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MONTEREY, CALIFORNIA

THESIS

OPTIMIZING TRAINING EVENT SCHEDULES AT NAVAL AIR STATION FALLON

by

Robert J. Slye

March 2018

Thesis Advisor: Robert Dell
Second Reader: Connor McLemore

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Naval Air Station (NAS) Fallon, located in Northwestern Nevada, is best known for one of its resident training schools, the United States Navy Fighter Weapons School, popularly known as Topgun. Fallon training range airspace overlays 10,200 square miles and contains ground ranges for bombing and electronic warfare. In addition to servicing the flight training requirements of its resident programs, NAS Fallon provides airspace, land, and logistical support for dozens of outside commands, ranging from carrier airwing detachments to special operations forces. It follows that scheduling training events at NAS Fallon is heavily constrained due to large demands on limited training airspace and aircraft availability. This thesis constructs, implements, and produces sample results using the Scheduling Assistance Tool (SAT), a mixed integer program designed as an aid to the operations department at NAS Fallon. SAT optimizes allocation of range space, subject to limited resources such as operational field hours, equipment, and event turnaround times. The primary output is a deconflicted daily flight schedule that includes unit, event, day, start time, and range assignment. We test SAT with 323 real-world event requests over a one-month period. SAT's baseline test results in 86% of events being scheduled. By giving optional ranges and start times to the unscheduled events, SAT is able to schedule 99% of the same events. Several additional excursions from the baseline scenario demonstrate how SAT can improve event schedules.

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OPTIMIZING TRAINING EVENT SCHEDULES AT NAVAL AIR STATION FALLON

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B.S., United States Naval Academy, 2014

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

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March 2018

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ABSTRACT

Naval Air Station (NAS) Fallon, located in Northwestern Nevada, is best known for one of its resident training schools, the United States Navy Fighter Weapons School, popularly known as Topgun. Fallon training range airspace overlays 10,200 square miles and contains ground ranges for bombing and electronic warfare. In addition to servicing the flight training requirements of its resident programs, NAS Fallon provides airspace, land, and logistical support for dozens of outside commands, ranging from carrier airwing detachments to special operations forces. It follows that scheduling training events at NAS Fallon is heavily constrained due to large demands on limited training airspace and aircraft availability. This thesis constructs, implements, and produces sample results using the Scheduling Assistance Tool (SAT), a mixed integer program designed as an aid to the operations department at NAS Fallon. SAT optimizes allocation of range space, subject to limited resources such as operational field hours, equipment, and event turnaround times. The primary output is a deconflicted daily flight schedule that includes unit, event, day, start time, and range assignment. We test SAT with 323 real-world event requests over a one-month period. SAT's baseline test results in 86% of events being scheduled. By giving optional ranges and start times to the unscheduled events, SAT is able to schedule 99% of the same events. Several additional excursions from the baseline scenario demonstrate how SAT can improve event schedules.

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List of Acronyms and Abbreviations

BLM	Bureau of Land Management
CPLEX	IBM ILOG CPLEX Optimization Studio
DCAST	Data Collection and Scheduling Tool
EW	Electronic Warfare
FRST	Fallon Range Scheduling Tool
FRTC	Fallon Range Training Complex
FRTP	Fleet Response Training Plan
GAMS	General Algebraic Modeling System
MIP	Mixed Integer Linear Program
MSISCHE	Multiple Squadron Input Schedule Enhancer
NAS	Naval Air Station
NAVSEA	Naval Sea Systems Command
NAWDC	Naval Air Warfighting Development Center
OPS	Operations
OPSO	Operations Officer
POC	Point of Contact
SAT	Scheduling Assistance Tool
TAD	Temporary Additional Duty
TCTS	Tactical Combat Training System
TT	Turn Around Time
VBA	Visual Basic for Applications
WTI	Weapons and Tactics Instructor

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Executive Summary

Naval Air Station (NAS) Fallon, located in Northwestern NV, is best known for one of its resident training schools, the United States Navy Fighter Weapons School, popularly known as Topgun. Fallon training range airspace overlays 10,200 square miles, and contains ground ranges for bombing and electronic warfare. In addition to servicing the flight training requirements of its resident programs, NAS Fallon provides airspace, land, and logistical support for dozens of outside commands, ranging from carrier airwing detachments to special forces.

Current flight event scheduling at NAS Fallon is manual, slow, and inefficient. The active duty and civilian personnel in the Operations Department at Naval Air Warfighting Development Center (NAWDC) spend hours readjusting and rewriting schedules to accommodate new requests. Naval aviation leadership desires the ability to automate this process. Such a program would have the potential to not only make schedulers' jobs faster and easier, but may result in a more efficient utilization of airspace and range resources.

This thesis presents a Mixed Integer Linear Program (MIP), known as Scheduling Assistance Tool (SAT), which aims to improve the Fallon schedulers' work flow. SAT produces a flight schedule detailing the day and time each unit's events will take place, along with the airspace grouping assigned to each event. Additional outputs include non-scheduled events, range utilization, emitter movement, and aircraft assignment.

We test SAT with real-world flight schedule data provided by NAWDC. The data set consists of 323 flight events, 23 units, and 31 different ranges over the course of a month. Each flight event request has associated requirements such as airspace, support aircraft, and emitter needs. SAT penalizes unscheduled events for units that have a higher priority, more heavily. It also penalizes schedule cancellations and deviations from original unit requests. In its baseline test, SAT schedules 86% of the given events in less than a minute with most of the unscheduled events being the lowest priority. By giving optional ranges and start times to the unscheduled events from the baseline scenario, SAT is able to schedule 99% of the same events. SAT also demonstrates competency to schedule updates. It maintains relatively consistent schedules across model runs, even with the addition of new inputs and/or flight event requests.

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CHAPTER 1: Background and Introduction

> Naval Air Station (NAS) Fallon is the center of United States Naval Aviation warfare development and training and home to the Naval Air Warfighting Development Center (NAWDC) and the 10,200 square mile Fallon Range Training Complex (FRTC). The FRTC consists of 39 airspace ranges that host 15 different types of units, including five Weapons and Tactics Instructor (WTI) courses, and are used for a variety of missions such as air-to-air engagements, bombing runs, electronic attack and low-level flights. (Macey, 2017)

Macey (2017) presents an integer linear program (The Fallon Range Scheduling Tool or FRST) to assist the NAWDC operations department with range scheduling over a long time horizon (6 months). Inputs to FRST include daily flight event requests by unit and their corresponding resource requirements. FRST's primary output is a deconflicted timetable of daily scheduled events. This thesis extends the FRST Mixed Integer Linear Program (MIP) to enhance its utility to NAWDC, and creates finer resolution schedules over the near term (half-hour time increments), models event prerequisites, turn-around time, and more realistic emitter constraints. In addition, it incorporates *persistence* (Brown, Dell, & Wood, 1997) to explicitly account for a past schedule when optimizing a current schedule.

1.1 NAS Fallon

While information on some Nevada military instillations is highly classified, there is plenty of readily available information on NAS Fallon an internet search away. The following from Navy Installations Command provides a nice summary.

> Home to the Fighting Saints of VFC-13, the Desert Outlaws of Strike Fighter Weapons Detachment, and NAWDC, NAS Fallon serves as the Navy's premier tactical air warfare training center. Known throughout the Navy as the only facility in existence where an entire carrier air wing can conduct comprehensive training while integrating every element of the wing into realistic battle

> scenarios. Fallon enjoys more than 300 clear flying days per year and gets the most out of each of those days with its four bombing ranges, the electronic warfare range and all of its other excellent training facilities. The 14,000-foot runway remains the longest in the Navy, making Fallon a one-stop training facility unequaled throughout the service. (U.S. Navy, 2017a)

1.1.1 FRTC

The FRTC is the geographic land and airspace operated and maintained by NAS Fallon. The area it encompasses is vast and supports numerous air and ground training operations. The FRTC, along with NAS Fallon, is located in the high desert of northern Nevada. It is composed of a set of connected geographic areas on the surface and within the air (see Figure 1.1). It is used primarily for training operations, with some support for research, development, test, and evaluation of military hardware, personnel, tactics, munitions, explosives, and electronic combat (U.S. Navy, 2017b).

> The FRTC is particularly significant to the Department of Defense (DoD) because of its unique training and tactics development capabilities, extensive instrumentation and target sets, live ordnance impact areas, and its capability to provide Basic, Integration and Sustainment Phase training of Naval forces in the Fleet Response Training Plan (FRTP). (U.S. Navy, 2017b)

1.1.2 NAWDC

NAWDC is the center of gravity for all scheduling and day-to-day operations that occur at NAS Fallon and the FRTC. The Operations (OPS) Department spends numerous hours, often starting months in advance of range events, deconflicting constantly changing flight schedules and providing logistical support for home and visiting unit event requests.

> NAWDC at Naval Air Station Fallon is the center of excellence for naval aviation training and tactics development. NAWDC provides service to aircrews, squadrons and air wings throughout the United States Navy through flight training, academic instructional classes, and direct operational and intelligence

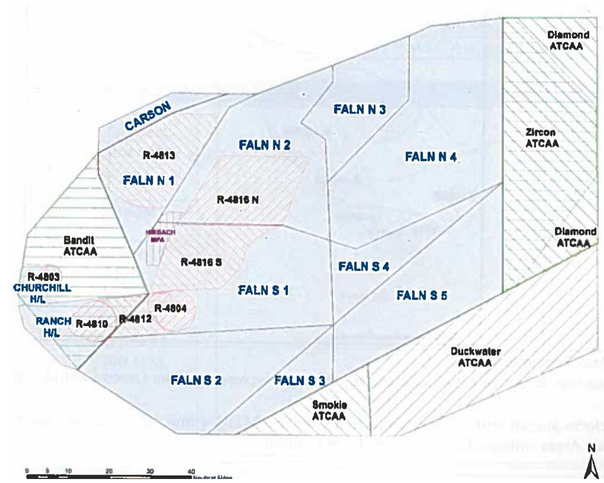

Figure 1.1. FRTC Airspace. Source: (Naval Air Warfighting Development Center, 2016)

support. The command consists of more than 120 officers, 140 enlisted and 50 contract personnel. NAWDC flies and maintains F/A-18C/D Hornets, F/A-18E/F Super Hornets, E/A-18G Growlers, F-16 Fighting Falcons and MH-60S Seahawk helicopters. (U.S. Navy, 2017c)

1.2 Flight Events

The following excerpt is taken verbatim from Macey (2017) and provides a straightforward explanation of what a flight event entails.

> A flight event involves a mission requiring specific resources that can include, but are not limited to, one or more support aircraft, emitters, and a specific range or set of ranges. Duration of flight events can vary based on type of flight event and aircraft platform. Multiple flight events can happen at the same time as long as the flight events do not occupy the same range or the flight events are deconflicted within a range, such as high flying fighter aircraft flying over low flying helicopters. Virtually all flight events originate and land from NAS Fallon.

Most events require a specified amount of Turn Around Time (TT) on top of the amount of time allocated for the event in the air. TT is the minimum amount of time a unit requires after an event before a follow on event can occur. This is to allow time for refueling, loading ordnance, maintenance, crew changes, etc. The amount of TT required is dependent on the type of unit, aircraft, and event involved. Typical TT is 1.5 to 2 hours for local units and 2 hours for visiting units or bombing events (Albrecht, 2017).

Most flight events require the completion of some prerequisite event before the follow-on event can take place. For instance, a hypothetical event ACT1 for unit VAQ-129 can be scheduled no earlier than January 15 at 1200, and requires 1.5 hours to complete the event and a minimum of 2.0 hours of TT. The follow on event, ACT2, can be scheduled at any time or day after 1530 on January 15. *Units often come to Fallon with flight syllabi dictating proper order for completion of events. Any flight schedule constructed must adhere to this proper flow of events.*

Often a unit requires support aircraft in addition to their own for a flight event. These additional aircraft can serve a variety of roles (e.g., red air hostiles, aircraft in need of escort). Examples of typical support aircraft are F-18, E-2, and EA-18Gs. Aircraft availability acts as another constraint when demand for additional support aircraft is high. Therefore, who gets what and when must be closely accounted for and tracked.

Within the FRTC, at ground level, exist emitter sites where specialized equipment can be set up to imitate hostile threats such as surface to air missiles and electronic attack equipment. Squadrons frequently utilize these emitters and request specific ones be placed in appropriate sites for their events. Naval Sea Systems Command (NAVSEA) Corona controls the sites where these emitters operate and contracts a company to operate the system (Elias, 2017). Movement of emitters is often limited due to fragile equipment and seasons. In fact, some emitters can not be moved at all. For these reasons, emitters are moved infrequently if at all (Albrecht, 2017).

1.3 Current Scheduling Method

The FRTC operations manual instructs that all FRTC air and ground operations adhere to Data Collection and Scheduling Tool (DCAST) and not from individual squadron flight schedules. All special use airspace, bombing ranges, ordnance, de-confliction procedures, ground training events and training system requirements must be scheduled in DCAST. It is the responsibility of individual squadrons to check the accuracy of events scheduled in DCAST and to comply with the DCAST Schedule of the Day (Naval Air Warfighting Development Center, 2016). In other words, when in doubt, DCAST is the final and true schedule regardless of what individual units might have on their squadron schedules.

The primary problem with this existing system stems from requesting units, especially visiting ones, often not knowing all the underlying requirements of each event. When a unit is unsure of required airspace for an event, it often requests more than is needed even if there's only a small chance they will require it (McLemore, 2017). This is extremely inefficient for obvious reasons and requires flight schedulers at NAWDC to manually review DCAST requests and determine proper and adequate allocation of airspace and resources (Dawn, 2017).

The NAWDC Range Scheduling Office requires at minimum the following list of information in order to properly schedule an event (Naval Air Warfighting Development Center, 2016).

- Primary point of contact for the event
- POC phone number (local number for Temporary Additional Duty (TAD) units)
- Mission Type (as listed in DCAST)
- Date and Timeframe
- Squadron(s)
- Number and type of aircraft
- Special Use Airspace requested and altitude(s)
- Specific ranges and target number(s)
- Training System Support Requirements (Tactical Combat Training System (TCTS), Electronic Warfare (EW), Target Scoring, etc.)

Whatever information a unit fails to provide in a request the scheduler and/or Operations Officer (OPSO) must determine from historical knowledge and experience (Dawn, 2017).

Once the scheduling office determines the correct requirements for a unit request, it may then attempt to schedule that event as long as it does not conflict with a higher priority event. Figure 1.2 lists the NAWDC priority structure. In practice, the flight schedulers schedule the highest priority events months in advance. Any free space in the schedule still available is then allocated to lower priority events. The current approach to determining a feasible schedule involves manually shifting events around on spreadsheets to fit as much in as possible.

Table 1.1. NAWDC Unit Scheduling Priority.

Order	Unit/Type of Unit
1	Joint exercises and Air Wing Strikes launched from carriers.
2	CVW deployed to NAS Fallon.
3	Marine/Composite Wing deployment (Once every 12 months)
4	Functional/Type Wing Weapon's Schools deployed to NAS Fallon for unit level training (SFARP, EWARP, and HARP)
5	NAWDC Weapons and Tactics Instructor (WTI) class events (TOPGUN SFTI, Seahawk WTI)
6	FRS detachments.
7	CNO/JCS sponsored projects.
8	Echelon Two projects.
9	Marine Air Group detachments.
10	Reserve Navy and Marine Air Wings and Air Groups detachments.
11	Unit Level Training for units permanently assigned to NAS Fallon (NAWDC, Fighter Squadron Composite 13).
12	Squadron training detachments, squadrons deployed to NAS Fallon.
13	Squadron training detachments, squadrons not deployed to NAS Fallon.
14	Ground weapons training.
15	All other units.

Figure 1.2. FRTC Scheduling Priority. Adapted from (Naval Air Warfighting Development Center, 2016)

1.4 Course of Study

Current scheduling methods at NAS Fallon are manual, slow, and inefficient. The active duty and civilian personnel in the OPS Department at NAWDC spend hours repeatedly readjusting and rewriting schedules to accommodate new requests. The ability to somehow automate this process, or at least assist with it, has been desired at Fallon for years. Such a program would have the potential to not only make schedulers' jobs faster and easier, but may result in a more efficient utilization of airspace and range resources.

This thesis presents a MIP, known as Scheduling Assistance Tool (SAT), which aims to fill the void in the Fallon schedulers' work flow. SAT produces a flight schedule detailing the day and time a unit's event will take place, along with the airspace grouping assigned to the event. Additional outputs include non-scheduled events, range utilization, emitter movement, and aircraft assignment. Chapter II discusses prior work related to optimizing schedules with special focus on the MIP from (Macey, 2017). Chapter III describes the mathematical formulation and assumptions behind SAT. Chapter IV discusses sample results and output. Chapter V concludes the thesis with final thoughts and recommendations.

CHAPTER 2:
Literature Review

This thesis' findings and model are all built on the foundation of knowledge of Macey's thesis. This chapter reviews the MIP, Fallon Range Scheduling Tool (FRST), from (Macey, 2017) and contrasts it with SAT. Section one describes the objective and output of Macey's work. Section two and three describe the primary similarities and differences between FRST and SAT. Section 4 reviews other work related to optimizing schedules.

2.1 Fallon Range Training Complex Flight Event Timetabling

Macey (2017) discusses the same scheduling issues faced by Fallon detailed in chapter one of this document. His solution to help Fallon flight schedulers is FRST, a MIP designed to help maximize scheduled events over multi-month time periods.

The objective of FRST is fairly straightforward and detailed below in (2.1) (Macey, 2017).

$$\text{minimize} \sum_{deout|es_{deout}>0} c_{dou} X_{deout} \;+ \sum_{eu|es_{deout}>0} pe_{eu} EE_{eu} \;+ \sum_{ad} pa_{ad} EA_{ad} \tag{2.1}$$

Sets

$a \in A$	Support aircraft [5]
$d, d' \in D$	Day [1-365+]
$t, t' \in T$	Time in half hour inc. [48]
$e, e' \in E$	Flight events [1-2000+]
$o \in O$	Option for flight event [4]
$u \in U$	Units [1-50+]

Data

c_{dou} Cost on day d under option o for unit u [unitless]

pa_{ad} Penalty cost for support aircraft a on day d not being available [unitless]

pe_{eu} Penalty cost for flight event e for unit u not being scheduled [unitless]

Variables

X_{deout} One if flight event e for unit u on day d at time t under option o is scheduled,

EE_{eu} One if flight event e for unit u is *not* scheduled, and zero otherwise [unitless]

EA_{ad} Number of additional support aircraft a required on day d [aircraft]

The objective of FRST primarily measures number of unscheduled events, with higher priority events weighing more heavily. The objective function also expresses deviations from the exact original request from a unit. Finally, it adds a small penalty for assigning additional support aircraft to units. Macey's program produces an output detailing a timetable of events for each day without providing specific times during the day or night. It also reports allocation of limited resources such as emitters and support aircraft. *Unlike SAT, it does not create an actual flight schedule with specific start times during the day.*

2.2 Similarities between FRST and SAT

As previously discussed, the primary goal of both FRST and SAT is to enable faster and more efficient flight scheduling. They are both solutions to the same problem, and are constrained by the same limited resources. Inputs are relatively similar. Both require unit-event request pairs, emitter and aircraft usage, and event duration. However, where FRST and SAT diverge is the level of resolution and time horizons in their solutions.

2.3 Differences between FRST and SAT

FRST produces aggregated daily schedules with the total number of events scheduled for each day and night. It does not go into detail as to when during the day these events are scheduled. In other words, FRST creates long term solutions that help schedulers get an idea of how much activity they can pack into each day over multiple months, not a detailed flight schedule with start times. SAT does have this capability. SAT makes use of a time index, divided into half hour increments. Because of the time index, SAT does not aggregate day or nighttime events. SAT also has the capability to assign exact airspace groupings. Therefore, a scheduled event contains the following information:

- Day
- Event
- Unit
- Start Time
- Range Grouping Assignment

Whereas, a FRST scheduled event would only contain the following information:

- Day
- Event
- Unit
- Option (How much of requested flight time is given)
- A Single Range Assignment

Therefore, the main trade-off between FRST and SAT is higher resolution for a smaller time window.

Macey focuses considerable effort and attention to emitter utilization. He models emitter movement and the available manpower hours to move them. However, after discussing his work with the Operations Officer at NAWDC, emitter availability and movement should not limit events as modeled by Macey (Albrecht, 2017). For this reason, SAT eliminates emitter manpower hours completely, and allowable emitter movement is drastically reduced to better fit reality.

Macey (2017) does not account for TT, considered critical by the OPSO at NAWDC. Otherwise, events for the same unit can potentially be scheduled back to back with no time in between (Albrecht, 2017). Thus, a daily schedule with the inability to take into account TT has little value to NAWDC.

Syllabus flow is also incorporated and controlled for in the SAT model. Events that require prerequisite events will not be scheduled if the prerequisite is not scheduled.

The final difference between FRST and SAT is the implementation of *persistence* (Brown, Dell, & Wood, 1997) into SAT. Flight schedules are constantly being updated and shuffled to incorporate new requests and cancellations. Obviously, when this happens the flight scheduler is going to try and minimize the changes to the original schedule. This helps ensure that events that have been previously scheduled, are still scheduled, and as close to the original schedule time as possible. This is the idea of *persistence*. A model with persistence built in makes changes to previous solutions only when extremely beneficial to the overall objective.

2.4 Related Literature

Very little work has been done on optimizing military flight scheduling. The majority of work in the civilian sector corresponds to the flow of aircraft into and out of major airports (Macey, 2017). An exception is the thesis by (Jacobs, 2014). However, the focus of this work is on maximizing scheduled flight events in a much smaller time horizon of one week. The underlying MIP also solves for a training squadron schedule with fewer resource limitations and without airspace de-confliction (Jacobs, 2014).

LT Macey cites other work of literature in his thesis relevant to military scheduling optimization (Macey, 2017). These develop MIPs to optimize training schedules for Explosive Ordnance Disposal units (DeWinter, 2012) and range scheduling at Naval Undersea Warfare Center (Blakenship, 2016). See (Macey, 2017) for additional information on these related MIPs. The following topics discuss additional relevant work.

2.4.1 Optimization and Peristence

Brown, Dell, & Wood (1997) describe how models sometimes produce drastic change in solutions from small changes in input. They note how this can be an enormous headache to management when it comes to building schedules or distributing of resources. Their solution to the problem is *persistence*. The concept of *persistence*, when applied to optimization models, limits changes from one solution to the next. This helps ensures that one solution does not differ drastically from another. Brown et al. (1997) discuss the numerous benefits of adopting *persitence* into a model and different implementations.

SAT incorporates *persistence* in two ways. It limits the number of cancellations of previously scheduled events by allowing the user to set the max number of cancellations. SAT also heavily penalizes canceled events through its objective function.

2.4.2 Optimization of NAS Lemoore Scheduling to Support a Growing Aircraft Population

Rosas (2017) focuses on the optimization of flight schedules at NAS Lemoore. Like NAS Fallon, NAS Lemoore serves multiple squadrons of tactical aircraft. Demands for scarce resources continue to grow to accommodate higher number of aircraft in the area. Rosas (2017) solution to the problem is Multiple Squadron Input Schedule Enhancer (MSISCHE), a MIP designed to produce the best daily flight schedule based on current NAS Lemoore squadrons, the squadrons' flying and training requirements, the refueling infrastructure, and Military Operations Area availability (Rosas, 2017).

Like MSISCHE, SAT constructs an optimal flight schedule based on limited resource requirements. However, the focus of MSISCHE is minimizing aircraft wait time in order to conserve refueling resources. SAT focuses much more on optimal allocation of airspace in order to maximize number of scheduled events.

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CHAPTER 3:
SAT Formulation

This chapter describes a representative SAT formulation. The model inputs are unit flight event requests along with any pertinent corresponding information such as range, emitter, and support aircraft requirements. The primary result is a deconflicted flight schedule detailing the day, time, and range for each event.

3.1 SAT Objective

SAT's objective is to schedule flight event requests based on unit priority level and available resources. Non-scheduled events are heavily penalized and any deviations from preferences within the requests are also slightly penalized. In other words, SAT attempts to schedule as many important events as possible and in the manner that the respective unit requested.

3.2 SAT Limitations

The following list of limitations apply to SAT but should be considered in future work:

- SAT is not integrated with DCAST. A trained flight scheduler must translate DCAST requests into usable inputs for the SAT model.
- SAT cannot process time windows. Each request must be accompanied by explicit days and times available for the event to take place.

3.3 SAT Assumptions

The following list of assumptions are made and incorporated into the design of SAT:

- Visiting units typically have their own support units. A unit may require additional support aircraft for an event.
- Emitters only move at most once during a predetermined time window (e.g., a week) and have sufficient manpower hours for operation.
- Emitter movement is assumed to be instantaneous. The reality is movement is planned to fit into empty four hour time blocks (Elias, 2017).

- Turnaround time can be modeled by adding time to an event for the same unit. Ranges are available during the turnaround time for other events.
- Each support aircraft supports at most one unit each day.
- Cost and penalty values are all arbitrary values reflective of priority and preferences.

3.4 SAT Formulation

3.4.1 Indices [~ Cardinality]

$a \in A$	Support aircraft [10]
$d, d' \in D$	Day [1-31+]
$e, e' \in E$	Flight events [1-333+]
$g \in G$	Airspace groupings [40]
$q \in Q$	Emitter equipment [33+]
$r \in R$	Airspace ranges within the FRTC [31]
$s, s' \in S$	Emitter sites [31+]
$t, t' \in T$	Time in half hour increments [48]
$u \in U$	Units [1-24+]
$w \in W$	Week [1-5+]

3.4.2 Index Sets

$g \in comb_r$	Range groupings g that contain range r
$(e, u) \in cqs_{qsd}$	Set of all combinations of event e for unit u that can occur for emitter q at site s on day d
$(d, t) \in DT_{eu}$	Set of all days d and times t that can occur for a unit u event e pair
$q \in mov$	Set of emitters q that can move
$(d, t, g) \in ms_{eu}$	Set of all combinations of days d, times t, and groupings g that can support event e for unit u
$(e, e') \in pr_u$	Set of events e that have prerequisite event e'
$e \in rqeu_u$	Set of flight events e required by unit u
$e \in TT_a$	Set of combinations of event e that require support aircraft type a
$d \in wk_w$	Subset of days d in week w

3.4.3 Data [Units]

ac	Number of previously scheduled events that are allowed to be cancelled [events]
ava_{ad}	Available number of support aircraft a on day d [aircraft]
cec_u	Cost of canceling a previously scheduled event, from a former solution, for unit u [cost/event]
$cm_{qss'}$	One if emitter q can move from site s to s' [movement/emitter]
$el_{deutt'}$	One if the range is required at time t' when event e begins at time t on day d for unit u [event/event]
$et_{deutt'}$	One if flight event e on day d that began at time t is occurring at time t' for unit u [event/event]
iq_{dqs}	Inventory of emitter q on site s for day d [emitters]
ra_{aeu}	Number of additional support aircraft a required by unit u for event e [aircraft]
rqq_{eqs}	Required emitters q for event e at site s [emitters]
$\hat{X}_{eu}$	One if event e for unit u was scheduled in the previous solution [event]

3.4.4 Derived Data [Units]

$cost_{deu}$	Cost of scheduling event e for unit u on day d [cost/event]
pe_{eu}	Penalty cost for flight event e for unit u not being scheduled [cost/event]

3.4.5 Variables [Units]

EA_{adu} Number of additional support aircraft a required on day d by unit u [aircraft]

EE_{eu} One if flight event e for unit u is *not* scheduled, and zero otherwise [event]

DN_{eu} One if event e for unit u was scheduled in the last solution but is *not* in the current [event]

I_{dqs} Number of emitters q at site s on day d [emitters]

$M_{dqss'}$ One if emitter q moved on day d from site s to s' and zero otherwise [emitter movment]

X_{deutg} One if on day d at time t event e for unit u occurs at range g, and zero otherwise [event]

3.4.6 Objective

$$\text{minimize} \sum_{eu,(d,t,g)\in ms_{eu}} cost_{deu} X_{deutg} + \sum_{u,e\in rqeu_u} pe_{eu} EE_{eu} + \sum_{e,u} cec_u DN_{eu} \quad (3.1)$$

3.4.7 Constraints

$$\sum_{(d,t,g)\in ms_{eu}} X_{deutg} = 1 - EE_{eu} \qquad \forall\ u \in U, e \in rqeu_u \quad (3.2)$$

$$\sum_{(e,t,g)|(d,t,g)\in ms_{eu}} ra_{aeu} X_{deutg} \leq EA_{adu} \qquad \forall\ a \in A, d \in D, u \in U \quad (3.3)$$

$$\sum_{u} EA_{adu} \leq ava_{ad} \qquad \forall\ a \in A, d \in D \quad (3.4)$$

$$I_{dqs} = iq_{dqs|d=1} + I_{d-1,qs|d>1} + \sum_{s'|cm_{qs's}>0} M_{dqs's} - \sum_{s'|cm_{qss'}>0} M_{dqss'}$$
$$\forall\ q \in Q, s \in S, d \in D, (e,u) \in cqs_{qsd} \quad (3.5)$$

$$\sum_{t,g} rqq_{eqs} X_{deutg} \leq I_{dqs} \qquad \forall\ q \in Q, s \in S, d \in D, (e,u) \in cqs_{qsd} \tag{3.6}$$

$$\sum_{d \in wk_w, ss' | cm_{qss'} > 0} M_{dqss'} \leq 1 \qquad \forall\ q \in mov, w \in W \tag{3.7}$$

$$\sum_{u, e \in rqeu_u, t \leq t', g \in comb_r} el_{deutt'} X_{deutg} \leq 1 \qquad \forall\ d \in D, r \in R, t' \in T \tag{3.8}$$

$$\sum_{e \in TT_a, t \leq t', g | (d,t,g) \in ms_{eu}} et_{deutt'} X_{deutg} \leq 1 \qquad \forall\ a \in A, d \in D, t' \in T, u \in U \tag{3.9}$$

$$\sum_{g | (d,t,g) \in ms_{eu}} X_{deutg} \leq \sum_{t' \leq t, g | (d,t',g) \in ms_{e'u}} X_{de'ut'g} + \sum_{d' \leq d, t', g | (d',t',g) \in ms_{e'u}} X_{d'e'ut'g}$$
$$\forall\ u \in U, (e, e') \in pr_u, (d, t) \in DT_{eu} \tag{3.10}$$

$$\sum_{d,t,g} X_{deutg} = \hat{X}_{eu} - DN_{eu} \qquad \forall\ u \in U, e \in rqeu_u, |\ \hat{X}_{eu} = 1 \tag{3.11}$$

$$\sum_{e,u} DN_{eu} \leq ac \tag{3.12}$$

$$EA_{adu} \geq 0 \ \ and \ \ Integer \qquad \forall\ a \in A, d \in D, u \in U \tag{3.13}$$

$$EE_{eu}, X_{deutg}, DN_{eu} \in \{0, 1\} \qquad \forall\ e \in E, u \in U \tag{3.14}$$

$$X_{deutg} \in \{0,1\} \qquad \forall\ d \in D, e \in E, u \in U, t \in T, g \in G \tag{3.15}$$

$$I_{dqs}, \geq 0 \ \ and \ \ Integer \qquad \forall\ d \in D, q \in Q, s \in S \tag{3.16}$$

$$M_{dqss'} \geq 0 \ \ and \ \ Integer \qquad \forall\ d \in D, (q, s, s') \in cm_{qss'} \tag{3.17}$$

The objective function (3.1) expresses the cost to schedule flight events and the penalty cost for violations of the elastic constraints.

Constraint (3.2) requires each flight event to be scheduled for every unit or accounts for any flight event that cannot be scheduled.

Constraint (3.3) ensures that the required additional support aircraft are available for each unit.

Constraint (3.4) ensures that the number of additional support aircraft distributed on a day does not exceed the number available.

Constraint (3.5) tracks the daily emitter inventory for each site.

Constraint (3.6) ensures scheduled flight events have access to an emitter, at the proper location, required for the respective event.

Constraint (3.7) limits the total number of emitter movements.

Constraint (3.8) deconflicts airspace by ensuring only one event occurs on a range at any given time.

Constraint (3.9) incorporates turnaround time for support aircraft.

Constraint (3.10) ensures proper event syllabus flow for each unit.

Constraint (3.11) incorporates persistence by ensuring events that were previously or not previously scheduled are accounted for.

Constraint (3.12) limits the number of event cancellations.

Constraints (3.13) to (3.17) declare variable types.

3.5 Summary

SAT generates a schedule listing the day, starting time, and range grouping assigned to a unit and its event. A list of non-scheduled units and events is also generated. In addition, SAT generates visual reports displaying scheduled/nonscheduled results and range utilization.

CHAPTER 4:
Analysis and Performance

This chapter details the implementation of SAT and sample results. Data sources, software usage, and model performance are the focus of attention. In addition, model excursions and sensitivity analysis demonstrate particular SAT strengths and weaknesses.

4.1 Implementation

SAT is run on a 64 bit Dell Precision T7910 with 128 GB of RAM and two Intel Xeon 2.30 GHz processors. The initial model run consists of about 46,000 equations and 460,000 discrete variables. Figure 4.1 depicts the entire process of entering data into SAT and retrieving usable solutions. It begins with the flight scheduler entering flight event requests and their respective requirements into a specific macro-enabled excel worksheet (Microsoftl, 2017). A series of VBA (VBA, 2017) subroutines converts these human inputs into usable data for General Algebraic Modeling System (GAMS). The GAMS IBM ILOG CPLEX Optimization Studio (CPLEX) (GAMS/CPLEX, 2017) solver uses this converted data to achieve an optimal solution/flight schedule. A series of VBA subroutines convert the GAMS solutions to operator friendly formats. These outputs are in-line with the products produced by the existing manual process and are understandable by trained operators. Figure 4.2 is an example of a flight schedule generated by SAT for one day. It includes the unit, event, day, start time, and range assignment. Figure 4.3 is an example a SAT report on non-scheduled events. It depicts the units that did not have certain events scheduled and what those events were.

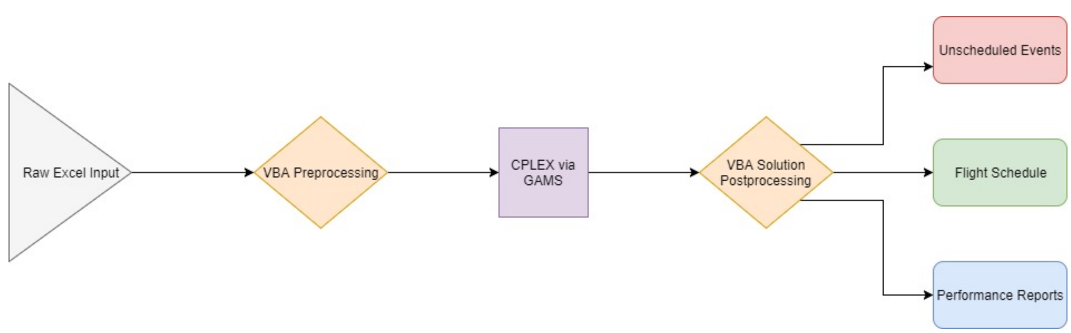

Figure 4.1. SAT Flow Diagram

	A	B	C	D	E
1	UNIT	EVENT	DAY	TIME	RANGE
2	VAQ_129	ACT1	d2	t15	g3
3	VAQ_129	ACT3	d2	t29	g1
21	NAWDC_N10	AES_1	d2	t18	g2
22	NAWDC_N10	AA11	d2	t27	g6
66	NAWDC_N5	PRO	d2	t22	g3
86	VFA_14	BOMB_STRAFE1	d2	t42	g3
87	VFA_14	BOMB_STRAFE2	d2	t34	g4
88	VFA_14	VX2	d2	t27	g1
108	VFA_41	SACT1	d2	t21	g6
115	NAWDC_N8	GUNEX	d2	t37	g4

Figure 4.2. Sat Example Flight Schedule Output

	A	B	C	D	E	F
1	UNIT	EVENT				
2	VAQ_129	ACT2	ACT6	ACT14		
3	NAWDC_N10	AA19	PW	AA22	AA26	AA32
4	NAWDC_N5	V01	V02	HABFM	SEAD1	1V05
5	VFA_14	SELF_ESCORT_STRIKE2				
6	NAWDC_N8	WE11	WE2_MVT_B_171	WE12	WE2_MVT_B_172	
7	VFC_13	ADTAC1	ADTAC8	PRO2	ADTAC15	
8	VFA_137	BOMB1				
9	VFA_97	SACT				
10	HSM_79	GUNEX3	TERF1	ERW_SACT	GUNEX5	
11	NAWDC_N3	ADTAC1				
12	NAWDC_N7	TAC3_2_1	TAC7_2_1			
13	VFA_122	BOMB				
14	VAQ_138	EW2_4	EW3_4	EW5_5		
15	NASF	MED_EVAC_TRAINING3				
16	VAQ_133	EW5_5				

Figure 4.3. SAT Example Non-Scheduled Events Output

4.2 Data Setup

Real life flight schedule data was acquired from the NAWDC Operations Department. The data consisted of 323 flight events and their corresponding resource requirements for a one month period of 31 days. These events represented actual scheduled flight events pulled directly from DCAST, not requests. Ideally, SAT would have been tested with raw request data; however, NAWDC was unable to provide this. During the data cleaning process, any missing elements in the data set were substituted with averages or standard parameters.

4.2.1 Day, Time, and Week Indices

Time is categorized into three groups: weeks, days, and half hour increments. The number of days and weeks can vary depending on the time span of the problem. Time, t, always consists of 48 half hour increments within a given day. This allows for easier model formulation and implementation. It also enables detailed flight schedules to be listed with exact start times.

4.2.2 Units

Real life units and event requests are used for initial testing of SAT. Table 4.1 provides a summary.

Unit	Priority	Total Event Requests	Total Flight Hours	Total Support Aircraft Required	Total Events Requiring Emitter(s)
VAQ 129	5	22	33	85	21
NAWDC N10	4	51	65	0	0
NAWDC N5	6	30	40.5	90	18
VFA 14	6	21	29.5	75	14
VFA 41	6	9	11.5	25	7
NAWDC N8	2	11	44	0	10
NAWDC N6	6	1	2.5	0	1
VFA 192	6	2	2.5	5	1
VFC 13	6	29	34	0	1
VFA 137	6	4	4.5	0	2
VFA 97	6	2	3	0	2
VFA 151	6	6	9	15	4
THUNDERBIRDS	6	2	3	0	0
HSM 79	6	16	59.5	20	4
NAWDC N3	4	29	46	105	46
NAWDC N7	4	29	55.5	60	27
VFA 122	6	6	8	20	4
VAQ 138	3	28	32	50	20
NASF	6	5	26.5	5	0
VAQ 133	3	17	18	35	7
VFA 125	4	1	1.5	0	0
VMA 311	6	1	2.5	5	0

Table 4.1. Summary of Unit Requirements

4.2.3 Emitter and Aircraft Availability

The biggest assumptions made with the data set involve the emitters and support aircraft availability. Actual emitter names and site locations are classified information. Therefore, dummy emitter and site names are assigned. Initial emitter locations and possible emitter movements are assumed due to the classification level. However, in a realistic run, the SAT operator would have very little difficulty acquiring this information.

SAT has the capability to handle support aircraft demand and availability. NAWDC did not provide support aircraft availability in the given data set. Therefore, aircraft availability was generated based on the event requirements. For initial runs more than enough support aircraft (100 per type) were available each day so as to not be a limiting factor. We know all these events were indeed scheduled so support aircraft availability could not have been an issue. See Table 4.2 for list of support aircraft used in the model.

Support Aircraft	
F-5	F-18
E-2	EA-18
F-16	H-60
T-34	T-34
C-130	Puma-Raven
UAS-UAV	

Table 4.2. List of Support Aircraft

4.2.4 Range groupings

As previously discussed the FRTC consists of 31 sectioned air spaces (See Table 4.3) that are assigned into groups for events. Air space groupings follow patterns so that specific combinations are routinely assigned. However, it is important for a range scheduler to not assign groupings that overlap at the same time. For instance, the range groupings displayed in Figures 4.4-4.5 are some of the most commonly assigned in Fallon. NAWDC1 does not contain any of the same airspace as NAWDC2, so different events can occur in each area at the same time.

Airspaces				
Restricted Areas	Associated Range	MOA (Stand Alone)	MOA/ATCASS (Associated)	ATCAA (Stand Aline)
R-4803	B-16	Churchill High	Fallon North 1	Bandit
R-4804A/B	B-17	Churchill Low	Fallon North 2	Smokie
R-4810	B-19	Ranch High	Fallon North 3	Diamond
R-4813A/B	B-20	Ranch Low	Fallon North 4	Duckwater
R-4812	None	Reno	Fallon South 1	Zircon
R-4812N	None		Fallon South 2	
R-4816S	None		Fallon South 3	
			Fallon South 4	
			Fallon South 5	
			Carson	

Table 4.3. FRTC Airspaces. Table adapted from Naval Air Warfighting Development Center, (2016)

Range requirements in the data set consist of 40 possible range groupings. Each event contains a list of possible range groupings for its event in order of preference. For instance, g1,g2,g3 indicates that a unit could use g1,g2, or g3 to conduct its event and would prefer g1 the most. Penalty values are assigned in the case that a unit did not receive its first choice in range group.

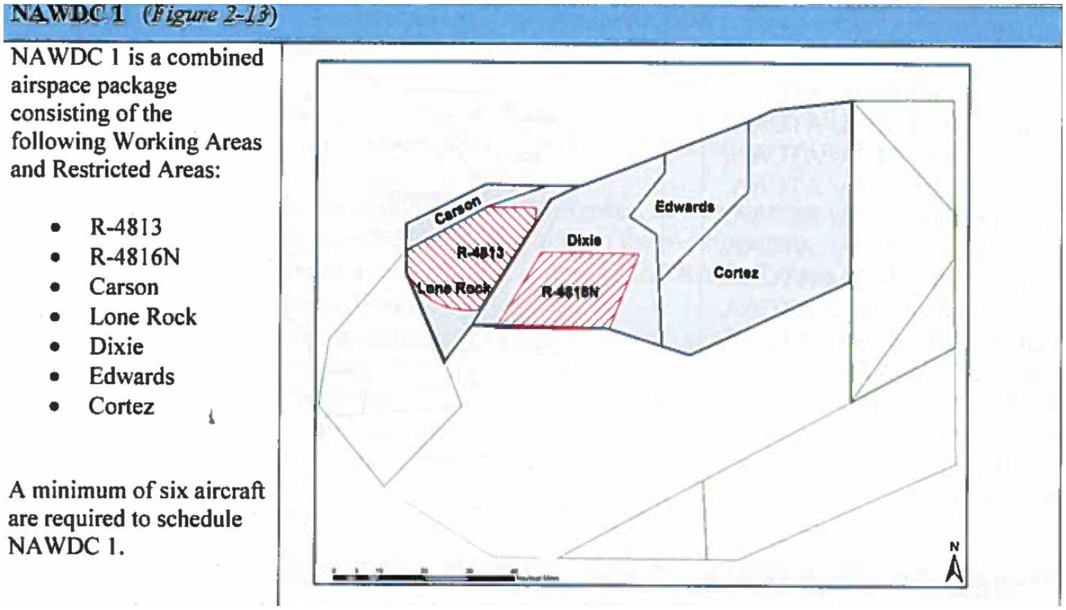

Figure 4.4. NAWDC1. Source: (Naval Air Warfighting Development Center, 2016)

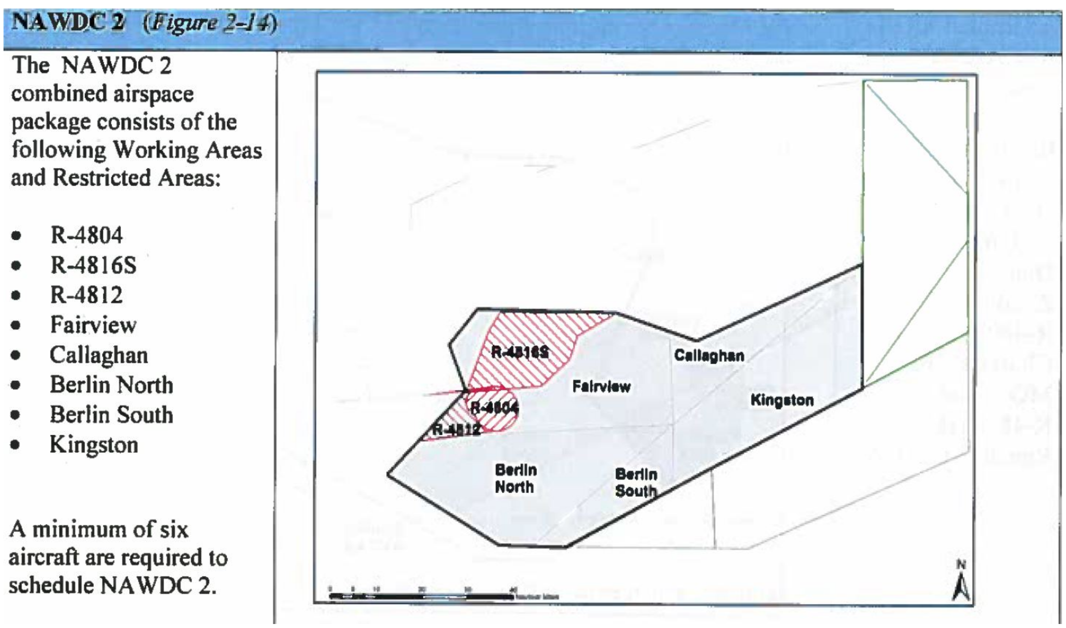

Figure 4.5. NAWDC2. Source: (Naval Air Warfighting Development Center, 2016)

4.2.5 Penalty Values

We construct penalty values to reflect the FRTC priority system in Figure 1.2. SAT's objective heavily penalizes nonscheduled high priority events such as those conducted by a carrier air wing. At the suggestion of the NAWDC Operations Officer (Albrecht, 2017), any event listed as a priority one event is a must schedule. Any event lower than a priority one event follows a five to one trade off ratio. For instance, a priority two event would be the equivalent of five priority three events, a priority three event would be the equivalent of five priority four events, and so on.

Small penalties also accrue for every day that an event is not scheduled from the first possible day the event can take place, extending to the last possible day the event can take place. This rewards earlier scheduling of events since most units would rather complete missions earlier rather than later. Finally, there is an additional penalty for assigning range groupings that differ from a unit's first choice. The equation used for generating these penalty values is listed below in Equation 4.1.

$$cost = (number\ of\ days\ past\ earliest\ day) + .1 * (range\ preference\ number - 1) \tag{4.1}$$

4.2.6 TT and Event Duration

Event duration specifies the amount of time an event occupies the assigned airspace. No other event can take place in the assigned airspace while another event is occurring. Event Duration is not to be confused with TT. TT is incorporated into the model by preventing a unit from proceeding with a follow on event until after a specified amount of time has passed since the completion of that event. It is important to keep in mind that a unit's TT does not affect the utilization of airspace. In other words, the airspace that a unit just used is free for other events once the unit begins its TT. Figure 4.6 lists the distribution of event durations. Each unit requires either 1.5 or 2.5 hours of TT, depending on whether it is a resident or visiting unit. The distribution of TT is roughly a 50/50 split.

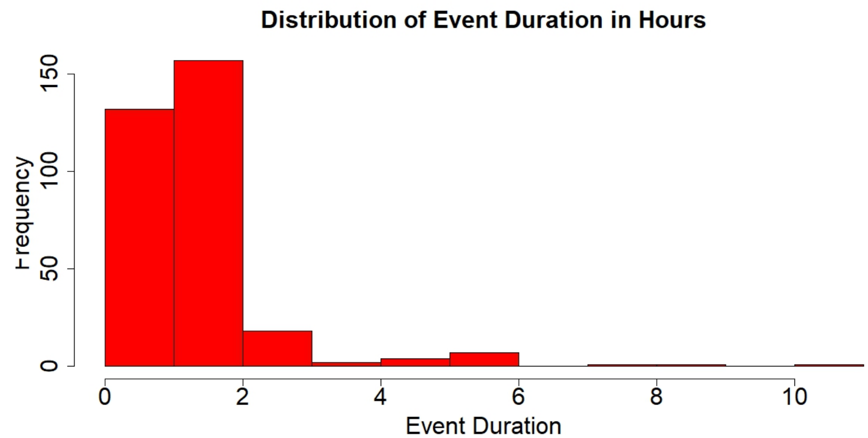

Figure 4.6. Event Duration Distribution

4.3 Effectiveness of SAT

4.3.1 Scenario 1 / Baseline Scenario

We conduct an initial model run of SAT, Scenario 1, to test SAT's performance in compiling a flight schedule for an entire month's worth of events. We acquired data from NAWDC which represents a list of events successfully scheduled via DCAST and the NAWDC scheduling office. Hypothetically, SAT should be able to schedule 100 percent of these events since they are already de-conflicted. However, only 86 percent of events are scheduled in the initial solution (See Table 4.4).

Total Event Requests	323
Number of Units	23
Number of Days	31
Percent Scheduled	86
Percent Non-Scheduled	14
Solver Run Time	55.4 sec

Table 4.4. Scenario 1 Results

After analyzing the solution results it becomes quickly apparent why SAT is not scheduling certain events. TT assigned to units and aircraft in the data set is too generalized. Each is assigned excessive TT which translates to SAT's inability to schedule follow on events that occur shortly after the first. In reality, Fallon would solve this problem by assigning less TT to a unit or using another aircraft for a follow on event. Bottom line is SAT is behaving exactly as programmed. Not only that, but a schedule that would take the OPS Department weeks to schedule, is created by SAT in less than a minute.

Figures 4.7 and 4.8 depict the total number of events scheduled per unit and total number of unscheduled events per unit, respectively.

Figure 4.7. Scheduled Performance for Scenario 1

Figure 4.8. Non Scheduled Performance for Scenario 1

Figure 4.9 depicts the total number of unscheduled events for each priority level. With a

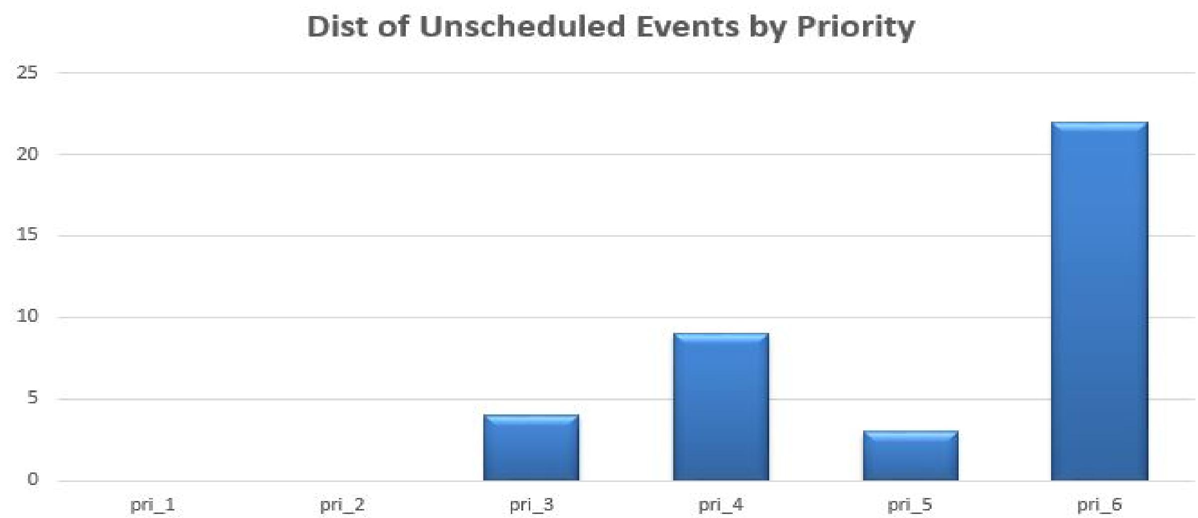

Figure 4.9. Distribution of Non-scheduled Events

quick glance, it can be seen that SAT is behaving correctly and giving preference to events with highest priority. SAT ensures none of the critical priority 1 events are unscheduled, but sacrifices several unimportant priority 6 events for a better schedule.

Figure 4.10 depicts the total hours each individual range is used over the 31 day time period. This allows the flight scheduler to see which ranges are being utilized the most. For instance, it is evident from the graph that NAWDC 1 and NAWDC 2 receive the most air traffic; whereas, R4912 receives none for the month time frame. This prompts the flight scheduler to try and allocate more traffic to ranges like R4912 that are not heavily congested.

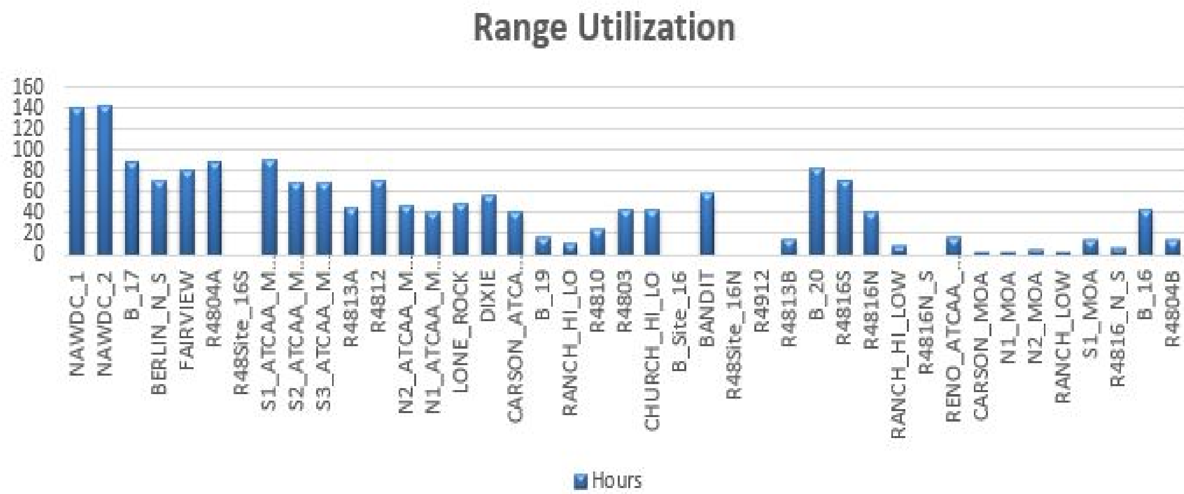

Figure 4.10. Example of Range Utilization

4.3.2 Scenario 2

In scenario 1 the primary reason identified for nonscheduled events is excessive assigned TT. Therefore, the logical step for the next scenario is to reduce TT. TT is reduced to one hour across the board for all events. Table 4.5 summarizes the results.

Total Event Requests	323
Number of Units	23
Number of Days	31
Percent Scheduled	91
Percent Non-Scheduled	9
Solver Run Time	54 sec

Table 4.5. Scenario 2 Results

The reduction in the excessive TT results in a 5 % increase in scheduled events. However, there still remains 9 % of unscheduled events. We examine these outliers to determine the source of their conflicts. The reason is once again a simple disparity between the input data and reality. A clear pattern emerges for the non-scheduled events. These events are requesting airspace that is already in demand at the same time. In reality, it would not be the same airspace because it would be on a different flight level or altitude. For instance, a helicopter could easily carry out its mission at 500 ft Above Ground Level in NAWDC1. At the same time a jet can perform a non-ordnance mission at 10,000 ft in NAWDC1. The simple solution to this problem is to create more airspace groupings that represent different airspaces and corresponding flight levels. Nothing in SAT's formulation or programming would need to be changed. The solution requires only a simple change in the data input.

4.3.3 Scenario 2.5

NAWDC did not provide associated flight levels in the original data set. However, we are able to test SAT's ability to incorporate flight levels by altering Constraint 3.8. The number on the right hand side of the equation is changed to a two to allow for an event to take place in the lower and upper half of a range. Except for this alteration, everything in Scenario 2 remains the same. In the new solution only five events remain unscheduled. Review of the data indicates that these events are not scheduled because of overlap for same unit events. Table 4.6 summarizes the results.

Total Event Requests	323
Number of Units	23
Number of Days	31
Percent Scheduled	99
Percent Non-Scheduled	1
Solver Run Time	1 min 29 sec

Table 4.6. Scenario 2 Results

4.3.4 Scenario 3

Scenario 3 tests SAT's ability to handle options for flights. The data from the baseline scenario (Scenario 1) is slightly altered to give flexibility to the flights which are not scheduled in the final solution. They are each allowed two possible days to occur and two different times on each of those days. In addition, they are allowed to occur on 3 different range groupings. Table 4.7 provides a Scenario 3 summary.

Total Event Requests	323
Number of Units	23
Number of Days	31
Percent Scheduled	96
Percent Non-Scheduled	4
Solver Run Time	1 min 37 sec

Table 4.7. Scenario 3 Results

The additional options allow SAT to schedule 10% more events than the baseline scenario. This is an interesting discovery because not only does the model take essentially the same amount of time to run, but it schedules more events with no additional resources.

4.3.5 Scenario 4

Scenarios 1-3 demonstrate that SAT schedules and deconflicts events as intended by the model developers. Scenario 4 tests its ability to add in events to an already congested schedule. An additional 32 events (10% of original data set) are added into the data from Scenario 1. The hypothesis being that SAT would be able to schedule the majority of these events. The solution from the scenario 4 model run indicates that all but 2 of the additional events are scheduled. In other words, SAT managed to schedule 30 extra events into an already heavily populated schedule. This would take manual schedulers hours, possibly days, to achieve, and SAT solves it in just over a minute. A summary of Scenario 4 results is listed in Table 4.8.

Additional Events	32
Additional Unit(s)	1
Number of Days	31
% of Additional Events Scheduled	94
% of Non-Scheduled Additional Events	6
Solver Run Time	1 min 04 sec

Table 4.8. Scenario 4 Results

4.4 Persistence

4.4.1 Penalizing and Limiting Cancellations

As previously discussed, the capability of *persistence* is built into SAT. It is important that SAT be able to generate new solutions based on previous ones. In this manner, deviations from original schedules are kept minimal as new event requests are added. SAT limits schedule changes in two ways. The first is implemented directly through the objective by penalizing cancellations (See Equation 3.1). The second allows the flight scheduler to set a max number of cancellations (See Equation 3.12).

In order to test SAT's ability to implement *persistence*, the schedule from Scenario 2 is entered into the model as the initial solution. Then the Scenario 4 data, which includes the additional events, is run through the model. Each of the Scenario 3 events is given a priority level of one, and range assignments are assigned to conflict with already scheduled events. This is to ensure that the new events are scheduled and that some previously scheduled events are forced to be canceled to make room.

The results of Persistence Test 1 are summarized in Table 4.9. The allowable number of cancellations is set to a maximum of five. Because the additional events are all given a priority level of one, SAT canceled as many events as possible to make room for the priority one events. This leads into Persistence Test 2, which allows for unlimited cancellations.

Additional events	32
Allowed cancellations	5
Number of cancellations	5
Percent of additional events scheduled	16
Solver Run Time	1 min 21 sec

Table 4.9. Persistence Test 1

4.4.2 Penalizing Unlimited Cancellations

Because Persistence Test 2 results in a maximum number of cancellations, the next logical step is to test persistence with an unlimited number cancellations. Results of Persistence

Test 2 are summarized in Table 4.10.

Since SAT is not limited by the number of cancellations in this scenario, it made as many as necessary to accommodate the additional priority one events. This results in a much lower objective value overall but a new schedule that differs tremendously from the old one. Therefore, the scheduler must keep in mind that high priority events typically take precedence over preserving former schedules. It is up to the user to determine a suitable number of allowable cancellations and how much a schedule can be altered.

Additional events	32
Allowed cancellations	Unlimited(365)
Number of cancellations	39
Percent of additional events scheduled	100
Solver Run Time	1 min 29 sec

Table 4.10. Persistence Test 2

CHAPTER 5: Conclusion and Recommendations

This thesis demonstrates the capability of SAT to quickly construct an optimal, persistent flight schedule using real world data acquired from NAWDC. We test SAT using one month's worth of historically scheduled events, under several what-if scenarios.

SAT's high percentage of scheduled events in each scenario along with its ability to maintain relatively consistent schedules across model runs demonstrates its effectiveness and flexibility.

There are numerous other excursions that can be applied to SAT. For example, its ability to handle limited support aircraft availability and emitter requirements should be tested in depth by NAWDC.

5.1 Recommendations

Ideally, SAT would be able to access event requests directly from DCAST. With this capability, flight schedulers would save valuable time and reduce translation errors. In its current form, SAT still requires that flight schedulers enter in flight event requests, as they receive them, one at a time. However, in order for SAT to directly use DCAST data, there would have to be some standardization in the way events are entered into DCAST.

The ease of use and effectiveness of SAT would be significantly improved if it could process possible time frames for event requests. As it stands now, SAT requires entry of exact combinations of start day and time. This becomes tedious for flight schedulers and would be simplified if it was possible to enter in a block of time for each day that an event can take place rather than a long list of times.

SAT can easily be implemented and utilized by other organizations. For example, air space deconfliction, support aircraft, and syllabus flow remain important issues at every Naval Air Station. If operations departments at squadrons, that share resources with other squadrons, are willing to put in the time to learn and adapt the model, SAT can help them achieve more efficient schedules at a faster rate. In addition, any organization that deals with range utilization issues could benefit from SAT.

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