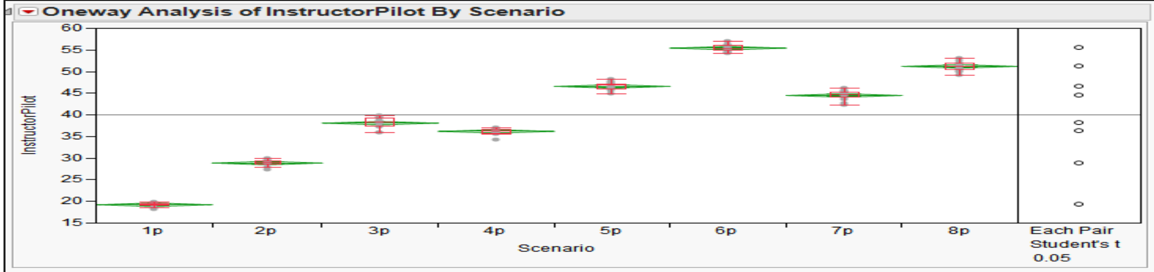
Abs(Dif)-LSD

	1p	4p	2p	3p	5p	7p	6p	8p
1p	-0.364	-0.364	-0.342	1.430	1.430	1.430	5.300	10.433
4p	-0.364	-0.364	-0.342	1.430	1.430	1.430	5.300	10.433
2p	-0.342	-0.342	-0.373	1.398	1.398	1.398	5.268	10.401
3p	1.430	1.430	1.398	-0.364	-0.364	-0.364	3.506	8.639
5p	1.430	1.430	1.398	-0.364	-0.364	-0.364	3.506	8.639
7p	1.430	1.430	1.398	-0.364	-0.364	-0.364	3.506	8.639
6p	5.300	5.300	5.268	3.506	3.506	3.506	-0.364	4.769
8p	10.433	10.433	10.401	8.639	8.639	8.639	4.769	-0.364

Positive values show pairs of means that are significantly different.

Figure 42. Model 5p Scenarios Comparison Analyses of Aircraft Utilization

Oneway Analysis of InstructorPilot By Scenario



Excluded Rows 1

Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
1p	18.20434	18.24504	19.07249	19.31155	19.52455	19.75086	19.93909
2p	27.30374	27.30384	28.57872	28.96456	29.29772	29.62901	29.90587
3p	35.88787	35.88843	37.38125	38.26689	39.20939	39.87265	39.87265
4p	34.18866	35.49955	35.76597	36.32915	36.61562	37.0783	37.10441
5p	44.78329	44.85432	45.99214	46.84996	47.18272	47.64734	48.28982
6p	54.15967	54.3562	54.96241	55.39582	56.0046	56.89808	57.00101
7p	42.31031	42.53852	44.03973	44.69055	45.28585	45.57136	46.18539
8p	49.17497	49.86309	50.50432	51.16934	51.99947	53.09538	53.16168

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
1.97580	0.05

LSD Threshold Matrix

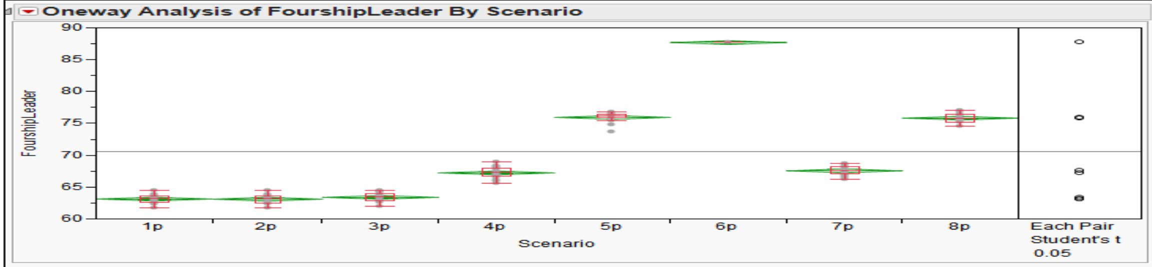
Abs(Dif)-LSD

	6p	8p	5p	7p	3p	4p	2p	1p
6p	-0.573	3.647	8.268	10.363	16.764	18.674	25.985	35.618
8p	3.647	-0.573	4.048	6.143	12.544	14.455	21.765	31.398
5p	8.268	4.048	-0.573	1.522	7.923	9.833	17.144	26.777
7p	10.363	6.143	1.522	-0.573	5.828	7.738	15.049	24.682
3p	16.764	12.544	7.923	5.828	-0.573	1.337	8.648	18.281
4p	18.674	14.455	9.833	7.738	1.337	-0.573	6.738	16.371
2p	25.985	21.765	17.144	15.049	8.648	6.738	-0.588	9.045
1p	35.618	31.398	26.777	24.682	18.281	16.371	9.045	-0.573

Positive values show pairs of means that are significantly different.

Figure 43. Model 5p Scenarios Comparison Analyses of Instructor Pilot

Oneway Analysis of FourshipLeader By Scenario



Excluded Rows 1

Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
1p	61.68413	61.79757	62.6054	63.2485	63.64329	63.84275	64.47978
2p	61.68413	61.73937	62.51574	63.20643	63.65042	63.84275	64.47978
3p	61.98834	62.07435	62.90213	63.4281	63.9952	64.38878	64.47967
4p	65.59729	65.94048	66.76019	67.33274	67.94981	68.28356	68.91842
5p	73.75519	74.8063	75.87258	76.13511	76.41196	76.51723	76.74481
6p	87.70764	87.70764	87.70764	87.70764	87.70764	87.70764	87.70764
7p	66.26061	66.47171	67.08289	67.553	68.18963	68.47545	68.69738
8p	74.58589	75.08971	75.20823	75.74865	76.41303	76.79407	77.07641

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
1.97580	0.05

LSD Threshold Matrix

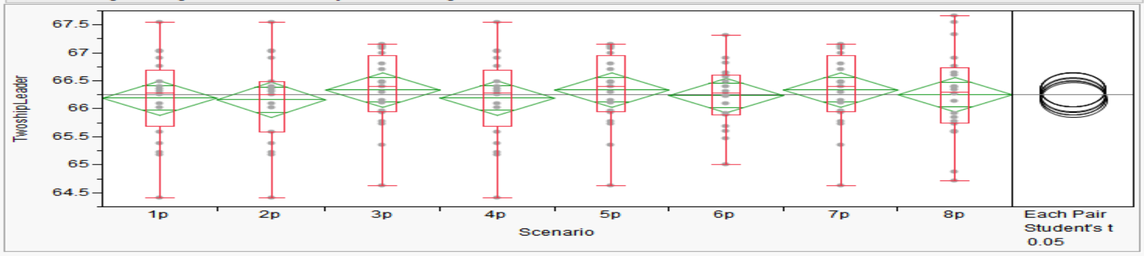
Abs(Dif)-LSD

	6p	5p	8p	7p	4p	3p	1p	2p
6p	-0.426	11.324	11.440	19.710	20.035	23.875	24.139	24.152
5p	11.324	-0.426	-0.310	7.961	8.286	12.125	12.389	12.403
8p	11.440	-0.310	-0.426	7.845	8.169	12.009	12.273	12.287
7p	19.710	7.961	7.845	-0.426	-0.101	3.738	4.003	4.016
4p	20.035	8.286	8.169	-0.101	-0.426	3.414	3.678	3.692
3p	23.875	12.125	12.009	3.738	3.414	-0.426	-0.162	-0.148
1p	24.139	12.389	12.273	4.003	3.678	-0.162	-0.426	-0.412
2p	24.152	12.403	12.287	4.016	3.692	-0.148	-0.412	-0.437

Positive values show pairs of means that are significantly different.

Figure 44. Model 5p Scenarios Comparison Analyses of Four Ship Leader

Oneway Analysis of TwoshipLeader By Scenario



Excluded Rows 1

Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
1p	64.41093	65.18874	65.69378	66.2801	66.69043	67.04267	67.55343
2p	64.41093	65.18419	65.5832	66.24714	66.49093	67.04495	67.55343
3p	64.63065	65.39842	65.94278	66.40193	66.94948	67.13051	67.15458
4p	64.41093	65.18874	65.69378	66.2801	66.69043	67.04267	67.55343
5p	64.63065	65.39842	65.94278	66.40193	66.94948	67.13051	67.15458
6p	65.00767	65.48474	65.89788	66.27962	66.59602	66.90268	67.31008
7p	64.63065	65.39842	65.94278	66.40193	66.94948	67.13051	67.15458
8p	64.71975	64.94505	65.7484	66.30302	66.72847	67.53142	67.66431

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
1.97580	0.05

LSD Threshold Matrix

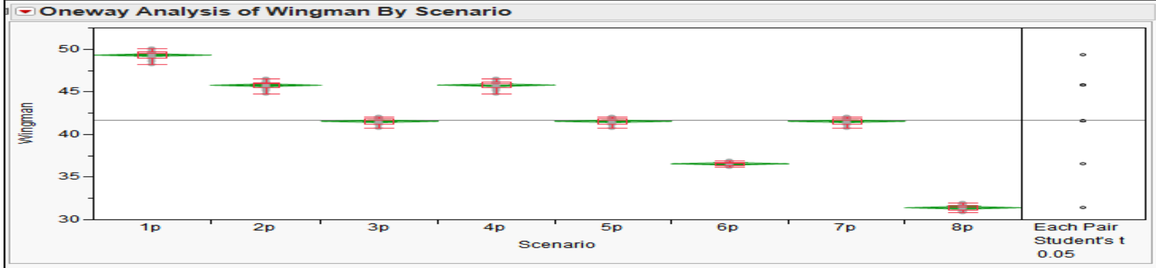
Abs(Dif)-LSD

	3p	5p	7p	8p	6p	1p	4p	2p
3p	-0.43530	-0.43530	-0.43530	-0.35151	-0.33700	-0.29051	-0.29051	-0.26646
5p	-0.43530	-0.43530	-0.43530	-0.35151	-0.33700	-0.29051	-0.29051	-0.26646
7p	-0.43530	-0.43530	-0.43530	-0.35151	-0.33700	-0.29051	-0.29051	-0.26646
8p	-0.35151	-0.35151	-0.35151	-0.43530	-0.42079	-0.37430	-0.37430	-0.35025
6p	-0.33700	-0.33700	-0.33700	-0.42079	-0.43530	-0.38881	-0.38881	-0.36475
1p	-0.29051	-0.29051	-0.29051	-0.37430	-0.38881	-0.43530	-0.43530	-0.41124
4p	-0.29051	-0.29051	-0.29051	-0.37430	-0.38881	-0.43530	-0.43530	-0.41124
2p	-0.26646	-0.26646	-0.26646	-0.35025	-0.36475	-0.41124	-0.41124	-0.44661

Positive values show pairs of means that are significantly different.

Figure 45. Model 5p Scenarios Comparison Analyses of Two Ship Leader

Oneway Analysis of Wingman By Scenario



Excluded Rows 1

Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
1p	48.20025	48.60624	48.97054	49.49353	49.65781	49.90797	50.05615
2p	44.75738	45.1121	45.46073	45.93462	46.06909	46.34627	46.48071
3p	40.71662	41.08675	41.24843	41.66171	41.87369	42.0057	42.08242
4p	44.75738	45.13437	45.47264	45.95827	46.11083	46.34312	46.48071
5p	40.71662	41.08675	41.24843	41.66171	41.87369	42.0057	42.08242
6p	36.17199	36.18448	36.37616	36.60779	36.71506	36.9094	36.91889
7p	40.71662	41.08675	41.24843	41.66171	41.87369	42.0057	42.08242
8p	30.81304	30.96008	31.12543	31.47097	31.658	31.82825	31.95281

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
1.97580	0.05

LSD Threshold Matrix

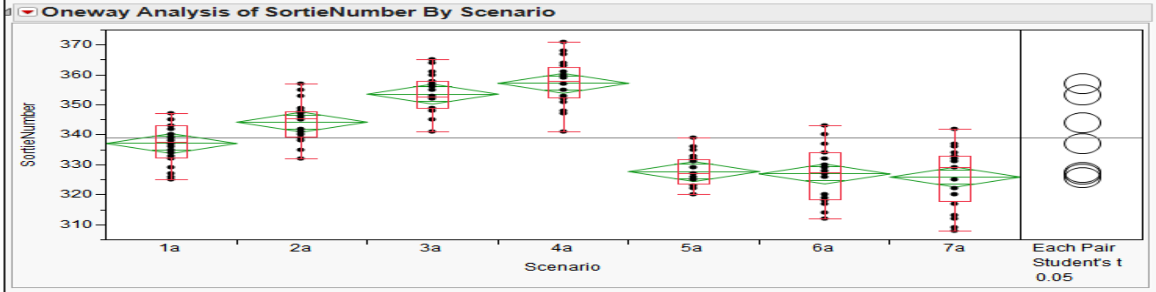
Abs(Dif)-LSD

	1p	4p	2p	3p	5p	7p	6p	8p
1p	-0.241	3.282	3.296	7.528	7.528	7.528	12.512	17.668
4p	3.282	-0.241	-0.228	4.004	4.004	4.004	8.988	14.144
2p	3.296	-0.228	-0.248	3.985	3.985	3.985	8.968	14.124
3p	7.528	4.004	3.985	-0.241	-0.241	-0.241	4.742	9.898
5p	7.528	4.004	3.985	-0.241	-0.241	-0.241	4.742	9.898
7p	7.528	4.004	3.985	-0.241	-0.241	-0.241	4.742	9.898
6p	12.512	8.988	8.968	4.742	4.742	4.742	-0.241	4.914
8p	17.668	14.144	14.124	9.898	9.898	9.898	4.914	-0.241

Positive values show pairs of means that are significantly different.

Figure 46. Model 5p Scenarios Comparison Analyses of Wingman

Oneway Analysis of SortieNumber By Scenario



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
1a	325	326.1	332.25	337.5	343	346.8	347
2a	332	335.3	339.25	345.5	347.75	354.8	357
3a	341	345.3	349	352.5	358	363.7	365
4a	341	347.1	352.25	358	362.5	367.9	371
5a	320	320.2	323.5	327	331.75	335.9	339
6a	312	314.3	318.25	327.5	334	339.7	343
7a	308	309.3	317.75	329	333	336.9	342

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
1.97796	0.05

LSD Threshold Matrix

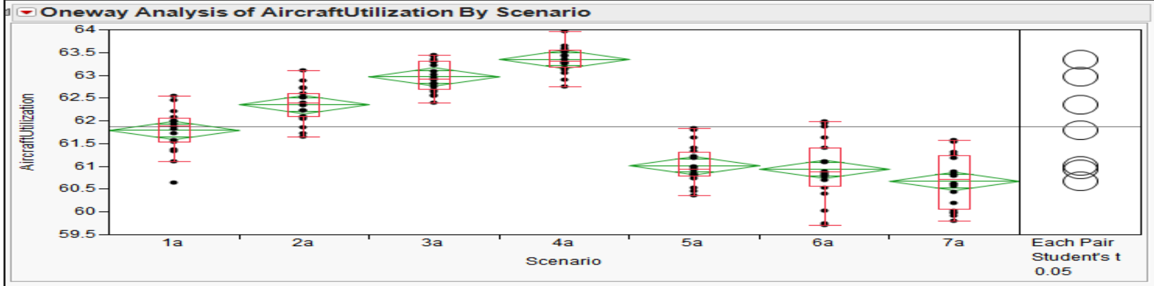
Abs(Dif)-LSD

	4a	3a	2a	1a	5a	6a	7a
4a	-4.712	-1.112	8.238	15.388	24.738	25.538	26.588
3a	-1.112	-4.712	4.638	11.788	21.138	21.938	22.988
2a	8.238	4.638	-4.712	2.438	11.788	12.588	13.638
1a	15.388	11.788	2.438	-4.712	4.638	5.438	6.488
5a	24.738	21.138	11.788	4.638	-4.712	-3.912	-2.862
6a	25.538	21.938	12.588	5.438	-3.912	-4.712	-3.662
7a	26.588	22.988	13.638	6.488	-2.862	-3.662	-4.712

Positive values show pairs of means that are significantly different.

Figure 47. Model 6a Scenarios Comparison Analyses of Sortie Number

Oneway Analysis of AircraftUtilization By Scenario



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
1a	60.64264	61.12439	61.54183	61.89309	62.05377	62.42622	62.53751
2a	61.65206	61.72873	62.08777	62.40046	62.59736	62.85919	63.104
3a	62.39332	62.54527	62.69161	62.91595	63.308	63.414	63.43906
4a	62.74086	62.92193	63.18522	63.31811	63.55066	63.65365	63.95349
5a	60.35134	60.45801	60.78423	60.93535	61.30301	61.77942	61.83503
6a	59.708	59.76587	60.5732	60.87619	61.39546	61.94345	61.97803
7a	59.79327	59.91753	60.06784	60.70806	61.23284	61.51258	61.56914

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
1.97796	0.05

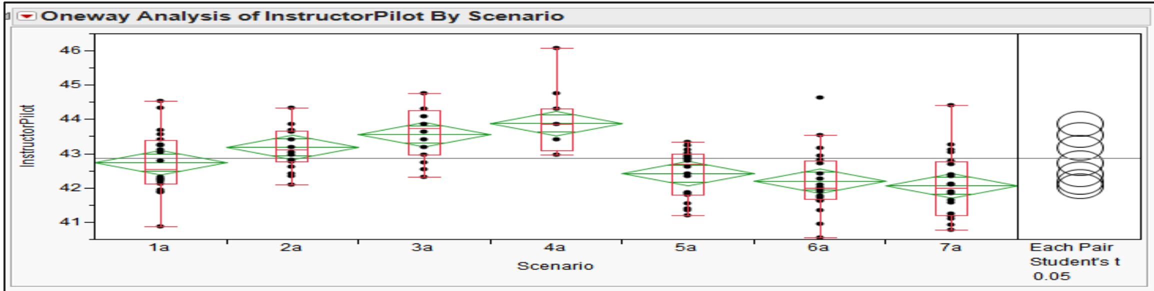
LSD Threshold Matrix

Abs(Dif)-LSD

	4a	3a	2a	1a	5a	6a	7a
4a	-0.2850	0.0973	0.7087	1.2749	2.0487	2.1278	2.3918
3a	0.0973	-0.2850	0.3264	0.8926	1.6664	1.7455	2.0095
2a	0.7087	0.3264	-0.2850	0.2812	1.0550	1.1341	1.3981
1a	1.2749	0.8926	0.2812	-0.2850	0.4888	0.5679	0.8319
5a	2.0487	1.6664	1.0550	0.4888	-0.2850	-0.2059	0.0580
6a	2.1278	1.7455	1.1341	0.5679	-0.2059	-0.2850	-0.0210
7a	2.3918	2.0095	1.3981	0.8319	0.0580	-0.0210	-0.2850

Positive values show pairs of means that are significantly different.

Figure 48. Model 6a Scenarios Comparison Analyses of Aircraft Utilization



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
1a	40.87235	41.87251	42.12546	42.55082	43.38071	44.27344	44.52421
2a	42.08912	42.3552	42.75317	43.12193	43.66649	43.85976	44.33959
3a	42.30928	42.33189	42.97373	43.74881	44.24708	44.30309	44.74605
4a	42.97342	42.97342	43.08416	43.85936	44.30233	44.701	46.0742
5a	41.20292	41.35432	41.80328	42.69909	42.99297	43.22149	43.34295
6a	40.54058	40.98848	41.66536	41.99813	42.79948	43.49094	44.63498
7a	40.76297	40.91005	41.18746	41.99691	42.76373	43.25586	44.41372

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
1.97796	0.05

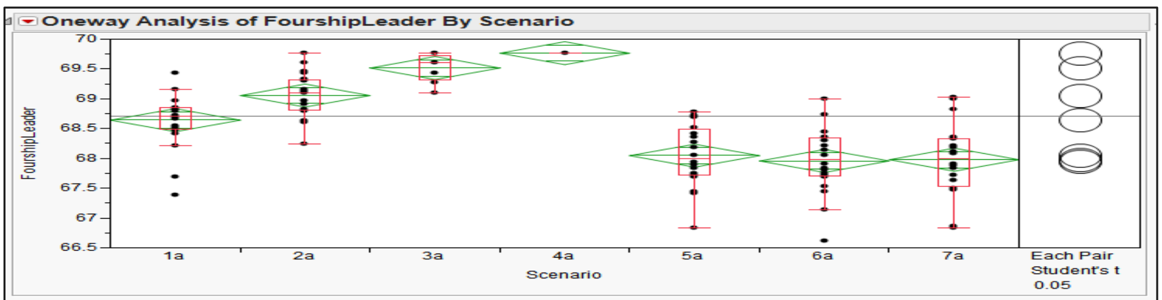
LSD Threshold Matrix

Abs(Dif)-LSD

	4a	3a	2a	1a	5a	6a	7a
4a	-0.5060	-0.1852	0.1873	0.6332	0.9502	1.1732	1.3093
3a	-0.1852	-0.5060	-0.1335	0.3124	0.6294	0.8525	0.9886
2a	0.1873	-0.1335	-0.5060	-0.0601	0.2569	0.4800	0.6161
1a	0.6332	0.3124	-0.0601	-0.5060	-0.1890	0.0341	0.1702
5a	0.9502	0.6294	0.2569	-0.1890	-0.5060	-0.2829	-0.1468
6a	1.1732	0.8525	0.4800	0.0341	-0.2829	-0.5060	-0.3699
7a	1.3093	0.9886	0.6161	0.1702	-0.1468	-0.3699	-0.5060

Positive values show pairs of means that are significantly different.

Figure 49. Model 6a Scenarios Comparison Analyses of Instructor Pilot



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
1a	67.38964	67.74528	68.48251	68.70281	68.84792	69.15912	69.43577
2a	68.24613	68.60878	68.80671	69.10397	69.31788	69.58766	69.76744
3a	69.10419	69.12093	69.31139	69.60156	69.72601	69.76744	69.76744
4a	69.76744	69.76744	69.76744	69.76744	69.76744	69.76744	69.76744
5a	66.83665	67.42039	67.72123	67.99794	68.49554	68.71692	68.77295
6a	66.61447	67.1714	67.70133	67.98379	68.34309	68.71327	68.99295
7a	66.83707	66.92421	67.5347	67.99789	68.33033	68.97644	69.02046

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
1.97796	0.05

LSD Threshold Matrix

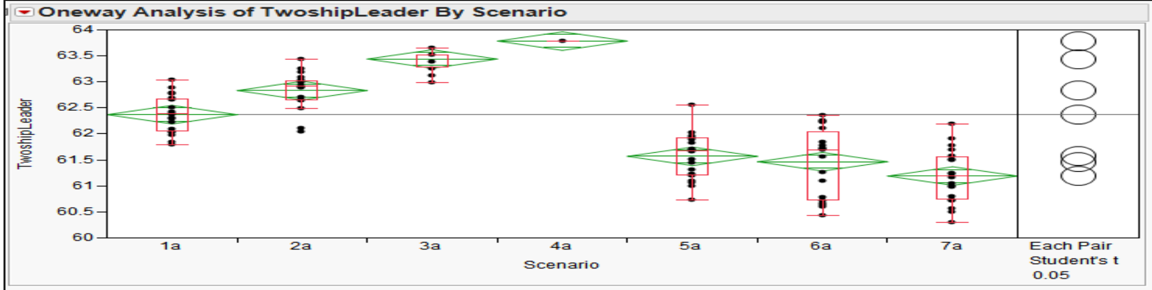
Abs(Dif)-LSD

	4a	3a	2a	1a	5a	7a	6a
4a	-0.2731	-0.0243	0.4376	0.8509	1.4467	1.5146	1.5356
3a	-0.0243	-0.2731	0.1888	0.6022	1.1979	1.2659	1.2868
2a	0.4376	0.1888	-0.2731	0.1403	0.7360	0.8040	0.8249
1a	0.8509	0.6022	0.1403	-0.2731	0.3227	0.3906	0.4116
5a	1.4467	1.1979	0.7360	0.3227	-0.2731	-0.2051	-0.1842
7a	1.5146	1.2659	0.8040	0.3906	-0.2051	-0.2731	-0.2521
6a	1.5356	1.2868	0.8249	0.4116	-0.1842	-0.2521	-0.2731

Positive values show pairs of means that are significantly different.

Figure 50. Model 6a Scenarios Comparison Analyses of Four Ship Leader

Oneway Analysis of TwoshipLeader By Scenario



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
1a	61.79628	61.8538	62.05106	62.38286	62.67552	62.87159	63.03529
2a	62.04	62.14448	62.65905	62.91346	63.02435	63.24983	63.43323
3a	62.99179	63.13725	63.29	63.52207	63.52218	63.6547	63.65476
4a	63.78738	63.78738	63.78738	63.78738	63.78738	63.78738	63.78738
5a	60.73565	61.00691	61.20434	61.67485	61.91811	62.01096	62.54869
6a	60.42504	60.60446	60.72977	61.69681	62.03918	62.25884	62.34907
7a	60.29156	60.49927	60.751	61.18795	61.55827	61.89375	62.19361

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
1.97796	0.05

LSD Threshold Matrix

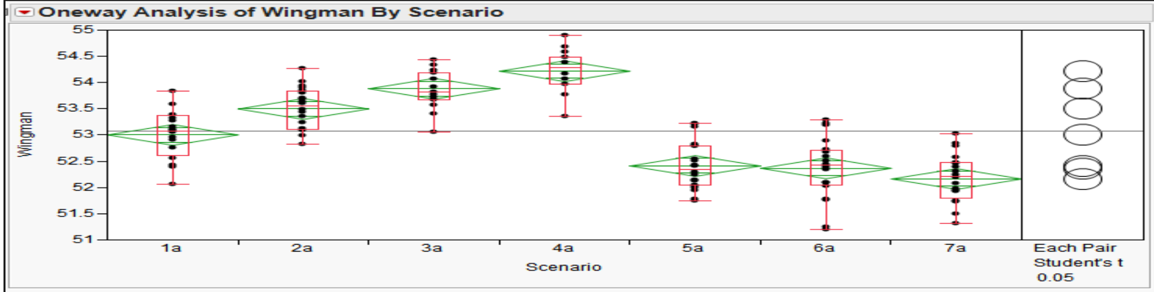
Abs(Dif)-LSD

	4a	3a	2a	1a	5a	6a	7a
4a	-0.2526	0.0923	0.6986	1.1621	1.9640	2.0670	2.3424
3a	0.0923	-0.2526	0.3537	0.8172	1.6191	1.7221	1.9975
2a	0.6986	0.3537	-0.2526	0.2109	1.0129	1.1159	1.3913
1a	1.1621	0.8172	0.2109	-0.2526	0.5494	0.6524	0.9278
5a	1.9640	1.6191	1.0129	0.5494	-0.2526	-0.1495	0.1258
6a	2.0670	1.7221	1.1159	0.6524	-0.1495	-0.2526	0.0228
7a	2.3424	1.9975	1.3913	0.9278	0.1258	0.0228	-0.2526

Positive values show pairs of means that are significantly different.

Figure 51. Model 6a Scenarios Comparison Analyses of Two Ship Leader

Oneway Analysis of Wingman By Scenario



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
1a	52.06807	52.39568	52.61229	53.07678	53.37219	53.56368	53.83029
2a	52.83333	52.9796	53.10649	53.54895	53.83862	54.0168	54.27244
3a	53.05427	53.42755	53.66786	53.82084	54.17893	54.32193	54.43417
4a	53.36059	53.76949	53.97393	54.2806	54.48505	54.67927	54.89394
5a	51.7525	51.79488	52.03836	52.34888	52.79842	53.20433	53.22598
6a	51.19928	51.30224	52.04338	52.43389	52.71133	53.21437	53.29377
7a	51.31896	51.49141	51.7898	52.21739	52.4786	52.83749	53.0299

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
1.97796	0.05

LSD Threshold Matrix

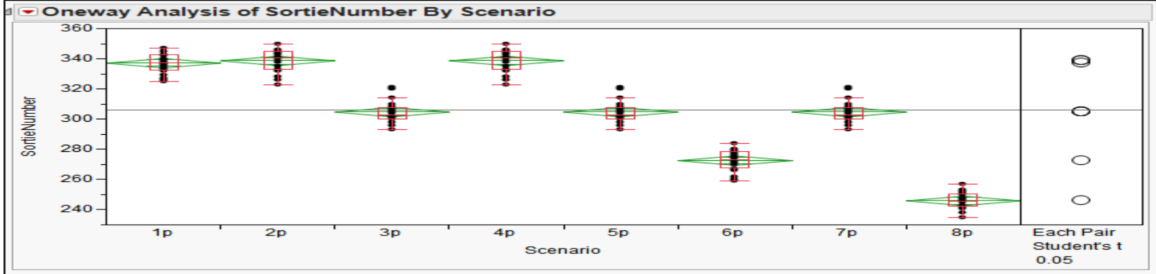
Abs(Dif)-LSD

	4a	3a	2a	1a	5a	6a	7a
4a	-0.2798	0.0546	0.4400	0.9353	1.5271	1.5718	1.7755
3a	0.0546	-0.2798	0.1057	0.6010	1.1928	1.2375	1.4412
2a	0.4400	0.1057	-0.2798	0.2155	0.8073	0.8520	1.0557
1a	0.9353	0.6010	0.2155	-0.2798	0.3120	0.3567	0.5604
5a	1.5271	1.1928	0.8073	0.3120	-0.2798	-0.2351	-0.0313
6a	1.5718	1.2375	0.8520	0.3567	-0.2351	-0.2798	-0.0761
7a	1.7755	1.4412	1.0557	0.5604	-0.0313	-0.0761	-0.2798

Positive values show pairs of means that are significantly different.

Figure 52. Model 6a Scenarios Comparison Analyses of Wingman

Oneway Analysis of SortieNumber By Scenario



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
1p	325	326.1	332.25	337.5	343	346.8	347
2p	323	326.2	333	340.5	345	349.6	350
3p	293	296.2	300.25	303	307.75	319.4	321
4p	323	326.2	333	340.5	345	349.6	350
5p	293	296.2	300.25	303	307.75	319.4	321
6p	259	260.2	267.75	273	278.75	280	284
7p	293	296.2	300.25	303	307.75	319.4	321
8p	235	238.3	242.25	245.5	250.75	252.9	257

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
1.97569	0.05

LSD Threshold Matrix

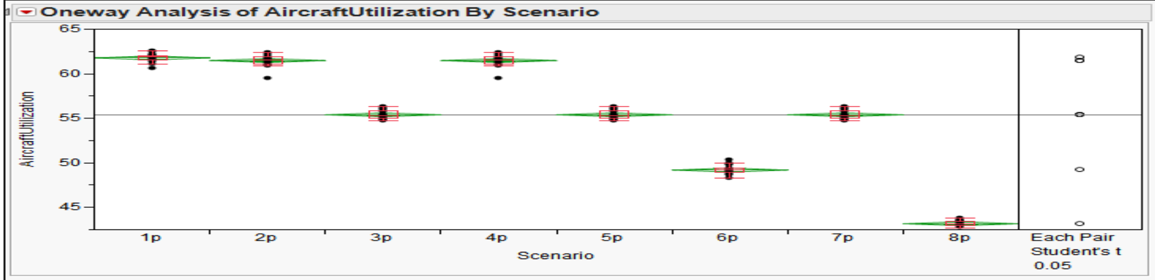
Abs(Dif)-LSD

	2p	4p	1p	3p	5p	7p	6p	8p
2p	-4.451	-4.451	-2.901	29.499	29.499	29.499	61.649	88.299
4p	-4.451	-4.451	-2.901	29.499	29.499	29.499	61.649	88.299
1p	-2.901	-2.901	-4.451	27.949	27.949	27.949	60.099	86.749
3p	29.499	29.499	27.949	-4.451	-4.451	-4.451	27.699	54.349
5p	29.499	29.499	27.949	-4.451	-4.451	-4.451	27.699	54.349
7p	29.499	29.499	27.949	-4.451	-4.451	-4.451	27.699	54.349
6p	61.649	61.649	60.099	27.699	27.699	27.699	-4.451	22.199
8p	88.299	88.299	86.749	54.349	54.349	54.349	22.199	-4.451

Positive values show pairs of means that are significantly different.

Figure 53. Model 6p Scenarios Comparison Analyses of Sortie Number

Oneway Analysis of AircraftUtilization By Scenario



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
1p	60.64264	61.12439	61.54183	61.89309	62.05377	62.42622	62.53751
2p	59.53565	60.90651	61.12341	61.56061	61.95847	62.15853	62.42947
3p	54.70578	54.80266	54.99886	55.3005	55.82616	56.15106	56.27404
4p	59.53565	60.90651	61.12341	61.56061	61.95847	62.15853	62.42947
5p	54.70578	54.80266	54.99886	55.3005	55.82616	56.15106	56.27404
6p	48.30485	48.34256	48.93748	49.18461	49.42521	49.95004	50.31666
7p	54.70578	54.80266	54.99886	55.3005	55.82616	56.15106	56.27404
8p	42.72613	42.74143	42.94241	43.15998	43.47267	43.75354	43.77136

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
1.97569	0.05

LSD Threshold Matrix

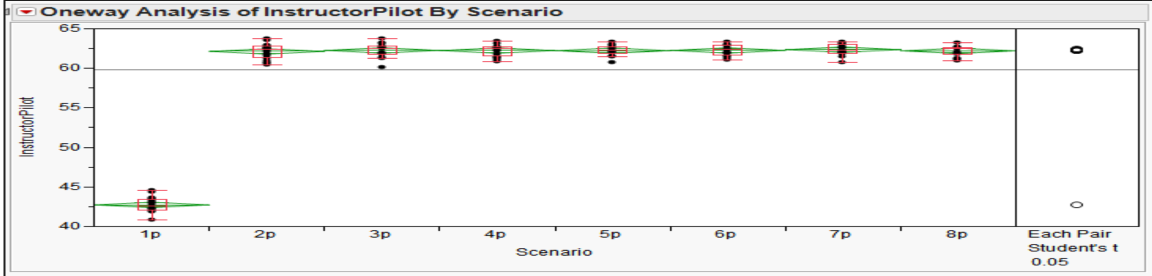
Abs(Dif)-LSD

	1p	2p	4p	3p	5p	7p	6p	8p
1p	-0.316	-0.017	-0.017	6.068	6.068	6.068	12.271	18.295
2p	-0.017	-0.316	-0.316	5.769	5.769	5.769	11.973	17.997
4p	-0.017	-0.316	-0.316	5.769	5.769	5.769	11.973	17.997
3p	6.068	5.769	5.769	-0.316	-0.316	-0.316	5.888	11.912
5p	6.068	5.769	5.769	-0.316	-0.316	-0.316	5.888	11.912
7p	6.068	5.769	5.769	-0.316	-0.316	-0.316	5.888	11.912
6p	12.271	11.973	11.973	5.888	5.888	5.888	-0.316	5.708
8p	18.295	17.997	17.997	11.912	11.912	11.912	5.708	-0.316

Positive values show pairs of means that are significantly different.

Figure 54. Model 6p Scenarios Comparison Analyses of Aircraft Utilization

Oneway Analysis of InstructorPilot By Scenario



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
1p	40.87235	41.87251	42.12546	42.55082	43.38071	44.27344	44.52421
2p	60.4741	60.65379	61.33343	62.43828	62.79807	63.45519	63.79291
3p	60.14338	61.24891	61.83007	62.5206	62.79623	63.22825	63.79291
4p	60.84496	61.05167	61.57188	62.50298	62.71511	63.16283	63.42377
5p	60.73267	61.47401	61.92235	62.28126	62.71447	62.97427	63.38712
6p	61.06576	61.27367	61.64541	62.42871	62.88107	62.98162	63.35082
7p	60.75113	61.50955	61.92756	62.30012	63.06047	63.18434	63.29457
8p	60.91458	61.15187	61.83057	62.46572	62.65816	63.2392	63.2392

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
1.97569	0.05

LSD Threshold Matrix

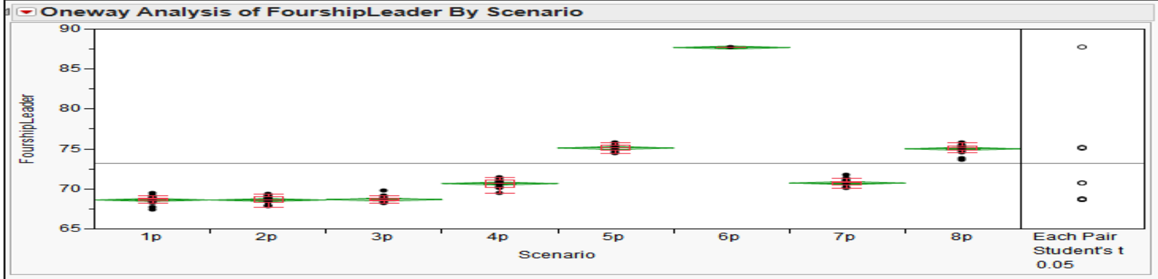
Abs(Dif)-LSD

	7p	3p	6p	4p	5p	8p	2p	1p
7p	-0.481	-0.384	-0.381	-0.363	-0.351	-0.329	-0.258	19.156
3p	-0.384	-0.481	-0.478	-0.460	-0.448	-0.426	-0.355	19.059
6p	-0.381	-0.478	-0.481	-0.463	-0.452	-0.430	-0.358	19.056
4p	-0.363	-0.460	-0.463	-0.481	-0.470	-0.447	-0.376	19.038
5p	-0.351	-0.448	-0.452	-0.470	-0.481	-0.459	-0.388	19.026
8p	-0.329	-0.426	-0.430	-0.447	-0.459	-0.481	-0.410	19.004
2p	-0.258	-0.355	-0.358	-0.376	-0.388	-0.410	-0.481	18.933
1p	19.156	19.059	19.056	19.038	19.026	19.004	18.933	-0.481

Positive values show pairs of means that are significantly different.

Figure 55. Model 6p Scenarios Comparison Analyses of Instructor Pilot

Oneway Analysis of FourshipLeader By Scenario



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
1p	67.38964	67.74528	68.48251	68.70281	68.84792	69.15912	69.43577
2p	67.74857	67.78486	68.37087	68.66159	69.08999	69.18349	69.32473
3p	68.1914	68.24638	68.49517	68.5917	68.82728	69.15668	69.76744
4p	69.51123	70.07291	70.19343	70.74669	71.13402	71.30371	71.39166
5p	74.42057	74.53026	74.80713	75.13906	75.45697	75.74751	75.74751
6p	87.70764	87.70764	87.70764	87.70764	87.70764	87.70764	87.70764
7p	70.10177	70.10545	70.47049	70.80175	70.94042	71.333	71.7608
8p	73.59011	73.93361	74.86202	75.13945	75.41585	75.47065	75.74751

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
1.97569	0.05

LSD Threshold Matrix

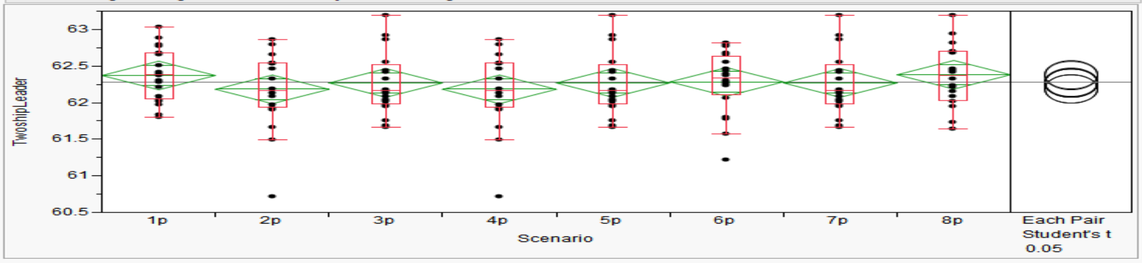
Abs(Dif)-LSD

	6p	5p	8p	7p	4p	3p	1p	2p
6p	-0.269	12.299	12.396	16.684	16.749	18.755	18.795	18.805
5p	12.299	-0.269	-0.172	4.116	4.180	6.186	6.226	6.236
8p	12.396	-0.172	-0.269	4.019	4.083	6.089	6.129	6.139
7p	16.684	4.116	4.019	-0.269	-0.205	1.801	1.841	1.851
4p	16.749	4.180	4.083	-0.205	-0.269	1.737	1.777	1.787
3p	18.755	6.186	6.089	1.801	1.737	-0.269	-0.229	-0.219
1p	18.795	6.226	6.129	1.841	1.777	-0.229	-0.269	-0.260
2p	18.805	6.236	6.139	1.851	1.787	-0.219	-0.260	-0.269

Positive values show pairs of means that are significantly different.

Figure 56. Model 6p Scenarios Comparison Analyses of Four Ship Leader

Oneway Analysis of TwoshipLeader By Scenario



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
1p	61.79628	61.8538	62.05106	62.38286	62.67552	62.87159	63.03529
2p	60.71184	61.50474	61.94043	62.16139	62.54278	62.79185	62.85762
3p	61.6633	61.6921	61.98384	62.16128	62.52084	62.92455	63.18994
4p	60.71184	61.50474	61.94043	62.16139	62.54278	62.79185	62.85762
5p	61.6633	61.6921	61.98384	62.16128	62.52084	62.92455	63.18994
6p	61.22222	61.59477	62.10594	62.33796	62.6316	62.78971	62.81393
7p	61.6633	61.6921	61.98384	62.16128	62.52084	62.92455	63.18994
8p	61.64156	61.75145	62.03445	62.37133	62.69754	62.94638	63.18972

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
1.97569	0.05

LSD Threshold Matrix

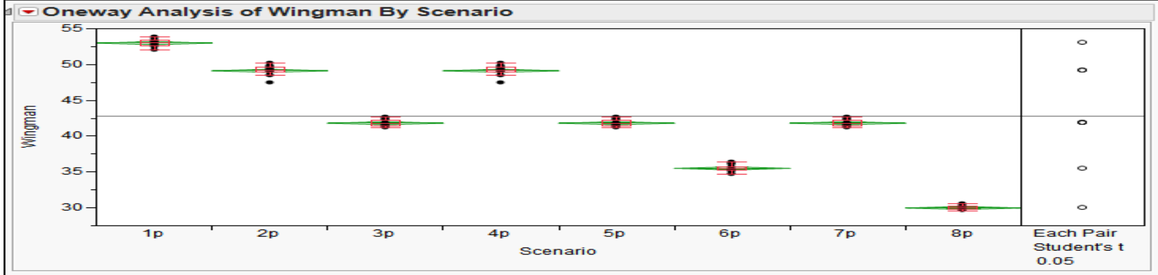
Abs(Dif)-LSD

	8p	1p	6p	3p	5p	7p	2p	4p
8p	-0.27648	-0.26677	-0.17925	-0.16474	-0.16474	-0.16474	-0.07752	-0.07752
1p	-0.26677	-0.27648	-0.18896	-0.17445	-0.17445	-0.17445	-0.08723	-0.08723
6p	-0.17925	-0.18896	-0.27648	-0.26197	-0.26197	-0.26197	-0.17476	-0.17476
3p	-0.16474	-0.17445	-0.26197	-0.27648	-0.27648	-0.27648	-0.18927	-0.18927
5p	-0.16474	-0.17445	-0.26197	-0.27648	-0.27648	-0.27648	-0.18927	-0.18927
7p	-0.16474	-0.17445	-0.26197	-0.27648	-0.27648	-0.27648	-0.18927	-0.18927
2p	-0.07752	-0.08723	-0.17476	-0.18927	-0.18927	-0.18927	-0.27648	-0.27648
4p	-0.07752	-0.08723	-0.17476	-0.18927	-0.18927	-0.18927	-0.27648	-0.27648

Positive values show pairs of means that are significantly different.

Figure 57. Model 6p Scenarios Comparison Analyses of Two Ship Leader

Oneway Analysis of Wingman By Scenario



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
1p	52.06807	52.39568	52.61229	53.07678	53.37219	53.56368	53.83029
2p	47.41583	48.46985	48.91436	49.18664	49.62576	49.87197	50.15133
3p	41.16032	41.23033	41.46844	41.71753	42.26543	42.5382	42.62874
4p	47.41583	48.46985	48.91436	49.18664	49.62576	49.87197	50.15133
5p	41.16032	41.23033	41.46844	41.71753	42.26543	42.5382	42.62874
6p	34.72541	34.82472	35.24632	35.49687	35.72596	36.23608	36.35862
7p	41.16032	41.23033	41.46844	41.71753	42.26543	42.5382	42.62874
8p	29.59477	29.65036	29.74819	29.96602	30.25243	30.32063	30.52605

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
1.97569	0.05

LSD Threshold Matrix

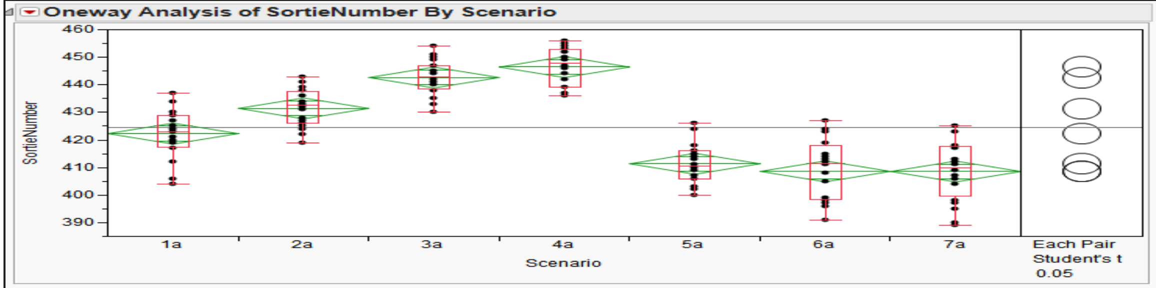
Abs(Dif)-LSD

	1p	2p	4p	3p	5p	7p	6p	8p
1p	-0.304	3.561	3.561	10.877	10.877	10.877	17.184	22.706
2p	3.561	-0.304	-0.304	7.012	7.012	7.012	13.319	18.842
4p	3.561	-0.304	-0.304	7.012	7.012	7.012	13.319	18.842
3p	10.877	7.012	7.012	-0.304	-0.304	-0.304	6.003	11.526
5p	10.877	7.012	7.012	-0.304	-0.304	-0.304	6.003	11.526
7p	10.877	7.012	7.012	-0.304	-0.304	-0.304	6.003	11.526
6p	17.184	13.319	13.319	6.003	6.003	6.003	-0.304	5.219
8p	22.706	18.842	18.842	11.526	11.526	11.526	5.219	-0.304

Positive values show pairs of means that are significantly different.

Figure 58. Model 6p Scenarios Comparison Analyses of Wingman

Oneway Analysis of SortieNumber By Scenario



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
1a	404	406.6	417.5	423	429	434	437
2a	419	422.2	426	432.5	437.5	440.8	443
3a	430	433.2	438.5	443	447	450.9	454
4a	436	436.1	439	448	452.75	455.9	456
5a	400	402	406	410.5	416	424	426
6a	391	391.5	398.25	411.5	418	423.9	427
7a	389	390.5	399.5	410	417.75	423	425

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
1.97796	0.05

LSD Threshold Matrix

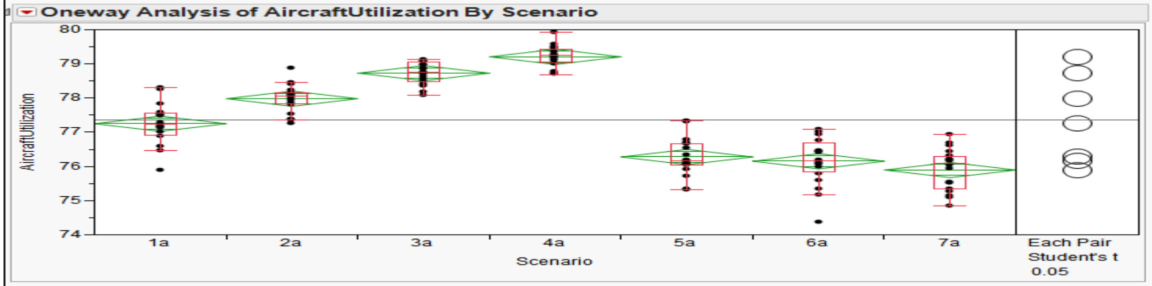
Abs(Dif)-LSD

	4a	3a	2a	1a	5a	6a	7a
4a	-5.370	-1.570	9.630	18.780	29.730	32.480	32.530
3a	-1.570	-5.370	5.830	14.980	25.930	28.680	28.730
2a	9.630	5.830	-5.370	3.780	14.730	17.480	17.530
1a	18.780	14.980	3.780	-5.370	5.580	8.330	8.380
5a	29.730	25.930	14.730	5.580	-5.370	-2.620	-2.570
6a	32.480	28.680	17.480	8.330	-2.620	-5.370	-5.320
7a	32.530	28.730	17.530	8.380	-2.570	-5.320	-5.370

Positive values show pairs of means that are significantly different.

Figure 59. Model 7a Scenarios Comparison Analyses of Sortie Number

Oneway Analysis of AircraftUtilization By Scenario



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
1a	75.89539	76.46745	76.92386	77.23946	77.56725	78.22204	78.31288
2a	77.2692	77.35511	77.8245	78.0594	78.15338	78.46157	78.87937
3a	78.07458	78.19155	78.49332	78.75447	79.04304	79.08513	79.12857
4a	78.68771	78.70017	79.02201	79.24419	79.41653	79.56894	79.91694
5a	75.31452	75.38155	76.04055	76.16759	76.67098	77.26078	77.33695
6a	74.37317	75.19614	75.84899	76.16704	76.69045	77.00863	77.08952
7a	74.83573	75.09949	75.34821	76.09461	76.29265	76.67472	76.93796

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
1.97796	0.05

LSD Threshold Matrix

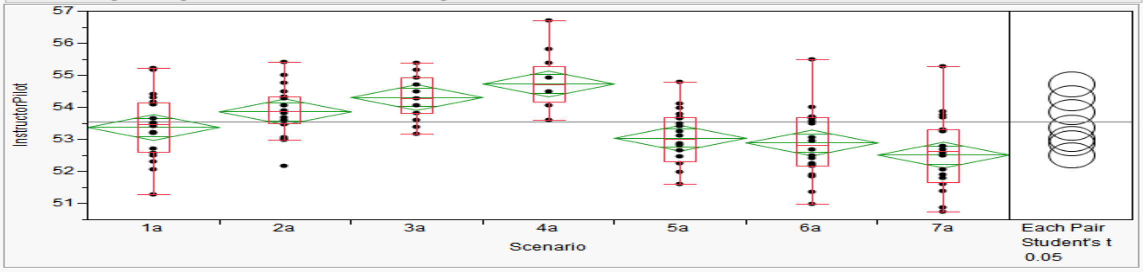
Abs(Dif)-LSD

	4a	3a	2a	1a	5a	6a	7a
4a	-0.3155	0.1618	0.9090	1.6412	2.6145	2.7387	2.9952
3a	0.1618	-0.3155	0.4317	1.1639	2.1372	2.2614	2.5179
2a	0.9090	0.4317	-0.3155	0.4167	1.3900	1.5142	1.7707
1a	1.6412	1.1639	0.4167	-0.3155	0.6578	0.7820	1.0386
5a	2.6145	2.1372	1.3900	0.6578	-0.3155	-0.1913	0.0653
6a	2.7387	2.2614	1.5142	0.7820	-0.1913	-0.3155	-0.0589
7a	2.9952	2.5179	1.7707	1.0386	0.0653	-0.0589	-0.3155

Positive values show pairs of means that are significantly different.

Figure 60. Model 7a Scenarios Comparison Analyses of Aircraft Utilization

Oneway Analysis of InstructorPilot By Scenario



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
1a	51.28276	52.08616	52.61158	53.45858	54.1426	55.08164	55.22934
2a	52.16664	52.98281	53.49477	53.86431	54.32499	54.98238	55.41379
3a	53.16168	53.40679	53.82647	54.26947	54.93355	55.13342	55.37728
4a	53.60465	53.60465	54.15836	54.71207	55.26578	55.77519	56.70543
5a	51.61332	52.00832	52.29726	52.99769	53.67023	54.11089	54.78666
6a	50.98833	51.40358	52.17714	52.8129	53.67139	54.01187	55.48807
7a	50.73139	50.87873	51.66099	52.62982	53.29303	53.85418	55.2668

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
1.97796	0.05

LSD Threshold Matrix

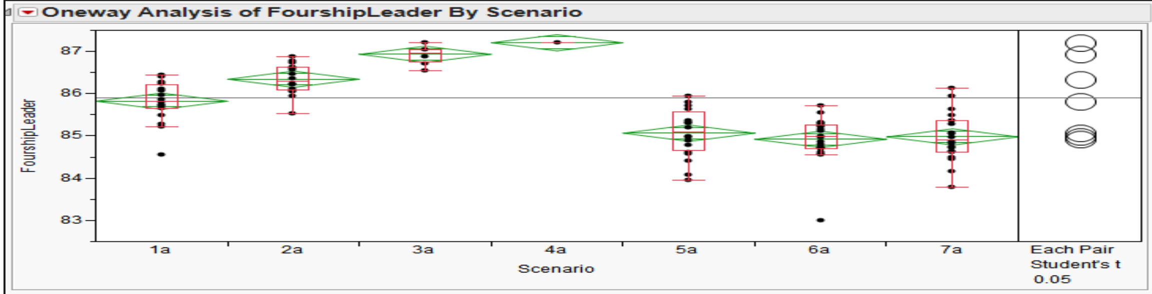
Abs(Dif)-LSD

	4a	3a	2a	1a	5a	6a	7a
4a	-0.5683	-0.1480	0.3000	0.7863	1.1218	1.2694	1.6450
3a	-0.1480	-0.5683	-0.1203	0.3660	0.7015	0.8491	1.2247
2a	0.3000	-0.1203	-0.5683	-0.0820	0.2534	0.4010	0.7766
1a	0.7863	0.3660	-0.0820	-0.5683	-0.2328	-0.0852	0.2904
5a	1.1218	0.7015	0.2534	-0.2328	-0.5683	-0.4207	-0.0451
6a	1.2694	0.8491	0.4010	-0.0852	-0.4207	-0.5683	-0.1927
7a	1.6450	1.2247	0.7766	0.2904	-0.0451	-0.1927	-0.5683

Positive values show pairs of means that are significantly different.

Figure 61. Model 7a Scenarios Comparison Analyses of Instructor Pilot

Oneway Analysis of FourshipLeader By Scenario



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
1a	84.55465	85.22465	85.66081	85.82688	86.20709	86.3935	86.4348
2a	85.52213	85.94832	86.08307	86.29659	86.62135	86.76386	86.87764
3a	86.54605	86.56279	86.75325	86.96054	87.04354	87.2093	87.2093
4a	87.2093	87.2093	87.2093	87.2093	87.2093	87.2093	87.2093
5a	83.94661	84.11839	84.65104	85.09482	85.56414	85.79085	85.93796
6a	83.00548	84.55754	84.69911	84.98236	85.26654	85.52793	85.71527
7a	83.78142	84.19448	84.61696	84.91358	85.35712	85.90731	86.13057

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
1.97796	0.05

LSD Threshold Matrix

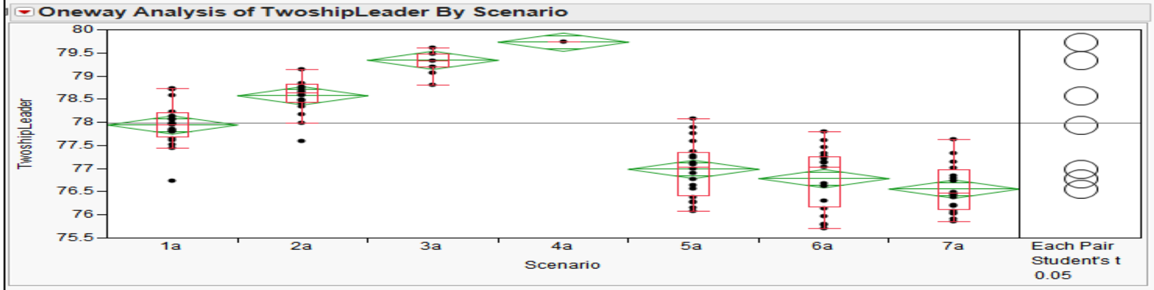
Abs(Dif)-LSD

	4a	3a	2a	1a	5a	7a	6a
4a	-0.2731	0.0005	0.5910	1.1107	1.8683	1.9569	2.0138
3a	0.0005	-0.2731	0.3174	0.8371	1.5947	1.6833	1.7402
2a	0.5910	0.3174	-0.2731	0.2466	1.0042	1.0928	1.1497
1a	1.1107	0.8371	0.2466	-0.2731	0.4844	0.5730	0.6300
5a	1.8683	1.5947	1.0042	0.4844	-0.2731	-0.1845	-0.1276
7a	1.9569	1.6833	1.0928	0.5730	-0.1845	-0.2731	-0.2162
6a	2.0138	1.7402	1.1497	0.6300	-0.1276	-0.2162	-0.2731

Positive values show pairs of means that are significantly different.

Figure 62. Model 7a Scenarios Comparison Analyses of Four Ship Leader

Oneway Analysis of TwoshipLeader By Scenario



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
1a	76.72575	77.4424	77.68779	77.95382	78.2075	78.70326	78.73867
2a	77.58887	78.0046	78.42318	78.62784	78.82699	79.1079	79.13663
3a	78.80595	79.08408	79.2037	79.33626	79.46896	79.60149	79.6016
4a	79.73422	79.73422	79.73422	79.73422	79.73422	79.73422	79.73422
5a	76.08416	76.16106	76.42262	77.03565	77.34487	77.88458	78.07548
6a	75.70766	75.77556	76.17264	77.03503	77.26193	77.59408	77.78838
7a	75.86224	75.91738	76.11163	76.47094	76.96937	77.30548	77.63177

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
1.97796	0.05

LSD Threshold Matrix

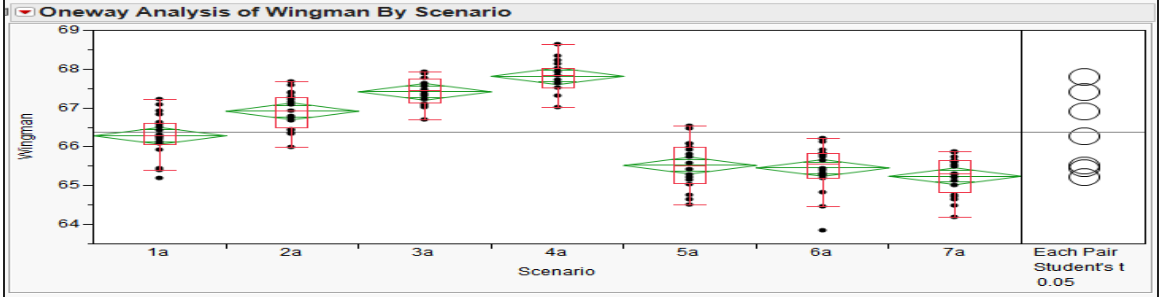
Abs(Dif)-LSD

	4a	3a	2a	1a	5a	6a	7a
4a	-0.2796	0.1118	0.8785	1.5100	2.4690	2.6695	2.8961
3a	0.1118	-0.2796	0.4872	1.1187	2.0777	2.2781	2.5048
2a	0.8785	0.4872	-0.2796	0.3520	1.3110	1.5114	1.7381
1a	1.5100	1.1187	0.3520	-0.2796	0.6795	0.8799	1.1066
5a	2.4690	2.0777	1.3110	0.6795	-0.2796	-0.0791	0.1476
6a	2.6695	2.2781	1.5114	0.8799	-0.0791	-0.2796	-0.0529
7a	2.8961	2.5048	1.7381	1.1066	0.1476	-0.0529	-0.2796

Positive values show pairs of means that are significantly different.

Figure 63. Model 7a Scenarios Comparison Analyses of Two Ship Leader

Oneway Analysis of Wingman By Scenario



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
1a	65.18736	65.40365	66.06621	66.28049	66.61469	67.06895	67.2302
2a	65.98625	66.33051	66.49779	66.93222	67.27671	67.56922	67.67235
3a	66.70126	67.01362	67.13583	67.44215	67.73601	67.86654	67.92802
4a	67.00741	67.33453	67.51853	67.8252	68.02964	68.32609	68.64298
5a	64.51473	64.6529	65.05307	65.49778	65.97723	66.41915	66.52421
6a	63.85024	64.49217	65.19795	65.54912	65.82985	66.17686	66.20819
7a	64.17426	64.49061	64.81502	65.29381	65.64837	65.84733	65.87683

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
1.97796	0.05

LSD Threshold Matrix

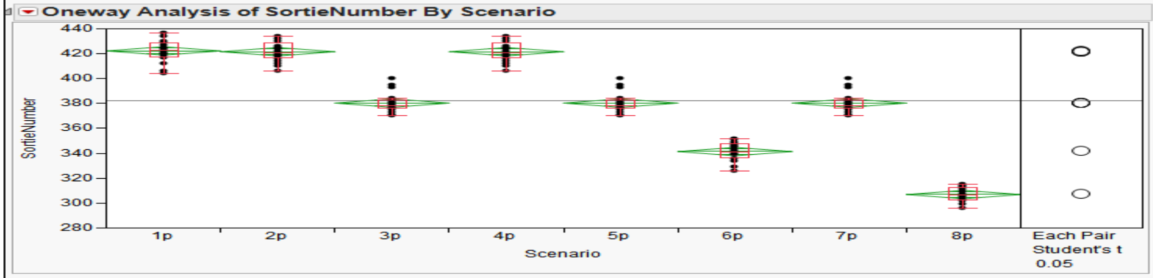
Abs(Dif)-LSD

	4a	3a	2a	1a	5a	6a	7a
4a	-0.3062	0.0945	0.5970	1.2288	1.9938	2.0564	2.2699
3a	0.0945	-0.3062	0.1963	0.8281	1.5931	1.6557	1.8692
2a	0.5970	0.1963	-0.3062	0.3256	1.0906	1.1533	1.3667
1a	1.2288	0.8281	0.3256	-0.3062	0.4588	0.5215	0.7349
5a	1.9938	1.5931	1.0906	0.4588	-0.3062	-0.2436	-0.0302
6a	2.0564	1.6557	1.1533	0.5215	-0.2436	-0.3062	-0.0928
7a	2.2699	1.8692	1.3667	0.7349	-0.0302	-0.0928	-0.3062

Positive values show pairs of means that are significantly different.

Figure 64. Model 7a Scenarios Comparison Analyses of Wingman

Oneway Analysis of SortieNumber By Scenario



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
1p	404	406.6	417.5	423	429	434	437
2p	406	410.2	416.5	421	429	433.8	434
3p	370	371.2	376	378.5	382.75	394.8	400
4p	406	410.2	416.5	421	429	433.8	434
5p	370	371.2	376	378.5	382.75	394.8	400
6p	326	329.5	336.75	341	347.75	351	352
7p	370	371.2	376	378.5	382.75	394.8	400
8p	296	299.3	302.25	306.5	312.5	314.9	315

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
1.97569	0.05

LSD Threshold Matrix

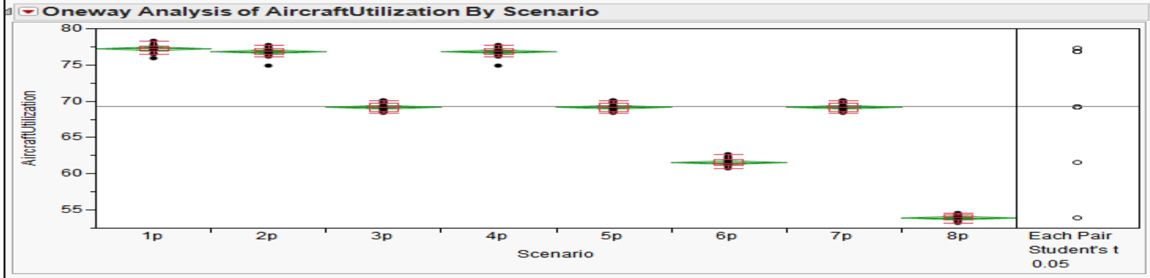
Abs(Dif)-LSD

	1p	2p	4p	3p	5p	7p	6p	8p
1p	-4.78	-4.13	-4.13	37.12	37.12	37.12	76.07	110.57
2p	-4.13	-4.78	-4.78	36.47	36.47	36.47	75.42	109.92
4p	-4.13	-4.78	-4.78	36.47	36.47	36.47	75.42	109.92
3p	37.12	36.47	36.47	-4.78	-4.78	-4.78	34.17	68.67
5p	37.12	36.47	36.47	-4.78	-4.78	-4.78	34.17	68.67
7p	37.12	36.47	36.47	-4.78	-4.78	-4.78	34.17	68.67
6p	76.07	75.42	75.42	34.17	34.17	34.17	-4.78	29.72
8p	110.57	109.92	109.92	68.67	68.67	68.67	29.72	-4.78

Positive values show pairs of means that are significantly different.

Figure 65. Model 7p Scenarios Comparison Analyses of Sortie Number

Oneway Analysis of AircraftUtilization By Scenario



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
1p	75.89539	76.46745	76.92386	77.23946	77.56725	78.22204	78.31288
2p	74.82386	76.1709	76.43655	76.96641	77.21117	77.46205	77.76773
3p	68.35504	68.37104	68.64278	69.15561	69.72449	70.07799	70.08662
4p	74.82386	76.1709	76.43655	76.96641	77.21117	77.46205	77.76773
5p	68.35504	68.37104	68.64278	69.15561	69.72449	70.07799	70.08662
6p	60.73278	61.00001	61.14218	61.4315	61.97944	62.30251	62.65907
7p	68.35504	68.37104	68.64278	69.15561	69.72449	70.07799	70.08662
8p	53.19884	53.43069	53.58892	53.92995	54.30994	54.4517	54.57974

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
1.97569	0.05

LSD Threshold Matrix

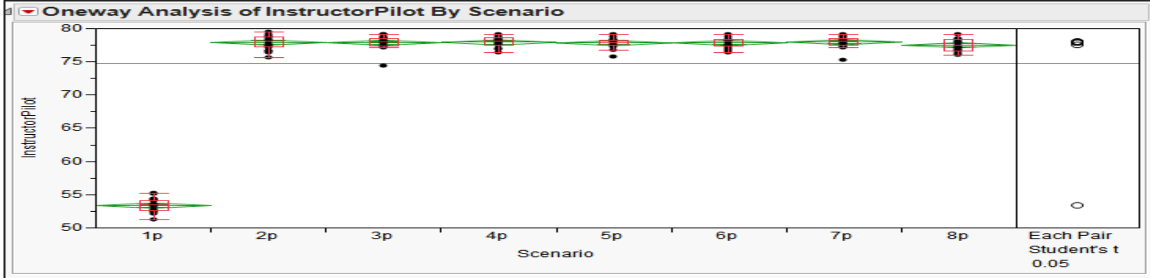
Abs(Dif)-LSD

	1p	2p	4p	3p	5p	7p	6p	8p
1p	-0.354	0.057	0.057	7.705	7.705	7.705	15.342	22.980
2p	0.057	-0.354	-0.354	7.294	7.294	7.294	14.931	22.568
4p	0.057	-0.354	-0.354	7.294	7.294	7.294	14.931	22.568
3p	7.705	7.294	7.294	-0.354	-0.354	-0.354	7.282	14.920
5p	7.705	7.294	7.294	-0.354	-0.354	-0.354	7.282	14.920
7p	7.705	7.294	7.294	-0.354	-0.354	-0.354	7.282	14.920
6p	15.342	14.931	14.931	7.282	7.282	7.282	-0.354	7.283
8p	22.980	22.568	22.568	14.920	14.920	14.920	7.283	-0.354

Positive values show pairs of means that are significantly different.

Figure 66. Model 7p Scenarios Comparison Analyses of Aircraft Utilization

Oneway Analysis of InstructorPilot By Scenario



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
1p	51.28276	52.08616	52.61158	53.45858	54.1426	55.08164	55.22934
2p	75.70451	76.43787	77.23855	78.19103	78.74485	79.05435	79.4629
3p	74.42909	77.19576	77.4157	77.96969	78.52278	79.04291	79.18605
4p	76.3499	76.43407	77.46347	78.17327	78.63382	78.83706	79.14994
5p	75.75666	76.83819	77.50096	77.91539	78.25665	78.67401	79.11295
6p	76.42127	76.66454	77.37664	78.10852	78.37201	78.79973	79.07629
7p	75.3137	77.1573	77.45932	78.1629	78.46844	79.10895	79.1312
8p	75.9788	76.22093	76.6696	77.47042	78.33008	79.11974	79.18605

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
1.97569	0.05

LSD Threshold Matrix

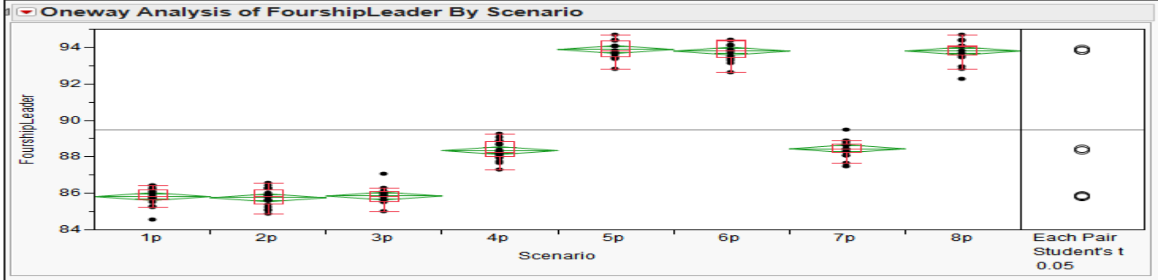
Abs(Dif)-LSD

	7p	4p	2p	3p	6p	5p	8p	1p
7p	-0.559	-0.512	-0.490	-0.465	-0.438	-0.415	-0.083	24.059
4p	-0.512	-0.559	-0.538	-0.512	-0.485	-0.463	-0.130	24.012
2p	-0.490	-0.538	-0.559	-0.534	-0.506	-0.484	-0.152	23.990
3p	-0.465	-0.512	-0.534	-0.559	-0.532	-0.509	-0.177	23.965
6p	-0.438	-0.485	-0.506	-0.532	-0.559	-0.537	-0.204	23.938
5p	-0.415	-0.463	-0.484	-0.509	-0.537	-0.559	-0.227	23.915
8p	-0.083	-0.130	-0.152	-0.177	-0.204	-0.227	-0.559	23.583
1p	24.059	24.012	23.990	23.965	23.938	23.915	23.583	-0.559

Positive values show pairs of means that are significantly different.

Figure 67. Model 7p Scenarios Comparison Analyses of Instructor Pilot

Oneway Analysis of FourshipLeader By Scenario



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
1p	84.55465	85.22465	85.66081	85.82688	86.20709	86.3935	86.4348
2p	84.88624	85.05793	85.43271	85.81272	86.17955	86.42103	86.57321
3p	84.99767	85.50065	85.54976	85.82679	86.10329	86.26964	87.04354
4p	87.26686	87.64734	87.99622	88.26274	88.81603	89.05589	89.25872
5p	92.80393	93.36301	93.49479	93.79903	94.35269	94.6567	94.68439
6p	92.63687	93.1461	93.46713	93.82646	94.35265	94.35288	94.40753
7p	87.48827	87.67735	88.24442	88.44739	88.72352	88.8859	89.47997
8p	92.25013	92.8206	93.56377	94.02113	94.07623	94.40203	94.68439

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
1.97569	0.05

LSD Threshold Matrix

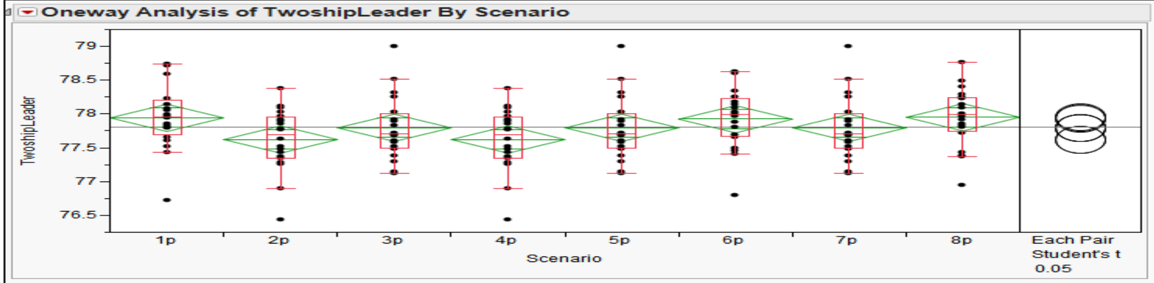
Abs(Dif)-LSD

	5p	8p	6p	7p	4p	3p	1p	2p
5p	-0.3042	-0.2239	-0.2182	5.1401	5.2396	7.7308	7.7638	7.8302
8p	-0.2239	-0.3042	-0.2985	5.0598	5.1593	7.6505	7.6835	7.7499
6p	-0.2182	-0.2985	-0.3042	5.0541	5.1536	7.6448	7.6778	7.7442
7p	5.1401	5.0598	5.0541	-0.3042	-0.2047	2.2865	2.3195	2.3859
4p	5.2396	5.1593	5.1536	-0.2047	-0.3042	2.1870	2.2200	2.2864
3p	7.7308	7.6505	7.6448	2.2865	2.1870	-0.3042	-0.2712	-0.2048
1p	7.7638	7.6835	7.6778	2.3195	2.2200	-0.2712	-0.3042	-0.2378
2p	7.8302	7.7499	7.7442	2.3859	2.2864	-0.2048	-0.2378	-0.3042

Positive values show pairs of means that are significantly different.

Figure 68. Model 7p Scenarios Comparison Analyses of Four Ship Leader

Oneway Analysis of TwoshipLeader By Scenario



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
1p	76.72575	77.4424	77.68779	77.95382	78.2075	78.70326	78.73867
2p	76.4372	76.93858	77.35104	77.6987	77.95354	78.11674	78.38465
3p	77.12341	77.1609	77.48896	77.71018	78.0028	78.49732	79.00412
4p	76.4372	76.93858	77.35104	77.6987	77.95354	78.11674	78.38465
5p	77.12341	77.1609	77.48896	77.71018	78.0028	78.49732	79.00412
6p	76.79294	77.41541	77.66531	77.98669	78.23501	78.57932	78.62815
7p	77.12341	77.1609	77.48896	77.71018	78.0028	78.49732	79.00412
8p	76.94588	77.3691	77.74334	77.98657	78.24666	78.48628	78.76056

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
1.97569	0.05

LSD Threshold Matrix

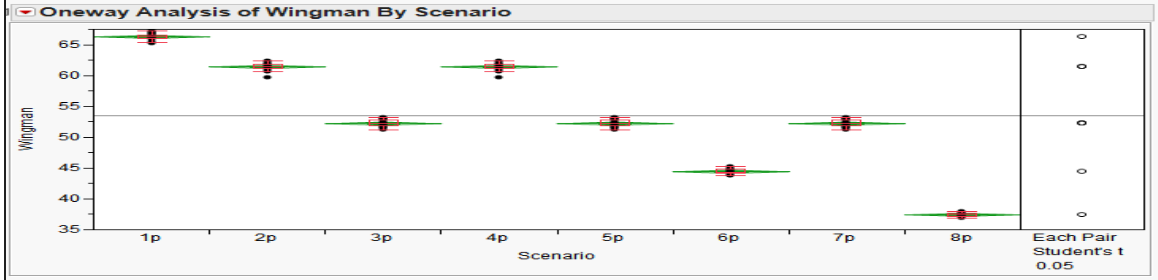
Abs(Dif)-LSD

	8p	1p	6p	3p	5p	7p	2p	4p
8p	-0.28529	-0.27679	-0.25668	-0.12926	-0.12926	-0.12926	0.04409	0.04409
1p	-0.27679	-0.28529	-0.26518	-0.13777	-0.13777	-0.13777	0.03558	0.03558
6p	-0.25668	-0.26518	-0.28529	-0.15787	-0.15787	-0.15787	0.01548	0.01548
3p	-0.12926	-0.13777	-0.15787	-0.28529	-0.28529	-0.28529	-0.11194	-0.11194
5p	-0.12926	-0.13777	-0.15787	-0.28529	-0.28529	-0.28529	-0.11194	-0.11194
7p	-0.12926	-0.13777	-0.15787	-0.28529	-0.28529	-0.28529	-0.11194	-0.11194
2p	0.04409	0.03558	0.01548	-0.11194	-0.11194	-0.11194	-0.28529	-0.28529
4p	0.04409	0.03558	0.01548	-0.11194	-0.11194	-0.11194	-0.28529	-0.28529

Positive values show pairs of means that are significantly different.

Figure 69. Model 7p Scenarios Comparison Analyses of Two Ship Leader

Oneway Analysis of Wingman By Scenario



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
1p	65.18736	65.40365	66.06621	66.28049	66.61469	67.06895	67.2302
2p	59.70048	60.64718	61.1102	61.45532	61.81739	62.25334	62.36494
3p	51.16432	51.50539	51.8008	52.2122	52.84482	53.09056	53.26849
4p	59.70048	60.64718	61.1102	61.45532	61.81739	62.25334	62.36494
5p	51.16432	51.50539	51.8008	52.2122	52.84482	53.09056	53.26849
6p	43.73733	43.89097	44.14036	44.31171	44.79966	45.01653	45.24581
7p	51.16432	51.50539	51.8008	52.2122	52.84482	53.09056	53.26849
8p	36.86471	37.07013	37.19385	37.42505	37.65469	37.9145	37.92644

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
1.97569	0.05

LSD Threshold Matrix

Abs(Dif)-LSD

	1p	2p	4p	3p	5p	7p	6p	8p
1p	-0.343	4.527	4.527	13.711	13.711	13.711	21.514	28.508
2p	4.527	-0.343	-0.343	8.841	8.841	8.841	16.644	23.638
4p	4.527	-0.343	-0.343	8.841	8.841	8.841	16.644	23.638
3p	13.711	8.841	8.841	-0.343	-0.343	-0.343	7.461	14.455
5p	13.711	8.841	8.841	-0.343	-0.343	-0.343	7.461	14.455
7p	13.711	8.841	8.841	-0.343	-0.343	-0.343	7.461	14.455
6p	21.514	16.644	16.644	7.461	7.461	7.461	-0.343	6.651
8p	28.508	23.638	23.638	14.455	14.455	14.455	6.651	-0.343

Positive values show pairs of means that are significantly different.

Figure 70. Model 7p Scenarios Comparison Analyses of Wingman

Table 27. An overall comparison between all models

Model	Scenario	Replication	SortieNumber	AircraftUtilization	InstructorPilot	FourshipLeader	TwoshipLeader	Wingman
1	1	20	288.00	51.14	16.62	57.92	57.59	43.80
2	1	20	266.45	55.64	19.26	63.14	66.19	49.33
3	1	20	337.15	61.79	42.74	68.64	62.37	53.00
4	1	20	422.85	77.28	53.75	85.78	77.92	66.33
5a	1	20	266.50	55.60	19.30	63.10	66.20	49.30
5a	2	20	275.20	56.60	19.40	64.00	67.40	50.10
5a	3	20	283.10	57.50	19.80	64.70	68.40	50.80
5a	4	20	288.00	58.10	19.90	65.10	69.10	51.20
5a	5	20	257.70	54.70	18.90	62.70	65.00	48.70
5a	6	20	250.70	54.20	18.70	62.40	64.40	48.30
5a	7	20	246.60	53.60	18.50	61.70	63.70	47.80
5p	1	20	266.50	55.60	19.30	63.10	66.20	49.30
5p	2	20	266.30	55.60	28.90	63.10	66.20	45.80
5p	3	20	255.50	53.80	38.10	63.40	66.30	41.60
5p	4	20	266.50	55.60	36.20	67.20	66.20	45.80
5p	5	20	255.50	53.80	46.60	76.00	66.30	41.60
5p	6	20	232.70	50.00	55.50	87.70	66.20	36.60
5p	7	20	255.50	53.80	44.50	67.60	66.30	41.60
5p	8	20	203.40	44.80	51.20	75.80	66.30	31.40
6a	1	20	337.2	61.8	42.7	68.6	62.4	53.0
6a	2	20	344.3	62.4	43.2	69.1	62.8	53.5
6a	3	20	353.7	63.0	43.6	69.5	63.4	53.9
6a	4	20	357.3	63.4	43.9	69.8	63.8	54.2
6a	5	20	327.8	61.0	42.4	68.0	61.6	52.4
6a	6	20	327.0	60.9	42.2	68.0	61.5	52.4
6a	7	20	326.0	60.7	42.1	68.0	61.2	52.2
6p	1	20	337.15	61.79	42.74	68.64	62.37	53.00
6p	2	20	327.38	59.47	62.23	69.34	62.21	46.70
6p	3	20	304.75	55.41	62.28	68.68	62.27	41.82
6p	4	20	338.70	61.49	62.26	70.69	62.18	49.14
6p	5	20	304.75	55.41	62.25	75.14	62.27	41.82
6p	6	20	272.60	49.21	62.28	87.71	62.29	35.52
6p	7	20	304.75	55.41	62.38	70.75	62.27	41.82
6p	8	20	245.95	43.18	62.23	75.04	62.38	29.99
7a	1	20	422.35	77.25	53.38	85.83	77.94	66.29
7a	2	20	431.50	77.99	53.87	86.35	78.58	66.92
7a	3	20	442.70	78.73	54.31	86.94	79.34	67.42
7a	4	20	446.50	79.21	54.73	87.21	79.73	67.82
7a	5	20	411.40	76.28	53.04	85.07	76.99	65.52
7a	6	20	408.65	76.16	52.90	84.92	76.79	65.46
7a	7	20	408.60	75.90	52.52	84.98	76.56	65.24
7p	1	20	421.85	77.27	53.69	85.81	77.96	66.23
7p	2	20	422.08	76.89	78.06	85.73	77.67	61.42
7p	3	20	379.00	69.19	78.09	85.81	77.74	52.22
7p	4	20	422.08	76.89	77.97	88.39	77.67	61.42
7p	5	20	379.00	69.19	77.88	93.85	77.74	52.22
7p	6	20	341.50	61.57	77.78	109.63	78.03	44.44
7p	7	20	379.00	69.19	78.13	88.36	77.74	52.22
7p	8	20	306.92	53.89	77.73	93.67	77.94	37.42

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Vita

Major Abdurrahman Sevimli was born in Bitlis. He graduated from Air Force Academy in İstanbul, in 2003 and he earned the degree of Bachelor of Science in Aviation Engineering. In the same year, he began his flight training in the 2nd Main Jet Base in İzmir. In 2006, after graduating from F-16 Basic Training Program, he was assigned to the 162nd Squadron, Bandirma as a wingman. In 2010, he was selected to Air War College and graduated in 2012. Next, he was assigned to 192th Squadron as a two ship leader. In 2014, he applied and selected for Operations Research Master Program in Graduation School of Engineering and Management, Air Force Institute of Technology in 2014.

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14. ABSTRACT The Turkish Air Force utilizes several fighter squadrons to enhance its military capabilities. One of the most critical challenges for these squadrons is generating sorties to meet the currency and demand during both peacetime and wartime. This sortie generation process directly affects the success of both training and operations. In this study, this process is assessed using a discrete event simulation. Air Force decision makers require a simulation tool to conduct "what-if" analysis on how potential changes in the environment affect an F-16 fighter squadron's sortie generation process. Creating a usable simulation provides decision makers with a flexible tool to analyze and evaluate the possible scenarios. The model assists in determining new concepts to provide benefits over current systems. These benefits may include increased operational availability and better system performance.							
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