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THESIS

OPTIMIZING ASSIGNMENTS OF STRIKE-FIGHTER SQUADRONS TO CARRIER-AIRWING DEPLOYMENTS

by

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September 2010

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13. ABSTRACT (maximum 200 words)

The Department of the Navy currently has 11 nuclear-powered aircraft carriers (CVN), which are the centerpiece of carrier strike groups (CSG). The Fleet Response Plan (FRP) dictates CSG deployment and readiness cycles. Based on the FRP, the Navy produces a Master Aviation Plan that assigns 10 carrier-airwings (CVW) to CVNs and carrier-based squadrons to CVWs. At any given time, there are at most 38 strike-fighter squadrons to fill 40 possible assignments. Because there are not enough to fill every possible assignment at one time, strike-fighter squadrons must move between carrier-airwings. Currently, heuristics determine moves using a set of predetermined rules. This thesis presents the Carrier Optimal Strike-fighter Scheduling Tool (COSST), which uses an integer-linear program that optimally assigns strike-fighter squadrons to carrier-airwings over a 10-year period. Assignments minimize moves and ensure sufficient time between deployments. Compared to an existing schedule, our analysis shows that COSST reduces the number of strike-fighter squadron moves from eleven to five in the first four years. Our analysis also examines the impact of reducing strike-fighter squadron availability and transitioning squadrons.

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OPTIMIZING ASSIGNMENTS OF STRIKE-FIGHTER SQUADRONS TO CARRIER-AIRWING DEPLOYMENTS

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ABSTRACT

The Department of the Navy currently has 11 nuclear-powered aircraft carriers (CVN), which are the centerpiece of carrier strike groups (CSG). The Fleet Response Plan (FRP) dictates CSG deployment and readiness cycles. Based on the FRP, the Navy produces a Master Aviation Plan that assigns 10 carrier-airwings (CVW) to CVNs and carrier-based squadrons to CVWs. At any given time, there are at most 38 strike-fighter squadrons to fill 40 possible assignments. Because there are not enough to fill every possible assignment at one time, strike-fighter squadrons must move between carrier-airwings. Currently, heuristics determine moves using a set of predetermined rules. This thesis presents the Carrier Optimal Strike-fighter Scheduling Tool (COSST), which uses an integer-linear program that optimally assigns strike-fighter squadrons to carrier-airwings over a 10-year period. Assignments minimize moves and ensure sufficient time between deployments. Compared to an existing schedule, our analysis shows that COSST reduces the number of strike-fighter squadron moves from eleven to five in the first four years. Our analysis also examines the impact of reducing strike-fighter squadron availability and transitioning squadrons.

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LIST OF ACRONYMS AND ABBREVIATIONS

CVN	Aircraft Carrier, Nuclear powered
CVW	Carrier-airwing
CNA	Center for Naval Analyses
CNAF	Commander, Naval Air Forces
CNAL	Commander, Naval Air Forces Atlantic
CONUS	Continental United States
COSST	Carrier Optimal Strike-fighter Scheduling Tool
COSST(vl)	Carrier Optimal Strike-fighter Scheduling Tool – Variation 1
CSG	Carrier Strike Group
DoD	Department of Defense
DON	Department of the Navy
FAC(A)	Forward Air Controller - Airborne
FDNF	Forward Deployed Naval Forces
FRP	Fleet Response Plan
ISIC	Immediate Superior in Command
JSF	Joint Strike Fighter
MAP	Master Aviation Plan
OCONUS	Outside the Continental United States
PDS	Permanent Duty Station
STOVL	Short-takeoff/vertical landing
USMC	United States Marine Corps
USN	United Stated Navy
VFA	Strike Fighter Squadron, Navy Fixed Wing
VMFA	Strike Fighter Squadron, Marine Corps Fixed Wing

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EXECUTIVE SUMMARY

Twice a year, the Department of the Navy designs a Master Aviation Plan (MAP), which is a document that assigns carrier-airwings (CVW) to aircraft carriers (CVN) and carrier-based squadrons to CVWs. The CVNs are the centerpiece of carrier strike groups (CSG), and the Fleet Response Plan dictates their deployment and readiness cycles. The Navy has 10 CVWs that the MAP assigns to 11 CVNs. At any given time, there are at most 38 strike-fighter squadrons to fill 40 possible assignments. This requires strike-fighter squadrons to move between carrier-airwings. Currently, myopic heuristics create and update the MAP to determine squadron moves.

When assigning strike-fighter squadrons to carrier-airwings, the highest priority is to reduce moves. There are three basic types of moves that can occur: same-coast moves, cross-country moves, and Outside the Continental United States (OCONUS) moves. The most costly of these is an OCONUS move, followed by cross-country moves. The second priority is ensuring that squadrons have adequate time off between deployments for maintenance and unit level training. The standard duration is at least six months, but never less than three months.

This thesis presents the Carrier Optimal Strike-fighter Scheduling Tool (COSST), which uses an integer-linear program that optimally assigns strike-fighter squadrons to carrier-airwings over a 10-year period. COSST aids the user by prescribing assignments that minimize moves and ensure sufficient time between deployments.

Analysis shows COSST reduces strike-fighter squadron moves in a typical four-year carrier-airwing schedule from eleven to five. Further analysis indicates that a reduction of more than three Legacy Hornet squadrons, more than two E-model squadrons, and more than one F-model squadron makes it impossible to satisfy carrier-airwing deployment requirements. Analysis also reveals that no more than three Legacy Hornet squadrons can transition to the Joint Strike Fighter during the same 12-month

period. Finally, analysis demonstrates it is impossible to satisfy all carrier-airwing requirements over 10 years when all squadrons have at least five months between their deployments.

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I. INTRODUCTION

The Department of the Navy (DON) determines deployment and readiness cycles of its carrier strike groups (CSGs) based on the Fleet Response Plan (FRP). The DON's 11 aircraft carriers (CVN) and their respective carrier-airwings (CVW) are the centerpieces of each CSG. DON produces a Master Aviation Plan (MAP) that assigns CVWs to CVNs and carrier-based squadrons to CVWs. At any given time, there are at most 38 strike-fighter squadrons (VFA) to fill 40 possible assignments. Because there are not enough strike-fighter squadrons to fill every possible assignment at one time, squadrons must move between carrier-airwings. DON currently plans these movements using myopic heuristics. This thesis presents the Carrier Optimal Strike-fighter Scheduling Tool (COSST), which uses an integer-linear program that optimally assigns strike-fighter squadrons to carrier-airwings over a 10-year period. Assignments minimize moves and ensure sufficient time between deployments.

A. REASON FOR STUDY

The FRP outlines how aircraft carriers train and deploy in basic, integrated, sustainment, and maintenance phases. There are currently ten CVWs, five on the east coast, four on the west coast of the United States, and one permanently deployed in support of forward deployed Naval Forces (FDNF) in Japan (Commander, United States Fleet Forces Command, 2007). A CVN has a CVW assigned to it during these phases, though the CVW sometimes changes assignments during the maintenance phase. Each CVW has four strike-fighter squadrons assigned during these phases. Strike-fighter squadrons might need to switch carrier-airwings during the maintenance phase (Elitzur, Roberts, & Ward, 2008). The United States Navy (USN) has 35 tactically deployable VFA squadrons for a requirement of 40. Due to this shortfall, the USN and the United States Marine Corps (USMC) have agreed to implement a gap-fill policy, referred to as Tactical Aircraft Integration. Currently, the USMC has three (four as of 2012) Marine strike-fighter squadrons (VMFA) that deploy with CVWs. The USN, in turn, has one

VFA deploy with the marine expeditionary forces. This means that at any given point, only 38 squadrons can fill the 40 possible assignments to CVWs.

The Commander, Naval Air Forces (CNAF), uses the MAP to schedule carrier-based squadrons to carrier-airwings over the course of 10 years. Until recently, the N40 office at Commander, Naval Air Forces Atlantic (CNAL), manually generated this schedule. As a step towards automating the schedule, the Center for Naval Analyses (CNA) developed a tool that uses commercial software to assist in creating the MAP (Figure 1). This tool allows the user to coordinate asset locations on multiple levels: aircraft carriers, carrier-airwings, individual squadrons, and individual aircraft. The user makes heuristic choices based on rules dictated by CNAF (Elitzur, Roberts, & Ward, 2008). While the tool can help generate the schedule, the actual scheduling of squadrons requires an operator to make the assignments.

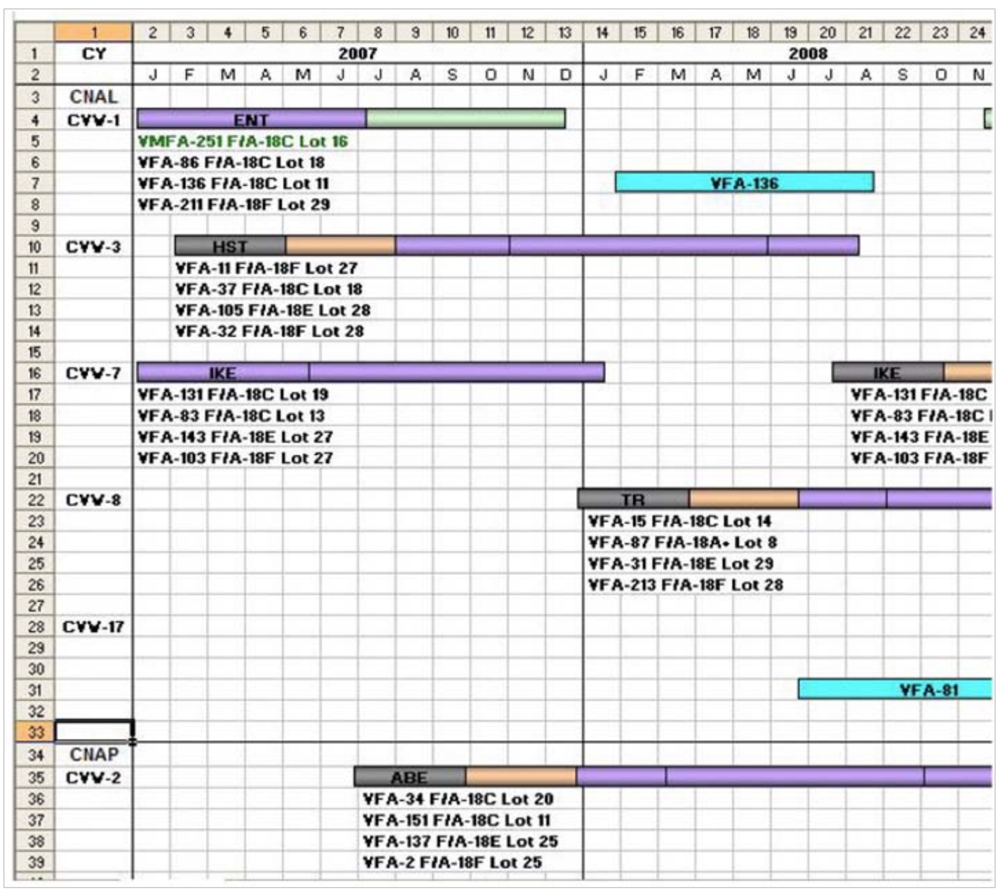

Figure 1. A view of the MAP (From Elitzur, Roberts, & Ward, 2008)

DON is concerned with the current strike-fighter squadron demand exceeding the supply and how this projected shortfall is expected to increase (Bolkom, 2009). In this constrained environment, optimizing assignments becomes essential to fill MAP requirements or determine it is not possible to do so.

CNAL uses certain “business rules” to schedule carrier-airwings. Each carrier-airwing deploys with four strike-fighter squadrons that have approximately 44 aircraft. Of the strike-fighters available, DON can have six models that deploy with a carrier-airwing. The older models, referred to as Legacy Hornets, consist of F/A-18 A, B, C, or D (Figure 2). The newest models, called Super Hornets, consist of F/A-18 E or F (Figure 3). The newer models have a larger airframe and additional capabilities beyond the legacy models (Figure 4). Because of the added capabilities of the Super Hornet, specifically the ability to serve as an airborne refueling asset, there is a requirement that a minimum of two strike-fighter squadrons in a carrier-airwing be Super Hornet models. Of those, at least one must be a Super Hornet F-model because only it can fulfill the mission of a forward air controller–airborne (FAC[A]).

Figure 2. F/A-18C Hornet on approach (From F/A-18C, n.d.)

Figure 3. F/A-18F Super Hornet on approach (From F/A-18F Super Hornet, n.d.)

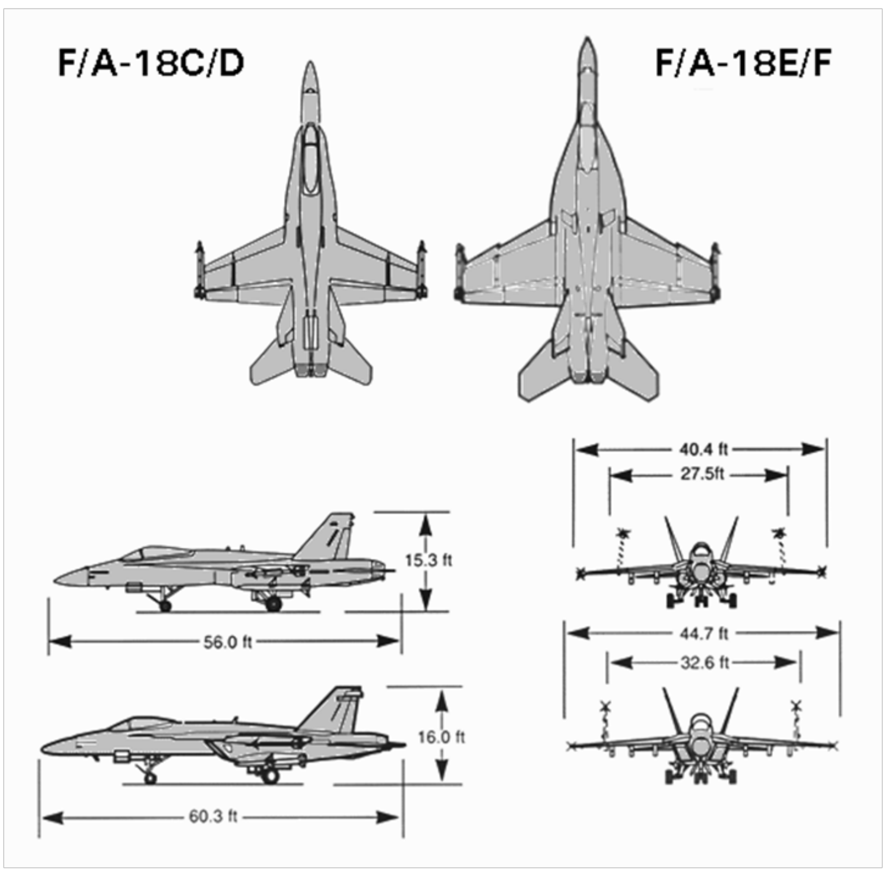

Figure 4. The physical differences between F/A-18 models (From Hornet Model Comparison, n.d.)

The DON will begin replacing legacy models with the F-35 Lightening II Joint Strike-fighter (JSF) in 2012 for the United States Marine Corps and in 2014 for the United States Navy (Roughead, 2010). The F-35 is a "next generation strike aircraft weapon system" that will be used by the Navy, Marine Corps, Air Force, and U.S. allied nations. The F-35C model (Figure 5) is an aircraft-carrier version designed to replace Navy Legacy Hornet models and complement the F/A-18E/F. The F-35B model (Figure 6) is a short-takeoff/vertical landing (STOVL) version. The F-35B will replace all Marine F/A-18 and AV-8Bs to become its only strike-fighter (F-35 Program Office, 2010). Legacy Hornet VFA and VMFA squadrons will be required to take approximately 12 months to transition to the F-35. During this period, they will be unavailable for carrier-airwing deployments.

Figure 5. F-35C model in test phase (From F-35 Program Office, 2010)

Figure 6. F-35B STOVL in test phase (From F-35 Program Office, 2010)

In order to meet operational requirements, CNAL is required to move strike-fighter squadrons between carrier-airwings when not deployed. Moves are required because there are not enough strike-fighter squadrons available to fill every possible assignment. With transition requirements and the projected shortfall of strike-fighter aircraft, the number of moves are expected to increase to meet operational requirements. There are three basic types of moves that can occur: same-coast moves, cross-country moves, and Outside the Continental United States (OCONUS) moves. When a move occurs, it can be considered either a permanent duty stations (PDS) change (where the squadron now permanently belongs to a new carrier-airwing) or an immediate superior in command (ISIC) change (where the squadron temporarily belongs to that carrier-airwing but is expected to return to its original carrier-airwing).

The primary preference CNAL uses when creating the strike-fighter squadron assignment schedule is the desire to minimize the movement of squadrons. Additionally, since movement is necessary to fulfill operational requirements, CNAL would like to minimize the moves that are away from the same coast. The final important consideration is the amount of unassigned time to a carrier-airwing deployment cycle for each strike-fighter squadron. During this time, the squadron will meet maintenance and unit level training requirements. The minimum time between squadron deployments should ideally be at least six months and never less than three.

B. THESIS SCOPE AND ORGANIZATION

The primary purpose of this thesis is to develop an optimization model to aid in the decisions used for strike-fighter squadron assignments to the MAP. The objective is to minimize the number of moves weighted by the moves distance and time between deployments for strike-fighter squadrons. Carrier Optimal Strike-fighter Scheduling Tool (COSST) not only prescribes the 10-year period assignment but also helps analyze scenarios such as squadron reductions or changes to the times squadrons are available.

This thesis has five chapters: Chapter I-Introduction, Chapter II-Background, Chapter III-Model Development, Chapter IV-Model Implementation, and Chapter V-Conclusions.

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II. BACKGROUND

A. THE MASTER AVIATION PLAN

The Master Aviation Plan (MAP) is a framework for assigning carrier-based squadrons to carrier strike groups (CSGs) over 10 years based on the Fleet Response Plan (FRP) cycles. It is reviewed biannually (Elitzur, Roberts, & Ward, 2008). In the past, the N40 office at Commander, Naval Air Forces Atlantic (CNAL) has done the assignments of carrier-based squadrons to carrier-airwings manually. In 2008, the Center for Naval Analyses (CNA) developed a tool to examine scenarios and long-term inventory-related questions for strike-fighters. The analysis tool works with commercial software provided by the ProModel Corporation (2010). This tool allows the user to coordinate asset locations on multiple levels: aircraft carriers, carrier-airwings, individual squadrons, and individual aircraft. This tool contains a computer simulation that generates a MAP-type spreadsheet while running through the various assignments over time (Elitzur, Roberts, & Ward, 2008).

The ProModel application uses a simulation for modeling event processes that take place over a period. Microsoft Excel (2010) macros input spreadsheet data to ProModel. The input includes aircraft carrier and carrier-airwing schedules, initial assignments of aircraft carriers, carrier-airwings, squadrons, and aircraft, transition schedules and Marine strike-fighter squadron (VMFA) assignments, and aircraft entitlements. The schedule spreadsheet inputs (Figure 7) are produced in the application Slider, developed by CNA to allow the user to easily create, manipulate, and present employment schedules (Elitzur, Roberts, & Ward, 2007).

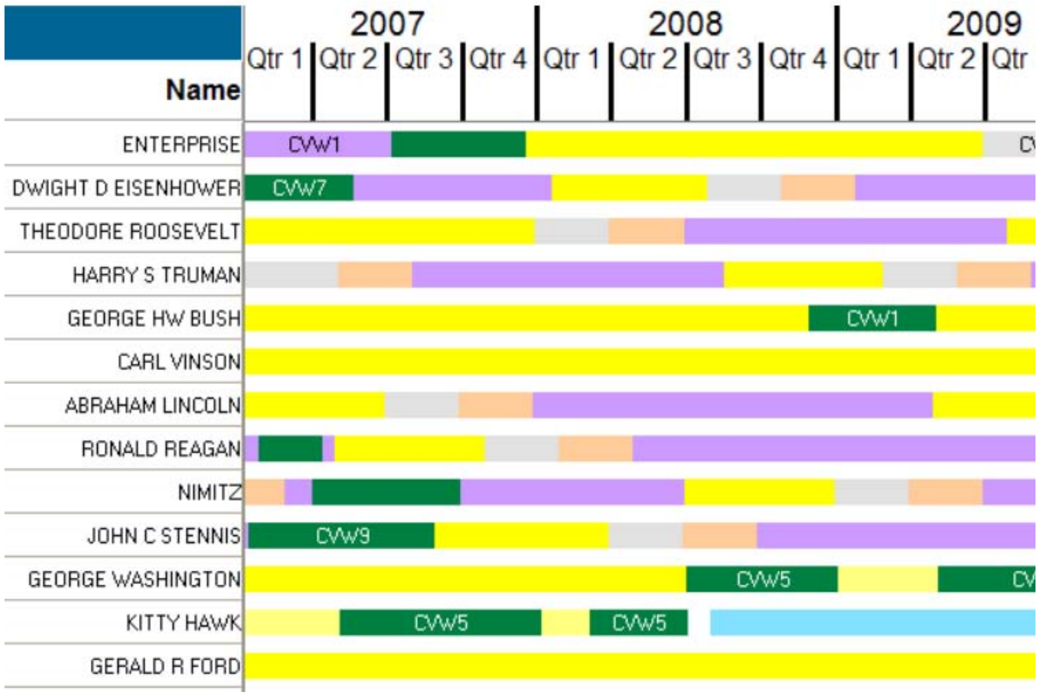

Figure 7. Example of a Slider schedule for aircraft carriers and carrier-airwings (Elitzur, Roberts, & Ward, 2008)

The MAP simulation runs in daily increments. Throughout the simulation, the model myopically assigns strike-fighter squadrons to carrier-airwings according to specific "business rules" (Elitzur, Roberts, & Ward, 2008). When there are conflicts with the desired business rules, the model makes recommendations for strike-fighter squadron moves and the user makes choices from the available strike-fighter squadrons. These recommendations do not necessarily consider the long-term consequences of the decisions. This thesis overcomes this myopic view by providing an optimization model that simultaneously prescribes all assignments over a 10-year horizon.

After the MAP simulation completes, the output is displayed in Excel spreadsheets in Slider. The output includes a view of the MAP (as shown earlier in Figure 1), a new view of aircraft carrier and carrier-airwing data, and views of strike-fighter squadron level data (Figure 8).

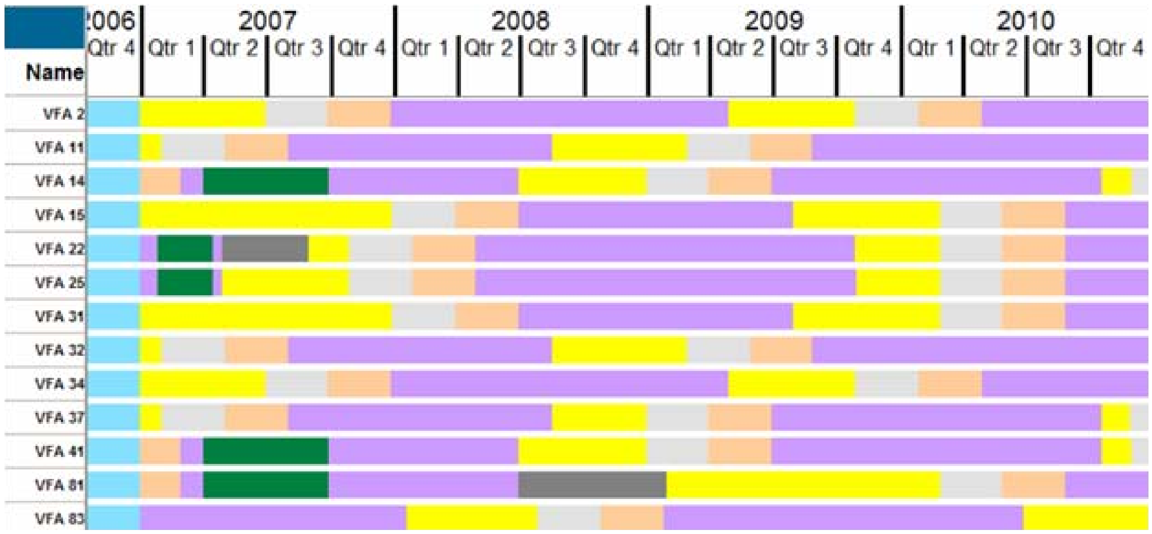

Figure 8. Strike-fighter squadron information output in Slider (From Elitzur, Roberts, & Ward, 2008)

B. WORK IN OPTIMIZING SCHEDULES

Using optimization for scheduling is not new to the Department of Defense. While nothing exists in the literature for the optimization of squadron to carrier-airwing assignments, there are similar optimization applications in the realm of aviation. Optimization work has been done for scheduling the acquisition and retirement of naval assets, for scheduling aircraft deployments and maintenance, squadron flight schedules, and scheduling of aviators for training, squadrons assignments, and even airframe transitions.

Field (1999) develops a force structure-planning tool Capital Investment Planning Aid (CIPA). Garcia (2001) expands on Field’s work with an Air Planning Update (CIPA APU). This tool suggests ship, submarine, and aircraft procurement and retirement schedules. These suggestions replace manual planning with optimization based on the fiscal, industrial, and mission requirements for aircraft and ship procurement. Like this thesis, it uses an integer-linear program to make recommendations over time. CIPA APU recommends a yearly force structure plan that minimizes penalties associated with violating budget constraints, production constraints, or inventory requirements.

Similarly, this thesis recommends a schedule of strike-fighter squadron assignment to carrier-airwings based on deployment requirements with considerations to moving costs and time between deployments.

The aviation community is concerned with specific aircraft and their lifetime. As military assets age, their availability becomes an issue, especially when the scheduling of maintenance is required. Baker (2000) addresses the problem of scheduling the aging EA-6B for necessary maintenance with consideration to maintaining an adequate aircraft inventory for combat readiness. He introduces an optimization (integer-linear programming) based decision tool to prescribe a yearly schedule that minimizes the time an aircraft is out of the primary inventory. Likewise, this thesis considers the time that a strike-fighter squadron will have available away from carrier-airwings for things such as maintenance.

Optimized schedules exist for aircraft and aircrew on a squadron level. Gokcen (2008) addresses the problem of fighter flight-schedule production in the United States Air Force. The procedure of creating a flight schedule is complex and typically done manually. Considerations include service regulations, squadron policy, and the squadron commander's, operations officer's, and flight-training officer's direction. The schedule is further complicated when a pilot is unable to fly and another pilot must be replaced on the daily flight schedule. Gokcen develops an integer-linear program to produce a robust flight schedule to handle unexpected pilot absenteeism. In a similar work, Brown (1995) examines the process for scheduling Marine Corps aviation training under the Training and Readiness Program. He develops a bi-criteria mixed integer-programming model to produce a 90-day aircrew-training schedule that takes into account readiness and equity. Similarly, this thesis looks at the effects on the carrier-airwing schedule in the event of absent or a reduced number of strike-fighter squadrons.

Whenever the DON transitions aircrew and squadrons to a new aircraft, there are scheduling concerns with how to do it most effectively. Culver (2002) creates an optimization model to distribute aircraft and pilots involved in the transition of a H-46 helicopters to the MH-60S. The goal is to minimize the number of lost helicopter and pilot flight days. Holloway (2010) presents an integer-linear program to evaluate the number of Marine Corps pilots for accession and conversion from the F/A-18 A/C/D Hornets and AV-8B Harriers to the F-35 Joint Strike Fighter (JSF). Although this thesis does not address specific aircraft and aircrew, it does look at the effects of the transition of multiple strike-fighter squadrons to the JSF on carrier-airwing schedules.

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III. MODEL DEVELOPMENT

A. CARRIER OPTIMAL STRIKE-FIGHTER SCHEDULING TOOL (COSST)

COSST optimally assigns strike-fighter squadrons to carrier-airwings over many years (10 for all computational results in this thesis) for each carrier-airwing deployment cycle and strike-fighter squadron deployment. The Master Aviation Plan (MAP) provides the time and location of each carrier-airwing deployment as COSST input. Because there are fewer strike-fighter squadrons than the number required for each carrier-airwing, the squadrons must move between carrier-airwings to fulfill the requirements for deployment.

1. Assumptions

a. COSST uses cost to capture the preferences for strike-fighter squadron to carrier-airwing assignments. These preferences consist of two components, the physical moves a strike-fighter squadron must make between carrier-airwings and the time squadrons have between carrier-airwing deployment assignments. The total cost is the sum of these two components.

b. The cost associated with moving a strike-fighter squadron to another carrier-airwing is based on whether the move is on the same coast, if a move is made to a carrier-airwing across country to the opposite coast within the Continental United States (CONUS), or if the move is to forward deployed naval forces (FDNF) Outside the Continental United States (OCONUS).

c. Squadrons require time between carrier-airwing assignments for maintenance and unit level training. COSST enforces a minimum number of months between deployments and penalizes any assignment that has more than the minimum but less than the desired time between assignments.

d. COSST also applies a discount as squadron deployments increase. This reflects the importance of optimizing earlier deployments as the overall schedule will likely change many times over a 10-year period.

2. Model Formulation

Indices

a, a' carrier-airwing (cvw1, cvw2,…, cvw17)

b, b' deployment cycle associated with a carrier-airwing (b0,b1,…,b9)

d deployment associated with strike-fighter squadron (d0,d1,…,d12)

s strike-fighter squadron (VFA2F, VFA11F,…, VMFA312C)

Index Sets

$s \in SH$ set of all Super Hornet squadrons

$s \in SH_F$ set of all Super Hornet F squadrons

$(a', b') \in IN_{a,b}$ set of all (a', b') combinations that intersect (in time with) (a, b)

Data

$initial_{a,s}$ one when strike-fighter squadron s is initially assigned to carrier-airwing a

$Cost_{a,b,a',b',s}$ cost associated with having squadron s deploy from a, b to a', b'

$moves$ maximum number of moves allowed for a squadron

$discount_d$ discount factor for squadron deployment d

$p1_b$ penalty cost for each squadron below the amount required for deployment b in the first constraint

$p2_b$ penalty cost for each Super Hornet squadron below the amount required for deployment b in the second constraint

$p3_b$ penalty cost for each Super Hornet F squadron below the amount required for deployment b in the third constraint

Binary Variables

$X_{a,b,d,s} \in \{0,1\}$ binary variable with a value of one if squadron s is assigned to carrier-airwing a for squadron deployment d during carrier-airwing deployment b

$Y_{a,b,a',b',d,s} \in \{0,1\}$ binary variable with a value of one if squadron s moves from (a,b) to (a',b') for squadron deployment d

Nonnegative Variables

$ec1_{a,b}$ number of strike-fighter squadrons assigned to carrier-airwing a for deployment b below the requirement (first constraint)

$ec2_{a,b}$ number of Super Hornet squadrons assigned to carrier-airwing a for deployment b below the requirement (second constraint)

$ec3_{a,b}$ number of Super Hornet F squadrons assigned to carrier-airwing a for deployment b below the requirement (third constraint)

Formulation

$$\text{Minimize } TotalCost = \sum_{a,b,a',b',d,s} discount_d Cost_{a,b,a',b',d,s} Y_{a,b,a',b',d,s}$$

$$+\sum_{a,b} (p1_b ec1_{a,b} + p2_b ec2_{a,b} + p3_b ec3_{a,b}) \qquad (0)$$

Subject to:

$$\sum_{d,s} X_{a,b,d,s} = 4 + ec1_{a,b} \qquad \forall a,b \qquad (1)$$

$$\sum_{d,s \in SH} X_{a,b,d,s} = 2 + ec2_{a,b} \qquad \forall a,b \qquad (2)$$

$$\sum_{d,s \in SH_F} X_{a,b,d,s} = 1 + ec3_{a,b} \qquad \forall a,b \qquad (3)$$

$$\sum_{d,(a',b') \in IN_{a,b}} X_{a',b',d,s} \le 3\left(1 - \sum_{d} X_{a,b,d,s}\right) \qquad \forall a,b,s \qquad (4)$$

$$\sum_{a,b} X_{a,b,d,s} \le 1 \qquad \forall d,s \qquad (5)$$

$$\sum_{a,b,a' \ne a,b',d} Y_{a,b,a',b',d,s} \le moves \qquad \forall s \qquad (6)$$

$$Y_{a,b,a',b',d,s} \ge X_{a,b,d-1,s} + X_{a',b',d,s} - 1 \qquad \forall a,b,a',b',s \quad (7)$$

$$\sum_{a',b'} X_{a',b',d-1,s} \ge X_{a,b,d,s} \qquad \forall a,b,d,s \qquad (8)$$

$$X_{a,b=0,d=0,s} = initial_{a,s} \qquad \forall a,b \qquad (9)$$

$$X_{a,b,d,s} \in \{0,1\} \qquad \forall a,b,d,s \qquad (10)$$

$$Y_{a,b,a',b',d,s} \in \{0,1\} \qquad \forall a,b,a',b',d,s \; (11)$$

$$ec1_{a,b}, ec2_{a,b}, ec3_{a,b} \ge 0 \qquad \forall a,b \qquad (12)$$

3. Explanation of Formulation

Equation (0) defines the objective function, that expresses the total cost associated with the schedule assignment. It is has four components (a) $discount_d$, (b) $Cost_{a,b,a',b',s}$, (c) $Y_{a,b,a',b',d,s}$, and (d) $\sum_{a,b}(p1_b ec1_{a,b} + p2_b ec2_{a,b} + p3_b ec3_{a,b})$. The first three terms express the cost of moves. The last component captures any penalty costs encountered by the use of elastic variables (indicating violation of one of the first three constraints). Constraint sets (1), (2), and (3) ensure that there are four strike-fighter squadrons, two Super Hornet squadrons, and one Super Hornet F squadron assigned to a carrier-airwing for all carrier-airwing deployments or measures any deviation. Constraint set (4) maintains the assignment of only one strike-fighter squadron to a carrier-airwing and carrier-airwing deployment at a given time. The number three is an upper bound on the number of partial carrier-airwing deployments that can occur (but not overlap with each other) during deployment b for carrier-airwing a. Such deployments should be excluded for a given squadron only when the squadron is assigned deployment b for carrier-airwing a. For example (Figure 9), during the CVW11 deployment b2, three carrier-airwings (CVW5 b3, CVW8 b1, and CVW9 b3) have deployments during that period but do not overlap with each other and could potentially be assigned to a given squadron if that squadron is not assigned to CVW11 deployment b2. Constraint set (5) restricts the deployment for each strike-fighter squadron to at most one carrier-airwing deployment. Constraint set (6) limits the number of moves for each strike-fighter squadron. Constraint (7) tracks when a strike-fighter squadron moves between carrier-airwings. Constraint (8) maintains ascending squadron deployments. Constraints (9) set the initial carrier-airwing assignments for each strike-fighter squadron. Constraints (10) and (11) identify binary variables. Constraint set (12) indicates non–negative variables.

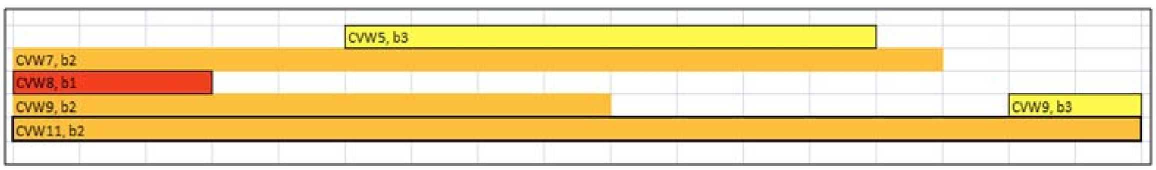

Figure 9. Portion of the carrier-airwing deployment schedule (best viewed in color)

4. Calculations of Specific Indices and Data

a. The months a carrier-airwing deployment cycle starts and ends establish $(a',b') \in IN_{a,b}$, the set of all (a',b') combinations that intersect (in time with) (a,b). Knowledge of overlap, as used in constraint (4), ensures that each strike-fighter squadron assignment is (at most) to one carrier-airwing deployment at a given time. We calculate $IN_{a,b}$ using the following calculation and data:

$(a',b') \in IN_{a,b}$ if $start_{a',b'} < end_{a,b} + lowMonths$ and

$end_{a',b'} + lowMonths > start_{a,b}$ where

$start_{a,b}$ is the month when carrier-airwing a deployment b starts;

$end_{a,b}$ is the month when carrier-airwing a deployment b ends; and

$lowMonths$ is the minimum number of months between carrier-airwing deployments.

b. The following factors comprise $Cost_{a,b,a',b',s}$:

$CTime_{a,b,a',b'}$ cost associated with the length of time between squadron deployments from a,b to a',b';

$CMove_{a,a'}$ cost associated with the distance squadrons move from a to a'; and

$Cost_{a,b,a',b',s} = CTime_{a,a',b,b'} + CMove_{a,a'}$.

c. Reducing the number of possible strike-fighter squadron to carrier-airwing deployment combinations can significantly decrease solution time. The set $(a',b') \in allow_{a,b}$ is the (a',b') combinations that start within a specified number of months from the end of (a,b). We find elements of the set $allow_{a,b}$ using the following calculation and data:

$(a',b') \in allow_{a,b}$ if $start_{a',b'} \geq end_{a,b} + shortest$ and

$start_{a',b'} < end_{a,b} + longest$, where

$shortest$ is the minimum months between deployments; and

$longest$ is the maximum months between deployments.

d. The set $(a,b,d) \in allowabd_{a,b,d}$ is all (a,b,d) combinations where squadron deployment d is within a specified range of deployment b.

We find elements of the set $allowabd_{a,b,d}$ using the following calculation and data:

$(a,b,d) \in allowabd_{a,b,d}$ if $b > d - between$ and $b < d + between$ where $between$ is the numbered range between carrier-airwing deployment b and squadron deployment d .

5. COSST Variation - COSST(v1)

COSST(v1) models immediate superior in charge (ISIC) moves whereas COSST models permanent duty station (PDS) moves. If the penalty for time between deployments $CTime_{a,b,a',b'}$ is eliminated with ISIC moves, this makes the binary variable $Y_{a,b,a',b',d,s}$ and constraints (6) and (7) no longer necessary. The resulting objective function is:

$$\text{Minimize } TotalCost = \sum_{a,b,d,s} discount_d RCost_{a,s} X_{a,b,d,s} + \sum_{a,b} (p1_b ec1_{a,b} + p2_b ec2_{a,b} + p3_b ec3_{a,b})$$

where $RCost_{a',s} = CMove_{a,a'}$ (for a as the starting airwing).

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IV. MODEL IMPLEMENTATION

A. COMPUTER IMPLEMENTATION

The commercial optimization software package Generalized Algebraic Modeling System (GAMS), revision 229 is used to generate Carrier Optimal Strike-fighter Scheduling Tool (COSST) and CPLEX 11.2.0 solves it (GAMS Development Corporation, 2010). All instances of COSST(v1) solve in a few seconds using a Dell desktop computer containing a 3.2 GHz processor. COSST takes longer to solve, and the solution time is restricted to one hour for all computational results presented in this thesis.

B. DATA IMPLEMENTATION

COSST is demonstrated using a 10-year carrier-airwing deployment schedule developed from an unclassified 4-year carrier-airwing schedule and its initial strike-fighter squadron assignments as provided by Center for Naval Analyses (CNA). Figure 10 shows the 10-year carrier-airwing schedule. From this carrier-airwing schedule, COSST obtains inputs of the start and end months of each deployment and the initial carrier-airwing location of each strike-fighter squadron.

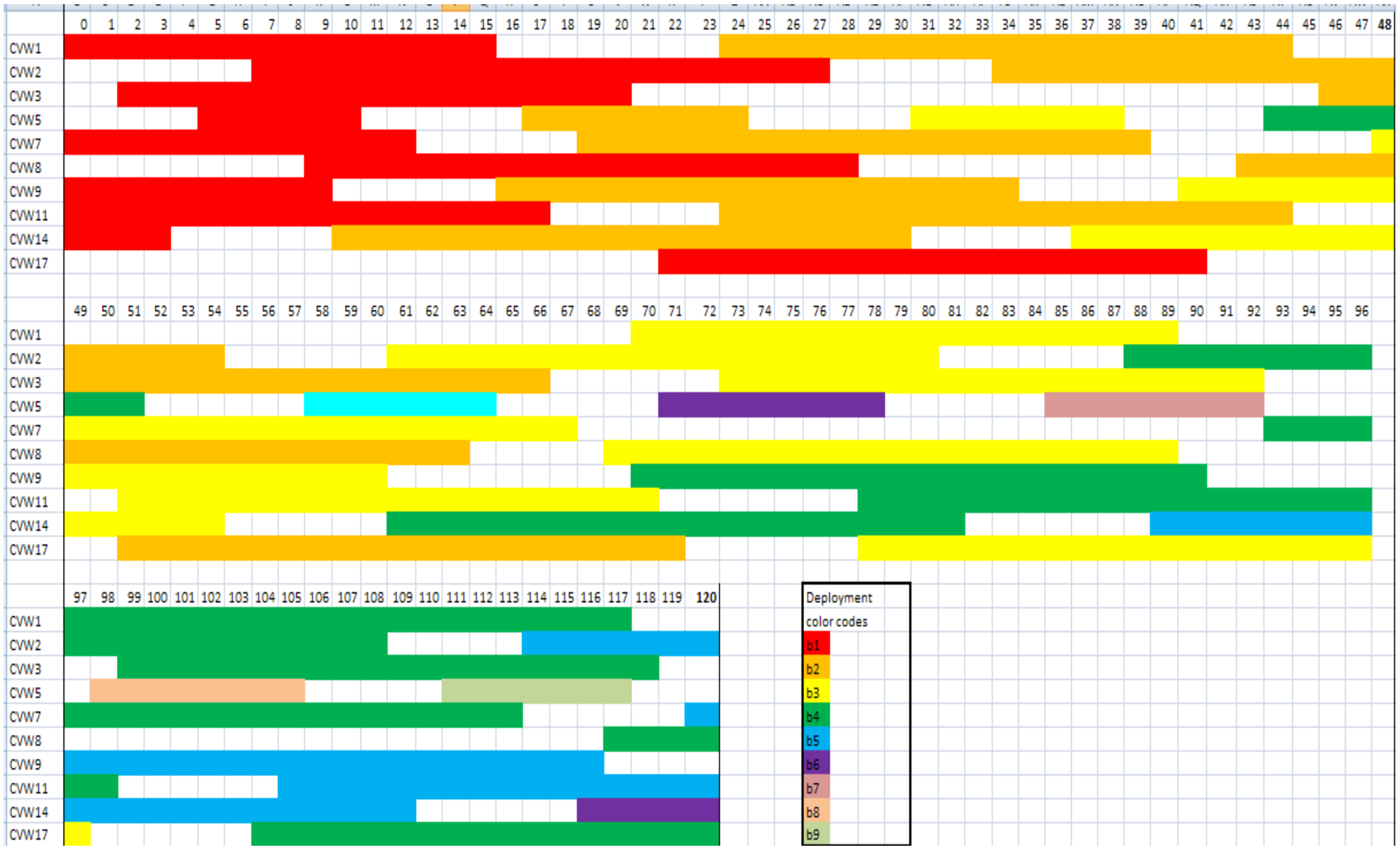

Figure 10. The 10-year carrier-airwing schedule in months used as input for COSST

1. Assumptions

The analysis of COSST uses the following assumptions:

a. The strike-fighter squadrons initially assigned to carrier-airwing 17 (CVW17) are the three squadrons without an assigned carrier-airwing from the schedule provided by CNA. CVW17 has no assigned squadrons in CNA's schedule and, therefore, start with the unassigned squadrons.

b. The most important factors for strike-fighter squadron assignments are the types of moves and the amount of time between carrier-airwing assignments. The goal for Commander, Naval Air Forces Atlantic (CNAL) is to reduce the number of cross-country moves away from the home carrier-airwing coast and Outside the Continental United States (OCONUS). A squadron may go less than six months between carrier-airwing assignments (CNAL desires six months or greater) but no less than three months. $Cost_{a,b,a',b',s}$ values capture the hierarchy of these preferences (Table 1).

Type of Move	Cost
No move	0
Same coast move	10
Opposite coast move	30
OCONUS move	100

Table 1. Cost assignments for strike-fighter squadron (carrier-airwing) moves

There is no cost to remain in the same carrier-airwing and a cost of 10 to move to another strike-fighter squadron on the same coast. While same-coast moves would be ideal, it is not always possible, so we set the cost to move across country to 30. This indicates that it is cheaper to do two moves on the same coast before doing one move across country. OCONUS moves cost 100 because they are the least desired. This indicates that it is preferred to have nine moves on the same coast or three moves across country than one OCONUS move.

A cost occurs if a strike-fighter squadron receives less than six months down time. A squadron is prevented from being selected if it has had less than three months off by the set $(a',b') \in IN_{a,b}$ and constraint (4), and setting $lowMonths = 3$. To discourage the selection of squadrons between three and six months off, COSST uses the following cost assignment:

If $start_{a',b'} = end_{a,b} + 3$ then $CTime_{a,b,a',b'} = 155$;

If $start_{a',b'} = end_{a,b} + 4$ then $CTime_{a,b,a',b'} = 75$;

If $start_{a',b'} = end_{a,b} + 5$ then $CTime_{a,b,a',b'} = 35$; and

If $start_{a',b'} \geq end_{a,b} + 6$ then $CTime_{a,b,a',b'} = 5$.

The cost more than doubles as the time length reduces by a month. In relation to the cost to move, it is more costly to have three months off than to execute an OCONUS move.

c. The *shortest* and *longest* values in $(a',b') \in allow_{a,b}$ are 3 and 36 months, respectively. The *between* value in $(a,b,d) \in allowabd_{a,b,d}$ is three.

d. Penalty costs assigned to the elastic variables are set to 10000, which should only be incurred when the first three constraints (regarding specific strike-fighter squadron types and numbers) can only be satisfied with elastic variables.

e. The discount factor is set as $discount_d = (0.95)^{(d-1)}$.

C. MODEL RESULTS

1. The COSST Output

The settings and assumptions outlined above produce a schedule that satisfies the desired requirements outlined by the constraints. After an hour, the resulting optimality gap for COSST is 35.87%. A summary output page gives the total moves to a new carrier-airwing and the number of each type of move over the 10-year schedule (Table 2). COSST prescribes 11 total moves, with 5 cross-country and 6 same-coast moves using the initial conditions established in the carrier-airwing schedule provided by CNA. Conceptually, the moves made with COSST are permanent duty station (PDS) changes, and strike-fighter squadrons will not typically return to their original carrier-airwing after they have moved.

Total Moves	11
OCONUS Moves	0
Cross Country Moves	5
Same Coast Moves	6

Table 2. Summary of moves from COSST

Model output for each individual strike-fighter squadron is included in the Appendix (Table 4). Two views of the schedule are provided, the carrier-airwing view (Appendix, Table 5) and strike-fighter squadron view (Appendix, Table 6).

2. The COSST(v1) Output

COSST(v1) prescribes 16 total moves, with all of them being on the same coast as seen in Table 3.

Total Moves	16
OCONUS Moves	0
Cross Country Moves	0
Same Coast Moves	16

Table 3. Summary of moves from COSST(v1)

Conceptually, COSST(v1) only incurs a move cost when the strike-fighter squadron deploys with a carrier-airwing that is different from its originating carrier-airwing. Moves to return to the original carrier-airwing after a deployment are not counted. This mimics an immediate superior in command (ISIC) change instead of a PDS move.

3. Four-Year Schedule Comparison

The first four years of the schedule provided by CNA contains strike-fighter squadron assignments. COSST(v1) restricted to four years provides a comparison. The CNA schedule contains 11 moves on the same coast for that period. The COSST(v1) schedule has five moves on the same coast (Appendix Table 8).

4. Analysis

Because of its fast runtime, COSST(v1) can quickly answer analysis questions about changes to deployment schedules on strike-fighter squadron availability. Sample results report the effects from a reduction of the total number of strike-fighter squadrons, the unavailability of squadrons during transition to a new aircraft, and an increase to the mandatory time between squadron deployments.

a. The Removal of Strike-Fighter Squadrons

Reducing the total available number of strike-fighter squadrons increases the required moves, until it is impossible to satisfy deployment requirements. After the removal of four Legacy Hornet squadrons (A and C-models), regardless of which coast they are from, the carrier-airwing deployment requirements cannot be satisfied (Figure 11). As would be expected, the removal of squadrons increases the number of required moves. While the moves only go up by two with the removal of one squadron, the largest jump is ten with the removal of two squadrons. The removal of three squadrons requires an additional five moves.

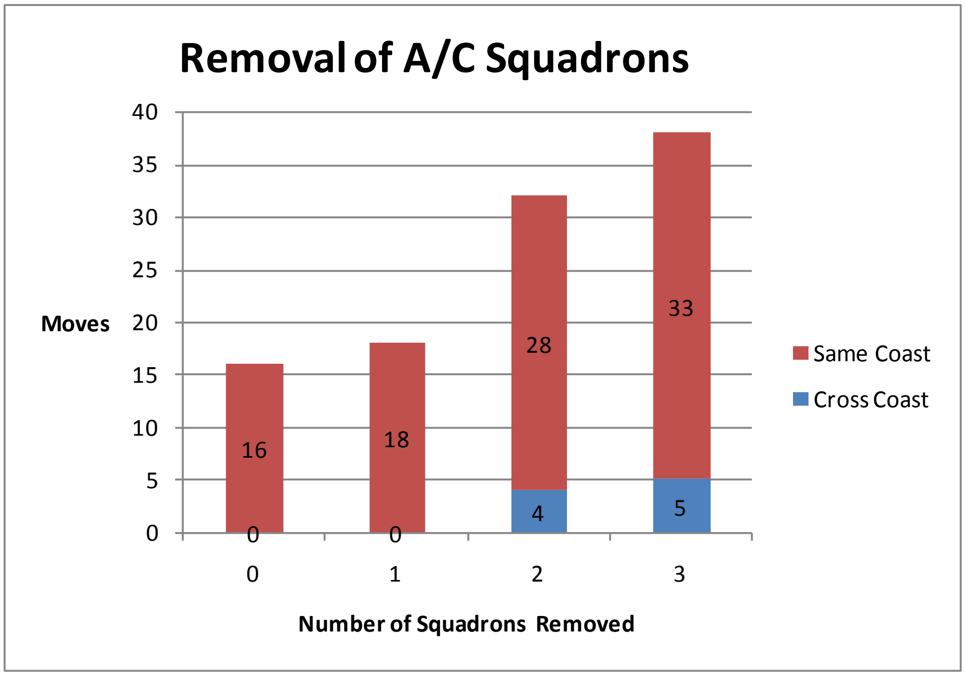

Figure 11. The removal of A/C squadrons.

This graph shows the changes in the number of moves caused by the removal of A- and C-model squadrons. It is impossible to satisfy all carrier-airwing requirements over 10 years after the removal of four squadrons.

The removal of three E-model Hornet squadrons makes it impossible to satisfy carrier-airwing deployment requirements (Figure 12). Here, the removal of squadrons causes the number of moves to increase more evenly each time. The moves increase by eight when one, and then two, squadrons are removed.

For F-models, carrier-airwing deployment requirements cannot be satisfied if two squadrons are removed (Figure 13). As with the E-model, there is an increase of eight moves after the removal of one squadron.

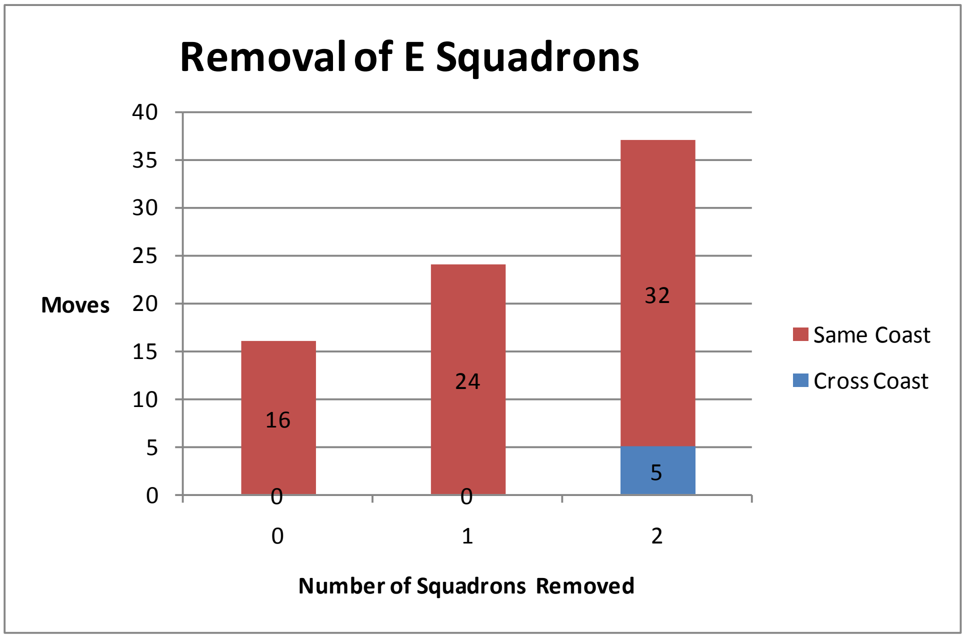

Figure 12. The removal of E squadrons.

This graph shows the changes in the number of moves caused by the removal of E-model squadrons. It is impossible to satisfy all carrier-airwing requirements over 10 years after the removal of three squadrons.

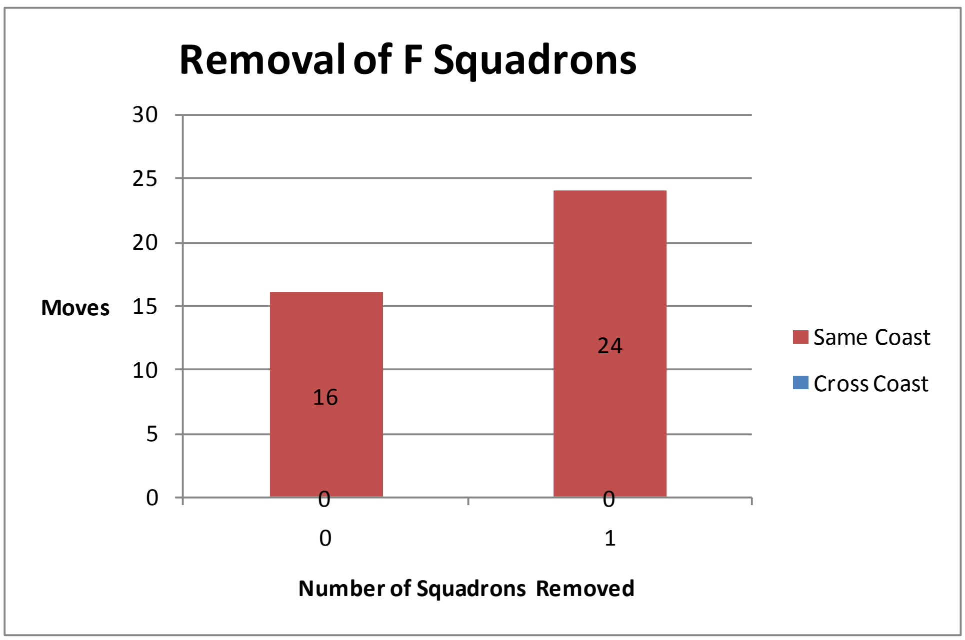

Figure 13. The removal of F squadrons.

This graph shows the changes in the number of moves caused by the removal of F-model squadrons. It is impossible to satisfy all carrier-airwing requirements over 10 years after the removal of two squadrons.

When four total squadrons (of any combination of models) are removed, COSST(v1) cannot satisfy carrier-airwing deployment requirements (Figure 14). The implication here is that the removal of an entire carrier-airwing makes it impossible to satisfy all carrier-airwing deployment requirements.

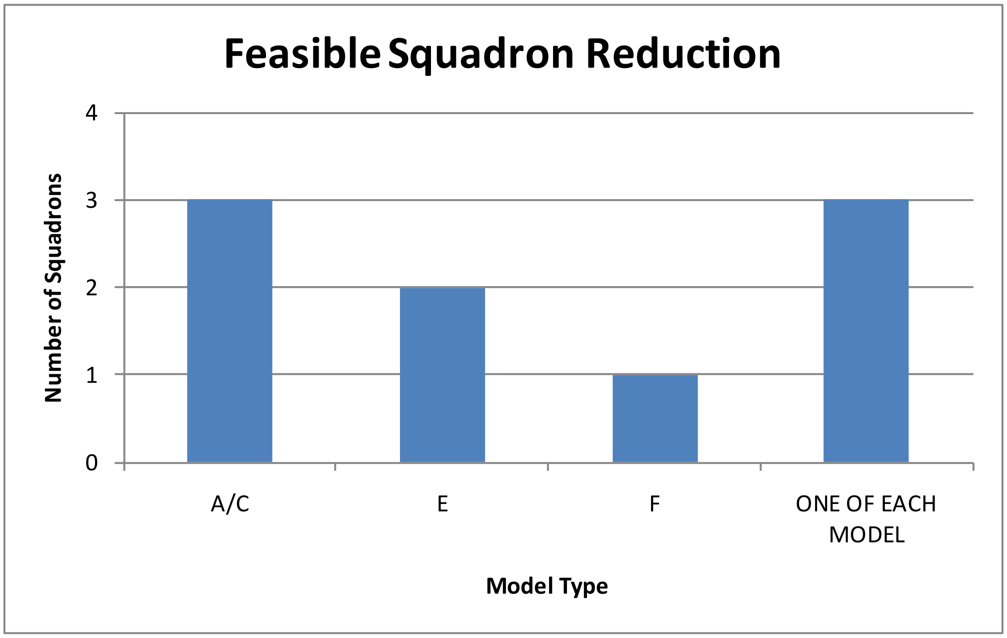

Figure 14. Feasible squadron reduction.

The total number of squadrons that, when removed, can still feasibly satisfy carrier-airwing deployment requirements. Not shown in this figure (see prior figures for details) is the significant increase in movement needed to satisfy requirements when eliminating squadrons.

b. The Removal of Strike-Fighter Squadrons for a Transition Period

Legacy Hornet squadrons are expected to be unavailable for 12 months when transitioning to the Joint Strike Fighter (JSF). This is modeled by the removal of squadrons between the 24th and 35th months. The removal of one and two squadrons results in no change from the original 16 same-coast moves. The removal of three squadrons increases the number of moves to 18 same-coast moves. It is no longer possible to satisfy carrier-airwing deployment requirements when removing four squadrons. This implies that the Navy can transition at most three Legacy Hornet squadrons to the F-35 simultaneously.

c. Changing the Minimum Number of Months Strike-Fighter Squadrons Have Between Deployments

The impact of adjusting the minimum time strike-fighter squadrons have between deployments is investigated. When increasing from three to four months, it is still possible to satisfy all requirements, but it requires one additional move (a cross-country move). When increased to five months, it is no longer possible to satisfy carrier-airwing deployment requirements.

d. A More Balanced Beginning

The schedule from CNA does not have the strike-fighter squadrons evenly balanced (two Legacy Hornets, one E-model squadron, and one F-model squadron) in the initial carrier-airwings. From the initial assignments, CVW3 and CVW11 have three Super Hornet squadrons and CVW17 has three Legacy Hornet squadrons. Right from the start, the user sees moves to balance out CVW17. How a more balanced start influences the number of moves is investigated. With more balanced initial assignments, where CVW3 and CVW11 have the typical two Legacy Hornets, one E-model, and one F-model, and CVW17 has one of each model, COSST(v1) prescribes only nine same-coast moves; seven less that its original prescription.

V. CONCLUSION AND RECOMMENDATIONS

A. CONCLUSION

This thesis presents the Carrier Optimal Strike-fighter Scheduling Tool (COSST) that optimally assigns strike-fighter squadrons to carrier-airwings over a 10-year period using an integer-linear program. The assignments seek to minimize moves and ensure sufficient time between deployments. COSST assists decision makers in assigning strike-fighter squadrons to carrier-airwings in the development of the Master Aviation Plan (MAP).

Analysis in this thesis shows using COSST can reduce strike-fighter squadron moves from a pre-existing typical four-year carrier-airwing schedule. Further analysis indicates that with the given 10-year schedule, that a reduction of more than three Legacy Hornet squadrons, more than two E-model squadrons, and more than one F-model squadrons makes it impossible to satisfy carrier-airwing deployment requirements. Analysis also reveals that up to, but not more than, three Legacy Hornet squadrons can transition to the Joint Strike Fighter (JSF) during the same 12-month period. Finally, analysis demonstrates it is impossible to satisfy all carrier-airwing requirements over 10 years when all squadrons have at least five months between their deployments.

B. RECOMMENDATIONS FOR FUTURE RESEARCH

It is recommended that COSST be implemented into Center for Naval Analyses' current ProModel tool for generating the MAP.

Future changes can include:

1. Incorporating the Aircraft Lot of Each Squadron

The lot number identifies the aircraft model a squadron flies and different lots can lack compatibility in maintenance and parts. An update to COSST can restrict or account for the preference of having certain lots in specific carrier-airwings together.

2. Restricting Consecutive Moves

The user may notice that some strike-fighter squadrons move more times than others. This can be a problem if a squadron moves too many times consecutively, because moves are not good for personnel or carrier-airwing integration and could possibly reduce the squadron's effectiveness. Consecutive moves could be easily restricted.

3. Creating a Constraint for VMFA Squadrons

New constraints could easily restrict no more than one VMFA squadron in a carrier-airwing, a constraint set can ensure the assignment of only one VMFA squadron. Additional constraints can address future modifications and/or implementations to the current tactical aircraft integration agreement.

4. Varying the Cost Amounts

Sensitivity analysis can easily be performed on the current cost structure to see how it affects the results. These costs could also be adjusted to capture changes to user preferences or to capture actual costs.

APPENDIX

This appendix presents output from COSST and COSST(v1).

Squadron	Total deployments	Total Home	Total Moves	Less than 6 off	Total Months deployed
VFA2F	5	5	0	0	84
VFA11F	4	1	1	1	77
VFA14E	5	1	1	1	91
VFA15C	5	4	2	2	82
VFA22F	6	6	0	0	84
VFA25C	6	6	0	0	84
VFA27E	9	9	0	0	59
VFA31E	4	4	0	0	62
VFA32F	4	4	0	0	76
VFA34C	5	5	0	0	84
VFA37C	4	4	0	0	76
VFA41F	5	5	0	0	91
VFA81E	5	5	0	0	91
VFA83C	5	2	1	0	90
VFA86C	4	4	0	0	74
VFA87A	4	4	0	0	62
VFA94C	4	0	1	0	74
VFA97C	4	4	0	0	74
VFA102F	9	9	0	0	59
VFA103F	5	5	0	0	71
VFA105E	4	4	0	0	76
VFA113C	6	6	0	0	84
VFA115E	6	6	0	0	84
VFA131C	5	3	1	1	90
VFA136E	4	4	0	0	74
VFA137E	5	5	0	0	84
VFA143E	5	5	0	0	71
VFA146C	5	5	0	0	85
VFA147E	5	5	0	0	85
VFA151C	5	5	0	0	84
VFA154F	5	5	0	0	85
VFA192C	9	9	0	0	59
VFA195C	9	9	0	0	59
VFA211F	5	1	1	0	89
VFA213F	4	4	0	0	62
VMFA232A	5	5	0	0	91
VMFA251C	5	2	1	0	90
VMFA312C	4	1	1	0	58
VMFA323C	6	5	1	1	85

Table 4. Strike-fighter squadron output from the COSST baseline.

This table includes the total number of deployments, the total deployments with the home carrier-airwing, the total moves to a new carrier-airwing, the number of times it has less than six months between deployments, and the total months spent deployed out of 120 months.

CVW1					**CVW8**				
b0	VFA86C	VFA136E	VFA211F	VMFA251C	b0	VFA15C	VFA31E	VFA87A	VFA213F
b1	VFA86C	VFA136E	VFA211F	VMFA251C	b1	VFA15C	VFA31E	VFA87A	VFA213F
b2	VFA11F	VFA86C	VFA136E	VMFA251C	b2	VFA15C	VFA31E	VFA87A	VFA213F
b3	VFA11F	VFA86C	VFA131C	VFA136E	b3	VFA15C	VFA31E	VFA87A	VFA213F
b4	VFA11F	VFA86C	VFA131C	VFA136E	b4	VFA15C	VFA31E	VFA87A	VFA213F
CVW2					**CVW9**				
b0	VFA2F	VFA34C	VFA137E	VFA151C	b0	VFA146C	VFA147E	VFA154F	VMFA323C
b1	VFA2F	VFA34C	VFA137E	VFA151C	b1	VFA146C	VFA147E	VFA154F	VMFA323C
b2	VFA2F	VFA34C	VFA137E	VFA151C	b2	VFA146C	VFA147E	VFA154F	VMFA323C
b3	VFA2F	VFA34C	VFA137E	VFA151C	b3	VFA146C	VFA147E	VFA154F	VMFA323C
b4	VFA2F	VFA34C	VFA137E	VFA151C	b4	VFA146C	VFA147E	VFA154F	VMFA323C
b5	VFA2F	VFA34C	VFA137E	VFA151C	b5	VFA146C	VFA147E	VFA154F	VMFA323C
CVW3					**CVW11**				
b0	VFA11F	VFA32F	VFA37C	VFA105E	b0	VFA14E	VFA41F	VFA81E	VMFA232A
b1	VFA11F	VFA32F	VFA37C	VFA105E	b1	VFA14E	VFA41F	VFA81E	VMFA232A
b2	VFA32F	VFA37C	VFA83C	VFA105E	b2	VFA41F	VFA81E	VFA94C	VMFA232A
b3	VFA32F	VFA37C	VFA83C	VFA105E	b3	VFA41F	VFA81E	VFA94C	VMFA232A
b4	VFA32F	VFA37C	VFA83C	VFA105E	b4	VFA41F	VFA81E	VFA94C	VMFA232A
CVW5					b5	VFA41F	VFA81E	VFA94C	VMFA232A
b0	VFA27E	VFA102F	VFA192C	VFA195C	**CVW14**				
b1	VFA27E	VFA102F	VFA192C	VFA195C	b0	VFA22F	VFA25C	VFA113C	VFA115E
b2	VFA27E	VFA102F	VFA192C	VFA195C	b1	VFA22F	VFA25C	VFA113C	VFA115E
b3	VFA27E	VFA102F	VFA192C	VFA195C	b2	VFA22F	VFA25C	VFA113C	VFA115E
b4	VFA27E	VFA102F	VFA192C	VFA195C	b3	VFA22F	VFA25C	VFA113C	VFA115E
b5	VFA27E	VFA102F	VFA192C	VFA195C	b4	VFA22F	VFA25C	VFA113C	VFA115E
b6	VFA27E	VFA102F	VFA192C	VFA195C	b5	VFA22F	VFA25C	VFA113C	VFA115E
b7	VFA27E	VFA102F	VFA192C	VFA195C	b6	VFA22F	VFA25C	VFA113C	VFA115E
b8	VFA27E	VFA102F	VFA192C	VFA195C	**CVW17**				
b9	VFA27E	VFA102F	VFA192C	VFA195C	b0	VFA94C	VFA97C	VMFA312C	
CVW7					b1	VFA14E	VFA97C	VFA211F	VMFA312C
b0	VFA83C	VFA103F	VFA131C	VFA143E	b2	VFA14E	VFA97C	VFA211F	VMFA251C
b1	VFA83C	VFA103F	VFA131C	VFA143E	b3	VFA14E	VFA97C	VFA211F	VMFA251C
b2	VFA83C	VFA103F	VFA131C	VFA143E	b4	VFA14E	VFA97C	VFA211F	VMFA251C
b3	VFA103F	VFA131C	VFA143E	VMFA312C					
b4	VFA15C	VFA103F	VFA143E	VMFA312C					
b5	VFA103F	VFA143E	VMFA312C	VMFA323C					

Table 5. The carrier-airwing view of the COSST baseline output schedule.

The carrier-airwing view indicates which strike-fighter squadrons (VFA2F, VFA11F, …, VMFA323C) are assigned for the carrier-airwing deployment (b1, b2, …, b9) for each carrier-airwing (CVW1, CVW2, …, CVW17). The deployment b0 indicates the squadrons' initial carrier-airwing assignments at the start of the schedule.

Squadron	d0	d1	d2	d3	d4	d5	d6	d7	d8	d9
VFA2F	CVW2	CVW2	CVW2	CVW2	CVW2	CVW2				
VFA11F	CVW3	CVW3	CVW1	CVW1	CVW1					
VFA14E	CVW11	CVW11	CVW17	CVW17	CVW17	CVW17				
VFA15C	CVW8	CVW8	CVW8	CVW8	CVW7	CVW8				
VFA22F	CVW14	CVW14	CVW14	CVW14	CVW14	CVW14	CVW14			
VFA25C	CVW14	CVW14	CVW14	CVW14	CVW14	CVW14	CVW14			
VFA27E	CVW5	CVW5	CVW5	CVW5	CVW5	CVW5	CVW5	CVW5	CVW5	CVW5
VFA31E	CVW8	CVW8	CVW8	CVW8	CVW8					
VFA32F	CVW3	CVW3	CVW3	CVW3	CVW3					
VFA34C	CVW2	CVW2	CVW2	CVW2	CVW2	CVW2				
VFA37C	CVW3	CVW3	CVW3	CVW3	CVW3					
VFA41F	CVW11	CVW11	CVW11	CVW11	CVW11	CVW11				
VFA81E	CVW11	CVW11	CVW11	CVW11	CVW11	CVW11				
VFA83C	CVW7	CVW7	CVW7	CVW3	CVW3	CVW3				
VFA86C	CVW1	CVW1	CVW1	CVW1	CVW1					
VFA87A	CVW8	CVW8	CVW8	CVW8	CVW8					
VFA94C	CVW17	CVW11	CVW11	CVW11	CVW11					
VFA97C	CVW17	CVW17	CVW17	CVW17	CVW17					
VFA102F	CVW5	CVW5	CVW5	CVW5	CVW5	CVW5	CVW5	CVW5	CVW5	CVW5
VFA103F	CVW7	CVW7	CVW7	CVW7	CVW7	CVW7				
VFA105E	CVW3	CVW3	CVW3	CVW3	CVW3					
VFA113C	CVW14	CVW14	CVW14	CVW14	CVW14	CVW14	CVW14			
VFA115E	CVW14	CVW14	CVW14	CVW14	CVW14	CVW14	CVW14			
VFA131C	CVW7	CVW7	CVW7	CVW7	CVW1	CVW1				
VFA136E	CVW1	CVW1	CVW1	CVW1	CVW1					
VFA137E	CVW2	CVW2	CVW2	CVW2	CVW2	CVW2				
VFA143E	CVW7	CVW7	CVW7	CVW7	CVW7	CVW7				
VFA146C	CVW9	CVW9	CVW9	CVW9	CVW9	CVW9				
VFA147E	CVW9	CVW9	CVW9	CVW9	CVW9	CVW9				
VFA151C	CVW2	CVW2	CVW2	CVW2	CVW2	CVW2				
VFA154F	CVW9	CVW9	CVW9	CVW9	CVW9	CVW9				
VFA192C	CVW5	CVW5	CVW5	CVW5	CVW5	CVW5	CVW5	CVW5	CVW5	CVW5
VFA195C	CVW5	CVW5	CVW5	CVW5	CVW5	CVW5	CVW5	CVW5	CVW5	CVW5
VFA211F	CVW1	CVW1	CVW17	CVW17	CVW17	CVW17				
VFA213F	CVW8	CVW8	CVW8	CVW8	CVW8					
VMFA232A	CVW11	CVW11	CVW11	CVW11	CVW11	CVW11				
VMFA251C	CVW1	CVW1	CVW1	CVW17	CVW17	CVW17				
VMFA312C	CVW17	CVW17	CVW7	CVW7	CVW7					
VMFA323C	CVW9	CVW9	CVW9	CVW9	CVW9	CVW9	CVW7			

Table 6. The strike-fighter squadron view of the COSST baseline.

The squadron view shows which carrier-airwings each squadron is assigned to for the squadron deployments (d1, d2, …, d9). The squadron deployment d0 is the initial carrier-airwing assignment.

Squadron	Total deployments	Total Home	Total Moves	Less than 6 off	Total Months deployed
VFA2F	5	5	0	0	84
VFA11F	5	1	4	1	93
VFA14E	5	5	0	0	91
VFA15C	4	4	0	0	62
VFA22F	6	6	0	0	84
VFA25C	6	6	0	0	84
VFA27E	9	9	0	0	59
VFA31E	5	4	1	2	82
VFA32F	4	3	1	1	77
VFA34C	5	5	0	0	84
VFA37C	4	4	0	0	76
VFA41F	5	5	0	0	91
VFA81E	5	5	0	0	91
VFA83C	5	5	0	0	71
VFA86C	4	4	0	0	74
VFA87A	4	4	0	0	62
VFA94C	4	1	3	1	77
VFA97C	4	4	0	0	74
VFA102F	9	9	0	0	59
VFA103F	6	5	1	2	90
VFA105E	4	4	0	0	76
VFA113C	6	6	0	0	84
VFA115E	6	6	0	0	84
VFA131C	5	5	0	0	71
VFA136E	5	2	3	1	74
VFA137E	5	5	0	0	84
VFA143E	5	3	2	0	86
VFA146C	5	5	0	0	85
VFA147E	5	5	0	0	85
VFA151C	5	5	0	0	84
VFA154F	5	5	0	0	85
VFA192C	9	9	0	0	59
VFA195C	9	9	0	0	59
VFA211F	4	4	0	0	74
VFA213F	4	4	0	0	62
VMFA232A	5	5	0	0	91
VMFA251C	4	4	0	0	74
VMFA312C	4	3	1	0	73
VMFA323C	5	5	0	0	85

Table 7. Strike-fighter squadron output from the initial COSST(v1) run.

This table includes the total number of deployments, the total deployments with the home carrier-airwing, the total moves to a new carrier-airwing, the number times it has less than six months between deployments, and the total months spent deployed out of 120 months.

CNA Schedule					COSSTv1 Schedule				
CVW1					CVW1				
b0	VFA86C	VFA136E	VFA211F	VMFA251C	b0	VFA86C	VFA136E	VFA211F	VMFA251C
b1	VFA86C	VFA136E	VFA211F	VMFA251C	b1	VFA86C	VFA136E	VFA211F	VMFA251C
b2	VFA32F	VFA37C	VFA81E	VFA86C	b2	VFA32F	VFA86C	VFA211F	VMFA251C
CVW2					CVW2				
b0	VFA2F	VFA34C	VFA137E	VFA151C	b0	VFA2F	VFA34C	VFA137E	VFA151C
b1	VFA2F	VFA34C	VFA137E	VFA151C	b1	VFA2F	VFA34C	VFA137E	VFA151C
b2	VFA2F	VFA34C	VFA137E	VFA151C	b2	VFA2F	VFA34C	VFA137E	VFA151C
CVW3					CVW3				
b0	VFA11F	VFA32F	VFA37C	VFA105E	b0	VFA11F	VFA32F	VFA37C	VFA105E
b1	VFA11F	VFA32F	VFA37C	VFA105E	b1	VFA32F	VFA37C	VFA94C	VFA105E
b2	VFA11F	VFA136E	VFA211F	VMFA251C	b2	VFA11F	VFA37C	VFA105E	VFA136E
CVW5					CVW5				
b0	VFA27E	VFA102F	VFA192C	VFA195C	b0	VFA27E	VFA102F	VFA192C	VFA195C
b1	VFA27E	VFA102F	VFA192C	VFA195C	b1	VFA27E	VFA102F	VFA192C	VFA195C
b2	VFA27E	VFA102F	VFA192C	VFA195C	b2	VFA27E	VFA102F	VFA192C	VFA195C
b3	VFA27E	VFA102F	VFA192C	VFA195C	b3	VFA27E	VFA102F	VFA192C	VFA195C
b4	VFA27E	VFA102F	VFA192C	VFA195C	b4	VFA27E	VFA102F	VFA192C	VFA195C
CVW7					CVW7				
b0	VFA83C	VFA103F	VFA131C	VFA143E	b0	VFA83C	VFA103F	VFA131C	VFA143E
b1	VFA83C	VFA103F	VFA131C	VFA143E	b1	VFA83C	VFA103F	VFA131C	VFA143E
b2	VFA83C	VFA103F	VFA131C	VFA143E	b2	VFA83C	VFA103F	VFA131C	VFA143E
b3	VFA83C	VFA103F	VFA131C	VFA143E	b3	VFA83C	VFA103F	VFA131C	VFA143E
CVW8					CVW8				
b0	VFA15C	VFA31E	VFA87A	VFA213F	b0	VFA15C	VFA31E	VFA87A	VFA213F
b1	VFA15C	VFA31E	VFA87A	VFA213F	b1	VFA15C	VFA31E	VFA87A	VFA213F
b2	VFA15C	VFA31E	VFA87A	VFA213F	b2	VFA15C	VFA31E	VFA87A	VFA213F
CVW9					CVW9				
b0	VFA146C	VFA147E	VFA154F	VMFA323C	b0	VFA146C	VFA147E	VFA154F	VMFA323C
b1	VFA146C	VFA147E	VFA154F	VMFA323C	b1	VFA146C	VFA147E	VFA154F	VMFA323C
b2	VFA146C	VFA147E	VFA154F	VMFA323C	b2	VFA146C	VFA147E	VFA154F	VMFA323C
b3	VFA146C	VFA147E	VFA154F	VMFA323C	b3	VFA146C	VFA147E	VFA154F	VMFA323C
CVW11					CVW11				
b0	VFA14E	VFA41F	VFA81E	VMFA232A	b0	VFA14E	VFA41F	VFA81E	VMFA232A
b1	VFA14E	VFA41F	VFA81E	VMFA232A	b1	VFA14E	VFA41F	VFA81E	VMFA232A
b2	VFA14E	VFA41F	VFA105E	VMFA232A	b2	VFA14E	VFA41F	VFA81E	VMFA232A
CVW14					CVW14				
b0	VFA22F	VFA25C	VFA113C	VFA115E	b0	VFA22F	VFA25C	VFA113C	VFA115E
b1	VFA22F	VFA25C	VFA113C	VFA115E	b1	VFA22F	VFA25C	VFA113C	VFA115E
b2	VFA22F	VFA25C	VFA113C	VFA115E	b2	VFA22F	VFA25C	VFA113C	VFA115E
b3	VFA22F	VFA25C	VFA113C	VFA115E	b3	VFA22F	VFA25C	VFA113C	VFA115E
CVW17					CVW17				
b0	VFA94C	VFA97C	VMFA312C		b0	VFA94C	VFA97C	VMFA312C	
b1	VFA11F	VFA136E	VFA211F	VMFA251C	b1	VFA11F	VFA97C	VFA136E	VMFA312C

Table 8. A comparison of the first four years.

This contains the provided CNA schedule and the COSST(v1) schedule. The areas highlighted indicate a move. The original schedule had 11 moves and the COSST(v1) schedule had five moves. All moves are the same-coast moves for both.

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