AIRBASE OPERATIONS

IN A CHEMICAL ENVIRONMENT

Thesis

Robert Edward Taft, Captain, USAF

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AIRBASE OPERATIONS IN A CHEMICAL ENVIRONMENT

THESIS

Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology
Air University
in Partial Fulfillment of the
Requirements for the Degree of
Master of Science

by

Robert Edward Taft, Captain, USAF
Graduate Strategic and Tactical Sciences

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Preface

In 1978, the Special Operations Wing at Hurlbert Field, Florida, became involved in training in the Air-crew Chemical Defense Ensemble. As a Life Support Officer for one of the three operational squadrons, I became directly involved in this test program that was conducted by the Tactical Air Warfare Center. Having flown in the ensemble, and therefore realizing some of its limitations, my interest in this field continued. The reports of chemical agents being used in Afghanistan and Southeast Asia stimulated both my interest and that of the Air Force.

I would like to acknowledge the help received from the Chemical Defense Division of the Aerospace Medical Research Laboratory. They provided publications in the field of air base operations and chemical effects, most of which were unpublished. The aid from instructors and fellow students in the field of computerization and statistics was greatly appreciated.

For the many months this thesis was worked on, from conceptualization and model development to final typing, heart-felt thanks is extended to my wife, Lara. Without her support, this thesis would not have been finished.
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Abstract

This thesis studies the effects of maintenance operations on a fighter base in a chemical environment. The desired goal is to determine if current manning for flight line maintenance is sufficient to support air operations.

A simulation model was developed to model the required tasks of maintenance in a wartime surge. The effects of wearing chemically protective clothing was incorporated to measure the results of operating with different numbers of aircraft and maintenance available. Analysis was performed using nonparametric tests, due to the nature of the data. The results of these tests indicate that the present manning is not sufficient.

Material is presented in the appendices that shows the nature of improvements being made in the chemical defense ensembles and aircraft systems. These improvements may reduce the limitations that are present in the current equipment used.
AIR BASE OPERATIONS IN A CHEMICAL ENVIRONMENT

I. Introduction

Historical Background

The first use of chemical warfare can be traced back to World War I. The Germans used Phosgene and Mustard gas against French and Canadian forces at the battle at Ypres in 1915. This caused fifteen thousand casualties the first day (Ref. 3:35). To reduce the possibilities of this type warfare being used again after World War I, the major powers put together the Geneva Protocol in 1925. The Geneva Protocol was against the use of gas (chemical weapons) by regular military forces. The problem arose, however, in that the major powers did not sign the Protocol. In 1928, the Soviet Union signed the Protocol, but with a stipulation, never to employ "first use" of poison gas against an adversary that had also signed the Protocol (Ref. 15:35). In 1948, Trygve Lie, the first General Secretary of the United Nations, made the following statement:

... The extended debate over the control of atomic energy and the immense destructive force of the atomic weapons which the United States has supplied to the world, has detracted attention from the developments in the field of bacteriological or chemical weapons. Some of these weapons are potentially as destructive to human
life as atomic weapons, but in spite of this fact not a single proposal for a system of prevention or control of their manufacture has been made by any member state, nor has there ever been any discussion or study of this problem within the United Nations. In the meantime, it is not incorrect to assume that, as with the case of atomic bombs, stocks of these weapons are increasing and that there are continuous new developments which make their use even deadlier. (Ref. 12:30)

Chemical agents were not publically used again until the United States started using defoliants and crowd-control agents in Viet Nam. President Nixon, in 1969, declared the United States would not produce or use biological weapons, and would destroy those in stockpile. He also stated the United States would, however, use chemical weapons in a retaliatory action if attacked with chemicals first (Ref. 1:12-17). On January 22, 1975, President Ford signed the Geneva Protocol of 1925, and the Biological Warfare Convention, the "first use" stipulation was included (Ref. 5:2).

From the mid-1970s to date, the Tactical Air Warfare Center at Eglin Air Force Base, Florida, has been developing Ground and Aircrew Chemical Defense Ensembles; and the threat has become more blatant (Ref. 13:4). In 1976, the Laotian General Vang Pao claimed the Soviet supported Pathet Lao were using chemical weapons on his irregular army. Reports of cases in Laos and Cambodia increased from 1976 to early 1980, at which time General Pikolov, chief of the Soviet Chemical Troops, was reported to be in Indochina. It was at this time that Soviet decontaminant equip-
ment appeared in Afghanistan and

... after Soviet and Afghan troops were unsuccessful in subduing Afghan rebels in their mountain redoubts, they began to spray poison gases into ravines and surrounding areas. This began in about mid-March 1980 (Ref.18:53).

To combat this new threat, the Department of Defense requested $43.8 million for chemical defense equipment research and development, for fiscal year 1981. They also requested over $20 million be spent on the procurement of equipment for that year (Ref.10:46).

The Current Threat

The Soviet Union has been developing a formidable force of chemical weapons since the mid-1950s. According to Professor John Erickson, a consultant on Soviet policy to the United Nations and the U.S. Department of Defense, the Soviet leaders

... do not dismiss the possibility of a 'large scale' resort to chemical weapons, both in theater operations and in targeting civilian populations in the rear... chemical weapons... are especially suitable for use in 'surprise attacks' against enemy forces... (Ref.6:64).

Targeting airfields with non-persistant agents that wear off in a matter of days, or even hours, is considered reasonable. These agents could be launched from forward units by tactical missiles, such as Frog or Scud, which have a range of 20 kilometers. More probable is attack by aircraft using rockets and bombs filled with nerve and blood
agents (see Appendix A). These would kill or incapacitate the forces at the airfield, yet leave intact the runway and facilities, if the personnel were not protected in some way (Ref.6:65).

The Soviets can consider performance of this type act because they are more capable of operating in this environment. They have 10 percent of their army, at least 80,000 men, in the Soviet Chemical Troops (Ref.3:34). These forces have the primary mission of detecting chemical and biological agents and decontaminating equipment, personnel, and even the ground (Ref.6:69). The individual troops, both air and ground, know the capabilities of the chemical defense equipment they are issued. They receive extensive hands-on training, including subjection to dilute agents and long-term exercises simulating operations in a chemical environment. The bottom line is that the Soviets do not "consider chemical warfare a special form of military struggle" (Ref.5:4).

Problem Statement

The operations of an air base during wartime are rigorous and complex. The functions of the maintenance teams to prepare aircraft for launch are hampered by attack and the fear of attack. The scenario developed in this thesis is of just such an attack, not by conventional or nuclear munitions, but by chemicals.

Currently, maintenance teams are assigned to fighter-
type aircraft at a ratio of one team for three aircraft (Ref. 25:10-22). With the increased burden of working on aircraft in chemically protective clothing, the amount of time required to generate aircraft should increase. The current chemical defense ensembles are presented in Appendix E. This increased time should change the number of flights per day capable of taking-off. The most common measure of effectiveness of this capability of maintenance to operate is the turn rate. The turn rate is a measure of the number of times each aircraft is capable of flying during one day. This rate is primarily a function of the number of aircraft and maintenance teams available, the time to perform the required maintenance, and for this scenario, the effects of operations in a chemical environment. By making comparisons between these factors, the number of maintenance teams required to meet an established turn rate can be measured. A simulation model was developed to make data available to make these comparisons.

Objectives

To measure the effectiveness of maintenance to operate in a chemical environment, some means of making comparisons showing the effects of changing maintenance levels is required. The first objective of this study was, therefore, the creation of a viable simulation model to make comparisons. Research into the inputs of aircraft
generation and effects of the chemical environment were the basis for the model creation. After the model was verified for each phase of operation, comparisons of the data could be made.

As previously mentioned, the most common measure of effectiveness for this type study is the turn rate. Without knowing the effects of changing the ratio of aircraft to maintenance, the turn rate does not give a clear understanding of effectiveness. By showing the effects of resource modifications in aircraft, personnel, and equipment, a clearer picture of the amount of personnel required to operate an airfield is presented. A method of ascertaining the number of maintenance teams required to meet this goal is the second objective. The methodology used to meet these two objectives is presented in the overview.

Overview

The development of the simulation model is an ongoing process. The research into a particular problem, in this case chemical warfare operations, requires the researcher to gain an understanding of this problem and many related areas to approach an answer. The methodology used in this thesis followed a similar approach.

The reasons for investigating the topic of air operation, as a function of maintenance, is presented in Chap-
ter I. With the threat of chemical weapons being used in a conflict, a means to establish manning requirements for the maintenance of fighter aircraft is crucial. The method used to answer this question was the development of a simulation model.

Chapter II covers the development of the simulation model used, from conceptualization through its final form. The conceptual model is presented in the form of a causal loop diagram, to show the major areas required to be modeled. Through further research, these terms were more fully defined, and an experimental model was developed. This model was then used to create a simulation model using the Q-GEAR simulation language. Throughout the development of the model the objective of required manning was in the forefront. This was to limit the inclusion of unnecessary detail in the model and to provide a framework to make analysis.

The model output is analyzed in Chapter III. The effects of changing the control variables and some of the stochastic variables is presented.

A nonparametric test, the Friedman test, was used in the analysis. This test uses the ranked order of the raw data to make comparisons between the levels of maintenance and aircraft modeled. The test is very similar to the parameter test of a one-way Analysis of Variance.
(ANOVA). This parametric test could not be used due to the restrictive nature of the assumptions for its use. These restrictions are removed when using the nonparametric test. By looking at the effects of these changes, as they apply to the turn rate of the aircraft, conclusions and recommendations can be drawn.

Chapter IV covers the conclusions drawn from the analysis and lists several recommendations for improvements in both the chemical defense ensemble used by the maintenance personnel and to the model. The changes in the model are for increasing its usefulness in analyzing air base operations to monitor supply utilization and add further realism.
II. Model Development

Introduction

Construction of the model began with a literature search of relevant material dealing with fighter aircraft maintenance and chemical warfare. From this research, a causal loop diagram was constructed and used as the basis for a simulation model using the Q-GERT computer language. The main impetus behind the construction of the basic model was a research effort done by Quest Research Corporation (Ref. 25), on air base operations in a chemical environment. The physical layout and capabilities of Ramstein Air Base, Germany, provided an input to the model. After the basic model was developed, it was expanded to include the factors encountered in aircraft generation, and used to collect data. This data will be used to answer the question of maintenance personnel required to meet the desired goal of aircraft turn rate.

Structural Model

A preliminary model to aid in both the conceptualization of the problem, and as the basis for establishment of a network using the Q-GERT simulation language (Ref. 14), a causal loop diagram was constructed, Figure 1. As the values of the elements enclosed in brackets goes up, the
Fig. 1 Causal Loop Diagram
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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<tr>
<td># of Aircraft</td>
<td>The number of available aircraft</td>
</tr>
<tr>
<td>Temp</td>
<td>The external ambient temperature and humidity (taken as fixed in this model as 70°F and 15%)</td>
</tr>
<tr>
<td>Aircraft Flight Time</td>
<td>Time spent flying, fueling, and towing aircraft</td>
</tr>
<tr>
<td>Fueling &amp; Towing</td>
<td></td>
</tr>
<tr>
<td># of Tasks</td>
<td>The number of tasks that need to be performed to take the aircraft from landing to ready for take-off</td>
</tr>
<tr>
<td># of Maint Teams</td>
<td>The number of teams available to perform maintenance on the aircraft</td>
</tr>
<tr>
<td>Time Required to Complete Tasks</td>
<td>The time required to perform each individual task</td>
</tr>
<tr>
<td>Rest</td>
<td>Delay time if team members heat build-up level exceeds a set value</td>
</tr>
<tr>
<td>Heat Level</td>
<td>Generated heat build-up inside protective clothing</td>
</tr>
<tr>
<td>Length of the Day</td>
<td>Time maintenance teams show for work until end of one day (1440 min)</td>
</tr>
<tr>
<td># of Aircraft Launches</td>
<td>Total number of aircraft launched</td>
</tr>
<tr>
<td># of Aircraft Damaged</td>
<td>Aircraft damaged but repairable</td>
</tr>
<tr>
<td># of Aircraft Destroyed</td>
<td>The number of aircraft destroyed</td>
</tr>
<tr>
<td># of Air Aborts</td>
<td>Aircraft with a flight time of 15 minutes or less</td>
</tr>
<tr>
<td># of Successful Sorties</td>
<td>The number of aircraft launched reduced by those destroyed or air aborted</td>
</tr>
</tbody>
</table>
The effect it has on the targeted element is increased if a plus (+) is indicated or decreased in its value if a minus (−). Table I contains definitions of terms used in the causal loop diagram.

The variables included in the model, as shown in the causal loop diagram, are the basic variables in the generation of aircraft by maintenance and sorties flown. With a given number of aircraft and maintenance teams, and the times to complete all required tasks, the time to turn an aircraft can be calculated.

The variables from the structural model were broken down into the following categories:

Table II

| Stochastic Variables          | # of tasks                      |
|                              | Time required to complete tasks |
|                              | Temp                            |
|                              | Aircraft Flight, Fueling & Towing|
|                              | Heat Level                       |
|                              | Rest                            |
|                              | Length c.: Day                  |
|                              | Percentage of aircraft destroyed|
|                              | Percentage of aircraft damaged   |
|                              | # of Air Aborts                  |

| Control Variables            | # of aircraft                   |
|                             | # of maintenance teams          |

| Response Variables           | # of aircraft launched          |
|                            | # of aircraft generated         |
|                            | # of successful sorties         |
By varying the control variables over a range and measuring the response variables, the desired levels of the control variables can be predicted to meet the required sortie turn rate. This response is measured by comparison with the desires of a theater commander to support his mission, and to minimize the hazards on his maintenance personnel in a chemical environment.

Assumptions

Several assumptions were required in the development of the thesis model. They shall be listed now, before describing the experimental model, to set the background for the rest of the model. The reasons for their use are also given.

1. The airfield is attacked with only chemical weapons. In this way the resources are not removed from the model due to destruction by conventional weapons while on the ground. The start-up conditions can be specified at the beginning of the simulation model run to impose the burden of operations in a chemical environment only on the results.

2. The alert status of the field has been upgraded prior to the attack. This is to ensure that all personnel are capable of surviving the attack. Decontamination equipment and chemically protective clothing are immediately available to all personnel.
3. All aircraft available at the start of the model have all maintenance completed on them. The normal functions of maintenance is to perform the required maintenance prior to the start of the following day. This would be done in an upgraded alert status.

4. The external ambient temperature and humidity are fixed at 70°F and 15% humidity. Heat stress is a major problem while wearing chemically protective clothing. To simulate this condition, the rate of heat dissipation must be calculable, as must be the rate of heat generation, both of which are functions of atmospheric conditions.

5. All personnel available at the start of the run are capable of working for the entire one day scenario (with the exception of crewmembers lost in destroyed aircraft). There are sufficient aircrew members available to fly the aircraft that are generated. During rest periods and refueling the maintenance teams are periodically transported to a secure, non-contaminated area to perform normal bodily functions and to change their chemical defense ensembles. The ensembles must be changed approximately every six hours, their considered useful life in a chemical environment. All individuals in a maintenance team are considered to be equally vulnerable, and thus are equally affected by the conditions.

6. Supply levels of fuel and munitions are unlimited.
If the threat of attack is imminent, the airfield should have sufficient fuel and munitions for at least one day.

7. After landing, all aircraft must go through the maintenance cycle. The maintenance that is modeled depicts the activities during a wartime surge, and therefore must be performed as a minimum. The time spent going through this cycle increases the delay on aircraft that air abort or are damaged, for required maintenance. This is to simulate the difficulty of locating and fixing maintenance problems while the personnel are wearing chemically protective clothing.

8. The threat of continued chemical attack is such that the entire ensemble must be worn for the one day scenario. The distributions on task times are therefore not changed during the run.

The simulation model is used to make comparisons between differing levels of maintenance and aircraft, and to recommend manning requirements to meet a desired turn rate.

**Experimental Design**

To generate a model, the variables and their values must be defined. This section shall expand on the variables used in the model presented in Figure 1. By use of the above assumptions, distribution types can be used to model the times required in performing each task of air-
Several sources were consulted as to the tasks that needed to be performed and the times to complete them. This data was finally taken from a document called The F-4E Aircraft Maintenance Support General Job Standards (Ref. 21). This document is currently used by the Tactical Air Command (TAC) to simulate fighter aircraft generation. The tasks required to take an aircraft from landing to its next launch in a wartime surge environment, as used in this model are: an Aero 7 inspection, reloading of the 20 mm gun, refueling, uploading of missiles, and preflight. Movement of the aircraft on the ground and the time it is in flight must be modeled to simulate the activities performed in the operations of an airfield. These areas and the physical resources of the field are taken into consideration in the development of the simulation model to ensure a measure of accuracy in modeling.

The Aero 7 inspection is a post flight inspection on the aircraft. The aircraft basic systems are inspected to ensure that the maintenance tasks required on it can be done safely and that it is capable of a follow-on flight. The major areas inspected are the electrical, hydraulic, fuel, and armament systems. The reloading of the 20 mm internally mounted gun is performed to give the aircraft both an air-to-air and an air-to-ground capability. This
task is started as soon as cleared by the personnel performing the Aero 7 inspection.

The refueling of the aircraft can be performed at either the hotpit or by fuel truck after the aircraft is parked. Aircraft use of the hotpit is a function of both its external fuel tank configuration and the availability of the hotpit. The hotpit has a physical limitation of only being able to refuel two vehicles at a time, based on the squadron operations areas used in the model. Aircraft must also have external fuel tanks to be refueled at the hotpit. If either of these conditions are not met, the aircraft taxi to the ramp to be refueled later. Aircraft that are refueled by the fuel trucks have an equal probability of changing their external fuel tank configuration. This is to simulate the scheduling of aircraft for a mission that either requires or does not require the use of the external fuel tanks.

The missiles used in this model are the AIM-9 or AIM-7 missiles. This again is to simulate the scheduling of aircraft for different missions. The AIM-9 is for air-to-air, and the AIM-7 is for air-to-ground. After the aircraft has its missiles uploaded, a preflight inspection is performed to check all preceding tasks and ensure the aircraft is ready for take-off.

The movement of aircraft on the ground is a function
of the airfield layout used. In this model a standardized ramp is assumed for the parking of aircraft as shown in Figure 2. The times to taxi the aircraft and drive the fuel trucks are derived from studies conducted at Ramstein Air Base, Germany, and will be given in the parametric model. The TABVEE shelter that the aircraft are backed into is diagrammed in Figure 3; as shown, all necessary ordinance and equipment is available in the shelter, with the exception of the fuel truck.

The task times as given in The F-4E Aircraft Maintenance Support General Job Standards, are for operations in a wartime surge, but does not include the effects of personnel operating in a chemical environment. To account for this, the times were adjusted upwards for the wearing of chemically protective garments by use of the PDGRAM model (Ref.27).

The aircraft flight time used in this model is an exponential distribution with a mean of 70 minutes. The 70 minute mean time is approximately the flight time of an F-4 aircraft without air refueling. The reason for the use of an exponential distribution was to ensure the aircraft did not have negative flight times and to skew the majority of flight toward the low side of this mean. This is to simulate the proximity of a majority of the targets to be hit and areas defended by the aircraft. The probab-
ility of a flight lasting less than 50 minutes, using the distributions established, is approximately .5.

All activities for aircraft movement and operations on the ground are considered to have lognormal distributions. This is the type distribution the data best fits from the actual studies conducted and used in TAC modeling. The parameters used in the model are presented in Table III.

The times to complete each task are used not only in the calculations of the time to turn an aircraft, but also in the heat build-up values. Heat build-up is the result of heat generated and not dissipated by the individuals while wearing a non-permeable chemical defense ensemble. Each task demands a different work load, and these differing work loads determine the heat generated by the individual. Under normal conditions this heat would be dissipated into the atmosphere to help regulate the individual's body core temperature. While wearing the chemical defense ensemble, this dissipation effect is greatly reduced, so heat stress becomes a factor. These values are listed in Table IV as functions of Kilocalories (KCal).

A value of 70 KCal of heat build-up is used as a maximum allowable level in this model, to preclude heat stress. If an individual reaches this value, he is required to rest until this value is reduced to 30 KCal of heat build-up. For ease of computation, the level of heat
Fig. 3 TABVEE Shelter
Table III  
PARAMETRIC MODEL

<table>
<thead>
<tr>
<th>Event</th>
<th>Type Distribution</th>
<th>Mean</th>
<th>St. Dev.</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flight</td>
<td>Exponential</td>
<td>70.00</td>
<td></td>
<td>0.00-140.00</td>
</tr>
<tr>
<td>Taxi to Hotpit</td>
<td>Lognormal</td>
<td>2.19</td>
<td>0.10</td>
<td>2.00-2.50</td>
</tr>
<tr>
<td>Hotpit Refueling</td>
<td>Lognormal</td>
<td>14.40</td>
<td>1.50</td>
<td>8.42-18.98</td>
</tr>
<tr>
<td>Taxi to Shelter</td>
<td>Lognormal</td>
<td>3.50</td>
<td>0.70</td>
<td>1.80-12.98</td>
</tr>
<tr>
<td>Aircraft Tow</td>
<td>Lognormal</td>
<td>4.70</td>
<td>0.60</td>
<td>3.00-6.76</td>
</tr>
<tr>
<td>Aero 7 Inspection</td>
<td>Lognormal</td>
<td>1.15</td>
<td>0.15</td>
<td>0.75-1.65</td>
</tr>
<tr>
<td>Reload Guns</td>
<td>Lognormal</td>
<td>10.80</td>
<td>1.30</td>
<td>6.89-15.53</td>
</tr>
<tr>
<td>Change External</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tank Configuration</td>
<td>Lognormal</td>
<td>16.80</td>
<td>2.00</td>
<td>10.72-24.15</td>
</tr>
<tr>
<td>Missile Upload</td>
<td>Lognormal</td>
<td>31.25</td>
<td>2.80</td>
<td>19.94-44.94</td>
</tr>
<tr>
<td>Preflight</td>
<td>Lognormal</td>
<td>5.90</td>
<td>0.60</td>
<td>3.77-8.49</td>
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<tr>
<td>Fueling</td>
<td>Lognormal</td>
<td>16.80</td>
<td>2.00</td>
<td>10.72-24.15</td>
</tr>
<tr>
<td>Drive Fuel Truck to Hotpit</td>
<td>Lognormal</td>
<td>2.00</td>
<td>0.30</td>
<td>0.95-3.03</td>
</tr>
<tr>
<td>Drive Fuel Truck to Fuel Dump</td>
<td>Constant</td>
<td>27.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table IV
HEAT BUILD-UP FACTORS (IN KCAL)

<table>
<thead>
<tr>
<th>Task</th>
<th>Heat Generated (per minute)</th>
<th>Heat Dissipation (per minute)</th>
<th>Heat Build-up (per minute)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aero 7 Inspection</td>
<td>2.30</td>
<td>0.83</td>
<td>1.47</td>
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<tr>
<td>Reload of Guns</td>
<td>2.80</td>
<td>0.83</td>
<td>1.97</td>
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<td>External Fuel Tanks</td>
<td>2.30</td>
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<td>1.47</td>
</tr>
<tr>
<td>Missile Upload</td>
<td>3.30</td>
<td>0.83</td>
<td>2.47</td>
</tr>
<tr>
<td>Preflight</td>
<td>1.30</td>
<td>0.83</td>
<td>0.47</td>
</tr>
<tr>
<td>Refueling or Rest</td>
<td>0.00</td>
<td>0.83</td>
<td>-0.83</td>
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Table V
PERCENTAGE HEAT CASUALTIES AS A FUNCTION OF BODY TEMPERATURE

<table>
<thead>
<tr>
<th>Body Temp</th>
<th>Percentage Casualties</th>
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<tbody>
<tr>
<td>C</td>
<td>F</td>
</tr>
<tr>
<td>37.78</td>
<td>100</td>
</tr>
<tr>
<td>38.33</td>
<td>101</td>
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<td>38.89</td>
<td>102</td>
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<td>39.44</td>
<td>103</td>
</tr>
<tr>
<td>40.00</td>
<td>104</td>
</tr>
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<td>40.55</td>
<td>105</td>
</tr>
<tr>
<td>41.11</td>
<td>106</td>
</tr>
<tr>
<td>41.67</td>
<td>107</td>
</tr>
</tbody>
</table>
build-up is calculated for the completion of the task that is started. If 70 KCal is exceeded a rest period is enforced prior to the start of the next task. Each rest period is 48.19 minutes, the time to reduce 70 KCal to 30 KCal at the heat build-up rate for rest.

The effect of heat build-up on an individual is shown in Table V. A heat build-up of KCal corresponds to increasing the body internal temperature by approximately one degree fahrenheit. As can be seen from Table V, if this level is exceeded, casualties result among the maintenance personnel wearing the chemical defense ensemble.

The input parameters are not completely validatable, due to the inclusion of the effects of the chemical defense ensembles. The effects of increased time required, and the forced rest periods are from controlled field test, laboratory experiments, and simulation modeling. Until actual data is available from a chemical attack upon an airfield these effects will be speculative.

**Model Development**

A network flow of events was developed to incorporate the tasks presented in the experimental design with the remaining activities of the causal loop diagram. The Q-GERT simulation language, with its basic form being a network diagram, was selected for use to create the simulation model.
The capability of Q-GERT to branch within the network, both probabilistically and deterministically, simplified computerization. Queues, to restrict movement and hold transactions, were necessary to model refueling and the assignment of maintenance teams to aircraft.

A network was established to model the different phases of aircraft generations, as described in the next section of this thesis, and these networks were verified to perform as desired. These networks were then linked together to create a flow network for the entire model. Verification of the flow was checked as each smaller network was added. The network capabilities of Q-GERT were not sufficient for the creation of the finalized model without the incorporation of User Subroutines (US). This allows the modeling of events in Fortran that can be called upon in the network. To simulate tasks with only the Q-GERT program would be difficult and cumbersome. In the finalized model, 16 user defined subroutines were used. These were used to simulate the performance of the maintenance tasks, the placement of aircraft into the different phases of operation, and for bookkeeping.

The User Subroutines (US) of the model are not given in the model description that follows, but are fully described in the program listing of Appendix C. By reference to the flow diagrams, the description of the tasks simula-
ted, and the program listing, an understanding of the model and its uses can be gained.

Model Description

The explanation of the simulation model shall be described in a segmented method, divided into its primary functions. A flow network will be given, followed by a description of the primary tasks performed in that section.

Fig. 4 Model Start

This portion of the model sets up the starting conditions of the aircraft and maintenance teams used in the model. Each aircraft is considered a transaction. By monitoring their values, the number of aircraft generated,
and a feel for the number of sorties flown during one
day are calculated. A list of the variables assigned to
the attributes of the model are as follows:

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>External fuel tank status</td>
</tr>
<tr>
<td>2</td>
<td>Fuel status</td>
</tr>
<tr>
<td>3</td>
<td>Aircraft number</td>
</tr>
<tr>
<td>4</td>
<td>Maintenance team number</td>
</tr>
<tr>
<td>5</td>
<td>Vehicle (aircraft or fuel truck)</td>
</tr>
<tr>
<td>6</td>
<td>Heat build-up on Maint teams</td>
</tr>
<tr>
<td>7</td>
<td>Heat build-up on Arming teams</td>
</tr>
</tbody>
</table>

Each of the aircraft are considered to be flyable
for the first launch of the day, which occurs 235 minutes
after attack of the field, the start of the model. This
delay is incorporated to account for recall of the air-
crew and maintenance personnel, issuance and donning of
the chemical defense ensembles, initial briefings to the
aircrews, and preflight of the aircraft.

The number of aircraft available at the airfield can
vary from one to fifty and is set in Activities 1 and 2,
with the incrementation of Attribute 3. The aircraft are
uniformly distributed as to the status of external fuel
tanks and are all considered fueled. As the aircraft are
readied for their first take-off of the day, they flow into
the next segment of the model.
As aircraft take-off, three options are available, the aircraft can be destroyed, damaged, or fly without damage. The probabilities associated with each are controlled in the Q-QERT model, Activity 45, and are set at the values of 6% destroyed and 9% damaged. If an aircraft is destroyed it is removed from the model. If damaged, it incurs a 240 minute delay to simulate repair when it lands, and then re-enters the network at Node 5. Those aircraft that are not damaged, but have a flight time of less than 15 minutes, are considered air aborts. An air aborted aircraft is given a 240 minute delay, regardless of the cause of the air abort. It then re-enters the network at Node 5. The cause of the air abort is not modeled,
but would include both maintenance problems with the aircraft and physiological problems with the aircrew, which must also wear chemical defense ensembles. After landing, the aircraft either taxi to the hotpit for refueling or to its parking spot on the ramp. Analysis of the model will be performed on both the percentage of aircraft destroyed or damaged, the time to perform maintenance on the aircraft after it has been damaged or air aborted, and the abort rate.
Refueling of the aircraft at the hotpit and refueling of the fuel trucks, that perform the remainder of the aircraft refueling, are diagrammed in Figure 6. Aircraft with external fuel tanks and the fuel trucks are the only vehicles that are fueled at the hotpit, which is limited to fueling only two vehicles at a time. If the hotpit is available, aircraft are refueled and then taxi to their parking spot on the ramp. If the hotpit is full, or the aircraft does not have external fuel tanks, it taxis to the ramp, and must be refueled later. Fuel trucks that are not fueled at the hotpit must drive to the fuel dump to be fueled prior to returning to the ramp to refuel aircraft.
After the aircraft have taxied to their parking spots, they must be backed into their TABVEE shelters. There are two tugs to perform this required function. Once the aircraft is parked, the times required to perform all the follow-on maintenance tasks are calculated (using User Subroutine 3). The heat build-up values are then calculated and the aircraft awaits assignment of a maintenance team. The number of maintenance teams available are fixed in Activity 61 where the number of servers is set to one less than the number of teams. This uses the blocking capabilities of Q-GERT to ensure an aircraft cannot be assigned to a maintenance team unless a team is available. Aircraft are not assigned unless a maintenance team is available, and is then assigned to the team that has worked on the least number of aircraft to that time.

Fig. 7 Parking and Maintenance Assignment
Figure 8 is the flow network of one of the sixteen subnetworks in the model that performs all the required maintenance on the aircraft, except refueling. Each maintenance team is considered a resource and is monitored as such. This is to ensure that a maintenance team does not work more than one aircraft at a time. The status of the aircraft is checked according to fuel and external fuel tank status. To simulate scheduling of aircraft for differing missions, aircraft that have not been refueled have a probability of .5 of changing its external fuel tank configuration. All aircraft are given a postflight inspection, have their guns reloaded and missiles uploaded, and a preflight inspection. Before aircraft can have the missiles uploaded, they must be refueled. If they were fueled in the hotpit, they proceed from Node 19 to Node 27, missiles upload, otherwise they proceed through the network to Node 15. Aircraft that proceed to Node 15 will await refueling and then re-enter the subnetwork at Node 27 and proceed. After an aircraft has all maintenance complete, it proceeds to take-off status.

The maintenance team is broken down into two teams, a maintenance team and an arming team. The maintenance team performs the inspections and aids the arming team, which work on the aircraft armament.
Fig. 9 Refueling by Fuel Truck

The refueling of aircraft by the fuel trucks is handled as a queueing system. The aircraft must wait until a fuel truck is available to refuel them, after refueling, they re-enter the subnetwork at Node 27. The time the aircraft must wait for refueling and the time required to refuel will reduce the thermal build-up on the maintenance teams. The reason for this is that a refueling team performs this function, rather than the maintenance team, so they can rest until refueling is complete. After the fuel truck had refueled two aircraft, it must be refueled. It drives to the hotpit, Node 6, and is either refueled or must drive to the fuel dump for refueling prior to returning to the ramp. Analysis was performed on the number of fuel trucks available. Results of the analysis will be presented in the next chapter.
After all maintenance functions are performed on an aircraft, the maintenance team is made available for assignment to another aircraft. All artificial activities generated in the maintenance cycle for that team are halted and the aircraft must await a formation take-off. Each formation take-off consists of two aircraft, this is controlled in User Subroutine 1.

Summary
The simulation model, based on the assumptions and the required tasks necessary to generate aircraft, generates data points by varying the control variables. The model output includes data on the number of aircraft generated and sorties flown for differing levels of maintenance support and available aircraft. The model is cap-
able of producing this data for both a chemical and non-
chemical environment, provided the physical resources of
the air base are not damaged. To use this model in a
conventional environment, the heat build-up factors are
changed to zero. The times to perform the tasks are not
increased due to the wearing of the ensemble, as they were
in the parametric model.
III. Data Collection and Analysis

Introduction

The model was created to generate data to make comparisons between different levels of maintenance. A nonparametric test was used to make the comparisons. This test, the Friedman Test, is used to make comparisons over the entire range modeled, as well as between each individual level. The model output provides data on the number of aircraft generated and the number of sorties flown. Each run corresponds to the operations of an air base for one day. By varying the number of aircraft and maintenance teams available, the effects of change can be analyzed on the turn rate of the aircraft. To gain a better understanding of the implications of the input parameters, sensitivity analysis was performed. The areas covered are the abort rate and its associated maintenance delay, the amount of fuel trucks available, and the percentage of aircraft destroyed and damaged.

Data Collection

The program was run a total of 90 times to obtain two observations per cell. A typical fighter squadron has 24 aircraft and approximately 6 maintenance teams to support them, on an air base there is usually more
than one squadron of aircraft assigned. To measure the capabilities of the maintenance teams to perform in the chemical environment, the number of teams for which data was collected ranges from 8 to 16. To correspond with the number of teams available, the range of available aircraft vary from 24 to 48. This is to maintain the same ratio of aircraft to maintenance support. The two observations per cell arc generated by holding all variables constant within that cell, and changing the random number seed. This is to ensure that the data is not biased due to the seed used.

Three sets of data were collected to measure the capabilities of the maintenance teams to support aircraft generation and sorties. The first of these is the number of aircraft generated after the first launch of the day. The second two deal with two methods of counting sorties flown. The first of these is counting all aircraft that take-off and land and the second is a reduction of this number by the amount of aircraft that air abort. Appendix D contains a portion of an output run to show the method of bookkeeping used in the model.

Data Analysis

The data was collected in such a manner as to make analysis of the effects of having different maintenance levels and numbers of aircraft possible. A nonparametric test was considered to measure the effects of operating
at those different levels. The test used is a Friedman's Test and its modification for multiple observations within a cell (Ref. 4:299-308).

The Friedman Test is a nonparametric test to analyze several related samples. It is used to detect differences between treatments. There are two assumptions that must hold to use this test: the observations must be able to be ranked, and the $bk$-variate random variables are mutually independant. This means the data need only be at an ordinal level and the data points in the set are mutually independant. The hypotheses to be tested are:

$H_0$: Each ranking of the random variables within a block is equally likely (i.e., the treatments have identical effects).

$H_1$: At least one of the treatments tends to yield larger observed values than at least one other treatment.

The data is arranged into the following format:

$$
\begin{array}{cccc}
\text{Block} & 1 & 2 & \cdots & k \\
1 & X_{11} & X_{12} & \cdots & X_{1k} \\
2 & X_{21} & X_{22} & \cdots & X_{2k} \\
\cdots & \cdots & \cdots & \cdots & \cdots \\
b & X_{b1} & X_{b2} & \cdots & X_{bk} \\
\end{array}
$$

where there are 'k' treatments and 'b' blocks. Each data point is then ranked within the block over the different treatments. These ranked values are designated as $R(X_{ij})$, treatments. The sum of the ranks within the treatments
is designated $R_j$.

The following three equations must be solved and then a decision rule applied. $A_2$ and $B_2$ are intermediate values needed to arrive at the test statistic $T_2$:

$$A_2 = \sum_{i=1}^{b} \sum_{j=1}^{k} \left( R(X_{ij}) \right)^2$$

$$B_2 = \frac{1}{b} \sum_{j=1}^{k} R_j^2$$

$$T_2 = \frac{(b-1)(B_2 - bk(k+1)^2/4)}{A_2 - B_2}$$

where: $R(X_{ij}) = \text{ranked values}$

$b = \text{number of blocks}$

$k = \text{number of treatments}$

The decision rule that is applied is to reject the null hypothesis at the desired $\alpha$ level if $T_2$ exceeds the $1-\alpha$ quantile of the tabled $F$ distribution. The degrees of freedom are given by $k_1 = k-1$ and $k_2 = (b-1)(k-1)$. The $F$ distribution approximates the exact distribution of $T_2$.

If multiple comparisons between the treatments are to be performed, as they are in this thesis, the following equation is used:

$$|R_j - R_i| > t_{1-\alpha/2} \frac{2b(A_2 - B_2)}{(b-1)(k-1)}^{1/2}$$

The values of $t_{1-\alpha/2}$ is the $1-\alpha/2$ quantile of the $t$ distribution with $(b-1)(k-1)$ degrees of freedom. The same level used for checking the entire range, $T_2$, must be used.
When there are several observations per experimental cell, the test is only slightly modified. The only parameter not previously defined is 'm', the number of observations in each cell.

The mean of $R_j$ becomes:

$$E(R_j) = \frac{b}{m} \sum_{i=1}^{m} \sum_{n=1}^{E} E[R(X_{ijn})]$$

$$= \frac{bm(mk+1)}{2}$$

The variance of $R_j$ is given by:

$$Var(R_j) = \frac{m(mk-1)}{k(mk-1)} \left[ \sum_{\text{all ranks}} R(X_{ijn})^2 - mkb(mk+1)^2/4 \right]$$

The test statistic is:

$$T_4 = \sum_{j=1}^{k} \frac{(k-1) \left[ R_j - E(R_j) \right]^2}{Var(R_j)}$$

This is tested against a chi-squared distribution with $k-1$ degrees of freedom. The null hypothesis is rejected if the value of $T_4$ exceeds the tabled chi-square value.

To make multiple comparisons, the below equation is solved, where $t_{1-\alpha/2}$ is the $1-\alpha/2$ quantile of the t distribution with $(mk-b+1)$ degrees of freedom.

$$\left| R_j - R_i \right| > t_{1-\alpha/2} \left\{ \frac{2kb(mk-1)Var(R_j)}{(k-1)(mbk-k-b+1)} \left[ 1-\frac{T_4}{b(mk-1)} \right] \right\}^{1/2}$$
The results of the test used for comparisons between the individual treatments are more significant to this thesis than the test over the entire range. This data is used to check for significant differences between the individual treatments. If the analysis indicates that 10 maintenance teams are required to meet a desired turn rate, and there is not a significant difference between having 9 or 10 teams, then having 9 teams is sufficient.

The test is run twice, once using the maintenance teams as the treatments, and then using the aircraft as the treatments. This was done to ensure that the different levels of maintenance were causing the changes in turn rate, not just the change in the number of aircraft available.

This test can be used without knowing the exact distribution of the data points to be analyzed. The assumptions to perform a similar test in the realm of parametric statistics, the two-way analysis of variance, (ANOVA), could not be met with the collected data. If the assumptions are not met, the results are questionable. The results of the two-way ANOVA are highly sensitive to the non-homogeneity of variances among the data set. If the variances are unequal it will result in significant differences even if the means of the treatments are the same.
A Bartletts Test was run on the data for generated aircraft, to check for homogeneity of variance, and it failed (Ref.19:325).

**Aircraft Generation.** The number of aircraft generated by maintenance during the one day operation does not include the first launches of the day for the aircraft. The reason for this is that all aircraft are considered flyable at the start of the day, with all maintenance complete. To avoid bias in the data caused by the random number stream, two observations were taken for each cell. This raw data, Table VI, was then converted to ranks, according to the procedures of the Friedman Test, and comparisons were made on the effects of varying the number of aircraft and maintenance teams. Table VII was used to measure the effects of increasing the number of aircraft at the different maintenance levels. Table VIII measures the effects of increasing maintenance personnel at the various levels of available aircraft.

In both cases the test results indicate a difference between the treatments throughout the ranges of the blocks. In Table VII, the aircraft were considered the treatments, and in Table VIII, the maintenance teams. By making comparisons between the treatments of each table, it was shown that there was not a significant difference between starting with 36 or 42 aircraft, and not a difference be-
between starting with 13 or 14 maintenance teams. All other comparisons showed a significant difference. Appendix F contains the results of the tests.

**TABLE VI**

RAW DATA ON THE NUMBER OF AIRCRAFT GENERATED BY MAINTENANCE AT VARIOUS LEVELS OF MAINTENANCE AND AIRCRAFT

<table>
<thead>
<tr>
<th># of Maintenance Teams</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
</tr>
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<tr>
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<td>67</td>
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<tr>
<td>51</td>
<td>51</td>
<td>57</td>
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<td>78</td>
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<tr>
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| Rj   | 34 | 73.5| 114 | 124 | 149.5 |

45
**TABLE VIII**

RANKED DATA ON THE NUMBER OF AIRCRAFT GENERATED BY MAINTENANCE CHECKING FOR DIFFERENCES IN MAINTENANCE LEVELS

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| R_j                                | 14.5| 35  | 55.5| 80  | 95.5| 123 | 134.5| 150 | 166 |

46
**Aircraft Sorties.** Table IX portrays the data on the number of sorties flown for the different levels of aircraft and maintenance teams. The definitions of sorties flown for this data include all aircraft that take-off and land, including the first launches of the day. Those aircraft that are destroyed are not included as sorties. The measurement was taken in this manner to see the effects on the maintenance teams when aircraft are destroyed and removed from the system. Again tests were run using both the number of aircraft and the number of maintenance teams available as treatments in the modified Friedman's Test. In both cases the test revealed there was a difference between the treatments.

The data using the numbers of aircraft as the treatments is presented in Table X. In the comparisons, there were no two treatments that were not different. This differs from the results of Table VII on the maintenance generated aircraft. The reason for this is that now the first launches of the aircraft are included.

Table XI contains the data to run the test using the maintenance teams as the treatments. Although the test revealed a difference between the treatments, when comparisons were made between the individual treatments, in all cases but one, it showed that there was not significant differences between the adjoining treatments.
This indicates that when increasing the maintenance teams available by one, except between 12 and 13 teams, there is no appreciable difference. Having ten maintenance teams does not significantly increase the number of sorties flown over having only nine teams, but is quite better than having only eight teams. Appendix F contains the results of the tests.

**TABLE IX**

RAW DATA ON THE NUMBER OF SORTIES FLOWN

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CHECKING FOR DIFFERENCES IN
MAINTENANCE LEVELS

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50
When the number of sorties flown is reduced by the number of air aborts, using the same definition of sorties flown as before, the number of flights is reduced. Table XII contains the data on the number of these flights. By comparing this data with that contained in Table IX, the result of not counting air aborts as sorties can be seen. As more aircraft are made available for flight, the number of aircraft that air abort increases, although the percentage of air aborts is fixed. This fact must be remembered when trying to increase the number of sorties flown by increasing the number of aircraft available to fly.

### TABLE XII

**RAW DATA ON THE NUMBER OF SORTIES REDUCED BY AIR ABORTS**

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<td>65</td>
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<td>78</td>
<td>71</td>
<td>75</td>
<td>88</td>
<td>87</td>
<td>86</td>
</tr>
<tr>
<td>73</td>
<td>76</td>
<td>80</td>
<td>79</td>
<td>83</td>
<td>95</td>
<td>93</td>
<td>93</td>
<td></td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>80</td>
<td>83</td>
<td>79</td>
<td>86</td>
<td>89</td>
<td>84</td>
<td>96</td>
<td>95</td>
<td>111</td>
</tr>
<tr>
<td>62</td>
<td>76</td>
<td>78</td>
<td>81</td>
<td>86</td>
<td>89</td>
<td>85</td>
<td>99</td>
<td>99</td>
<td></td>
</tr>
</tbody>
</table>
Turn Rate. The turn rate on aircraft is one of the usual ways at looking at data dealing with maintenance and aircraft generation. The turn rate is arrived at by adding the number of aircraft available to those generated in the one day scenario, and then dividing by the number of aircraft available at the start of the day. The data presented in Table XIII shows the breakdown of this statistic over the differing levels of maintenance teams and aircraft modeled. Comparisons can be made between this table and the desired turn rate of a theater commander. For example, the Quest document stated this desired turn rate at 3.22. By looking at the table, this corresponds to having ten maintenance teams for 24 aircraft, or approximately one team for every 2.5 aircraft. This ratio is also seen at the different levels of available aircraft modeled. By knowing the desired turn rate, a ratio of maintenance personnel to aircraft can be established.

Remembering that turn rate is based on the number of aircraft that are capable of flying, the results of the tests run on maintenance generated aircraft is used. This showed that each level of maintenance is significantly different from the others, except between 13 and 14 teams available.

Sensitivity Analysis

Sensitivity analysis was performed on several of the
<table>
<thead>
<tr>
<th># of Aircraft</th>
<th># of Maintenance Teams</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>8</td>
</tr>
<tr>
<td>36</td>
<td>2.4167</td>
</tr>
<tr>
<td>42</td>
<td>2.2140</td>
</tr>
<tr>
<td>48</td>
<td>2.0938</td>
</tr>
</tbody>
</table>

**TABLE XIII**

**TURN RATE OF AIRCRAFT**
variables to measure the effects that changes in their values have on the results of the model output. The reason for this type analysis is to measure which variables have a significant effect on the output. The items checked in this thesis are an item that could be changed in the operations, the number of fuel trucks, and the variables that decrease the number of sorties flown. These items are the air abort rate, the maintenance delay on air aborted aircraft, and the percentage of aircraft destroyed and damaged.

The times to complete the individual tasks and the effects of heat build-up were not considered for follow-on analysis. These areas are not well established and are, therefore, used only as comparative factors for analysis between the ranges of aircraft and maintenance teams available. Due to the nature of the model, a summing of the tasks performed, an increase or decrease in the maintenance task times would cause an inverse result in the number of aircraft that could be generated. The heat build-up level and factors used to change the task times would have the same type results. The first area presented is the air abort rate.

Air Abort Rate. The air abort rate is set in US 16. The flight time is an exponential distribution, and by setting a limit on aircraft by flight time, a percentage of aircraft are termed air aborts. By varying the time
limit for air abort flights, the number of aircraft available for maintenance generation and follow-on sorties is varied. In the main model a flight time less than 15 minutes is considered an air abort, this works out to approximately 19 percent of all flights terminating in air aborts.

With the flight time an exponential with a mean of 70 minutes, the probability of a flight less than the one designated as an air abort is given by:

$$P(T < x) = 1 - e^{-x/70}$$

For a cut-off set at 10 minutes, approximately 13 percent of all aircraft air abort, and for 5 minutes the air abort rate is only 7 percent. As shown in Table XIV, the value used to set the air abort rate is more noticeable when there are less aircraft available on the number of sorties flown. The prime factor limiting the number of aircraft flown is the number of aircraft. As the number of aircraft increase, the abort rate is not as important, because the maintenance teams are constantly working or in forced rest periods.

At the range of personnel to aircraft recommended in the turn rate analysis, of 2.5 aircraft per team, the air abort rate is significant on the number of aircraft flown, but not on the capability to generate aircraft. As the turn rate is based on the capability to fly aircraft, not actual flights, the abort rate used does not greatly change the turn rate.
Maintenance Delay on Aborted Aircraft. Maintenance delays are primarily a factor of the maintenance team's ability to analyze the problem with the aircraft and then correct the problem. When wearing the chemical defense ensemble, several senses of the personnel are limited. The obvious restrictions of visibility and reduced dexterity are further hampered by the removal of the sense of smell. Electronic sniffers must be used to aid in checking for fuel and hydraulic leaks. Only two sets of runs were made on this factor. The maintenance delay used in the model is 240 minutes. This delay is added to the time the aircraft must spend going through the maintenance cycle again. The delay of zero time added to the time required by going through the maintenance cycle was used for comparison. A similar trend to that shown in the air abort rate section presented above, is repeated. By reducing the delay, an increase in both the number of sorties flown and aircraft generated is realized. This increase is of less significance when the number of aircraft to teams approaches the 2.5 level proposed in the turn rate analysis. As these delays are modeled in this thesis, maintenance delays do not greatly effect the turn rate at the 2.5 to 1 ratio recommended. Table XV presents this information.
### TABLE XIV

RESULTS OF VARYING THE AIR ABORT RATE ON THE NUMBER OF AIRCRAFT GENERATED AND FLOWN AT VARIOUS AIRCRAFT LEVELS WITH 16 MAINTENANCE TEAMS

<table>
<thead>
<tr>
<th>Maintenance Generated Aircraft</th>
<th>Flight Time for Air Aborts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Number of Aircraft</td>
<td>24</td>
</tr>
<tr>
<td>Number of Aircraft</td>
<td>30</td>
</tr>
<tr>
<td>Number of Aircraft</td>
<td>36</td>
</tr>
<tr>
<td>Number of Aircraft</td>
<td>42</td>
</tr>
<tr>
<td>Number of Aircraft</td>
<td>48</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of Sorties Reduced by the Number of Air Aborts</th>
<th>Flight Time for Air Aborts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>48</td>
</tr>
</tbody>
</table>
TABLE XV
EFFECTS OF VARYING THE TIME DELAY FOR AIR ABORTED AIRCRAFT AT VARIOUS AIRCRAFT LEVELS WITH 16 MAINTENANCE TEAMS

<table>
<thead>
<tr>
<th>Maintenance Generated Aircraft</th>
<th>Time Delay</th>
<th>Percent Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>240.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Number of Aircraft</td>
<td>24</td>
<td>71</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>71</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>36</td>
<td>92</td>
</tr>
<tr>
<td></td>
<td>42</td>
<td>93</td>
</tr>
<tr>
<td></td>
<td>48</td>
<td>95</td>
</tr>
<tr>
<td>Number of Sorties Flown</td>
<td>240.0</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>78</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>93</td>
</tr>
<tr>
<td></td>
<td>36</td>
<td>114</td>
</tr>
<tr>
<td></td>
<td>42</td>
<td>111</td>
</tr>
<tr>
<td></td>
<td>48</td>
<td>130</td>
</tr>
</tbody>
</table>
Aircraft Destroyed and Damaged. Table XVI shows the effect of varying the percentage of aircraft destroyed and damaged. The model parameters were increased to 0.1 and 0.2 respectively. It is important to remember that destroyed aircraft are not considered as sorties flown for this data. By increasing the percentage of aircraft that receive little damage, a decrease in the number of aircraft generated and flown would be realized. This decrease would result in a decrease in the turn rate over all ranges of aircraft and maintenance. The percentage of little damaged aircraft is a function of the aircrew members wearing the chemical defense ensemble. It is for this reason that research is being performed at reducing the need for the full chemical defense ensemble to be worn in the aircraft. Appendix B contains material on the environmental control system for the aircraft.

Fuel Trucks. The final areas of sensitivity analysis deals with the number of fuel trucks available, Table XVII. It would seem reasonable to assume that if more fuel trucks were available, the aircraft turn rate would be higher. This, however, is not the case. The primary restriction on the maintenance teams is the heat build-up level. With a limited number of fuel trucks, the aircraft must spend more time awaiting refueling, allowing the teams to rest. When the number of trucks increases, the aircraft are re-
fueled quicker, but the teams are forced to rest at a later time to reduce their heat build-up, which off-sets any benefit of increased fuel trucks. There is not any benefit of increased fuel trucks. There is not any benefit to increasing the number of fuel trucks at the ranges of aircraft and personnel modeled.

**TABLE XVI**

EFFECTS OF VARYING THE PERCENTAGE OF DESTROYED AND DAMAGED AIRCRAFT AT VARIOUS AIRCRAFT LEVELS WITH 16 MAINTENANCE TEAMS

<table>
<thead>
<tr>
<th>Maintenance Generated Aircraft</th>
<th>Destroyed 0.06</th>
<th>0.1</th>
<th>Percent Decrease</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Damaged 0.09</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>Number of Aircraft 24</td>
<td>68.5</td>
<td>53</td>
<td>22.6</td>
</tr>
<tr>
<td>Number of Aircraft 30</td>
<td>78</td>
<td>65</td>
<td>16.7</td>
</tr>
<tr>
<td>Number of Aircraft 36</td>
<td>91.5</td>
<td>80.5</td>
<td>12.0</td>
</tr>
<tr>
<td>Number of Aircraft 42</td>
<td>93.5</td>
<td>86</td>
<td>8.0</td>
</tr>
<tr>
<td>Number of Aircraft 48</td>
<td>96</td>
<td>93</td>
<td>3.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of Sorties Flown</th>
<th>Destroyed 0.06</th>
<th>0.1</th>
<th>Percent Decrease</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Damaged 0.09</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>Number of Aircraft 24</td>
<td>76.5</td>
<td>62.5</td>
<td>18.3</td>
</tr>
<tr>
<td>Number of Aircraft 30</td>
<td>91</td>
<td>78</td>
<td>14.3</td>
</tr>
<tr>
<td>Number of Aircraft 36</td>
<td>113</td>
<td>95</td>
<td>15.9</td>
</tr>
<tr>
<td>Number of Aircraft 42</td>
<td>114.5</td>
<td>98</td>
<td>14.4</td>
</tr>
<tr>
<td>Number of Aircraft 48</td>
<td>124.5</td>
<td>108.5</td>
<td>12.9</td>
</tr>
</tbody>
</table>
TABLE XVII
EFFECTS OF VARYING THE NUMBER
OF FUEL TRUCKS
AT VARIOUS AIRCRAFT LEVELS
WITH 16 MAINTENANCE TEAMS

<table>
<thead>
<tr>
<th>Maintenance Generated Aircraft</th>
<th># of Fuel Trucks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>24</td>
</tr>
<tr>
<td>Number</td>
<td>30</td>
</tr>
<tr>
<td>of Aircraft</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>48</td>
</tr>
</tbody>
</table>
The model output was constructed with bookkeeping in mind. The capability to vary both the levels of aircraft and maintenance teams, as well as the individual variables, gives the result of changes in a tabular manner, aiding analysis. The method of analysis used is that of a nonparametric test, the Friedman Test. This test was used to measure the effects of changing the levels of maintenance manning at differing levels of aircraft available. The roles of these two variables were then reversed to ensure that the level of manning were causing the changes in aircraft generations and, hence, the turn rate, not merely the level of aircraft. Parametric analysis of the data was not possible due to the failure of meeting the assumptions required for their use. These tests were run to measure the effects caused by changes in the levels used, as they applied to the resultant turn rate.

The turn rate is the measure of effectiveness used in this thesis. The results of running the model at various levels was to tabularize the turn rates achieved at these levels, and then select a level of maintenance to best meet the desired turn rate for a given level of aircraft. For the example used, of 24 aircraft and a desired turn rate of 3.22, an increase of 25 percent in manning is required, from the present eight teams to ten.
The results of the analysis on the levels of maintenance indicate a significant difference between adjoining maintenance team levels at this range, so the increase of two teams over the present eight available is recommended.

The number of sorties flown was also of interest, as it is a measure of the capability of the air base to fight the war. The results of these tests are similar to that for aircraft generation, and therefore do not change the previous results.

Sensitivity analysis was performed on four different variables to measure their impact on the model results. Of the four variables analyzed, only the percentage of little damaged aircraft was significant. This indicated that small changes in the percentage of aircraft destroyed and damaged in flight could vary the percentage of aircraft generated by approximately 10 percent at the ratio of aircraft to maintenance recommended for the desired turn rate. The remaining three variables analyzed were the abort rate, maintenance delays on aborted aircraft, and the number of fuel trucks available. At the recommended level of maintenance to aircraft they did not drastically effect the results, less than five percent.

As previously mentioned, the results of this analysis is for comparison of the effects of varying the different levels of maintenance to aircraft. Precise re-
commendations are not possible due to the uncertainty of the input parameters. The first method of validating the output of this model was by making comparisons against the results of the Quest model. Similar input parameters were used for both models, Quest and the one presented here, and the results of the two models on turn rate achieved are comparable. Reasons for the differing results are based on the degree of realism modeled, their model does not take into account aborts and battle damaged aircraft or formation take-offs. Both reports indicate a need to increase the level of maintenance required to reach the turn rate used as an example, of 3.22.

In the next chapter, the results of this analysis, as it applies to the goals specified in Chapter I of model development and required maintenance manning, will be presented. Recommended changes to the model, based on the loosening of some of the assumptions used in its development will also be presented.

The second way of validation is by an intuitive process. It is reasonable to assume that an increase in the time to perform maintenance tasks will result in a lower turn rate, for a specified level of maintenance and aircraft. Therefore, an increase in maintenance manning is required to reach a required turn rate.
Summary

The maintenance manning requirements for an air base of fighter aircraft in a chemical environment was the topic of this thesis. The reasons behind this study were covered as the current threat, and the contention that the present manning might not be sufficient. Data is not currently in existence for the maintenance operations of an F-4 squadron in a chemical environment. For this reason data was used from operations in a conventional war scenario and modified to account for chemical war. A simulation model was constructed to measure the capabilities of maintenance to support the air operations. Data was then collected and analyzed to determine if the current level of maintenance, or some higher level, is needed to reach a turn rate consistent with current policy. The two objectives, or goals, of this thesis have been realized.

Conclusions

Three areas will be covered in this section. The first will be on the simulation model. The second area is on the significant factors presented in the sensitivity analysis section of the last chapter. The final area cov-
ers the manning requirements of maintenance. The first and last of these are to meet the objectives of this thesis and the middle one to explain the effects of changing parameters.

Model Viability. A simulation model, that is highly flexible, is the only viable method to make comparisons within the chemical warfare scenario. It cannot give exact answers to the effects on operations in this threat, but it does make estimates. By changing the inputs, comparisons can be made, and the effects of the changes can be seen quickly. The flexibility designed into the model allows changes to be made easily and allows for additions of further capabilities.

Significant Factors. The effects of changing the air abort rate, maintenance delays on aborted aircraft, and the number of fuel trucks available, do not significantly change the number of aircraft generated at the level of maintenance to aircraft recommended for use. The results of changing the percentage of aircraft destroyed and damaged from .06 and .09, to .10 and .20, respectively, did have a significant effect on the number of aircraft that could be generated, approximately 10 percent. The primary factor that led to the results of this model is the burden imposed by wearing the chemical defense ensemble. As mentioned at the introduction of sensitivity
analysis, further analysis on these parameters was not performed, beyond their development for the model.

Maintenance Manning. The current level of maintenance manning, of one team to three aircraft, is not sufficient to meet the desires of a theater commander, as presented in the Quest document. As presented in the previous chapter, a ratio of one team per 2.5 aircraft is more realistic. This corresponds to an increase of nearly 25 percent. The model given in this thesis does not take into account the effects of incapacitation and death that would be encountered in a chemical attack. Therefore, the turn rates given in the analysis need to be lowered if personnel are removed from operations. An increase in manning of 25 percent would not be unreasonable and may, in fact, be low when personnel are removed from the system.
Recommendaions

The model presented is but a first cut at the operations of maintenance, let alone an air base, in a chemical environment. Several areas need to be researched and included in this model, or in one similar to it, to remove the restrictive assumptions made in Chapter II.

Personnel Incapacitation. In this model, advanced warning and the availability of equipment is assumed, so all personnel remain operational. There are presently several studies and models being utilized by the Chemical Warfare Division of the Aerospace Medical Research Laboratory (AMRL) that deal with incapacitation of personnel. These models need to be analyzed for their capabilities to make predictions on incapacitation, and the results incorporated in this model.

Equipment Improvements. The equipment that is utilized in the chemical defense ensembles are continuously being improved. These improvements will reduce both the heat build-up factors and the time to perform tasks. Research into the future status of the ensembles and the effects the improvements bring about must be continued. Appendix E gives a listing of the current ensembles.

Improvements are also being made in the aircraft systems that may reduce the air abort rate. The abort rate in this model includes physiological effects on the aircrew.
Appendix B gives a brief description of the environmental control systems that are under development for most aircraft types. This would reduce the number of aircraft that abort. It could also have an effect on the percentages of aircraft that are destroyed and damaged. The capabilities of the aircrew is somewhat limited by the current ensemble.

As the equipment is improved, the overall capabilities of the personnel, both ground and aircrew, will be improved. Not only must the amount of research into new equipment be increased, the ability of a modeler to incorporate these changes on an unclassified level in a model, must be expanded.

Resource Availability. The amount of resources at the field are considered limitless. This includes the amount of fuel and munitions, and the amount of chemically protective equipment. The actual amounts of these commodities at particular fields need to be incorporated into the model. This could be done, based on the time it takes for the particular events, fuel and loading of guns and missiles, to occur. A second method could be based on the flight time of the aircraft. The longer the flight, the more fuel used and the more likely that armaments were expended. In both cases, time could be used to model the amount of resources used by each aircraft. Then
as they are used, a bookkeeping system could be used to ensure that the levels of supply are not exceeded.

Comments

The main benefit of a simulation model is the learning process it forces on the modeler. The methodology used on the design of this model was systematic, from literature search through problem definition, to the simulation model. As assumptions are loosened, or more detail is required, the size of the model must increase. The material presented in this thesis incorporates research into many areas and should provide a good reference on the problems of operations in a chemical environment.


APPENDIX A

This appendix contains two tables. Table XVIII is a partial list of chemical agents that would be used as weapons (Ref. 15:196-197). Table XIX shows the survival rates and times of experimental animals exposed to Soman and Sarin, both nerve agents, after being given antidotes (Ref. 20:10-3).

As shown in Table XIX, if a person is exposed to a nerve agent when unprotected, the probability of survival is less than assured. Those that do survive would be incapacitated and not able to perform their designated tasks.

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### TABLE XVIII
CHEMICALS USED AS WEAPONS

<table>
<thead>
<tr>
<th>Name of Agent</th>
<th>Physical State at 68°F</th>
<th>Dissipated Form</th>
<th>Other</th>
<th>Median Lethal Dose on Inhalation* mg.min./m²</th>
<th>Median Incapacitating Dose on Inhalation mg.min./m²</th>
<th>Eye and Skin Toxicity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosgene CG</td>
<td>Colorless gas.</td>
<td>Gas.</td>
<td>New-mown hay; green corn.</td>
<td>1,200</td>
<td>1,600</td>
<td>None.</td>
</tr>
<tr>
<td>Sarin GB</td>
<td>Colorless liquid.</td>
<td>Gas or liquid.</td>
<td>Almost none when pure.</td>
<td>70 (mild activity)</td>
<td>35 (mild activity)</td>
<td>Eyes: Very high. Skin: 15,000 * lethal for gas. 2 grams liquid (40 drops) thru ordinary clothing. 8,000 ** incapacitating for gas.</td>
</tr>
<tr>
<td>Mustard HD</td>
<td>Colorless to pale yellow liquid.</td>
<td>Gas or liquid.</td>
<td>Garlic. Very little if pure.</td>
<td>1,500 (resting men)</td>
<td>400 (active men)</td>
<td>Eyes: 200 ** incapacitating. Skin: 2,000 ** incapacitating for gas.</td>
</tr>
<tr>
<td>CS</td>
<td>White crystalline solid.</td>
<td>Aerosol. Pungent, peppery.</td>
<td>Lethality low but incapacitating at 1-5 mg/min.²</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Concentration times exposure (milligrams per cubic meter times minutes) to cause death in 50% of subjects. The numbers are directly comparable to indicate lethality of the agents.

** Same as above but to cause incapacitation in 50% of subjects.
<table>
<thead>
<tr>
<th>Time of Onset of Symptoms</th>
<th>Physiological Action</th>
<th>Protection Required</th>
<th>Decontamination</th>
<th>Tactical Use</th>
<th>First Aid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immediate to 24 hours</td>
<td>Damages the lungs.</td>
<td>Mask.</td>
<td>None in open. Aeration in closed spaces.</td>
<td>Lethal agent, delayed or immediate action.</td>
<td>If shortness of breath occurs, rest and keep warm.</td>
</tr>
<tr>
<td>Inhalation:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very rapid.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skin: 15–1 hour.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skin: 15–1 hour.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inhalation:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very rapid.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skin: 15–1 hour.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delayed. 4–6 hours.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Instantaneous.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extreme burning and tearing of eyes.</td>
<td>Mask.</td>
<td>None</td>
<td>Incapacitating agent on inhalation.</td>
<td>Face wind in fresh air. Do not rub eyes.</td>
<td></td>
</tr>
<tr>
<td>Difficult breathing. Stinging of skin. Nausea.</td>
<td></td>
<td></td>
<td>Normally a riot agent, but may be used as a war agent.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### TABLE XIX
SURVIVAL RATE AND SURVIVAL TIME AFTER POISONING

#### WITH 5 LD<sub>50</sub> OF SOMAN

<table>
<thead>
<tr>
<th>Antidotes</th>
<th>uMol/kg</th>
<th>number of animals</th>
<th>survived</th>
<th>survival rate %</th>
<th>survival time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HGG 12-Cl</td>
<td>3</td>
<td>8</td>
<td>3</td>
<td>37</td>
<td>3840</td>
</tr>
<tr>
<td>HGG 42-J</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HGG 12-Cl</td>
<td>15</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>183</td>
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<tr>
<td>HGG 12-Cl</td>
<td>40</td>
<td>6</td>
<td>4</td>
<td>66</td>
<td>1490</td>
</tr>
<tr>
<td>HGG 42-J</td>
<td>15</td>
<td>5</td>
<td>1</td>
<td>20</td>
<td>450</td>
</tr>
<tr>
<td>HGG 42-J</td>
<td>30</td>
<td>6</td>
<td>5</td>
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<td>HGG 42-J</td>
<td>30</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>1788</td>
</tr>
<tr>
<td>OBIDOXIN</td>
<td>50</td>
<td>6</td>
<td>1</td>
<td>17</td>
<td>471</td>
</tr>
<tr>
<td>HGG 42-J</td>
<td>30</td>
<td>6</td>
<td>3</td>
<td>50</td>
<td>2880</td>
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</table>

#### WITH 5 LD<sub>50</sub> CF SARIN

<table>
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<tr>
<th>Antidotes</th>
<th>uMol/kg</th>
<th>number of animals</th>
<th>survived</th>
<th>survival rate %</th>
<th>survival time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HGG 12-Cl</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>50</td>
<td>48</td>
</tr>
<tr>
<td>HGG 42-J</td>
<td>3</td>
<td>6</td>
<td>1</td>
<td>17</td>
<td>13</td>
</tr>
<tr>
<td>HGG 12-Cl</td>
<td>30</td>
<td>6</td>
<td>3</td>
<td>50</td>
<td>33</td>
</tr>
<tr>
<td>OBIDOXIN</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</table>

#### 10 LD<sub>50</sub> VX

<table>
<thead>
<tr>
<th>Antidotes</th>
<th>uMol/kg</th>
<th>number of animals</th>
<th>survived</th>
<th>survival rate %</th>
<th>survival time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HGG 12-Cl</td>
<td>3</td>
<td>6</td>
<td>4</td>
<td>66</td>
<td>3333</td>
</tr>
</tbody>
</table>

#### 15 LD<sub>50</sub> VX

<table>
<thead>
<tr>
<th>Antidotes</th>
<th>uMol/kg</th>
<th>number of animals</th>
<th>survived</th>
<th>survival rate %</th>
<th>survival time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HGG 12-Cl</td>
<td>30</td>
<td>6</td>
<td>2</td>
<td>33</td>
<td>120</td>
</tr>
<tr>
<td>HGG 42-J</td>
<td>30</td>
<td>6</td>
<td>4</td>
<td>66</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX B

The aircrew members are currently required to wear the chemical defense ensemble for all flights in a chemical environment. The effects of wearing the ensemble are taken account of in the rates of air aborted, destroyed, and damaged aircraft. Research is currently underway to reduce the amount of agents that can enter the aircraft, and remove the agents that do enter. With a reduced threat, the wearing of the full ensemble might not be required. This would reduce the physiological effects on the crew members and remove some limitations of dexterity and vision. The effects would be a reduced percentage of aircraft that air abort or are damaged and destroyed.
Pertinent Data on the Environmental Control System

The concentration of contaminants in the cockpit/cargo compartment is dependent on the air supply inlet concentration of chemical agents and the exchange rate of air in the cockpit/cargo compartment.

These variables are related by the following equation.

\[
\frac{C_{\text{in}} - C_{\text{d0}}}{C_{\text{in}} - C_{\text{initial}}} = e^{-(\frac{w d0}{p V})}
\]

where

- \(C_{\text{in}}\) concentration of the incoming air
- \(C_{\text{d0}}\) concentration in the cabin at the end of the time interval
- \(C_{\text{initial}}\) concentration in the cabin at the start of the time interval
- \(w\) inflow rate of cabin air
- \(d0\) time interval
- \(p\) density of the air entering the cabin
- \(V\) cabin volume
- \(\frac{w}{p V}\) rate of air changes

The top charts of Figures 11 and 12 are computer verification runs (CVR) and the bottom charts are for an F-4 aircraft. The measurement of concentration is expressed as parts per million (PPM) or milligrams per cubic meter.

Table XX gives data on the different aircraft if they were to use the Environmental Control System (Ref. 24: Appendix 6).
NOTES:
1. Test Data From CVR-7 & -9
2. Max Concentration,
   25.1 mg/m³ (=30.7 PPM)
3. Aircrew Breathing Rate,
   15 liters Air/Minute
NOTES:
1. Test Data From CVR-7 & -9, Noted
2. Max Concentration, 50.7 PPM
   (Delta-During Test CVR-7)

Figure 12

TIME, MINUTES

COCKPIT CONCENTRATION, % MAX

TIME, MINUTES

COCKPIT CONCENTRATION, PPM
### Aircraft ECS Characteristics - Sea Level Static, Standard Atmosphere

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>Volume FT³</th>
<th>Crew Station</th>
<th>Engine Bleed Air</th>
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<tr>
<td></td>
<td>Air Changes Per Minute</td>
<td>Airflow LB/Min</td>
<td>Flow Rate LB/Min</td>
</tr>
<tr>
<td></td>
<td>Max</td>
<td>Idle</td>
<td>Max</td>
</tr>
<tr>
<td>A-7</td>
<td>60</td>
<td>5.2</td>
<td>2.0</td>
</tr>
<tr>
<td>A-10</td>
<td>60</td>
<td>5.5</td>
<td>25</td>
</tr>
<tr>
<td>F-4E</td>
<td>150</td>
<td>2.58</td>
<td>85</td>
</tr>
<tr>
<td>F-5E</td>
<td>50</td>
<td>8.1</td>
<td>.9</td>
</tr>
<tr>
<td>F-15</td>
<td>75</td>
<td>7.4</td>
<td>43</td>
</tr>
<tr>
<td>F-16</td>
<td>60</td>
<td>4.4</td>
<td>20</td>
</tr>
<tr>
<td>F-111F</td>
<td>90</td>
<td>8.7</td>
<td>1.75</td>
</tr>
<tr>
<td>B-1*</td>
<td>600</td>
<td>.52</td>
<td>.56</td>
</tr>
<tr>
<td>B-52D</td>
<td>1830</td>
<td>1.1</td>
<td>170</td>
</tr>
<tr>
<td>B-52H</td>
<td>1830</td>
<td>1.5</td>
<td>.23</td>
</tr>
<tr>
<td>C130E</td>
<td>750</td>
<td>.55</td>
<td>.55</td>
</tr>
<tr>
<td>C-141</td>
<td>1250</td>
<td>.96</td>
<td>100</td>
</tr>
<tr>
<td>KC-135</td>
<td>1300</td>
<td>1.2</td>
<td>118</td>
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</tbody>
</table>

*Hot Atmosphere

**Table XX**
APPENDIX C
PROGRAM LISTING
SUBROUTINE UI

VARIABLE LIST

C++ A1 TIME TO PERFORM AERO 7 INSPECTION
C++ A2 TIME TO PERFORM RELOADING OF GUNS
C++ A3 TIME TO PERFORM EXTERNAL FUEL TANK PLACEMENT OR REMOVAL
C++ A4 TIME TO PERFORM MISSILE UPLOAD
C++ A5 TIME TO PERFORM PREFLIGHT
C++ A6 TIME TO PERFORM REFueling
C++ A7 HEAT BUILDUP ENCOUNTERED DURING AERO7 AND RELOADING
C++ A8 HEAT BUILDUP ENCOUNTERED DURING CHANGEOVER OF EXTERNAL TANK
C++ A9 HEAT BUILDUP ENCOUNTERED DURING MISSILE UPLOAD
C++ A10 HEAT BUILDUP ENCOUNTERED DURING REFueling
C++ A11 HEAT BUILDUP ENCOUNTERED DURING REFueling
C++ A12 SIMULATION TIME THAT PREFLIGHT IS COMPLETE
C++ A13 SIMULATION TIME THAT AIRCRAFT IS AVAILABLE FOR REFueling
C++ A14 TIME SPENT WAITING REFueling BY AIRCRAFT
C++ A15 CURRENT HEAT BUILDUP INSIDE SUITS OF MAINT TEAM
C++ A16 CURRENT HEAT BUILDUP INSIDE SUITS OF ARMING TEAMS

ATTRIBUTE LIST

C++ 1 WING TANK STATUS
C++ 2 FUEL STATUS
C++ 3 AIRCRAFT NUMBER
C++ 4 MA TEAM NUMBER
C++ 5 AIRCRAFT OR FUEL TRUCK
C++ 6 HEAT BUILDUP OF MAINT TEAM
C++ 7 HEAT BUILDUP OF ARMING TEAM

84
C++ AFTER AIRCRAFT HAVE FINISHED PREFLIGHT A FLT OF THO 000940
C++ TAKEOFF. UPON TAKEOFF THEY RE-ENTER THE SYSTEM AT 000955.
C++ NODE 45. 000960
C++ 000970

1 X=X+1
RT=GATRD(3)
CALL PATRS(RT,3)
PRINT*, 'TIME IS ' , TIME, ' ACRF ' , RT
DTIM=10000.0
IF(X.LT.1.5) THEN
C++ LEAD AIRCRAFT
CALL GETAT(BATT)
TKOFF1=0.0
CALL STSER(45)
RETURN
ENDIF
CALL GETAT(RATT)
C++ SECOND AIRCRAFT
TKOFF2=0.501
FLTS=FLTS+1
C++ PLACES FORMATION IN NODE 45
CALL PTIN(45,TKOFF1,TNOW+RATT)
CALL PTIN(45,TKOFF2,TNOW+RATT)
CALL STSER(45)
Y=0
RETURN
C++ SET PARAMETERS ON AIRCRAFT
C++ THESE PARAMETERS MAY BE CHANGED IN THE 001210
C++ G0ERT MODEL. UP TO 50 AIRCRAFT MAY BE USED; 001220
C++ TO ALLOW FOR MORE AIRCRAFT RESET ARRAY SIZES 001240
C++ IN COMMON RET. NUMBER OF AIRCRAFT MUST ALSO 001250
C++ BE SET IN ACTIVITY 1. 001260
C++ 001270
2 I=FIX(GATRD(3))+0.1
J=FIX(GATRB(4))+0.1
A1(I)=L0(8)
A2(I)=L0(9)
A3(I)=L0(10)
A4(I)=L0(11)
A5(I)=L0(12)
A6(I)=L0(13)
A7(I)=1.07*A1(I)+1.97*A2(I)
A8(I)=1.47*A3(I)
A9(I)=2.47*A4(I)
A10(I)=3.63*A5(I)
A11(I)=0.47*A6(I)
DTIM=0.0
PRINT*, 'AIRCRAFT ' , I , ' PLACES IN NODE 5 AT ' , TNOW 001420
RETURN 001430
PLACES AIRCRAFT INTO THE SUBNETWORK

UP TO 16 MX TEAMS ARE ALLOWED. THE LIMIT

THE NUMBER OF MX TEAMS USED, THE NUMBER OF

TEAMS MUST BE SET IN GENT MODEL ACTIVITY 31.

THE LAST NUMBER MUST EQUAL THE NUMBER OF MX

TEAMS MINUS 1; THIS ELIMINATES TRANSACTION PASSAGE

UNLESS AT LEAST ONE MX TEAM IS AVAILABLE.

THE STATEMENT L=59 IS PLACED IN THE IF STATEMENT

FOR THE LAST MX TEAM TO BE USED.

THE VALUE OF N MUST ALSO BE SET IN U3.

CALL GETAT(RATT)

DTIN=0.0

K=IFIX(GATR8(3)+0.1)

NUMB=0

ICOUNT=1.0E20

N=16

DO 50 I=1,N

IF(CSRA(I).GT.0.5) THEN

IF(ICOUNT.LT.IC(1)) THEN

ICOUNT=IC(1)

NUMB=I

ENDIF

ENDIF

CONTINUE

GO TO (121,102,103,104,105,106,107,108,109,110)

ASSIGNS MX TEAM 1

CHECK STATUS OF MX TEAM 1, IF AVAILABLE

ASSIGNS AIRCRAFT TO APPROPRIATE SUBNETWORK.

IF NOT, CHECK STATUS OF NEXT MX TEAM.

THESE LINES ARE THE SAME FOR ALL

TEAM "IF" LOOPS

FLUS=NOCFL(98,1)

CALL PTRANSPLUS,5,7,NOW,RATT)

I=1

IC(1)=IFIX(IC(1)+1.1)

GO TO 600

ASSIGNS MX TEAM 2

PLUS=NOCV(98,2)

CALL PTRANSPLUS,5,7,NOW,RATT)

I=2

IC(1)=IFIX(IC(1)+1.1)

GO TO 600

ASSIGNS MX TEAM 3

PLUS=NOCV(98,3)

CALL PTRANSPLUS,5,7,NOW,RATT)

I=3

IC(1)=IFIX(IC(1)+1.1)

GO TO 600
CALLPTWIN(PLUSI0.0I0,IN0:RATT)
I = 4
IC(I) = IFIX(IC(I) + 1.1)
GO TO 600

CALLPTWIN(PLUSI0.0I0,IN0:RATT)
I = 5
IC(I) = IFIX(IC(I) + 1.1)
GO TO 600

CALLPTWIN(PLUSI0.0I0,IN0:RATT)
I = 6
IC(I) = IFIX(IC(I) + 1.1)
GO TO 600

CALLPTWIN(PLUSI0.0I0,IN0:RATT)
I = 7
IC(I) = IFIX(IC(I) + 1.1)
GO TO 600

CALLPTWIN(PLUSI0.0I0,IN0:RATT)
I = 8
IC(I) = IFIX(IC(I) + 1.1)
GO TO 600

CALLPTWIN(PLUSI0.0I0,IN0:RATT)
I = 9
IC(I) = IFIX(IC(I) + 1.1)
GO TO 600

CALLPTWIN(PLUSI0.0I0,IN0:RATT)
I = 10
IC(I) = IFIX(IC(I) + 1.1)
GO TO 600

CALLPTWIN(PLUSI0.0I0,IN0:RATT)
I = 11
IC(I) = IFIX(IC(I) + 1.1)
GO TO 600
C44 ASSIGNS MX TEAM 12
112 PLUS=NODCV(95;12)
   CALL PTIN(PLUS;0.0;TNOW;RATT)
   I=12
   IC(I)=IFIX(IC(I)+1.1)
   GO TO 600
C44 ASSIGNS MX TEAM 13
113 PLUS=NODCV(95;13)
   CALL PTIN(PLUS;0.5;TNOW;RATT)
   I=13
   IC(I)=IFIX(IC(I)+1.1)
   GO TO 600
C44 ASSIGNS MX TEAM 14
114 PLUS=NODCV(95;14)
   CALL PTIN(PLUS;0.5;TNOW;RATT)
   I=14
   IC(I)=IFIX(IC(I)+1.1)
   GO TO 600
C44 ASSIGNS MX TEAM 15
115 PLUS=NODCV(95;15)
   CALL PTIN(PLUS;0.5;TNOW;RATT)
   I=15
   IC(I)=IFIX(IC(I)+1.1)
   GO TO 600
C44 ASSIGNS MX TEAM 16
116 PLUS=NODCV(95;16)
   CALL PTIN(PLUS;0.5;TNOW;RATT)
   I=16
   IC(I)=IFIX(IC(I)+1.1)
   L=50
   GO TO 600
C44 IF ALL MX TEAMS HAVE BEEN ASSIGNED AT LEAST ONCE;
C44 THE HEAT BUILD UP OF THE TEAM IS PLACED ON THE
C44 TEAMS THAT HAVE ALREADY BEEN ASSIGNED AT LEAST ONCE;
660 IF (L.GT.25) THEN
   RT=A15(I)-.034*(TNOW-A12(I))
   IF(RT.LT.30.0) THEN
      RT=30.0
      ENDBIF
   E=A16(I)-.8*(TNOW-A12(I))
   IF(E.LT.30.0) THEN
      E=30.0
      ENDBIF
   CALL PATR(S(RT;6))
   CALL PATR(S(E;7))
   ENDBIF
   PRINT,'PAINT TEAM ',I,' WORKED ',W(I),' TO THIS POINT.'
   PRINT,'AIRCRAFT ',K, ' PLACED IN NODE 93',I,' AT ',TNOW
   RETURN
002490
002500
002510
002520
002530
002540
002550
002560
002570
002580
002590
002600
002610
002620
002630
002640
002650
002660
002670
002680
002690
002700
002720
002730
002760
002770
002780
002790
002800
002810
002820
002830
002840
002850
002860
002870
002880
002890
002900
002910
89
C++ # RELOAD GUN AND AERO 7 INSPECTION IF AIRCRAFT HAS WING TANKS
C++ # THERMAL STRESS VALUES ON MX TEAMS ARE
C++ # RESET AND TIMES ADJUSTED FOR REQUIRED
C++ # DELAYS, IF APPLICABLE, PLACES AIRCRAFT
C++ # INTO NEXT PHASE OF MAINTENANCE REQUIRED
C++ # AT APPROPRIATE TIME. THIS IS THE SAME
C++ # FROM US 4 THROUGH US 12.
C++ #
C++ # GET AIRCRAFT NUMBER
C++ # I = IFIX(GATRB(3) + 0.1)
C++ # GET MX TEAM WORKING ON AIRCRAFT
C++ # J = IFIX(GATRB(4) + 0.1)
C++ # PRINT T*, TIME IS ', TNOW', AIRCRAFT ', I', HAS WING TANKS
C++ # TTN = 600.0
C++ # INCREASE HEAT BUILDUP ON MX TEAM
C++ # RT = GATRB(6) + A7(I)
C++ # E = GATRB(7) + A7(I)
C++ # INCREASED WORK TIME OF MX TEAM
C++ # W(J) = W(J) + A2(I)
C++ # GET NODE NUMBER IN SUBNETWORK
C++ # S' = NODEV(19)
C++ # IF HEAT BUILDUP EXCEEDS 70 ON EITHER MAINT OR
C++ # MX, MX PLACE TEAM IN REST
C++ # IF(RT.GT.75.0 OR E .GT.75.0) THEN
C++ # DECREASE HEAT BUILDUP
C++ # T+=RT-40.0
C++ # V=V-40.0
C++ # CALCULATE TIME TO COMPLETE TASK INCLUDING REST PERIOD
C++ # S=V+10.0
C++ # PLACE VALUES IN ATTRIBUTES ON AIRCRAFT
C++ # CALL PATRB(V+6)
C++ # CALL PATRB(V+7)
C++ # CALL GETAT(RATT)
C++ # PLACE TRANSACTION INTO SYSTEM AT NEXT NODE
C++ # CALL PTIN(S,TNOW,RATT)
C++ # RETURN
C++ # ENDIF
C++ # IF A REST IS NOT REQUIRED
C++ # PLACE VALUES IN ATTRIBUTES ON AIRCRAFT
C++ # CALL PATRB(RT+6)
C++ # CALL PATRB(E+7)
C++ # CALL GETAT(RATT)
C++ # PLACE TRANSACTION INTO SYSTEM AT NEXT NODE
C++ # CALL PTIN(S+10.0,TNOW,RATT)
C++ # RETURN
C++

90
FELDO4 SENS AND AERD 7 INSPECTION IF AIRCRAFT DOES NOT
HAVE WING TANKS. (CHECK COMMENTS IN US 4)

C**

3 I = I+1
J = I+1

PRINT"TIME IS NOT NOW; AIRCRAFT 1,15 HAS NO WING TANKS"

DTX = $.5

RT = CATR8(4)+A7(I)

E = CATR8(7)+A7(I)

H(J) = M(J)+A2(I)

SUN = NDCV(21,J)

IF (RT.GT.70.0.OR.E.GT.70.0) THEN

TM = RT-40.0

V = E-40.0

S = A2(I)+48.19

CALL PATRE(TM,1)

CALL PATRE(V,7)

CALL GETAT(RATT)

CALL PTIN(SUN,S,TNOW,RATT)

RETURN

ENDIF

CALL PATRE(RT,6)

CALL PATRE(E,7)

CALL GETAT(RATT)

CALL PTIN(SUN,A2(I),TNOW,RATT)

RETURN
C** PUT TANKS ON AIRCRAFT
C** IF AIRCRAFT DOES NOT HAVE WING TANKS:
C** IT PLACES THEM ON THE AIRCRAFT WITH A PROBABILITY
C** OF .5. THIS IS TO SIMULATE SCHEDULING
C** OF AIRCRAFT FOR A MISSION THAT REQUIRES
C** WING TANKS
C** GET AIRCRAFT NUMBER
6 = IFIX((CATAB(13) + 0.1)
C** GET NX TEAM NUMBER WORKING ON AIRCRAFT
J = IFIX((CATAB(4)+0.1)
PRINT 'TIME IS ',TNOW,' AIRCRAFT ',I,' TANKS PUT ON'
DTIM = 600.0
C** INCREASE HEAT BUILDUP ON NX TEAM
RT = CATAB(6)+AS(1)
E = CATAB(7)-AS(1)
C** INCREMENT WORK TIME ON NX TEAM
W(J) = W(J)+AS(1)
C** CHECK NODE NUMBER IN SUBNETWORK
SUN = NODCV(24)+J
IF (RT+GT.70.0) THEN
C** IF HEAT BUILDUP EXCEEDS 70:
S = AS(1)+48.19
C** INCREASE TIME TO COMPLETE TASK BY REST PERIOD
TM = RT - 40.0
V = E - 40
C** PLACE VALUES IN ATTRIBUTES ON AIRCRAFT
CALL PATRD(TM)
CALL PATRD(V)
CALL GETAT(RATT)
C** PLACE TRANSACTION INTO SYSTEM AT NEXT NODE
CALL PTIN(SUN+S+TNOW+RATT)
RETURN
ENDIF
C** IF NO REST PERIOD IS REQUIRED
C** PLACE VALUES IN ATTRIBUTES ON AIRCRAFT
CALL PATRD(RT)
CALL *ATRE(ET)
CALL GETAT(RATT)
C** PLACE TRANSACTION INTO SYSTEM AT NEXT NODE
CALL PTIN(SUN+AS(1)+TNOW+RATT)
RETURN
C44 TAKE TANKS OFF AIRCRAFT
C44 IF AIRCRAFT HAVE WING TANKS ON IT.
C44 REMOVES THE TANKS WITH A PROBABILITY
C44 OF .5, TO SIMULATE SCHEDULING OF AIRCRAFT
C44 THAT REQUIRE NO EXTERNAL FUEL TANKS.
C44
C44 GET AIRCRAFT NUMBER
C44 I = IFIX(GATRB(3) + 0.1)
C44 GET MX TEAM NUMBER WORKING ON AIRCRAFT
C44 J = IFIX(GATRB(4) + 0.1)
C44 PRINT*, 'TIME IS ', TNOW, ' AIRCRAFT ', I, ' TANKS COMING OFF'
C44 GTIM = 600.0
C44 INCREASE HEAT BUILDUP ON MX TEAM
C44 RT = GATRB(j) + 0.1
C44 E = GATRB(7) - A8(1)
C44 INCREASE MURP TIME ON MX TEAM
C44 H(j) = H(j) + 0.01
C44 CHECK NODE NUMBER IN SUBNETWORK
C44 SUM = NOCV(25, j)
C44 IF (RT .GT. 79.6) THEN
C44 IF HEAT BUILDUP ON MAINT TEAM EXCEEDS 70
C44 INCREASE TIME TO COMPLETE TASK BY INCLUDING REST PERIOD
C44 S = A3(j) + 0.19
C44 DECREASE HEAT BUILDUP ON MX TEAM
C44 TH = RT - 40.0
C44 V = E - 40
C44 PLACE VALUES IN ATTRIBUTES ON AIRCRAFT
C44 CALL FATRB(TM, 6)
C44 CALL FATRB(TH, 7)
C44 CALL GETAT(RATT)
C44 PLACE TRANSACTION INTO SYSTEM AT NEXT NODE
C44 CALL PTIN(SUM, TH, TH, RATT)
C44 RETURN
C44 ENIGF
C44 IF A REST PERIOD WAS NOT REQUIRED
C44 PLACE VALUES IN ATTRIBUTES ON AIRCRAFT
C44 CALL FATRB(RT, 6)
C44 CALL FATRB(TH, 7)
C44 CALL GETAT(RATT)
C44 PLACE TRANSACTION INTO SYSTEM AT NEXT NODE
C44 CALL PTIN(SUM, A3(I), TH, RATT)
C44 RETURN
C44
C** LOAD MISSILES
C** AIRCRAFT IS FUELED, ALL AIRCRAFT ARE
C** SCHEDULED TO HAVE MISSILES UPLOADED.
C** THESE ARE EITHER AIR-TO-AIR OR AIR-
C** TO-GROUND MISSILES.
C**
C** GET AIRCRAFT NUMBER
C**
C** GET MX TEAM NUMBER WORKING ON AIRCRAFT
C**
C** INCREASE HEAT BUILUP ON MX TEAM
C**
C** INCREMENT WORK TIME ON MX TEAM
C**
C** CHECK NODE NUMBER IN SUBNETWORK
C**
C** IF HEAT BUILUP EXCEEDS 70, INCREASE TIME TO COMPLETE
C**
C** TASK 81 INCLUDING REST PERIOD AND DECREASE HEAT BUILUP
C**
C** IF HEAT BUILUP STILL EXCEEDS 70 WITH A REST PERIOD,
C**
C** DECREASE HEAT BUILUP AND INCREASE TIME TO COMPLETE THE
C**
C** TASK WITH A SECOND REST PERIOD
C**
C** PLACE VALUES IN ATTRIBUTES ON AIRCRAFT AND INTO NEXT NODE
C**
C** PLACE VALUES IN ATTRIBUTES ON AIRCRAFT AND INTO NEXT NODE
C**
UPON COMPLETION OF PREFLIGHT: THE AIRCRAFT AWAIT A FORMATION TAKEOFF.

GET AIRCRAFT NUMBER

I = IFIX(CATRB(3) + 0.1)

GET MX TEAM NUMBER WORKING ON AIRCRAFT

J = IFIX(CATRB(4) + 0.1)

PRINT: TIME IS \"THW\", AIRCRAFT \"1\", PREFLIGHT\n
DTH = 600.0

INCREASE HEAT BUILDUP ON MX TEAM

RT = CATRB(I) + AI(1)

E = CATRB(I) + AI(1)

INCREASE WORK TIME ON MX TEAM

W(J) = W(J) + AS(I)

CHECK NODE NUMBER IN SUBNETWORK

SUM = NODCV(28, J)

IF (RT.CT.70.3) THEN

IF HEAT BUILDUP EXCEEDS 70, INCREASE

TIME TO COMPLETE TASK BY INCLUDING

REST PERIOD: AND DECREASE HEAT BUILDUP

S = AS(I) + 48.19

TM = RT - 48.0

V = E - 48.0

PLACE VALUES IN ATTRIBUTES ON AIRCRAFT

CALL PATRB(V,7)

CALL PATRB(WK,6)

CALL GETAT(RATT)

PLACE TRANSACTION INTO SYSTEM AT NEXT NODE

CALL PT(ISUM, S, THW, RATT)

GET CURRENT TIME

A12(J) = THW + S

SET HEAT BUILDUP VALUES FOR START OF NEXT CYCLE

AIS(J) = TM

A16(J) = V

RETURN

IF REST IS NOT REQUIRED

PLACE VALUES IN ATTRIBUTES ON AIRCRAFT

CALL PATRB(R, 6)

CALL PATRB(S, 7)

CALL GETAT(RATT)

PLACE TRANSACTION INTO SYSTEM AT NEXT NODE

CALL PT(ISUM, AS(I), THW, RATT)

GET CURRENT TIME

A12(J) = THW + AS(I)

SET HEAT BUILDUP VALUES FOR START OF NEXT CYCLE

AIS(J) = RT

A16(J) = E

RETURN
**C4**

AIRCRAFT ARE AWAITING REFUELING

BY THE FUEL TRUCKS.

12

I = IIFIX(CATRB(3)+0.1)

J = IIFIX(CATRB(4)+0.1)

DTIM = 0.0

A13(J) = THW

RETURN

C4*

C4

A FUEL TRUCK IS AVAILABLE

REFUELING STARTS AND THERMAL STRESS

IS REDUCED ON THE MX TEAMS BY THE

TIME REQUIRED TO FUEL THE AIRCRAFT

AND THE TIME SPENT AWAITING REFUELING.

THE NUMBER OF TRUCKS AVAILABLE IS

SET IN ACTIVITY 37.

C4*

GET AIRCRAFT NUMBER

I = IIFIX(CATRB(3) + 3.1)

GET MX TEAM NUMBER WORKING ON AIRCRAFT

J = IIFIX(CATRB(4)+0.1)

PRINT *, 'TIME IS ', THW, ' AIRCRAFT ', I, ' FUELED'

DTIM = 0.0

C4*

FIND TIME THE AIRCRAFT WAITED PRIOR TO REFUELING

A14(J) = THW - A13(J)

C4*

GET HEAT BUILDUP VALUES FOR MX TEAM

RT = CATRB(6)

E = CATRB(7)

C4*

REDUCE VALUES OF HEAT BUILDUP ON MX TEAM

C4*

BY PRODUCT OF TIME AIRCRAFT AWAITED REFUELING

AND TIME REQUIRED FOR REFUELING.

TH = RT - A10(I) - 0.25*THW(J)

V = E - A18(I) - 0.25*A14(J)

C4*

PLACE VALUES IN ATTRIBUTES ON AIRCRAFT

CALL PATRP(IN,6)

CALL PATRP(IN,7)

CALL C3T3AT(RATT)

C4*

PLACE TRANSACTION INTO SYSTEM AT NODE 39

CALL PTINT39, A10(I), THW, RATT

RETURN

C4
THIS STOPS ALL ACTIVITIES THAT THE UNIT IS DOING IN THE MODEL AND MAKES THE TEAM AVAILABLE FOR REASSIGNMENT TO ANOTHER AIRCRAFT.

GET AIRCRAFT NUMBER

GET MX TEAM NUMBER WORKING ON AIRCRAFT

KEEP TRACK OF THE FUEL TRUCKS.

EACH TRUCK IS ABLE TO FUEL TWO AIRCRAFT PRIOR TO IT NEEDING REFUELING.

STOP ARTIFICIAL ACTIVITIES

GET AIRCRAFT NUMBER

GET MX TEAM NUMBER WORKING ON AIRCRAFT

KEEPS TRACK OF AIRCRAFT DESTROYED AND THE TIME OF OCCURRENCE. PROBABILITY IS SET IN CGERT MODEL, ACTIVITY 45-46.

GET AIRCRAFT NUMBER

MAKE TEAM AVAILABLE FOR OTHER AIRCRAFT.
**C++**

\*\* Maintain track of aircraft damaged and the time of occurrence. Probability \*\*

\*\* Set initial model, activity 45,47. \*\*

\*\* GET AIRCRAFT NUMBER \*\*

15 \#=FIX(GATRB(3)+0.1)

\*\* GET FLIGHT TIME \*\*

\*\* RT=EX(1) \*\*

\*\* PRINT* 'AIRCRAFT \#1' damaged and landed at time \#'s \*\*

\*\* DARK=DARK+1 \*\*

\*\* SET ACTIVITY TIME TO FLIGHT TIME AND HX DELAY \*\*

\*\* OF 240 MINUTES TO FIX AIRCRAFT \*\*

\*\* DTIM=240.0+RT \*\*

\*\* RETURN \*\*

\*\* AN AIR ABORT IS ANY FLIGHT THAT LASTS \*\*

\*\* LESS THAN 15 MINUTES. THESE FLIGHTS \*\*

\*\* SHOULD BE SUBTRACTED FROM THE TRANS- \*\*

\*\* ACTION PASSAGES OF MODE 5 TO OBTAIN \*\*

\*\* A MORE ACCURATE COUNT OF SUCCESSFUL \*\*

\*\* SORTIES. \*\*

\*\* \*\*

\*\* GET FLIGHT TIME \*\*

16 \*\* RT=EX(1) \*\*

\*\* GET AIRCRAFT NUMBER \*\*

1=FIX(GATRB(3)+0.1)

\*\* SET ACTIVITY TIME TO FLIGHT TIME \*\*

\*\* DTIM=RT \*\*

\*\* IF(RT.LT.15.) THEN \*\*

\*\* IF AIRCRAFT AIR ABORTS, SET ACTIVITY TIME TO \*\*

\*\* FLIGHT TIME PLUS MAINT DELAY OF 240 MINUTES \*\*

\*\* TO FIX AIRCRAFT \*\*

\*\* DTIM=240.0+RT \*\*

\*\* RETURN \*\*

\*\* END \*\*

\*\* SUBROUTINE UD \*\*

\*\* COMMON/VR/NOE,NTFBU(500),NACZ(500),HREL(500),HREL2(500), \*\*

\*\* +KMG,NRCHS,HTC(500),PARAN(1000),TSEG,TKN \*\*


\*\* +W(16),I(16) \*\*
COMMON/VAR/1,J,K,L,N,X,AIRAB,DEST,DANG,FLTS
REAL LO
INTEGER PLUS,SUM,X,K1,K2,K3,K4,K5,K6,NUMB+
+AIRAB,DEST,DANG,FLTS
PRINT
PRINT,'*******************************'
PRINT
PRINT,'THE NUMBER OF FLTS GENERATED IS ',FLTS
PRINT,'THE NUMBER OF AIR ABORTS IS ',AIRAB
PRINT,'THE NUMBER OF DESTROYED AIRCRAFT IS ',DEST
PRINT,'THE NUMBER OF DAMAGED AIRCRAFT IS ',DANG
PRINT
DO 300 I=1,N
PRINT,'THE WORK TIME FOR TEAM ',I,' IS ',N(I)
300 CONTINUE
PRINT
PRINT,'*******************************'
RETURN
END
START

GENERATE AIRCRAFT

FIRST LANDING

ASSIGN WING TANKS

ASSIGN NO WING TANKS

AIRCRAFT LAND

HOTPIT

AIRCRAFT; FUELTRUCK FUELED

HOTPIT FILLED FOR AIRCRAFT

HOTPIT FILLED FOR FUELTRUCK

REFUEL FUELTRUCK

DATA ON FUELTRUCKS

RETURN FUEL TRUCKS

END LINE

TAXI TO RAMP

AIRWAIT TOW TRUCK

AIRCRAFT IN REFINERY

AIRWAIT NX TEAM

END LINE

NX TEAM I

CHECK AIRCRAFT STATUS

CHECK IF FUELED

CHECK IF NEED WING TANKS

TANKS ON NOT FUELED

PUT WING TANKS ON

TAKE WING TANKS OFF

LEAVE ALONE

LINK AWAITING REFUELING

MISSILES UPLOADED

LINK PREFLIGHT

CONNECT TO LINK

CONNECT TO LINK

CONNECT TO LINK
AIRPLANE LANDING

AIRPLANE DESTROYED

AIRPLANE DAMAGED

END OF HOPEL

END

TAXI TO HOT PIT

TAXI TO HOT PIT

HOT PIT REFUEL

TAXI TO SHELTER

DRIVE TRUCK

TOW

AERO T

RELOAD

TANKS

MISSILES

PRE FLT

FUEL

ACT 42:1 CO 235, 33 START

ACT 1:1 CO 8, 11 PLANES, 1 (9) A3 LE 23

ACT 1:1 9 CO 8, 2/WH 21, (9) A3 LE 24

ACT 43:3 LO 2, 24, 0.5

ACT 43:1 LO 2, 142, 14

ACT 43:1 (7) 24

ACT 1:6 5 CO 8, 172, 24, (9) A1 G1 1.4

ACT 1:6 7 LO 4, 11 FUEL

ACT 1:6 9 CO 27, 9, 1 (9) A5 GE 1.4

ACT 1:5 14 CO 5, 824, (9) A5 LT 1.4

ACT 1:3 16 CO 6, 110, 1 (9) A5 LT 1.4

ACT 1:9 10 CO 8, 142

ACT 1:7 16 CO 6, 132, 1 (9) A5 GE 1.4

ACT 1:5 11 LO 5, 12, 1 (9) A5 LT 1.4

ACT 1:6 11 LO 6, 15, 4, 24 DRI 

ACT 1:1 12 16, 14, 1

ACT 1:2 49 US 13, 41

ACT 1:9 14 LO 5, 17

ACT 1:4 16 LO 7, 18, 24

ACT 1:6 51 US 3, 68, 3 US 16

ACT 1:5 32 CO 2, 16, 1, 1 DECEND 13

ACT 1:4 29 US 18, 36

ACT 1:3 17 US 11

ACT 1:3 38 2 CO 600, 42, 1

SET FUEL TRUCKS AVAILABLE

008740

008750

008760

008770

008780

008790

008800

008810

008820

008830

008840

008850

008860

008870

008880

008890

008900

008910

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009010

009020

009030

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009070
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APPENDIX D
SAMPLE OUTPUT

The sample output gives a listing of all events that transpire for the last four hours of the model day. The listing shows these occurrences based on time. The flow of an aircraft can be followed throughout its maintenance cycle. Fuel trucks are listed as to the time they are fueled and the number of the last aircraft they refueled. The amount of time the maintenance teams have worked is also followed.

The final section of output gives a listing of the number of flights, a flight consists of two aircraft, the number of air aborts, and destroyed and damaged aircraft. The total amount of time each team has worked is also listed.
AIRCRAFT 11 PLACED IN NODE 5 AT 1201.73871835 02/0520
TIME IS 1203.47665417 FUEL TRUCK 22 6 02/0030
TIME IS 1207.49558947 AIRCRAFT 31 PREFLIGHT 02/0040
AIRCRAFT 13 PLACED IN NODE 5 AT 1210.24375292 02/0050
MAINT TEAM 15 WORKED 273.9142353847 TO THIS POINT. 02/0060
AIRCRAFT 4 PLACED IN NODE 90/15 AT 1212.969839142 02/0070
TIME IS 1212.969839142 AIRCRAFT 31. 02/0080
AIRCRAFT 31 AIR GEAR AND LANDED AT 1223.668482255 02/0090
TIME IS 1212.969839142 AIRCRAFT 4 HAS NO WING TANKS 02/0100
TIME IS 1215.984508447 AIRCRAFT 23 MISSILES UPLOAD 02/0110
TIME IS 1218.086476891 AIRCRAFT 30 PREFLIGHT 02/0120
AIRCRAFT 15 PLACED IN NODE 5 AT 1221.301557593 02/0130
TIME IS 1222.067277366 AIRCRAFT 24 FUELED 02/0140
AIRCRAFT 37 PLACED IN NODE 5 AT 1224.151004393 02/0150
MAINT TEAM 2 WORKED 317.6325769493 TO THIS POINT. 02/0160
AIRCRAFT 28 PLACED IN NODE 90/2 AT 1224.611818752 02/0170
TIME IS 1224.611818752 AIRCRAFT 30. 02/0180
TIME IS 1224.611818752 AIRCRAFT 23 HAS WING TANKS 02/0190
TIME IS 1225.899468017 AIRCRAFT 21 PREFLIGHT 02/0200
TIME IS 1226.049291219 AIRCRAFT 45 FUELED 02/0210
TIME IS 1227.265176906 AIRCRAFT 10 FUELED 02/0220
TIME IS 1228.4263801 AIRCRAFT 39 PREFLIGHT 02/0230
MAINT TEAM 11 WORKED 272.7972672351 TO THIS POINT. 02/0240
AIRCRAFT 8 PLACED IN NODE 99/11 AT 1231.629432757 02/0250
TIME IS 1231.629432757 AIRCRAFT 21. 02/0260
TIME IS 1231.649634721 AIRCRAFT 8 HAS NO WING TANKS 02/0270
TIME IS 1234.6455091678 AIRCRAFT 23 MISSILES UPLOAD 02/0280
MAINT TEAM 8 WORKED 312.6447307146 TO THIS POINT. 02/0290
AIRCRAFT 12 PLACED IN NODE 99/8 AT 1234.822952468 02/0300
TIME IS 1234.822952468 AIRCRAFT 30. 02/0310
TIME IS 1234.822952468 AIRCRAFT 12 HAS WING TANKS 02/0320
TIME IS 1237.006459588 AIRCRAFT 24 MISSILES UPLOAD 02/0330
AIRCRAFT 26 PLACED IN NODE 5 AT 1237.467252243 02/0340
TIME IS 1237.467252243 AIRCRAFT 48 MISSILES UPLOAD 02/0350
TIME IS 1237.467252243 AIRCRAFT 45 MISSILES UPLOAD 02/0360
TIME IS 1237.970681352 AIRCRAFT 8 TANKS PUT ON 02/0370
TIME IS 1237.980759956 AIRCRAFT 10 MISSILES UPLOAD 02/0380
TIME IS 1237.991285411 AIRCRAFT 12 MISSILES UPLOAD 02/0390
AIRCRAFT 30 PLACED IN NODE 5 AT 1247.78435254 02/0400
TIME IS 1247.78435254 AIRCRAFT 30 02/0410
TIME IS 1248.94806913 FUEL TRUCK 19 13 02/0420
TIME IS 1248.94806913 AIRCRAFT 41 FUELED 02/0430
TIME IS 1248.94806913 FUEL TRUCK 24 5 02/0440
AIRCRAFT 7 PLACED IN NODE 5 AT 1248.431463194 02/0450
TIME IS 1248.94806913 AIRCRAFT 24 TANKS PUT ON 02/0460
TIME IS 1248.94806913 AIRCRAFT 4 TANKS PUT ON 02/0470
TIME IS 1248.94806913 AIRCRAFT 11 MISSILES UPLOAD 02/0480
TIME IS 1248.94806913 AIRCRAFT 4 FUELTRUCK 1 PREFLIGHT 02/0490
AIRCRAFT 29 PLACED IN NODE 5 AT 1248.427462299 02/0500
TIME IS 1248.427462299 AIRCRAFT 29 FUELED 02/0510
TIME IS 1248.427462299 AIRCRAFT 4 FUELED 02/0520
IN TEAM 1 WORKED 355.2 44473674 TO THIS POINT.
AIRCRAFT 4 PLACED IN NODE 98/4 AT 1288.73451453
TIME IS 1288.73451453 ACF 1.
TIME IS 1288.73451453 ACF 4 HAS KING TANKS
TIME IS 1288.73451453 ACF 23 MISSILES UPLOAD
TIME IS 1288.73451453 ACF 33 PREFLIGHT
TIME IS 1288.73451453 ACF 4 MISSILES UPLOAD
TIME IS 1288.73451453 ACF 8 FUELED
TIME IS 1288.73451453 ACF 22 PREFLIGHT
MAINT TEAM 1 WORKED 384.3353671436 TO THIS POINT.
AIRCRAFT 32 PLACED IN NODE 99/4 AT 1297.221249182
TIME IS 1297.221249182 ACF 21.
TIME IS 1297.221249182 ACF 32 HAS KING TANKS
MAINT TEAM 6 WORKED 322.363354238 TO THIS POINT.
AIRCRAFT 17 PLACED IN NODE 99/4 AT 1312.36677251
TIME IS 1312.36677251 ACF 22.
TIME IS 1312.36677251 ACF 17 HAS KING TANKS
TIME IS 1312.36677251 ACF 24 PREFLIGHT
TIME IS 1312.36677251 FUEL TRUCK 28 2
TIME IS 1312.36677251 AIRCRAFT 3 PREFLIGHT
TIME IS 1312.36677251 AIRCRAFT 4 TANKS COMING OFF
AIRCRAFT 32 PLACED IN NODE 5 AT 1321.69758683
TIME IS 1321.69758683 ACF 23 MISSILES UPLOAD
AIRCRAFT 43 PLACED IN NODE 5 AT 1324.225968537
AIRCRAFT 21 PLACED IN NODE 5 AT 1331.46854638
AIRCRAFT 47 PLACED IN NODE 5 AT 1332.59633958
AIRCRAFT 33 PLACED IN NODE 5 AT 1342.07985724
AIRCRAFT 39 PLACED IN NODE 5 AT 1347.076373279
TIME IS 1347.076373279 FUEL TRUCK 8 11
AIRCRAFT 35 PLACED IN NODE 5 AT 1347.52413735
TIME IS 1347.52413735 ACF 23 PREFLIGHT
AIRCRAFT 33 PLACED IN NODE 5 AT 1347.53575431
AIRCRAFT 46 MISSILES UPLOAD
TIME IS 1347.53575431 AIRCRAFT 6 WORKED 322.42254937 TO THIS POINT.
AIRCRAFT 19 PLACED IN NODE 99/4 AT 1360.90759322
TIME IS 1360.90759322 ACF 36.
TIME IS 1360.90759322 ACF 19 HAS KING TANKS
TIME IS 1360.90759322 ACF 41 PREFLIGHT
AIRCRAFT 24 PLACED IN NODE 5 AT 1365.09075421
AIRCRAFT 25 PLACED IN NODE 5 AT 1365.59633958
TIME IS 1362.045205689 AIRCRAFT 25 PREFLIGHT
AIRCRAFT 34 PLACED IN NODE 5 AT 1366.20232109
TIME IS 1366.20232109 AIRCRAFT 45 PREFLIGHT
MAINT TEAM 12 WORKED 313.195663268 TO THIS POINT.
AIRCRAFT 42 PLACED IN NODE 99/12 AT 1367.971898729
TIME IS 1367.971898729 ACF 26.
TIME IS 1367.971898729 ACF 42 HAS NO KING TANKS
TIME IS 1367.971898729 ACF 49 PREFLIGHT
TIME IS 1367.971898729 ACF 17 MISSILES UPLOAD
MAINT TEAM 5 WORKED 349.335649391 TO THIS POINT.
AIRCRAFT 5 PLACED IN NODE 99/5 AT 1371.27289479
TIME IS 1371.27289479 ACF 24.
TIME IS 1371.27289479 AIRCRAFT 5 HAS KING TANKS
AIRCRAFT 1 PLACED IN NODE 5 AT 1371.487184238
TIME IS 1371.487184238
MAINT TEAM 7 WORKED 327.1534896971 TO THIS POINT.
AIRCRAFT 11 PLACED IN NODE 90/17 AT 1371.64869441
TIME IS 1371.64069441 ACIRF 45.
AIRCRAFT 45 AIR ABORT AND LANDED AT 1389.351596718
TIME IS 1371.64069441 AIRCRAFT 11 HAS NO TANKS
MAINT TEAM 3 WORKED 306.298622292 TO THIS POINT.
AIRCRAFT 13 PLACED IN NODE 90/3 AT 1372.49912314
TIME IS 1372.49912314 ACIRF 3.
TIME IS 1372.49912314 AIRCRAFT 15 HAS NO TANKS
MAINT TEAM 14 WORKED 343.905419477 TO THIS POINT.
AIRCRAFT 15 PLACED IN NODE 90/14 AT 1373.02753915
TIME IS 1373.02753915 ACIRF 49.
TIME IS 1373.02753915 AIRCRAFT 15 HAS NO TANKS
AIRCRAFT 15 DESTROYED AT TIME 1373.9712199
MAINT TEAM 9 WORKED 310.471138746 TO THIS POINT.
AIRCRAFT 37 PLACED IN NODE 90/13 AT 1377.803377659
TIME IS 1377.803377659 ACIRF 10.
TIME IS 1377.803377659 AIRCRAFT 37 HAS NO TANKS
MAINT TEAM 8 WORKED 341.254696666 TO THIS POINT.
AIRCRAFT 38 PLACED IN NODE 90/8 AT 1379.8071822
TIME IS 1379.8071822 ACIRF 12.
TIME IS 1379.8071822 AIRCRAFT 38 HAS NO TANKS
TIME IS 1379.8071822 AIRCRAFT 2 PLACED IN NODE 90/7.
TIME IS 1379.8071822 AIRCRAFT 2 PREFLIGHT.
TIME IS 1381.864226565 AIRCRAFT 15 FUELED.
TIME IS 1383.49781879 AIRCRAFT 13 TANKS PUT ON.
TIME IS 1383.83705101 AIRCRAFT 32 FUELED.
TIME IS 1385.643207442 AIRCRAFT 27 MISILES UPLOAD.
MAINT TEAM 3 WORKED 336.229119821 TO THIS POINT.
AIRCRAFT 25 PLACED IN NODE 39/9 AT 1385.987411337
TIME IS 1385.987411337 ACIRF 2.
TIME IS 1385.987411337 AIRCRAFT 26 HAS NO TANKS.
AIRCRAFT 9 PLACED IN NODE 5 AT 1390.24396519.
AIRCRAFT 16 PLACED IN NODE 5 AT 1395.16979306.
TIME IS 1397.224127736 AIRCRAFT 15 MISILES UPLOAD.
TIME IS 1398.9859691 AIRCRAFT 32 MISILES UPLOAD.
AIRCRAFT 23 PLACED IN NODE 5 AT 1398.593972667.
AIRCRAFT 12 PLACED IN NODE 5 AT 1399.569997777.
TIME IS 1403.78720492 AIRCRAFT 6 PREFLIGHT.
AIRCRAFT 44 PLACED IN NODE 5 AT 1405.88292524.
MAINT TEAM 10 WORKED 358.8437441442 TO THIS POINT.
AIRCRAFT 7 PLACED IN NODE 90/10 AT 1405.439525619.
TIME IS 1405.439525619 ACIRF 41.
TIME IS 1405.439525619 AIRCRAFT 7 HAS NO TANKS.
MAINT TEAM 11 WORKED 327.885586443 TO THIS POINT.
AIRCRAFT 29 PLACED IN NODE 90/11 AT 1410.579843137.
TIME IS 1410.579843137 ACIRF 8.
TIME IS 1410.579843137 AIRCRAFT 29 HAS NO TANKS.
TIME IS 1411.26628433 AIRCRAFT 19 FUELED.
TIME IS 1411.26628433 ACIRF 19.
TIME IS 1411.26628433 ACIRF 19.
TIME IS 1411.26628433 ACIRF 19.
TIME IS 1411.26628433 ACIRF 19.
TIME IS 14:15.362227879 AIRCRAFT 7 FUELED
TIME IS 14:16.336316362 AIRCRAFT 19 MISSILES UPLOAD
TIME IS 14:26.49638946 AIRCRAFT 28 PREFLIGHT
TIME IS 14:27.14654528 AIRCRAFT 7 MISSILES UPLOAD
TIME IS 14:28.593359881 AIRCRAFT 42 TANKS PUT ON
TIME IS 14:29.452225219 AIRCRAFT 11 FUELED
TIME IS 14:29.97043986 FUEL TRUCK 32 1
TIME IS 14:30.67420748 AIRCRAFT 5 MISSILES UPLOAD

TIME IS 14:28.328301969 AIROCRAFT 25 PREFLIGHT
TIME IS 14:29.142679528 AIRCRAFT 7 TANKS PUT ON
TIME IS 14:29.987295791 AIRCRAFT 11 FUELED
TIME IS 14:30.42839586 FUEL TRUCK 32 1
TIME IS 14:31.67420748 AIRCRAFT 5 MISSILES UPLOAD

TIME IS 14:29.142679528 MAINT TEAM 2 WORKED 345.965675056 TO THIS POINT.
AIRCRAFT 43 PLACED IN NODE 99/2 AT 1432.436235866
TIME IS 14:31.48225586 AIRCRAFT 28 29
AIRCRAFT 28 AIR ABORT AND LANDED AT 1441.238703907
TIME IS 14:32.168235866 AIRCRAFT 43 HAS WING TANKS
TIME IS 14:32.63711282 AIRCRAFT 4 PREFLIGHT
MAINT TEAM 15 WORKED 339.339571886 TO THIS POINT.
AIRCRAFT 21 PLACED IN NODE 99/15 AT 1430.364576145
TIME IS 14:32.345476145 AIRCRAFT 11
TIME IS 14:33.34576145 AIRCRAFT 21 HAS WING TANKS

THE NUMBER OF FLTS GENERATED IS 49
THE NUMBER OF AIR ABORTS IS 27
THE NUMBER OF DESTROYED AIRCRAFT IS 5
THE NUMBER OF DAMAGED AIRCRAFT IS 14

THE WORK TIME FOR TEAM 1 IS 368.0498174765
THE WORK TIME FOR TEAM 2 IS 377.2115815407
THE WORK TIME FOR TEAM 3 IS 335.336965999
THE WORK TIME FOR TEAM 4 IS 399.403354386
THE WORK TIME FOR TEAM 5 IS 351.9722924462
THE WORK TIME FOR TEAM 6 IS 364.7399281962
THE WORK TIME FOR TEAM 7 IS 336.2216235554
THE WORK TIME FOR TEAM 8 IS 370.745595663
THE WORK TIME FOR TEAM 9 IS 338.6120925858
THE WORK TIME FOR TEAM 10 IS 396.6487444678
THE WORK TIME FOR TEAM 11 IS 351.972997414
THE WORK TIME FOR TEAM 12 IS 342.8210533424
THE WORK TIME FOR TEAM 13 IS 351.336931627
THE WORK TIME FOR TEAM 14 IS 356.2815431149
THE WORK TIME FOR TEAM 15 IS 351.1356489991
THE WORK TIME FOR TEAM 16 IS 376.9256471523
APPENDIX E

CHEMICAL DEFENCE ENSEMBLES

The material contained in this appendix came from two technical orders. The information on the Aircrew Chemical Defense Ensemble is from TO 14P3 - 1 - 131, and the information on the Groundcrew Ensemble is from TO 14P3 - 1 - 141. A majority of the material presented is directly quoted from these documents, therefore, quotations are not annotated or footnoted separately.
Aircrew Chemical Defense Ensemble

The complete Aircrew Chemical Defense Ensemble consists of thirteen items. When worn together they protect users against toxic chemical agents. The diagrams of these items are shown in Figure 13. The numbers in the figure correspond to the numbered items described below.

1. **Protective Hood, HGU-41/P.** The HGU-41/P hood protects the head, neck, and shoulders. The hood is furnished in one size only. It has elastic around the neck to give a snug fit. Elastic webbing is used to give a snug fit around the face and visor portion of a CBO mask. Slide buckles are used to adjust the length of the underarm straps. Hook and pile fastener tape is used to close the front opening.

2. **Flyer's Helmet, HGU-39/P.** The HGU-39/P is a plastic shell with an energy-absorbing liner. The helmet is coated with white epoxy paint. It comes in Regular and Extra Large sizes, and provides head protection. An adjustable suspension and headband assembly inside the shell is used to improve fit. An adjustable retention system assembly is used to mount the ear cup assembly and chin strap. The ear assembly is used to hold the earphones.

3. **CBO Mask, MBU-13/P.** The CBO mask is a full face silicone mask with a butyl hose. The mask is used both on
the ground and in flight. It attaches to the filter assembly and to the aircraft radio system. It protects the eyes, face, nose, throat, and lungs from chemical agents. It has a rigid plastic faceplate, adjustable head harness, oxygen hose, nose cup, pressure compensated valves, microphone, and tabs for mounting eyeglasses.

4. **COBO Mask Filter Assembly, CRU-80/P.** The COBO Mask Filter Assembly is a butyl rubber flat pack with two M13A2 filter elements inside. A modified CRU-60/P assembly is mounted to the flat pack. The filter assembly can be used in air, or connected to an aircraft oxygen system or a bailout bottle, as needed. It cannot be used to protect against ammonia or carbon monoxide fumes, or in an oxygen deficient atmosphere.

5. **Suspension Strap Assembly PN 854-17 or EC-100-815-M1.** The suspension strap assembly (also called a Waist/Shoulder Strap Assembly) is an adjustable nylon or cotton strap with snap hooks on both ends. For crew members who do not wear parachute harnesses, these straps hold the CRU-80/P filter assembly in place.

6. **Filter Elements Type M13A2.** The M13A2 filter element set is used with the CRU-80/P filter assembly. Incoming air is routed through the filtering materials of the element to the COBO mask inlet port.
7. **White Cotton Undershirt and Cotton Drawers.** These items are 100% cotton. These items are worn under the flyer's undercoverall to prevent skin irritation from the charcoal lining and to limit perspiration taint of the coverall.

8. **Flyer's Undercoverall, Chemical Protective.** This one piece coverall is made from a non-woven fabric. The fabric is treated with a fluorocherical which protects from organic chemicals. The inner surface is coated with activated charcoal.

9. **Plastic Tube Socks.** The plastic tube socks protect the feet from chemical agents. They are made from 4 mil polyethylene. They are worn over cotton socks inside the flyer's boot.

10. **Plastic Overboots.** The overboots are worn over the flyer's boot. They protect the user from contamination enroute from the shelter and the aircraft. They are removed before entering the aircraft or shelter.

11. **Plastic Disposable Cape.** The disposable cape is a large plastic bag worn over the body. It protects the user from contamination enroute from the shelter and the aircraft. It is removed before entering the aircraft or shelter.

12. **Gloves, Chemical Protective and White Cotton Inserts.** The chemical protective gloves protect the hands from chemical agents. They are made of neoprene, and are
17 mil thick and 12 inches long. They are worn over optional absorbant white knit cotton inserts. The neoprene gloves can be worn over or under the Nomex flyer's gloves at the option of the MAJCOM.

13. Optional Skull Cap. This optional item keeps the user's hair away from the mask sealing area, preventing leaks. The cap also helps to prevent hot spots.
Fig. 13 Aircrew Chemical Defense Ensemble
The Groundcrew Ensemble will be briefly described, and the purpose of the individual items. Figure E-2 shows the ensemble as it looks while being worn.

1. **M6A2 Protective Hood.** The M6A2 Hood is made of butyl rubber coated nylon cloth. It covers the head and neck of the wearer. When properly fitted to the protective mask, it provides protection against vapors, aerosols, and agent droplets. The hood does not protect against radiation. It will prevent the wearer from being contaminated with radioactive materials or dust. The hood covers the head without interfering with the combat helmet.

2. **NM17A1 Protective Mask.** The NM17A1 mask consists of the facepiece assembly, a pair of eyepieces outsers, and a mask carrier. It is a combat mask which protects the face, eyes, and respiratory tract of the wearer from field concentrations of chemical and biological agents.

3. **Chemical Protective Suit.** The Chemical Protective Suit (Overgarment) is a two-layer permeable fabric, jacket and trouser suit designed to be worn over long sleeve fatigues and normal underclothing. The garment outer layer is a nylon/cotton twill, dyed olive drab, and treated with a water resistant chemical. The inner layer is a charcoal impregnated polyurethane foam laminated to nylon tricot. It is intended primarily for protection of per-
sonnel exposed to vapors, aerosols, and liquid droplets of blister agents and nerve agents in the field.

4. Chemical Protective Footwear Covers. The Chemical Protective Footwear Cover (Overboot) is a butyl rubber boot. The footwear covers are designed to exclude contamination from the boots and feet, and provide a rapid means for removal of the contamination.

5. Chemical Protective Glove Set. The Chemical Protective Glove Set consists of a pair of 14.5 inch length, 0.025 inch thick butyl rubber outer gloves and a pair of thin white inner cotton gloves. They are designed to exclude contamination from the hands, and provide a rapid means for removal of contamination. Since the outer cover does not allow the passage of air, the cotton inner glove serves to absorb perspiration.
Fig. 14 Groundcrew Chemical Defense Ensemble
Data for Table VII

$H_0$: There is no difference between the treatments, the level of aircraft.

$H_1$: There is a difference.

With $\alpha = .05$, $X^2_{4,.95} = 9.488$

Reject $H_0$ if $T_4$ exceeds $X^2_{4,.95}$

$E(R_j) = 99$

$\text{Var}(R_j) = 128$

$T_4 = 51.722 > X^2_{4,.95}$ so reject $H_0$

$\left| R_j - R_1 \right| > 22.343$ with $\alpha = .05$ and $t_{1-.05} = 2.0$

$R_3$ and $R_4$ are not different. There is not a significant difference in aircraft generated with start-up conditions of 36 to 42 aircraft. There is a difference between all other levels.
Data for Table VIII

H₀: There is no difference between the treatments, the level of maintenance teams.

H₁: There is a difference.

With α = .05, $X^2_{8, .95} = 15.51$

Reject H₀ if $T_4$ exceeds $X^2_{8, .95}$

$E(R_j) = .95$

$Var (R_j) = 252.549$

$T_4 = 78.404 > X^2_{8, .95}$ so reject H₀

$|R_j - R_i| > 13.954$ with α = .05 and $t_{1-α_α} = 2.0$

$R_6$ and $R_7$ are not different. There is not a significant difference between having 13 or 14 maintenance teams available.
Data for Table X

$H_0$: There is no difference between the treatments, the level of aircraft.

$H_1$: There is a difference.

With $\alpha = .05$ $X^2_4, .95 = 9.488$

Reject $H_0$ if $T_4$ exceeds $X^2_4, .95$

$E(R_j) = 99$

Var $(R_j) = 131.467$

$T_4 = 73.36 > X^2_4, .95$ so reject $H_0$

$|R_j - R_1| > 11.4212$ with $\alpha = .05$ and $t_1-\alpha^2 = 2.0$

They are all different.
Data for Table XI

$H_0$: There is no difference between the treatments, the level of maintenance teams.

$H_1$: There is no difference.

With $\alpha = .05$, $X^2_{8, .95} = 15.51$

Reject $H_0$ if $T_4$ exceeds $X^2_{8, .95}$.

$E(R_j) = 95$

$\text{Var} (R_j) = 234.144$

$T_4 = 74.420 > X^2_{8, .95}$ so reject $H_0$

$|R_j - R_i| > 24.065$ with $\alpha = .05$ and $t_{1-\alpha/2} = 2.0$

The following treatments are not different:

$R_1$ and $R_2$; $R_2$ and $R_3$; $R_3$ and $R_4$; $R_4$ and $R_5$; $R_6$ to $R_8$; and $R_7$ to $R_9$. There is not a significant difference by increasing the level of maintenance teams by one except between 12 and 13 teams.
Vita

Captain Robert Edward Taft was born on 3 September, 1950 in Chester County, Pennsylvania. He graduated from high school in Virginia Beach, Virginia in 1968. Upon graduation from the U.S. Air Force Academy, with Bachelor of Science Degrees in History and Soviet Area Studies, he was commissioned in the U.S. Air Force. He attended Pilot Training at Vance AFB, Oklahoma and went on to fly MC-130 Special Operations Aircraft. He entered the School of Engineering, at the Air Force Institute of Technology, in the Strategic and Tactical Sciences Program in August of 1980.

Captain Taft is married to the former Miss Lara Edmonston of Moore, Oklahoma. They have a daughter, Jennifer, and a son, Robert, Jr.

Permanent address: 32 E. Casa Loma Dr.

Mary Esther, Florida 32569
AIRBASE OPERATIONS IN A CHEMICAL ENVIRONMENT

Robert E. Taft
Captain

Air Force Institute of Technology
AFIT/EN, Wright-Patterson AFB, OH 45433

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This thesis studies the effects of maintenance operations on a fighter base in a chemical environment. The desired goal is to determine if current manning for flight line maintenance is sufficient to support air operations.

A simulation model was developed to model the required tasks of maintenance in a wartime surge. The effects of wearing chemically protective clothing were incorporated to measure the results of operating with different numbers of aircraft and maintenance available. Analysis was performed using nonparametric
Item 20 (continued):

tests, due to the nature of the data. The results of these tests indicate that the present manning is not sufficient.

Material is presented in the appendices that shows the nature of improvements being made in the chemical defense ensembles and aircraft systems. These improvements may reduce the limitations that are present in the current equipment used.