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The F-15E Availability Model is an analysis tool used in the operational suitability evaluation of the F-15E aircraft during Developmental Test and Evaluation (DT&E) and Operational Test and Evaluation (OT&E). The model is programmed using FORTRAN and Simulation Language for Alternative Modeling (SLAM). The model is used to evaluate the availability, mission reliability, and maintainability of a mature F-15E squadron during various scenarios. Specific parameters being evaluated include mission capable rate, sortie generation rate, break rate, fix rate, and mean repair time. The simulation model uses the information gathered during the DT&E and OT&E combined with information on the operational Tactical Air Force environment. The model was verified and validated using F-15C/D MSIP aircraft data inputs by comparing the model output to actual field performance of the F-15C/D MSIP aircraft. Volume I includes the background, scenarios, computer language, description, assumptions, verification and validation. Volume II contains the appendices of logic flow charts, list of variables, computer code, output files and run instructions. Keywords:

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F-15E AVAILABILITY MODEL

VOLUME I

Captain Alice J. Chen
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June 1989

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LIST OF ACRONYMS

AFALC	Air Force Acquisition Logistics Center
AFOTEC	Air Force Operational Test and Evaluation Center
AFSC	Air Force Specialty Code
AGE	Aerospace Ground Equipment
AGS	Aircraft Generation Squadron
AIS	avionics intermediate station
BCM	baseline correlation matrix
BCOK	bench check okay
BLSS	base level self-sufficiency spares
BPO	basic postflight
BR	break rate
CND	can not duplicate
COMO	combat oriented maintenance organization
COND	condemn the shop replaceable unit
CONUS	continental United States
CRS	Component Repair Squadron
DT&E	Developmental Test and Evaluation
ECS	environmental control system
ECU	environmental control unit
EMS	Equipment Maintenance Squadron
FH	flying hours
FLIR	forward looking infrared
FMC	fully mission capable
FOM	facilitate other maintenance
FR	fix rate

HPO	hourly postflight
HQ	headquarters
HRR	high resolution radar
ICT	integrated combat turnaround
IR	infrared
JRMET	Joint Reliability and Maintainability Evaluation Team
LANTIRN	low altitude navigation targeting infrared for night
LCOM	logistics composite model
LRU	line replaceable unit
MC	mission capable rate
MDC	Maintenance Data Collection
MDT	mean down time
METS	Mobile Electronic Test Set
MRT	mean repair time
MMH	maintenance man-hours
MMH/FH	maintenance man-hours per flying hour
MSIP	multi-staged improvement program
MTBM	mean time between maintenance
MTBMTC	mean time between maintenance total corrective
NDI	non-destructive inspection
NMC	not mission capable
NMCR	not mission capable due to resources
NMCS	not mission capable due to supply
NRTS	not repairable this station
OT&E	Operational Test and Evaluation
PE	physical examination

PMC	partially mission capable
POS	peacetime operating supply
R&R	remove and replace
RIP	repair in place
RTS	repair this station
SGR	sortie generation rate
SLAM	Simulation Language for Alternative Modeling
SORD	System Operational Requirements Document
SPA	Manpower spaces per aircraft
SPO	system program office
SRU	shop replaceable unit
TAC	Tactical Air Command
TEWS	Tactical Electronic Warfare System
TFW	Tactical Fighter Wing
TISS	TEWS intermediate support station
WRSK	wartime readiness spares kit
WUC	work unit code

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1. INTRODUCTION

HQ AFOTEC/LG4A sponsored the development and use of the F-15E Availability Model. This model was developed because the existing F-15E Logistic Composite Model (LCOM) did not have the capability to address several key issues, break rate and fix rate which were required by HQ TAC. The purpose of the model is to evaluate the F-15E aircraft in terms of reliability, maintainability and availability. This document describes the model use, capabilities, and assumptions.

1.1. PURPOSE

The F-15E Availability Model is an analysis tool used in the operational suitability evaluation of the F-15E during combined Developmental Test and Evaluation and Operational Test and Evaluation (DT&E/OT&E) and the dedicated Operational Test and Evaluation (OT&E) phases. The model is used to evaluate the availability, mission reliability, and maintainability of a mature F-15E squadron during various scenarios. Availability is measured by mission capable (MC) rate and sortie generation rate (SGR). Mission reliability is measured by break rate (BR). Maintainability is measured by fix rate (FR), mean repair time (MRT), and manpower spaces per aircraft (SPA).

1.2. DEFINITIONS

Availability is the parameter that translates the reliability, maintainability, and logistics supportability characteristics of the system into a measure of interest to the user (7:110). It is the probability an item is in an operable and commitable state at any random time. A system is MC when it is capable of performing at least one of its assigned peacetime or wartime missions. MC rate is the percent of possessed time a system is MC. A system is fully mission capable (FMC) when it is capable of performing all of its assigned missions. A system is partially mission capable (PMC) when it cannot perform one or more of its assigned missions, but is capable of performing at least one of its assigned missions. MC rate is the sum of the FMC and PMC rates. SGR is the average number of sorties produced per aircraft in a defined operating day (9:1-38-1-41).

Mission reliability is the probability a system performs its required function(s) at a specified mission time or for a mission of a stated duration, given it was initially capable. BR is the percent of sorties flown during a specified period of time that returned with one or more previously working critical systems/subsystems inoperable (9:1-38-1-41). BR renders the aircraft not mission capable (NMC).

Maintainability is a measure of a system's ability to be repaired or restored to a specified condition under stated conditions. FR is the percent of aircraft returning from a sortie with a critical failure(s) which are repaired and returned to a MC status within a specified period of time (9:1-39-1-40), normally 2, 4, or 8 hours. The times used in FR includes the corrective maintenance and any associated delay times. It is the length of time the aircraft is down due to the critical failure. MRT is the total on-equipment corrective maintenance time accumulated during a specific period divided by the total number of on-equipment corrective maintenance actions completed during the same period. MRT considers active maintenance time only, it does not include delay times (7:155). SPA is the total manpower requirement in spaces per system to accomplish direct on- and off-equipment maintenance (9:1-40).

1.3. WHY USE A SIMULATION MODEL

The HQ TAC suitability requirements are based upon a mature system operated at a generic TAC base. Table 1.1 summarizes the differences between the test environment and the operational environment. Due to these differences, the suitability results measured in the test environment would not be an accurate assessment of the suitability of a F-15E squadron in the operational environment. However, certain parameters measured during test can be used toward the evaluation of the system in the operational environment. A special analysis tool is needed to organize and combine data measured during test with an outline of the intended operational environment of the system to evaluate how the system will perform in its intended environment.

TEST ENVIRONMENT	OPERATIONAL ENVIRONMENT
1-4 Aircraft	Over 24 aircraft per location
Test flying schedule	Operational flying schedule
Test pilots	Operational pilots
DT&E/OT&E sorties	Operational sorties
Maintenance personnel	Maintenance personnel
Contractor	Air Force personnel
Unconstrained	Constrained
Contractor supply support	Air Force supply support
Sparse support equipment	Support equipment available
Edwards AFB	CONUS and overseas TAC bases
Evolving system design	Mature system

Table 1.1. Environmental Differences

A computer simulation model is the special analysis tool used to incorporate test data with the "real world" to obtain a fair evaluation of the system. The model "simulates" the operational environment (flight schedules, scheduled and unscheduled maintenance, spares levels, available maintenance personnel) and uses the test data (failure rates, task times, reliability growth) as input to evaluate the system.

1.4. CAPABILITIES

The model was built to describe the major aspects of the HQ TAC operational environment. Similar flying schedules, sortie length, maintenance priorities, maintenance concepts, resource allocation per Air Force Specialty Code (AFSC), resource usage per AFSC, scheduled and unscheduled maintenance per four digit work unit code (WUC) are included. Mean time between maintenance (MTBM), and maintenance task times are inputs to the model and can be modified to perform sensitivity analyses. Unknowns in the model such as what time items fail are calculated in the model using MTBM data and probabilities.

Resources are specified by AFSC and in some cases skill level. The F-15E resource allocations and usage follow the intended maintenance concept (Rivet Workforce). Quantities of maintenance personnel of a certain AFSC can be decreased or increased to determine the effect on F-15E availability. Many other items, such as support equipment availability, spares levels, MTBM, and task times, may be varied to answer "what if" questions.

The model operates by beginning the simulation at time = 0, and permitting scheduled events to occur, such as scheduled maintenance and flying sorties. After each sortie, the failure clocks for each WUC are checked to see if a failure occurred on that sortie. If a failure did occur, the necessary maintenance is performed, the thruflight maintenance performed, and the aircraft is ready to fly again. Shop maintenance is also begun if needed. The simulation continues until the end of the simulation time is reached. The model actually "simulates" what occurs at a TAC flying squadron.

A random number generator is used to obtain random samples from a specific statistical distribution: triangular, normal, exponential, or lognormal. For each simulation of a scenario, at least five different random number seeds are used for the random number generator. The five simulation results are averaged to obtain the "final" results.

1.5. LIMITATIONS

The model does not consider perturbations in the every day operation of a TAC squadron, such as weather, deployments, working on the weekend during peacetime, and downdays. Rather, the model treats every day as an average day.

Maintenance is performed in parallel in the model. The model defines parallel maintenance as several maintenance actions being performed simultaneously. Currently the model does not perform serial maintenance - maintenance actions being performed one at a time, one after another. However, once TAC specifies some actions must be performed before other actions, such as maintenance on fuel systems performed before maintenance on electrical systems, the model can be easily modified to include this capability.

The model includes cannibalizations, but does not consider the deterioration of part reliability due to the additional maintenance actions. The model also does not halt maintenance tasks if a more critical action appears. Once a task is begun during a shift, it finishes the task or particular shift, whichever comes first.

Only major avionics intermediate test stations are modeled as support equipment. Availability of other support or test equipment, such as air conditioners, power carts, tools, ladders, jacks, etc., are assumed to be infinite.

Since the model uses WUC data to the four digit WUC, spares are assigned to corresponding four digit WUCs. The spares allocation levels are maintained such that the not mission capable due to supply (NMCS) rate is comparable to the F-15C/D Multi-Staged Improvement Program (MSIP) NMCS rate. However, spares which need to be increased to maintain the "normal" NMCS rate are documented and briefed with model results.

The model does not consider battle damage or attrition. The criteria used to evaluate the F-15E system does not include battle damage or attrition; this is the main reason it was not considered in the model. However, once the information is available it may be added to the model to answer more "what if" questions.

2. BACKGROUND

2.1. SYSTEM DESCRIPTION

The F-15E is an advanced two-place, 81000 pound maximum gross weight, aircraft designed for superiority over enemy surface and air threats. It is tailored for survivable and effective first pass weapon delivery. The F-15E also retains the basic F-15C MSIP capability for the air-to-air role; however, air-to-air performance characteristics may be limited by the increased basic aircraft weight compared to the F-15C. The aircraft shall be capable of performing air-to-surface and air-to-air missions day or night, in and under the weather. Major aircraft subsystems include low-altitude navigation and targeting infrared for night (LANTIRN) and the APG-70 high resolution radar (HRR). LANTIRN pods will provide manual and automatic terrain following, forward looking infrared (FLIR) video, precision infrared (IR) targeting, and laser ranging/designation for precise weapons deliveries day and night. The HRR will provide accurate target information for in-the-weather weapon deliveries. The F-15E will be equipped with conformal fuel tanks and will have a maneuvering capability of up to nine g's (4:i,3).

2.2. OPERATIONAL CONCEPT

The F-15E will be primarily employed for day/night, all-weather surface attack in air interdiction, offensive counterair, nuclear, and limited defense suppression roles. It will provide a day/night, all-weather capability to navigate at low altitude using manual or automatic terrain following. The target acquisition system should provide the capability to acquire, track, and destroy mobile or fixed ground targets, employing guided or unguided weapons.

The F-15E will also be used to augment dedicated air defense fighters in a defensive counter-air role.

The F-15E will have the capability to operate singly, in pairs, or in multiples. Specific tactics depend on theater, mission, targets, and threats at the time of employment (4:12-14).

2.3. MAINTENANCE CONCEPT

The maintenance organization will consist of a three-level combat oriented maintenance organization (COMO) concept (direct on-equipment, direct off-equipment, and depot). Direct off-equipment maintenance will include complete end-to-end checks, repair of line-replaceable units (LRUs), servicing, and calibration of F-15 common components. Repair beyond this scope will require depot level maintenance (4:14).

3. SCENARIOS EVALUATED

HQ TAC has specified the suitability parameters to be evaluated during certain scenarios. MC rate will be evaluated during a peacetime scenario. SGR will be evaluated during surge and sustained wartime scenarios. BR, FR, MRT and SPA will be evaluated during both the peacetime and wartime scenarios.

3.1. SCENARIO PARAMETERS

The scenarios modeled represent a mature squadron of F-15Es. The maintenance structure and operational flying schedule is representative of an F-15 base.

The following parameters and assumptions made in the model are common to the peacetime and wartime scenarios. There are 24 aircraft modeled. The F-15E has four primary missions: air-to-air, air-to-ground, air-to-ground nuclear, and dual role (both air-to-air and air-to-ground). Failure times, repairs and spares are aggregrated to no lower than the four digit WUC level. The total time to cannibalize a part is assumed to be twice the remove and replace (R&R) time of that part. The aircraft will fly singly or in pairs. The squadron has only F-15Es with typical manpower skill level allocations. Reliability growth techniques from MIL-HDBK-189 are applied to project the F-15E unique WUC's MTBM to maturity (approximately 55000 flight hours.) The projected values are input to the model to estimate mature aircraft performance.

3.2. PEACETIME SCENARIO

The peacetime simulation period is one year; the desired SGR is 1.05. Seventeen of the 24 aircraft are preflighted each day, including two aircraft preflighted as spares. There are three 8-hour shifts, five days per week. The first shift of the day is a servicing shift with a minimum of maintenance personnel. The spares levels include the peacetime operating stock (POS) and the wartime readiness spares kit (WRSK).

3.3. WARTIME SCENARIO

The wartime simulation period is 30 days divided into a 7 day surge period, and a 23 day sustained period. The desired SGR is classified (3). All aircraft are used each day, there are two 12-hour shifts, seven days per week. The spares levels include the POS, WRSK and base level self-sufficiency spares (BLSS).

4. COMPUTER LANGUAGE

The F-15E Availability Model was developed using the Simulation Language for Alternative Modeling (SLAM). SLAM is an advanced FORTRAN based language which allows the combination of network, discrete event, and continuous modeling capabilities. Models using SLAM can be developed from a process-interaction, next-event, or activity-scanning perspective (8:ix).

The F-15E Simulation Model uses both the process-interaction and next-event techniques. Due to the complexity of the model, the next-event (FORTRAN) portion of the model is more extensive than the process-interaction (network) portion.

The process-interaction technique uses statements which describe a sequence of events. These statements are used to model the flow of entities through the system. The network structure is made up of nodes and branches. These symbols model elements such as queues, servers, and decision points. The entities of the system, such as people or parts, flow through the network (8:68,69,73).

The network is used to represent the process the aircraft or LRU undergoes to be maintained.

The event-interaction technique concentrates on the events that can change the state of the system. Each event is executed according to a specific time-ordered sequence, with simulated time being advanced from one event to another (8:68-69). This technique uses FORTRAN to code the discrete event model. FORTRAN subroutines control certain changes associated with each event, which may include assigning attribute values, manipulating files, collecting statistics, and printing status or output reports.

The events are used for determining shift schedules, initiating scheduled maintenance, scheduling sorties, checking aircraft for failures after sorties, determining what maintenance needs to be done, allocating and freeing resources and spares, and calculating statistics.

5. NARRATIVE DESCRIPTION OF COMPUTER CODE

This section provides a narrative description of data files, network, and FORTRAN files used in the F-15E simulation model. It gives a basic overview of the contents of the model. Refer to the appendices for more detailed information.

Appendix C: Computer Code -- Input Files
Appendix D: Computer Code - Network
Appendix E: Computer Code - FORTRAN

5.1. DATA FILES

There are several different data files used in this model, F15EM.INP, F15ET.INP, and F15EDAT.FOR.

F15EM.INP contains WUC, mean time between maintenance total corrective (MTBMTC), POS, WRSK, and BLSS spares levels, and failure probabilities for air-to-air, air-to-ground, or dual role critical failures. During the OT&E test phase, the MTBMTC and probability data for F-15E unique WUCs change periodically. Approximately once every three months a Joint Reliability and Maintainability Evaluation Team (JRMET) is held at the test site. The JRMET consists of representatives from the AFOTEC test team, F-15 System Program Office (SPO), HQ AFOTEC, HQ TAC, AFFTC, AFALC and the contractor. The JRMET's responsibility is to ensure the maintenance data is correct, and to categorize each failure in terms of type and severity. The approved JRMET data is used to derive the F-15E unique mature MTBMTC and probability data used in this simulation, therefore this file may change after each JRMET. Similar data for the WUCs common to the F-15E and F-15C/D MSIP aircraft are obtained from mature F-15C/D MSIP operational data, ie., from the Maintenance Data Collection (MDC) System at the 33 Tactical Fighter Wing (TFW) at Eglin AFB, Florida.

F15ET.INP contains WUC, maintenance task type, percent of time the maintenance task type is performed, mean or mode, standard deviation, minimum and maximum maintenance times, type of statistical distribution to use on task times, and resources and quantity of those resources needed for each particular WUC. This input file uses MDC data for the F-15E and F-15C/D common WUCs and AFOTEC test team experienced judgment and JRMET data for F-15E unique WUCs. This data file will change as needed as additional information on the F-15E aircraft is obtained.

F15EDAT.FOR contains type of aircraft, phase times, resource availability, probability of breaks occurring, and ground abort times. It also includes number of aircraft, sorties, and shifts, and scenario type. Also sortie length, shift lengths, warmup times, time between individual sorties and sortie phases and desired SGR rate for warmup and regular portions of the simulation are included. This input file changes for each type of scenario simulated.

5.2. NETWORKS

The SLAM network file, F15.DAT, contains the maintenance networks, simulation run times and random number seeds. The simulation run times are changed for each scenario simulated, while the random number seeds are changed with every simulation describing a certain scenario.

Each entity, represented by an aircraft, LRU, or dummy job, is assigned attribute values in FORTRAN subroutines to describe maintenance task type, times, and resources needed. The entity then flows through the appropriate network. If resources are available, the entity continues in the network, if the resources are not available, the entity is filed in the appropriate queue to await availability of the resource. The networks check to see if maintenance needs to be continued through the next shift. If maintenance needs to be continued, the entity continues through the network again, or continues to the next applicable network or FORTRAN subroutine. After flowing through the network, the entity is filed in a queue, or terminated as appropriate. An entity would be terminated if it were a dummy job.

The networks describe different maintenance processes. There is a different network for each of the following types of maintenance: preflight, checking for failures, on-equipment maintenance, remove and replace, off-equipment maintenance, depot turnaround times, and cannibalization.

5.3. FORTRAN SUBROUTINES

Except for INTLC, the subroutines are listed alphabetically. Each subroutine description includes how the subroutine is called or scheduled, what the subroutine does, and what subroutines it calls or schedules.

INTLC - Is called internally by SLAM at the beginning of each run or simulation. It initializes manning and equipment allocations for each shift, calls READAT, sets initial values for parameters, assigns values from F15.FOR, calculates SPA, initializes spares levels, defines failure clocks for each WUC, and creates the planes. It then schedules the following subroutines: SHIFT - which calculates shift start and end times, FLYING - which schedules the sorties, WARMUP - which updates parameters from the warmup scenario to the main scenario parameters, and DISPLAY - which prints the daily values of various parameters. INTLC concludes by setting up the header on the output file F15.RPT.

ALLOK - Is called by the SLAM networks when resources are needed. It determines whether the people and equipment needed for each task are available. If resources are not available, it will store the maintenance task time in memory until the resources become available. It will terminate non-critical parallel maintenance entities if resources are not available. Critical maintenance entities are filed in the appropriate queue to wait for resources to become available. ALLOK is written to allocate a maximum of five different types of resources per task. The model can be expanded to handle more than five types of resources with little difficulty. The model has an option of permitting allocation of resources according to an availability probability. Choosing this option will cause subroutine REAV to be scheduled.

ALSPAR - Is called by the SLAM networks when a spare is needed. It determines whether the spare is available in supply. If the spare is available, the entity returns to the network to continue maintenance. If the spare is unavailable, the entity is filed into the NMCS queue, and subroutine CANN is called to check if cannibalization will produce the desirable spare.

BPO - Is scheduled by FLYING to occur after the last sortie of the day has launched. It checks the ready queues for aircraft that have flown that day which require basic postflight (BPO). If an aircraft needs BPO, the entity is sent to the network and then CHECK to determine the BPO task time.

CANN - Is scheduled by ALSPAR when a spare is needed. It compares the needed spare on the new NMCS aircraft with what is available on an aircraft in a NMCS status for more than one spare. If the needed spare is available, aircraft maintenance continues, and the other aircraft is filed in the NMCS queue needing another spare. If the needed spare is not available on multiple NMCS status aircraft, the spare is compared with what is available on an aircraft in a NMCS status for only one spare. If the needed spare is available, aircraft maintenance continues, the other aircraft is filed in the NMCS queue now needing two spares, and the "hangar queen" timer begins to ensure it does not stay a "hangar queen" for 21 days. At approximately day 19, subroutine INSPET is scheduled to check if maintenance on the hangar queen should be initiated. If the needed spare is not available, cannibalization is not possible.

CHCKCD - Is called by CHECK when the simulation is being run for F-15C/D MSIP aircraft, as for validation of the model. CHCKCD performs the same function as CHCKE.

CHCKE - Is called by CHECK when the simulation is being run for F-15E aircraft. CHCKE determines which file is appropriate for a MC aircraft after maintenance. CHCKE2 is called to reorganize failure storage arrays. If a sortie has just been flown, all WUCs will be checked to determine if a failure(s) has occurred. The criticality of each failure is determined using probabilities. After all WUCs have been checked, failures are totaled and the status of the aircraft is determined for the BR analysis. Next, the types of maintenance are determined. First priority is given to any dual role critical failure. These failures render the aircraft NMC and must go to maintenance. Second priority is given to a combination of air-to-air and air-to-ground failures which render the aircraft NMC. The type of maintenance performed in this case is determined by the previous status of the aircraft. For example, if the aircraft was air-to-air PMC (had air-to-ground critical failures) then maintenance will begin on the new air-to-air failures to produce an air-to-air PMC aircraft again. The logic behind this decision is to perform the least amount of maintenance to result in a PMC aircraft. Third priority is given to the case where only one type of failure is present. The maintenance decision again depends on the previous status of the aircraft. For example, if the aircraft was air-to-air PMC, then maintenance will begin if the new failures are all air-to-air critical failures since the plane is NMC. However, if the new failures are all air-to-ground type failures the aircraft is still air-to-air PMC and can be filed into the ready queue after postflight. Once the need for maintenance has been determined, subroutine PARAP will be scheduled to initiate the aircraft maintenance. The last priority is given to all non-critical failures. In this case, no maintenance is done and the aircraft is filed in the appropriate ready queue after postflight. This subroutine calls CHECK2 which determines the correct postflight to be done on the aircraft.

CHCKE2 - Is called by CHCKE after any maintenance is completed on the aircraft. It organizes the failures stored in the PWUC and PMAINT arrays. If an aircraft has 40 failures stored in its PWUC array (the maximum size of the PWUC array), then PARALL is called and parallel maintenance is begun to reduce the number of failures on that aircraft. HQ TAC stated an aircraft can have an "unlimited" number of non-critical failures. For the purpose of this model, that "unlimited" number is 40. A message is printed to notify the analyst if the number of non-critical failures exceeds 40.

CHECK - Is called from the network after a sortie or maintenance is completed. It checks first if the aircraft has just completed some type of scheduled maintenance, turnaround, BPO or phase inspection. If this is true, the aircraft is filed into the appropriate ready queue. If the aircraft is missing more than one spare, RELPLN is called to determine the correct queue in which the aircraft should be filed. Statistics on MDT, FR, and mean down time (MDT) are calculated. It then cleans up storage arrays if parallel unscheduled maintenance has just been completed. The subroutine then calls CHCKE or CHCKCD, depending on the type of simulation being run, to determine what maintenance to do next.

CHECK2 - Is called from either CHCKCD or CHCKE. After maintenance is completed or a sortie has flown with no failures, this subroutine checks which type of postflight is necessary for the aircraft. If the last sortie of the day has launched, BPO will begin. If not, thruflight will begin. This subroutine sends the aircraft entities to the network to begin postflight and also sends a dummy entity to queue 16. This dummy entity remains in the file 16 for the duration of the thruflight. The average number of dummy entities in the file become part of the MC rate calculation, since all aircraft in postflight maintenance are considered MC.

CLEAN - Is called from FLYING after the last sortie of the day has launched. It checks the ready queues for any aircraft with failures, and sends those aircraft to maintenance via the PARALL subroutine. This subroutine gets as many PMC aircraft to FMC or close to FMC status as possible without affecting the SGR.

DISPLAY - Is called from INTLC at the end of the first day of simulation. DISPLAY reschedules itself at the end of each day. It checks the values of parameters, then calculates and prints out the current value of number of sorties flown and missed, SGR, FMC, PMC, MC, NMCS, and not mission capable due to resources (NMCR), breaks, and ground aborts.

EMPTYQ - Is called from FREER whenever a resource is freed. EMPTYQ checks if an aircraft is waiting in a queue for that resource. It checks aircraft needing on-equipment maintenance before LRUs needing off-equipment maintenance. If there is a match, the aircraft or LRU enters the appropriate network node. If there is no match, the aircraft or LRU is returned to the waiting queue.

EVENT - Is called from the network and other FORTRAN subroutines. A GOTO statement is used to choose the correct event (subroutine) needed.

FLYING - Is called from INTLC at the beginning of the first day. It reschedules itself at the beginning of each subsequent day. It determines how many sorties to schedule that day, how many of those sorties to schedule in the morning shift, and how many in the afternoon shift. It determines the primary mission of the sortie and the quantity of aircraft to fly the sortie. This subroutine schedules SORTIE - to allocate the aircraft for each sortie, BPO - to initiate BPO maintenance after the sorties land, and CLEAN - to perform non-essential maintenance after all sorties have launched.

FREER - Is called from the network after maintenance is completed. This subroutine releases the resources used in the task. Maintenance man-hours (MMH) are also collected. This subroutine schedules EMPTYQ to initiate maintenance on entities needing the resources just released.

FRSPAR - Is called from the network after off-equipment or shop maintenance is completed or a spare arrives from depot. It increments the spare supply level. The subroutine checks planes in the NMCS queue to see if there is a match between the released spare and a needed spare. Aircraft needing only one spare undergoing parallel maintenance have first priority, then those aircraft not in parallel maintenance are checked. Aircraft needing more than one spare have next priority. If there is a match, the entity is sent to the appropriate network to continue maintenance. If the NMCS aircraft does not match with an available spare, it is returned to the appropriate NMCS queue.

GNDAB1 - Is scheduled from SORTIE after a sortie has just launched. A few minutes after a sortie has "begun" GNDAB1 checks to see if there has been a ground abort. If a ground abort has occurred, the last aircraft put in the sortie queue is removed and sent to CHECK via the network to determine the type of maintenance to perform. If aircraft remain flying the sortie, GNDAB1 schedules REMOVE to remove the flying aircraft from queue 4 after the sortie duration has passed.

INSPET - Is scheduled from CANN after the creation of a "hangar queen". At day 19, a FMC aircraft becomes the donor aircraft for the missing spares on the "hangar queen". The old "hangar queen" is sent to STUFF to begin maintenance. The donor aircraft becomes a new "hangar queen" and the hangar queen timer starts all over.

LAST - Is called from SLAM subroutine OTPUT at the end of the simulation. This subroutine calculates BR, SPA, and FR. It tabulates the number of times a resource or spare was requested, how many times it was available, how many times it was unavailable and the number of times it went to depot. This subroutine tabulates also the number of times a WUC failed, and its MDT and MRT, and summarizes these parameters for the entire system. Maintenance man-hours per flying hour (MMH/FH) is tabulated by WUC and summarized for the system. At the end of the output file, it lists those NMCS planes which lack single or multiple spares. LAST provides the majority of output printed to F15.RPT.

MAINT - Is called from the network when task times for on-equipment maintenance need to be calculated. It restarts the task time if resources were not available last time and the task was halted. If there is no failure, the appropriate scheduled maintenance time for turnaround, preflight, BPO or phase is calculated. If the first portion of a R&R action (remove) has been completed, the task time for the second portion (replace) is calculated. The type of maintenance (can not duplicate (CND), R&R, repair in place (RIP), and facilitate other maintenance (FOM)) is determined from the probabilities given in F15E.INP data file. When there are new failures to be repaired, maintenance times are calculated using the task times and statistical distribution data in F15E.INP. Non-critical parallel maintenance is postponed if the maintenance takes longer than the critical maintenance, or no spare is available for the R&R action. When non-critical maintenance has been initiated by CLEAN, entities whose task times extend past the end of the shift are postponed. When there are over 40 failures on an aircraft, entities whose task times extend past the end of the week are postponed. Repair time for MRT is summed in this subroutine. Lastly, the subroutine TSHIFT is called to divide the maintenance time into the remaining shift and next shift time.

NEED - Is scheduled during SHIFT at the beginning of each day to determine aircraft preflight requirements. If preflight is necessary, subroutine PRFLGT is scheduled.

NMAINT - Is scheduled during SSHIFT at the beginning of each shift. It sends aircraft waiting for resources or next shift maintenance to the network to begin such maintenance. On-equipment maintenance is sent to the network before off-equipment maintenance. During peacetime when the servicing shift exists, only preflight and BPO maintenance are initiated during the servicing shift. During the two normal shifts, all maintenance is initiated by this subroutine.

NONAV - Is called by SSHIFT at the beginning of each normal shift. It determines which resources are available to work each shift. The availability of resources is determined by the availability parameter specified in F15.FOR.

OTPUT - Is automatically executed by SLAM at the end of the simulation. It calls DISPLY and LAST to print out the results of the simulation.

PARALL - Is called by CLEAN after the last sortie of the day has launched and is called by CHCKE2 when an aircraft has 40 failures. It defines values of attributes and other parameters before sending the entities to the network for maintenance on all the failures stored in the failure array. If the task was postponed earlier, the original maintenance task time is retrieved.

PARAP - Is called by CHCKE (or CHCKCD) when critical maintenance is needed. It defines values of attributes and other parameters before sending the entities to the network for maintenance on selected failures stored in the failure array. It initiates maintenance on existing non-critical failures, new critical failures, and new non-critical failures. These entities reach the subroutine MAINT in an important sequence - the critical failures are first, followed by the non-critical failures.

PHASE - Is called from SHIFT when phase is needed. It selects an aircraft for phase and determines which type of phase is needed. Inspection parameters are defined and the aircraft is sent to begin maintenance via the network. When the phase to be performed is HPO1 or HPO2, a dummy entity is filed in queue 16 (MC file) so the HPO1 and HPO2 phase times are included in the MC rate.

PRFLGT - Is called from NEED when preflight is needed. It is also called from the network when preflight is finished. PRFLGT assigns values to attributes and other parameters, determines the preflight task time and sends the aircraft to the network to begin preflight. It also sends a dummy entity to queue 16 to include the preflight time in the MC rate. After preflight is finished, the network sends the entity back to PRFLGT and the aircraft is filed into the appropriate ready queue and the dummy entity is removed from queue 16. PRFLGT then calls TSHIFT to divide the task time into shift times.

READAT - Is called from INTLC at the beginning of the simulation. It reads the data from the two input files, F15EM.INP and F15ET.INP, and files the information in the appropriate arrays.

REAV - Is called from ALLOK if a resource is normally available, but not available at that specific time. It removes planes from wait queues and resubmits planes back into the maintenance network after one hour. The purpose of this subroutine is to model support equipment down time. This subroutine may be called only if V(2) and V(3) probabilities are less than 1.0.

RELPLN - Is called from CHECK after a multiple status NMCS plane receives one spare. This subroutine files the plane into the appropriate NMCS queue.

REMOVE - Is scheduled from GNDAB1 at the end of a sortie. It removes aircraft from the sortie queue after the flight has ended, assigns values for attributes and parameters, increments counters, and sends the aircraft to begin maintenance via the network.

SHIFT - Is called from INTLC initially at the beginning of the simulation and then schedules to execute itself at the beginning of each subsequent day. It determines whether it is a week day or weekend, and calls NEED to check if preflight is needed. Removes all aircraft from queue 2 (ready queue) and places them in queue 1 (need to check for preflight queue). It defines the time when shifts change, and determines if phase is needed. Subroutine PHASE is scheduled if phase is needed. SHIFT schedules SSHIFT to be executed at the beginning of each shift that day.

SHOP2 - Is called from the network when off-equipment maintenance is needed. It calculates the task times for all the shop maintenance events - bench check okay (BCOK), repair this station (RTS), not repairable this station (NRTS) and condemn (COND) the shop replaceable unit (SRU). If a task was previously postponed due to lack of resources, the task time is restored. TSHIFT is called to divide the task time into shift times. SHOP2 also identifies broken parts which will eventually be sent to depot for repair.

SORTIE - Is called from FLYING after all sorties are scheduled. Depending on the type of mission the sortie will fly, SORTIE checks the appropriate PMC queues for ready aircraft. If more aircraft are needed for the sortie, the FMC ready queue is checked for aircraft. If the number of aircraft needed are found to be available the sortie is initiated by filing the aircraft in the sortie queue. GNDAB1 is scheduled to check for ground aborts. If the number of aircraft available is lacking, SORTIE schedules to call itself in 0.5 hour to check for aircraft availability again. This occurs a total of three times if aircraft remain unavailable. At the start of the fourth time, the sortie has been postponed for 2.0 hours. If aircraft are still not available, the sortie is cancelled and counted as missed flight(s). If a smaller number of aircraft are available to fly, these aircraft will fly and the missing aircraft will count toward missed sortie(s).

SSHIFT - Is called from SHIFT at the beginning of each shift. It determines manpower levels for the servicing shift in peacetime. Subroutine NONAV is called to determine the availability of manpower at the beginning of each shift. NMAINT is called to resubmit waiting aircraft back into the maintenance networks.

STUFF - Is called from INSPET when a "hangar queen" is 19 days old. It assigns values of attributes and parameters, sends the receiving aircraft to maintenance via the network and files the donor aircraft minus parts into the "hangar queen" queue.

TSHIFT - Is called from MAINT, PRFLGT and SHOP2. It determines how much time remains in the present shift. It assigns the remaining shift time or the task time, whichever is smaller, as the first shift task time. The remaining task time, if any, is reserved for the subsequent shift(s).

WARMUP - Is scheduled from INTLC at the end of the warmup period. It allocates the number of spares available for the new scenario, taking into account the spares presently in the maintenance system. It redefines scenario parameters, and reinitializes counters and failure clocks.

6. ASSUMPTIONS

6.1. DATA ASSUMPTIONS

Data assumptions are normally quantitative assumptions and are generally part of the input data file and can be easily changed. The Table 6.1 lists the source of this information.

Many of these assumptions were initially crude assumptions prior to testing, but as experience was gained from testing, these assumptions became observations. Again, as more experience or information becomes available, the data may change. Since this data is quantitative, it is easy to change and to perform sensitivity analyses to determine what effect a change in certain parameters have on the outcome.

Spares levels of critical WUCs are adjusted in the model input data file so the NMCS rate is similar to the NMCS rates experienced by the 33rd TFW.

6.2. STRUCTURAL ASSUMPTIONS

Structural assumptions are developed from the intended operational and maintenance concepts of the system. Since the model represents a simplification of reality, major concepts are modeled but some details are simplified or generalized. These assumptions are part of the actual coding of the model, and may not be easy to change. Figure 6.1 illustrates the basic structural flow of the model.

Data Element	Source
sortie length of 1.7 hours	HQ TAC F-15E BCM
spares delivery time of 15 min	TAC standard
aircraft support equipment availability of 100%	discussion with HQ TAC
LANTIRN support equipment availability of 100%	discussion with HQ TAC
personnel allocation of 85%	discussion with HQ TAC
19% of missions are air-to-air	HQ TAC/DR
59% of missions are air-to-ground	HQ TAC/DR
19% of missions are dual role	HQ TAC/DR
3% of missions are air-to-ground nuclear	HQ TAC/DR
50% of air-to-air, air-to-ground, and dual role missions are flown single ship, 50% of these missions are flown dual ship	HQ TAC/DR
100% of air-to-ground nuclear missions are flown single ship formation	HQ TAC/DR
peacetime thruflight (BPO) is performed after 96% of all peacetime missions	discussion with HQ TAC
wartime ICT (keep aircraft in same configuration) is performed after 4% of all peacetime missions and 50% of wartime missions	discussion with HQ TAC
wartime ICT (change aircraft to different configuration) is performed after 50% of wartime missions	discussion with HQ TAC
mean and standard deviation task times for BPO is 1.5 hr and 0.25 hr	TAC standard
mean and standard deviation task times for wartime ICT (same configuration) is 0.42 hr and 0.10 hr	F-15E SORD
mean and standard deviation task times for wartime ICT (different configuration) is 0.67 hr and 0.17 hr	F-15E SORD

Table 6.1. Data Assumptions

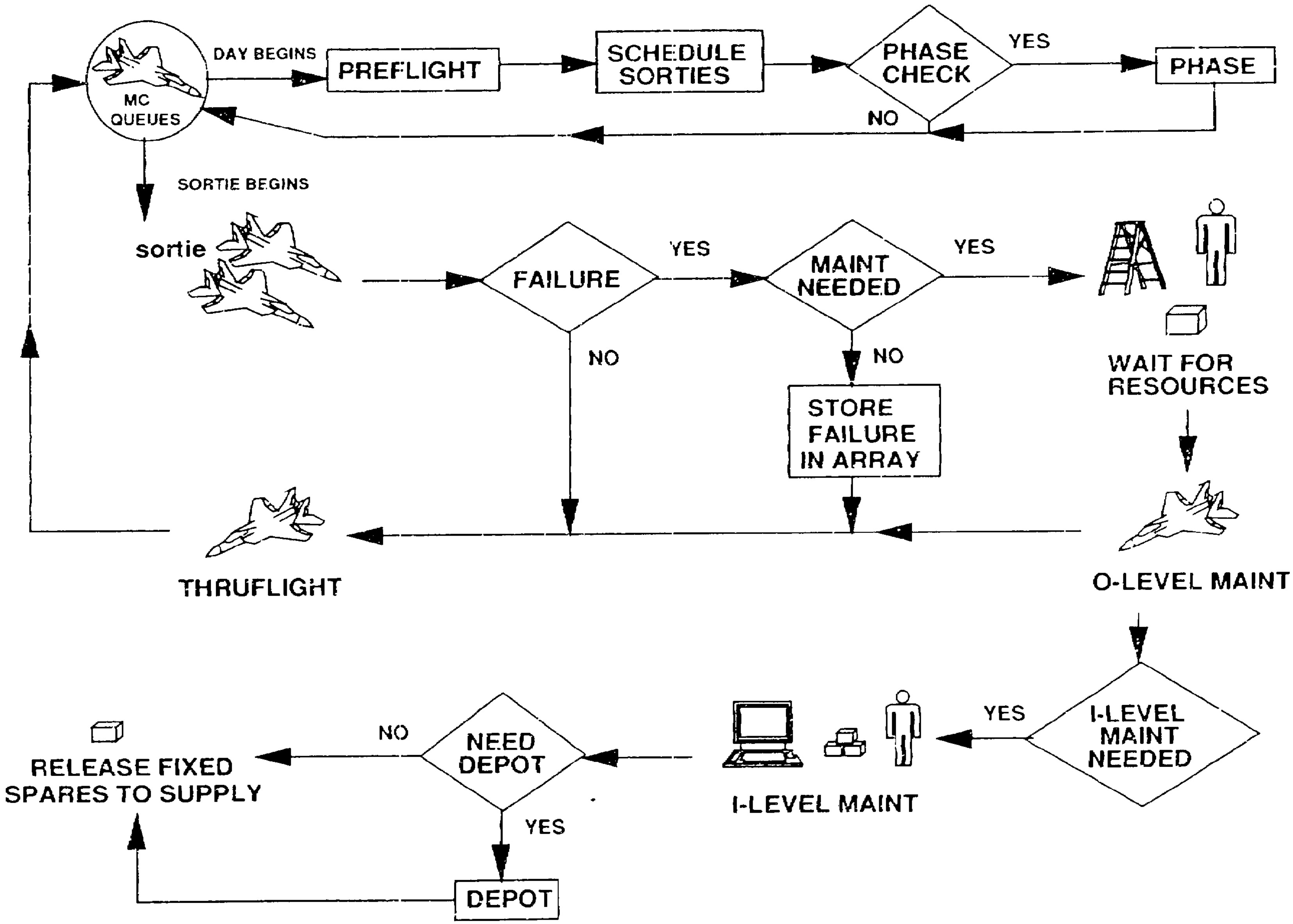

Figure 6.1. F-15E SLAM Model Flow

In the peacetime scenario at the beginning of the servicing shift, BPO maintenance actions are continued and preflight inspections are begun on aircraft due to fly that day if it had no BPO in the last 48 hours. No unscheduled maintenance is performed during the servicing shift. In wartime, preflight is performed in the first shift of the day if required. At the beginning of other shifts in any scenario, personnel are reinitialized, and aircraft are removed from waiting queues and sent to the network to continue maintenance.

Maintenance is scheduled to be performed in "parallel", meaning if multiple maintenance actions need to be completed, they are performed at the same time if the resources are available. There are three cases when parallel maintenance is initiated.

a) After a sortie with a critical failure lands. Critical failures must have maintenance performed before the aircraft can fly again. Maintenance on non-critical failures will be performed in parallel if the task(s) can be completed before the critical failure(s) is repaired.

b) After the last sortie of the day has launched. The intent is to repair PMC aircraft to FMC status without impacting sortie generation. Tasks must have available resources and be completed by the end of the shift.

c) When the failure storage array becomes full. This is a very rare occurrence. The array has space for 40 failures. When an aircraft has 40 failures, parallel maintenance is performed on all failures which have available resources and can be completed by the weekend.

Series maintenance, when failures are fixed one at a time, one after another, can easily be added to the model once TAC determines which tasks, by WUC, should be done in series.

BPO is performed on all aircraft which flew that day, and is initiated after the last sortie of the day has launched. BPOs and preflights are good for 48 hours if the aircraft does not fly, otherwise the aircraft must be preflighted to fly. Aircraft are considered mission capable during thruflight, preflight and BPO.

Cannibalization of parts is considered when an aircraft needs a spare and it is unavailable. The model attempts to find a donor aircraft in the NMCS queue, looking at aircraft which are already missing more than one part. If no donor is available then aircraft which are already missing only one part are checked. According to HQ TAC, there is no such thing as a 21 day old "hangar queen". A "hangar queen" is an aircraft which does not fly for several days, usually due to a shortage of parts. In the model, on day 19 of a "hangar queen", a FMC aircraft is selected as the donor aircraft and parts are switched. Maintenance manhours are collected, the new hangar queen's timer is begun, and the old hangar queen is made FMC.

Phase inspections in the operational field are scheduled so only a few aircraft are in phase at the same time. This is done by scheduling aircraft to fly so the flying hours on each aircraft reach key quantities at the right time. Table 6.2.1 shows the important parameters of each phase inspection. The information was obtained from HQ TAC/LG.

Phase	Task Length (in days)	Task Frequency (in cumulative aircraft hours)
HPO 1	2	100,300,500,700,900,1100
HPO 2	3	200,1000
HPO 3	4	400,800
PE 1	6	600
PE 2	10	1200

Table 6.2.1. Operational Phase Inspection Parameters

The model does not schedule aircraft to fly by tail number, therefore phase inspections cannot be scheduled in the same way as in the field. However, phase timing can be scheduled by cumulative squadron flying hours. The basis for this schedule is an examination of the phase schedule of the 33 TFW at Eglin AFB over a six month period. From a study of this data, the phase inspections in the model are scheduled according to Table 6.2.2.

Phase	Task Frequency (in total cumulative squadron FH)
HPO 1	6
HPO 2	66
HPO 1	156
HPO 3	216
HPO 1	336
PE 1	396
HPO 1	576
repeat cycle at 630 cumulative squadron flying hours	

Table 6.2.2. Model Phase Inspection Schedule

6.3. RESOURCE ASSUMPTIONS

The model considers only the major pieces of support equipment. It is assumed there are enough tools, ladders, power carts, air conditioners, etc, to go around. Table 6.3.1 shows the support equipment modeled and their quantity.

The model assumes maintenance personnel belong to three shops, the aircraft generation squadron (AGS) which perform on-line maintainance, the equipment maintenance squadron (EMS), and the component repair squadron (CRS) which perform shop maintenance.

Quantity	Support Equipment
1	Displays Avionics Intermediate Station (AIS)
1	Microwave AIS
1	Integrated Antenna AIS
1	Mobile Electronics Test Set (METS)
1	Forward Firing Armament Test Set
1	Air to Ground Armament Test Set
1	LANTIRN Power Supply Test Station
1	LANTIRN ECU Test Station
1	LANTIRN Other LRU Test Station
1	TEWS Intermediate Support Station (TISS)

Table 6.3.1. Support Equipment Modeled

HQ TAC/XPMQM provided a list of manpower authorizations for the F-15E. Tables 6.3.2 through 6.3.4 show the breakdown of personnel by shop, AFSC and some by skill level. This data was then modified according to Rivet Workforce rules supplied by AF/LEYM. This data represents the personnel authorized to maintain a wing of aircraft. Since the model assumes only a squadron, the personnel are divided by three and rounded to the nearest whole person before being written into the model. The personnel allocations are also shown for the 33rd TFW at Eglin AFB. This information was used during the validation portion of the model development.

AFSC/Description	F-15 C/D MSIP (33 TFW)	F-15E (from HQ TAC/XP)	F-15E (Rivet Workforce)	
423X0 Electrical	31	22	452X5	39
423X1 ECS	23	17		
423X4 Pneudraulics	24	24		
426X2 Propulsion	80	78	452X4	332
431X1 Crew Chief	257	230		
427X5 Airframe Repair	25	24	458X2	24
452X1A Rdr/Nav, Fire Cntl, LANTIRN			No change	
3-7 level	53	54		
452X1B Flt Cntls/Instr				
3-7 level	43	33		
452X1C Com/Nav				
3-7 level	35	39		
45271, 7 level	0	30		
462X0 Armament, Fuel	197	242	No change	

Table 6.3.2. AGS Personnel Authorizations and Allocations

AFSC/Description	F-15 C/D MSIP (33 TFW)	F-15E (from HQ TAC/XP)	F-15E (Rivet Workforce)	
423X5 AGE	87	81	454X1	
426X2 Propulsion	8	9	454X0A	
427X0 Machinist	6	7	458X0	14
427X4 Metal Processing	8	7		
427X2 NDI	15	15	458X1	
427X3 Fabric and Para	6	14	458X3	
427X1 Corrosion Control	13	14	458X2	27
427X5 Airframe Repair	14	13		
431X1 Crew Chief	66	61	452X4A	
462X0 Armament, Fuels	40	49	No change	
461X0 Munitions Sys	95	192	No change	

Table 6.3.3. EMS Personnel Authorizations and Allocations

AFSC/Description	F-15 C/D MSIP (33 TFW)	F-15E (from HQ TAC/XP)	F-15E (Rivet Workforce)	
423X0 Electrical	9	16	452X5	23
423X1 ECS	7	7		
423X2 Egress	14	33	454X2	
423X3 Fuel Systems	37	44	454X3	
423X4 Pneudraulics	10	10	454X4	
426X2 Propulsion	107	98	454X0	
451X4A Auto Test Station			No change	
3-7 level	51	30		
451X4B Manual Test Station				
3-7 level	60	46		
45174, 7 level	0	16		
455X0B Photo Systems	16	15	No change	
455X0A LANTIRN	0	43	No change	

Table 6.3.4. CRS Personnel Authorizations and Allocations

7. VERIFICATION AND VALIDATION

Verification is defined as the process of ensuring a model/simulation executes as intended (8:10). It generally addresses the actual coding/syntax of the model. Validation is defined as the process of establishing that a desired accuracy or correspondence exists between the model/simulation and the real world (8:10). This addresses the data and structural assumptions made in the formation and use of the model. Verification and validation are an integral part of model development, and will increase the credibility of the model/simulation.

The model underwent a detailed review by the HQ AFOTEC/LG4 F-15E Availability Model Committee. Objectives of the Model Committee were to verify and validate the F-15E Availability model for use during F-15E OT&E and to approve the model for release to other AF agencies. The committee consisted of a chairperson, the model developer, and four other LG4 analysts.

7.1 VERIFICATION

The SLAM language has ECHO, MONTR, summary and trace, and FILE statements which can be used to verify the code is executing correctly. The ECHO statement provides a summary of the simulation model as interpreted by the SLAM processor. The MONTR statement can cause summary reports to be printed, or initiate a trace of entities flowing through the network. The FILE statement can print the content of each file to ensure entities are not being inadvertently created, destroyed, or changed.

The SLAM output listing will contain error statements when an error in the input statements is found by the SLAM processor. The listing also contains information on file lengths, wait times, and activity utilization. Print statements were written at strategic locations in the FORTRAN code to cause messages stating when significant activities occurred in the simulation, ie, when sorties launched, when sorties were rescheduled or missed, when and what failures or ground aborts occurred, which maintenance was initiated, if resources and spares were unavailable, etc.

7.2 VALIDATION

There are two methods of validation - subjective and objective. Subjective validation is an iterative process. It involves evaluation of the model by people knowledgeable with the intended operational environment of the F-15E. This evaluation was based on examination of logic flow charts, input parameters and assumptions. The sensitivity of the model outputs to changes in inputs were examined to ensure the outputs changed in a logical manner.

Objective validation is more quantitative. It involves collecting data on the system and statistically comparing this to model output. Since there is no squadron of operational F-15Es at this time, a good substitute would be a similar aircraft which is operated in a similar manner. The F-15C/D MSIP aircraft was chosen due to its similarity to the F-15E. The data used in the validation process was obtained from the 33rd TFW at Eglin AFB Florida. The 33rd TFW was chosen since it was the only operational wing with mainly F-15C/D

MSIP aircraft. The inputs used in the model consisted of Aug 87 through Jan 88 MDC data, the 33rd TFW maintenance summaries, the 33rd TFW maintenance and utilization plans, and expert judgment from experienced maintenance personnel at the 33rd TFW and the F-15E OT&E test team at Edwards AFB California. The data from this six month period were averaged to obtain the 33rd TFW average. The model was run using a one month warmup period, the statistics were cleared, and then a six month simulation was run. This simulation was run seven times with a different random number seed. The results of these seven runs were averaged to obtain the model average. Table 7.1 lists the comparison.

	33rd TFW	Model
MC	89.3	88.3
BR	9.7	10.2
FR (8 hr)	82.3	90.9
MRT	1.8	1.9

Table 7.1. Model Validation using F-15C/D MSIP

These results, as well as the definitions, assumptions, logical flow, and input data requirements were briefed to the 33 TFW and HQ TAC representatives for model familiarization and validation (2). HQ AFOTEC/LG4A received a message from HQ TAC/DRF stating HQ TAC has validated and granted concurrence to AFOTEC to implement the F-15E model during OT&E (6).

8. OUTPUT

There are two output files, F15.OUT and F15.RPT. F15.OUT is the standard SLAM output file and contains statistics on all the files and activities. It could also contain numerous statements which outline when every significant activity happened. Most of the print statements responsible for these statements are commented out in the FORTRAN program now, but they were used extensively in the model development process and verification procedures.

The second output file, F15.RPT, is the primary output file. It tabulates the critical information and results of the simulation. Appendix F contains a a sample copy of the file. This file echoes back some of the inputs, to identify the run, and contains the primary parameters outlined in the purpose of the model. It also includes additional information such as sorties flown, sorties missed, total flying hours, NMCS rate, NMCR rate, number of breaks, and number of ground aborts per flying day. Availability of resources and spares are tabulated to determine at a glance which WUCs cause the most delays due to nonavailability of resources or spares. MRT and MDT are also tabulated by WUC to determine which WUCs take the longest to repair. MMH/FH is also tabulated by WUC to determine which WUCs contribute the most to MMH/FH.

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