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Mobility Aircraft Availability Forecasting (MAAF) Model

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Final Report for June 2003 to July 2004

Approved for public release; distribution is unlimited.

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FOR THE COMMANDER

//SIGNED//

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14. ABSTRACT

The primary objectives of the Mobility Aircraft Availability Forecasting (MAAF) research effort included: 1) defining an initial set of requirements and a design for a simulation based modeling application to assist Air Mobility Command (AMC) logistics planners and analysts in assessing and predicting AMC aircraft availability based on mission requirements, and 2) developing a proof-of-concept demonstration to convey the important characteristics and features of MAAF. To achieve these objectives, the MAAF research effort was divided into three primary tasks that included defining functional and technical requirements, designing the critical components of an object-oriented modeling and simulation application to address these requirements, and developing a proof-of-concept demonstration.

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PREFACE

This report documents the results of research conducted under Delivery Order #25 of the Technology for Readiness and Sustainment (TRS) contract (F33615-99-D-6001) supporting the definition, design, development and conceptual demonstration of a simulation-based decision support tool referred to as the Mobility Aircraft Availability Forecasting (MAAF) model. The period of performance for this research extended from 3 July 2003 through 3 May 2004. The MAAF project team members are listed in Appendix 1.

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Mobility Aircraft Availability Forecasting (MAAF) Model
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1.0 Background

The mission of the Air Mobility Command (AMC) is to provide airlift, air refueling, special air mission, and aeromedical evacuation for U.S. forces. AMC also supplies forces to theater commands to support wartime tasking. As the Air Force component of the United States Transportation Command (USTRANSCOM), AMC is the single manager for air mobility. The command operates from 13 stateside bases, six units at non-AMC bases (stateside and overseas), and 71 Air Reserve Component units (associates and unit equipped) gained by AMC in mobilization (42 Guard and 29 Reserve). The AMC Directorate of Logistics (AMC/A4) develops concepts and manages logistic support for all AMC missions in peacetime and contingencies. It is responsible for ensuring the mobility fleet, consisting of 544 aircraft (C-5, C-17, C-141, C-130, KC-10, KC-135, and C-9 aircraft), is capable of accomplishing the mission of AMC. Currently, the AMC Logistics Directorate cannot forecast, assess, or evaluate alternatives impacting aircraft availability - key to the AMC decision-making process. This deficiency has made it very difficult for the Maintenance Division to perform quick, accurate, and effective analyses of potential limiting factors and policy changes. The current methods utilize "after the fact" analyses and experience of various managers to determine the best courses of action. These procedures are very labor intensive and forecasts are based solely on the experience of the personnel involved. To address this deficiency, AMC/A4 requested the support of AFRL/HE in conducting a study to research the requirements for, and demonstrate an object-oriented based modeling and simulation (M&S) application that planners and analysts could use to help gain better insight on problems or limiting factors impacting aircraft availability in both the short and long term. In addition to predicting aircraft availability based on projected mission requirements, MAAF should be capable of assisting logistics planners and analysts in assessing potential resource shortfalls that may occur due to policy changes and quantify their impact to mission capability before they are implemented.

2.0 Objective

The primary objectives of the MAAF research effort included 1) defining an initial set of requirements and a design for a simulation based modeling application to assist AMC logistics planners and analysts in assessing and predicting AMC aircraft availability based on mission requirements, and 2) developing a proof-of-concept demonstration to convey the important characteristics and features of MAAF. To achieve these objectives, the MAAF research effort was divided into three primary tasks that included defining functional and technical requirements, designing the critical components of an object-oriented (OO) modeling and simulation application to address these requirements, and developing a proof-of-concept demonstration.

3.0 MAAF Requirements Definition

This phase of the research effort focused on defining the top-level functional and technical requirements for design and development of the MAAF model and concept demonstration. This included defining aircraft availability from an AMC perspective, identifying the significant factors impacting the prediction of aircraft availability, and most importantly, gaining a general understanding of how a MAAF modeling application might be used by AMC staff personnel in the context of a decision support tool to effectively assist analysts in accomplishing their day-to-day tasks.

3.1 Aircraft Availability

The *AMC Metrics Handbook for Mobility Air Forces* [1] defines Mission Capable (MC) rate as "the percentage of possessed hours that an aircraft is either partially or fully-mission capable." The prescribed formula is:

$$\frac{\text{FMC Hours} + \text{PMCB Hours} + \text{PMCM Hours} + \text{PMCS Hours}}{\text{Possessed Hours}} \text{ X } 100$$

where:

- FMC (Fully Mission Capable)
- PMCB (Partially Mission Capable for Both Supply and Maintenance)
- PMCM (Partially Mission Capable for Maintenance)
- PMCS (Partially Mission Capable for Supply)

Air Force Instruction (AFI) 10-602 [2] defines "Possessed Hours" as the "total hours in a calendar period where assigned equipment is under the operational control of the designated operating organization." The calculation of possessed hours is not trivial, since there are a variety of factors that impact the proper classification of possessed hours (e.g., the hours an aircraft is in programmed depot maintenance is not counted as possessed hours by the designated operating location). AFI 21-103 [3] provides a more thorough discussion of aircraft status and utilization reporting, including the criteria impacting the calculation of aircraft possessed hours. For this research effort, it is important to identify the specific criteria that are important in the design of MAAF as a tool for predicting aircraft availability.

While the MC rate is an important *indicator* of aircraft availability, and a metric that would certainly need to be derived and reported by MAAF, we discovered through later conversations with AMC personnel that the MC rate does not directly define aircraft availability. Rather, AMC defined aircraft availability as the *actual number of aircraft that are projected to be available in a specified time period for mission assignment – referred to as "taskable" aircraft.* This is the definition that we adopted for the MAAF research effort. Currently, AMC uses an application called the Aircrew / Aircraft Tasking System (AATS) to compute the number of "taskable" aircraft that are projected to be available in a given time period (usually projected one to three months ahead on a per week basis) for each main operating base or location (not including enroute locations). Based on AATS, the number of "taskable" or available aircraft is derived as:

[(Possessed A/C – Deployed) x Commitment Rate] – Adjustments – Unit Training

- Possessed A/C: Adjusted for aircraft in PDM, etc.
- Commitment Rate: Percentage estimate accounting for aircraft in maintenance [3]
- Adjustment A/C: Aircraft allocated to Weapons Instructor Course (WIC), etc.
- Local Training: Assigned by HQ AMC/DOO

The number of available aircraft computed by AATS becomes the allocation of the number of "taskable tails" by location that is provided to the Tanker Airlift Control Center (TACC) which they in-turn use for mission planning. It is important to note that while AATS is the current method the AMC/A4 staff uses to project aircraft availability, is only a point-in-time estimate that does not account for activities at enroute locations, nor does it assess potential resource shortfalls, or maintenance problems that may occur in the future that could potentially impact aircraft availability and mission accomplishment. This is where MAAF can help. By simulating the number of "taskable" aircraft projected by AATS directly in the context of the missions that the TACC is planning, the A4 staff would be in a much better position of assessing the validity of "taskable" aircraft numbers derived by AATS and furthermore, gain much more insight into potential chokepoints or problems that may arise during mission execution due to aircraft reliability and maintainability (R&M), resource allocations at locations, and maintenance policies, etc.

3.2 MAAF Questionnaire and Literature Search

A questionnaire was developed (see Appendix 2) to gain insight from HQ AMC logistics personnel on 1) the need for a decision support tool like MAAF to help predict aircraft availability, 2) the factors that impact aircraft availability and relative ratings of importance, 3) the utility of MAAF as a decision support tool for helping address questions or staff "taskers" that relate to aircraft availability and resource utilization, and 4) the potential inputs to, and outputs from a MAAF model. This questionnaire was distributed to select organizations and personnel on the AMC staff, but only three responses were received back from AMC, so it would be premature at this point to draw any specific conclusions pertaining to questions such as what specific outputs a MAAF model should produce, what specific user audience should MAAF target, etc. The few responses we received did seem to confirm the need for a decision support tool like MAAF to assist analysts 1) in quickly and accurately forecasting aircraft availability, 2) assessing and evaluating the impact of policy changes or limiting factors on aircraft availability; and 3) performing "what-if" type analyses of alternative strategies (e.g., resource allocation) or policies impacting aircraft availability to determine "best" solutions or courses of action.

To supplement the questionnaire, we conducted a literature search of research efforts and technical reports related to the topic of modeling and predicting aircraft availability. This research identified two studies worth noting in this report. The first is the *Air Force Mission Capable Rate and Aircraft Availability Model Study* [4]. This report was produced by Air Force Logistics Management Agency (AFLMA) and documented the results of a study conducted in CY 2003 at the request of HQ USAF/ILM. The objectives of the study were to 1) document the requirements (purpose, inputs, outputs) for an AF Modeling and Simulation (M&S) application capable of forecasting mission capable (MC) rates, assessing aircraft maintenance production capability, and projecting aircraft availability, and 2) provide AF/ILM recommendations for an implementation road map designed to establish the proper framework for the development and management of their logistics M&S decision support tools. As part of this study, a survey of existing models was conducted to determine their suitability for forecasting MC rates and predicting aircraft availability. Based on this assessment, the team concluded that the Air Force does not currently possess a single model that will meet the diverse user requirements for forecasting MC rates, assessing aircraft maintenance production capability, and projecting aircraft availability. More importantly for MAAF, which is primarily focused on projecting aircraft availability, the study revealed that their is no current model that directly models AMC mission profiles (e.g., a multi-leg channel missions that traverse multiple locations, with varying levels of maintenance capabilities at each location), nor do any existing models address AMC missions from a global perspective – in essence, modeling and flying missions originating from multiple locations simultaneously. These are two of the more significant challenges that we focused on addressing as part of defining the requirements and design for a simulation based MAAF modeling application.

The second report, *Forecasting Readiness* [5], focused on identifying factors that impact aircraft MC rates, which as we've previously stated, is a key indicator of aircraft availability, and their relative impact on and contribution to the computation of MC rates. The report outlined six categories of factors that affect MC rates including Personnel, Environment, R&M, Funding, Aircraft Operations, and Logistics Operations. For each category, the report identified factors from previous research that were felt to have some impact on aircraft MC rate predictions (e.g., for the Personnel category, the number of personnel assigned, skill levels, etc.) and constructed correlation and regression models to understand and test the relative importance of these factors in predicting MC rates. In part, the study proposed that the two most significant categories of factors impacting MC rates were aircraft R&M and personnel. The study also revealed that certain categories of factors, when assessed individually, did not have a strong correlation to MC rates, but when combined with factors from other categories such as R&M or personnel, demonstrated stronger correlation with MC rates. In conclusion, the study proposed that "simultaneous analysis" was important to provide a more "holistic approach" and understanding of how some of the key factors addressed in this report collectively affect MC rates and their prediction. This is the one of the key reasons that simulation is appropriate for modeling complex stochastic (random variation) systems such as AMC mobility operations and the primary reason we have chosen this approach for MAAF.

3.3 MAAF Demonstration Scenario and Use Case

The literature search and questionnaire responses did not provide a conclusive or definitive set of factors that should be addressed in the design of a MAAF simulation model. While we agree that factors such as personnel, R&M, spares, support equipment, funding, etc., do have an impact on MC rates and aircraft availability, the question remains as to what degree these factors need to be addressed in a simulation model that can "accurately" predict aircraft availability or MC rates? This is a matter of determining the "right" level of model fidelity, particularly for purposes of verifying and validating the performance of a model so that users and decision makers can have some level of confidence in the results produced by the model. Completely addressing and answering the model fidelity question is beyond the scope of the current MAAF research effort. Hence, in defining a baseline set of requirements for MAAF that could be used to guide design and development activities, as well as the context of the concept demonstration, we developed and coordinated a very basic scenario (see Appendix 3) to help identify some of the key requirements for MAAF that we feel are important to modeling and predicting aircraft availability. The scenario encompasses both a baseline and "what-if" use case. The baseline use case depicted in Figure 1 involves the modeling of a hypothetical AMC channel mission. The notional channel mission in Figure 1 originates at Ramstein AB on a daily basis and transits both Sigonella IAP and Kuwait City IAP dropping cargo off at each of these locations before returning to Ramstein AB. Each of these locations has different types of resources and maintenance capabilities that will be reflected in the concept demonstration. To address even this simplified use case in MAAF involves 1) directly modeling a mission and specific aircraft that originates at one location and transits multiple locations as part of its mission before returning to its home station, and 2) modeling varying levels of resources at each location to support both ground handling, servicing, and unscheduled maintenance that may occur at each location. Some of these tasks could include various combinations of resources such as personnel, support equipment, material handling equipment, spare parts, facilities, etc. For purposes of the concept demonstration, we will focus attention on modeling one resource type – maintenance personnel.

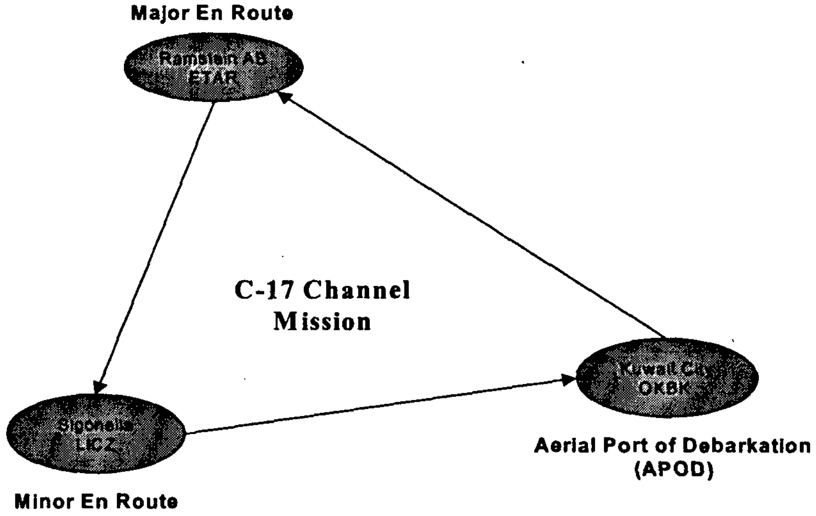


Figure 1. MAAF Demonstration Scenario – Baseline Case

The "what-if" use case in Figure 2 builds upon the baseline use case and includes an additional location, namely Dover AFB. This use case focuses on modeling the potential impact on aircraft availability associated with supporting an additional mission workload (attributed to supporting a notional humanitarian relief operation), with current levels of resources at Ramstein AB, Sigonella IAP, and Kuwait City IAP. The questions that we attempted to address in the "what-if" use case include:

- Can the C-17s currently based at Ramstein AB support the additional channel missions required to support the humanitarian relief operation without additional C-17s? If not, how many additional "taskable" C-17 aircraft would be needed at Ramstein?
- How long can the C-17s currently based at Ramstein AB support the additional channel missions before more aircraft will be required?
- How does additional flow of transient C-5 aircraft from Dover AFB to Ramstein AB impact Ramstein's ability to generate "taskable" C-17 aircraft?
- Can the maintenance manpower already in-place at Ramstein AB, Sigonella AB, and Kuwait City IAP support this new tasking for 60 days? If not, how many additional maintenance personnel would be needed at each location?

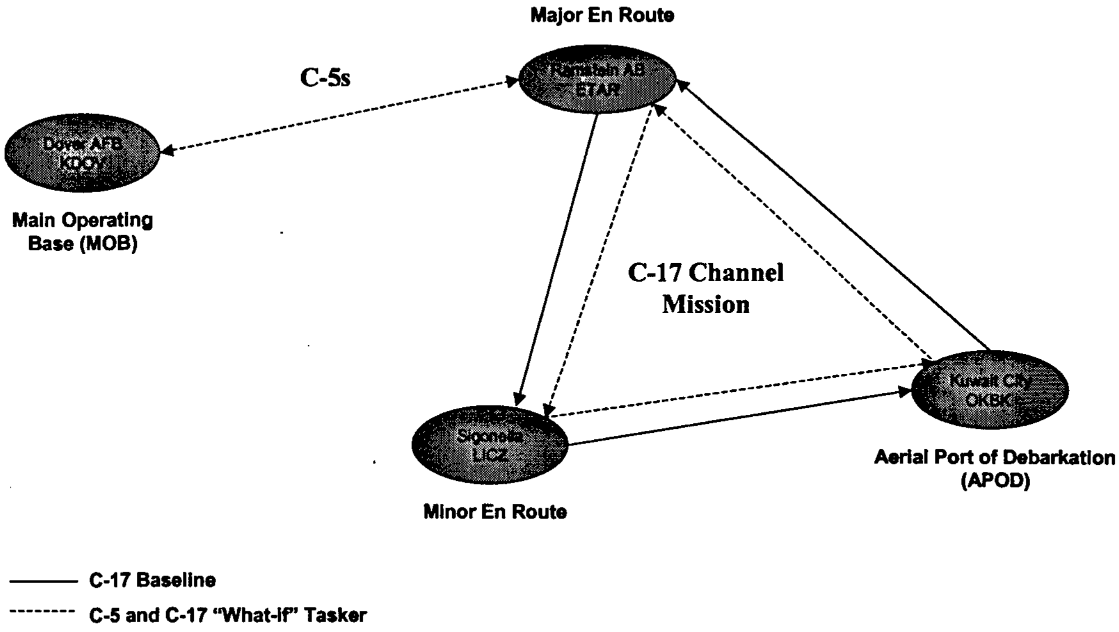


Figure 2. MAAF Demonstration Scenario – "What-if" Case

3.4 MAAF Model Core Requirements (Concept Demonstration)

Based on the scenario and use cases described above, our attention focused on deriving an initial set of core modeling and simulation requirements specifically for the purpose of focusing design and development activities for the MAAF concept demonstration. The initial set of requirements identified below will be expanded based on customer feedback from concept demonstration activities.

a. Providing a capability to create, modify, and save MAAF simulation projects and experiments.

b. Providing a capability to re-use data from previous MAAF simulation projects or experiments to create new MAAF projects.

c. Providing a capability to create or modify AMC operating bases or locations in MAAF simulation projects and experiments.

d. Providing a capability to create and specify resources for each AMC operating base or location. For the concept demonstration, we focused only on the modeling of personnel resources.

e. Providing a capability to create and model AMC tanker and airlift missions (complete mission itinerary) in a MAAF simulation project. For the concept demonstration, we focused attention on supporting the capability to create and model the channel missions described in the MAAF demonstration scenario.

f. Providing a capability to create and model aircraft scheduled maintenance activities in a MAAF simulation project. For the concept demonstration, we focused attention on supporting the capability to create and model home station, isochronal and aircraft wash activities.

g. Providing a capability to schedule and simulate the execution of AMC tanker and airlift missions.

h. Providing a capability to simulate the execution of aircraft scheduled maintenance activities.

i. Providing a capability to create and model maintenance and cargo/personnel handling events associated with processing an aircraft mission at both home station and enroute locations.

j. Providing a capability to specify the resources and time required to perform scheduled and unscheduled maintenance tasks.

k. Providing a capability to model aircraft unscheduled maintenance events.

l. Providing the capability to model aircraft status including Fully Mission Capable (FMC), Partially Mission Capable (PMC), and Not Mission Capable (NMC) based on Minimum Essential Subsystem List (MESL) requirements.

m. Providing a capability to model the selection of aircraft for missions based on aircraft status and MESL requirements.

n. Providing a capability for users to specify simulation experiment parameters, including mission schedules, warm-up period, number of simulation runs, etc.

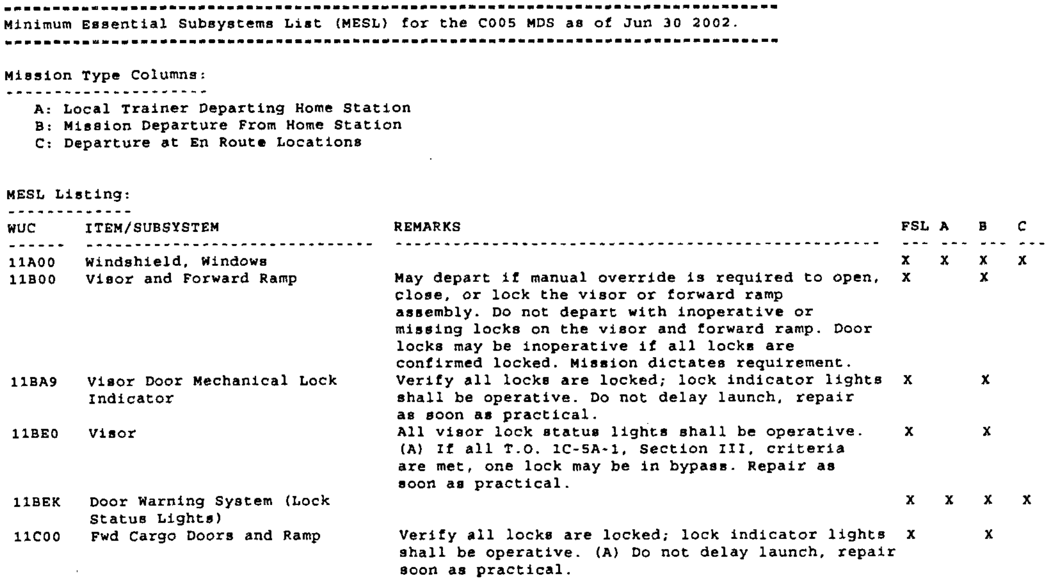
o. Providing a capability to collect and generate simulation data, reports and graphs. For the concept demonstration, we focused attention on collecting and generating data associated with aircraft availability, MC Rates, and personnel utilization.

3.5 Potential Input Data Sources / Systems

During our research, we identified three Air Force / AMC data sources or systems worth mentioning in this report that could potentially be leveraged to support the setup of a MAAF project or experiment. The first system is the Consolidated Air Mobility Planning System (CAMPS) which is used by the TACC to plan AMC tanker and airlift missions. This system contains all the essential data elements required by MAAF to describe and model AMC tanker and airlift missions. Providing a capability for directly importing mission planning information from CAMPS would eliminate the need for a MAAF analyst to have to manually construct numerous mission profiles and schedules in MAAF. This could be a significant time saver particularly when an analyst's interest is in attempting to quickly model and assess aircraft availability at numerous locations in the AMC home station and enroute system. The second system of potential interest is the CAMS for Airlift (G081) maintenance information system. G081 is the primary system used by AMC personnel for reporting aircraft scheduled and unscheduled maintenance actions and activities. The maintenance information reported in G081 could potentially support the automated update of R&M information on aircraft systems in MAAF, thereby reducing the time associated with creating and updating MAAF simulation projects and experiments. The final system worth mentioning is the Logistics Composite Model (LCOM). LCOM is an Air Force standard system model used by AMC (and other MAJCOMs) to determine and justify manpower requirements for select maintenance Air Force Speciality Codes (AFSCs). There are two outputs from LCOM that are potentially important for MAAF, these include personnel AFSC requirements and crew sizes for maintenance tasks modeled in MAAF, and initial quantities of maintenance personnel for select AFSCs based on the type locations addressed by LCOM modeling studies for AMC aircraft. It is important to highlight that MAAF is not intended to replace LCOM as a tool for determining and justifying AMC maintenance manpower requirements. This requirement is already well addressed by AMC LCOM personnel in the A5 staff. The intent of MAAF is to leverage the outputs from existing systems or applications as data sources for MAAF to provide AMC logistics planners and analysts with the capability to *quickly* model and address questions related to aircraft availability.

3.6 The Relationship of the MESL to Aircraft Availability

One of the more significant challenges of the MAAF research effort was in addressing the use of the Minimum Essential Subsystem List (MESL) for determining aircraft status in a simulation model. Each type aircraft has a specific MESL that encapsulates the "business rules" or policies used by maintenance personnel to help make decisions related to the proper classification of aircraft status (i.e., FMC, PMC, NMC, etc.). AFI 21-103 provides guidance for aircraft logistics status reporting based on MESL requirements, as well as the proper reporting of aircraft status for aircraft undergoing scheduled inspections or maintenance, functional check flight, and other activities. Since the actual MC rates reported for aircraft are derived from aircraft status reporting data, and MC rates are a key indicator of aircraft availability, it would appear that for at least future validation purposes, that a MAAF model must be able to represent (to some level of fidelity) the underlying logic and business rules incorporated in the MESL, as well as the policies set forth in AFI 21-103 for aircraft logistics status reporting. We spent considerable time attempting to understand the content and application of the MESL, and the guidance provided in AFI 21-103 as it applied to modeling aircraft status and availability in MAAF. Our research shows that there are complexities in trying to model the complete business logic encapsulated in a MESL and AFI 21-103.



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---------------------------------------------------------------------------------
Minimum Essential Subsystems List (MESL) for the C005 MDS as of Jun 30 2002.
---------------------------------------------------------------------------------

Mission Type Columns:
---------------------
   A: Local Trainer Departing Home Station
   B: Mission Departure From Home Station
   C: Departure at En Route Locations

MESL Listing:
-------------
WUC     ITEM/SUBSYSTEM                  REMARKS                                               FSL A   B   C
------  ------------------------------  ---------------------------------------------------   --- --- --- ---
11A00   Windshield, Windows                                                                   X   X   X   X
11B00   Visor and Forward Ramp          May depart if manual override is required to open,   X       X
                                        close, or lock the visor or forward ramp
                                        assembly. Do not depart with inoperative or
                                        missing locks on the visor and forward ramp. Door
                                        locks may be inoperative if all locks are
                                        confirmed locked. Mission dictates requirement.
11BA9   Visor Door Mechanical Lock      Verify all locks are locked; lock indicator lights    X       X
        Indicator                       shall be operative. Do not delay launch, repair
                                        as soon as practical.
11BE0   Visor                           All visor lock status lights shall be operative.      X       X
                                        (A) If all T.O. 1C-5A-1, Section III, criteria
                                        are met, one lock may be in bypass. Repair as
                                        soon as practical.
11BEK   Door Warning System (Lock                                                             X   X   X   X
        Status Lights)
11C00   Fwd Cargo Doors and Ramp        Verify all locks are locked; lock indicator lights    X       X
                                        shall be operative. (A) Do not delay launch, repair
                                        soon as practical.
```

Figure 3. Sample C-5 MESL (Extract)

Figure 3 depicts an excerpt from the C-5 MESL to help point out these complexities and to help better understand the approach we adopted for addressing status reporting and MESL requirements in the MAAF demonstration. The MESL provides the business rules that maintenance personnel use to determine the status of the aircraft based on the severity of failures to systems identified in a MESL, and the impact of these failures on operational requirements necessary to support the mission types specified on the MESL for a specific type aircraft. For instance, referring to the sample in Figure 3, there are four columns labeled "FSL", "A", "B" and "C" respectively. The "FSL" column indicates those systems required for full mission performance. The lettered columns correspond to the types of missions (or conditions) that apply to the C-5 and identify the basic systems (Basic Systems List - BSL) that are required to be operational for each particular mission type. For example, in Figure 3 we see that the "Door Warning System" (Work Unit Code (WUC) "11BEK") is required for all C-5 missions. So if there is a failure in a system that causes it to become inoperative, the aircraft would be placed in an NMC status based on the rules specified in AFI 21-103 until such time that the system is repaired. For other systems or components specified on a MESL there may be "notes" referenced in the FSL or BSL columns that are intended to help maintenance personnel more accurately assess the severity of a failure as it applies to status reporting. In short, not all failures to systems or components listed in a MESL directly cause the status of the aircraft to be changed to PMC or NMC. Hence, the first complexity in trying to model the business logic encapsulated in a MESL involves trying to translate and codify the "notes" that may appear in the FSL and/or BSL columns of a MESL. While the number of note references varies by aircraft MESL, some of the notes would be extremely complex to codify in a model. The second complexity in modeling the requirements of a MESL is that the mission types (or conditions) and level of WUC indenture can vary from MESL to MESL. For instance, the C-5 MESL assesses aircraft status depending on the type of location a mission departs from – not the actual type of mission, such as a "cargo channel" mission. In addition, some MESLs are defined at the subsystem (3 digit WUC) level, and in others, as exemplified by the C-5, the MESL is defined at a different level of WUC indenture. The final complexity we noted in modeling the concept of a MESL is that by regulation, the MESL is not intended as an operational "go/no go" decision tool for determining whether an aircraft can perform a particular mission. This decision is made by operations personnel (e.g., aircraft commander) based on criteria specified in what is referred to as the Minimum Equipment List (MEL). Suffice to say that these complexities need to examined in more detail to determine what essential components or logic associated with a MESL are suitable for inclusion in a MAAF simulation model. For purposes of modeling the concept of a MESL to some level of fidelity in the MAAF demonstration, we derived a set of business logic that is outlined in Appendix 4.

4.0 MAAF Design Definition

4.1 Overview of Object-Oriented Design Concepts for MAAF

The MAAF simulation architecture for the concept demonstration is based on object-oriented (OO) design principles. An object model is well-suited for the design and development of a MAAF simulation-based decision support application primarily because it more closely relates to the real world environment and promotes a better understanding of requirements, clearer designs, and more maintainable systems [6].

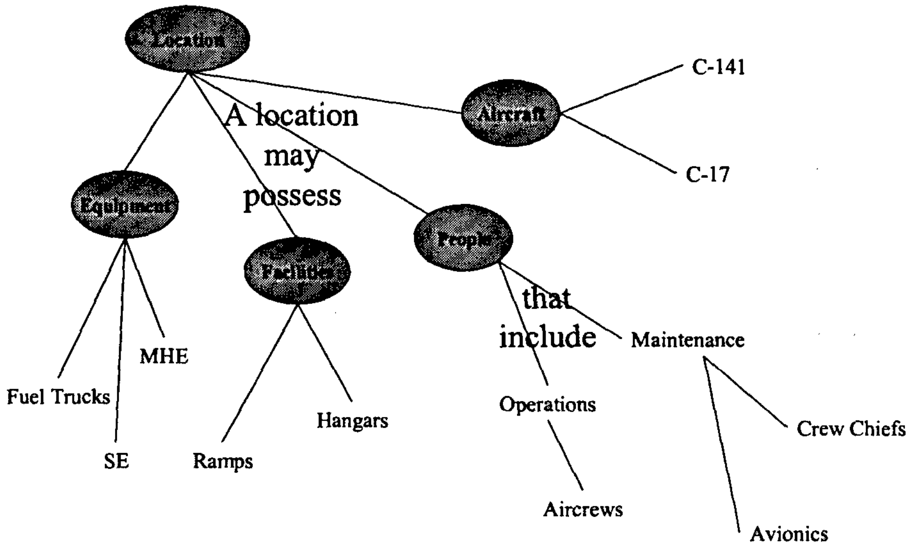

Figure 4. MAAF OO-Based Design Concept

Figure 4 provides a simplified representation to aid in understanding the application of OO-based design concepts to MAAF. The ovals in Figure 4 are intended to represent *object classes* that can encapsulate both *methods* (functions) and *attributes*. In MAAF, a *method* could describe the unscheduled repair of an aircraft system or component, and an *attribute*, could represent aircraft flying hours. Referring to the example in Figure 4, an *Aircraft* can be described as an object class for which specific types of objects can be defined (e.g., *C-17* or *C-141*). Each object within a class can inherent the methods and attributes defined for the object class. These methods and attributes can then be tailored to represent the specific methods and attributes for each respective object. For example, the C-17 and C-141are both types of aircraft that have cargo capacity, so this characteristic could be defined as an *attribute* called "cargo capacity" of the object class *Aircraft*, and the specific objects of *C-17* and *C-141* that descend from this class can inherit the "cargo capacity" attribute that can then be tailored to describe the specific cargo capacity of each type of aircraft. The OO-based design concept provides a tremendous amount of flexibility for modeling complex systems, helps reduce the amount of programming required (through code re-use), and promotes scalability in model development.

4.2 MAAF Global, Project, and Experiment Templates

The design concept for constructing simulation models in MAAF strongly emphasizes the OO feature of component reusability. The MAAF concept encompasses three types of reusable "templates" that for MAAF purposes, are referred to as *Global, Project*, and *Experiment* templates. *Global* templates are intended to support the definition of baseline capabilities, resources, and policies for locations as well as aircraft mission profiles. *Project* templates support the modeling of specific questions or "taskers." For example, an analyst might be tasked to assess the resource impact of opening a new enroute location on aircraft availability or throughput. In this case, the analyst could create a MAAF project specifically to address this "tasker", select an existing location from one of the Global templates that possessed similar capabilities and resources, and create the new enroute location, and tailor the existing information in the Global template to model the capabilities and resources at the enroute location. Once a MAAF project is created, the user can then save this information in a Project template, then define and execute multiple simulation experiments using *Experiment* templates. Experiment templates allow a user to specify mission and activity schedules, the number of simulation runs, etc. In addition, the Experiment templates are also intended to support parametric analysis, and assess changes to policies affecting aircraft maintenance, personnel, etc.

4.3 MAAF Architecture (Concept Demonstration)

Figure 5 provides a top-level overview of the primary components of the MAAF architecture specifically designed to support the concept demonstration. The user interface component provides the capability to create and modify MAAF simulation projects, the setup and running of MAAF simulation experiments, as well as viewing and analyzing simulation outputs. The database component of MAAF provides the capability to store the data and information associated with each MAAF project or experiment, or "global" templates that are intended to support the rapid development of MAAF simulation projects and experiments. The database and reports interface components of MAAF provide the mechanism for communicating with the MAAF simulation database and to access the results generated from a simulation, currently stored in flat files. The simulation model and engine is where objects and business rules are described, and where the actual simulation of events described in an experiment takes place. In an operational environment, it is anticipated that there would be other data or system inputs to the MAAF database (e.g., CAMPS mission data, G081 R&M data, etc.) that would be leveraged to help support the development and/or update of MAAF projects and experiments, but since these systems are not included as part of the MAAF concept demonstration, they were not depicted in architecture diagram shown in Figure 5. In addition, it is anticipated that simulation results would be stored in the MAAF database to support the integration of future MAAF simulation analysis and reporting capabilities.

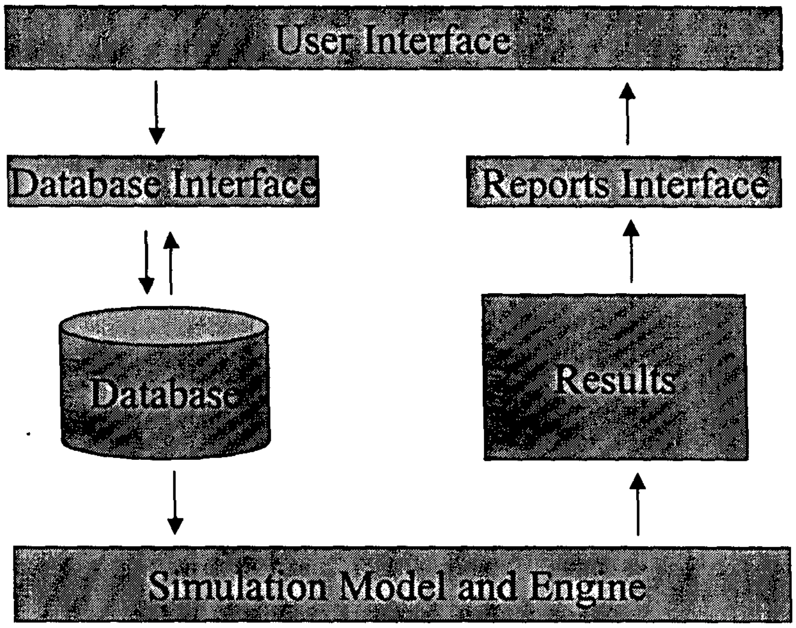

Figure 5. Top-Level MAAF Architecture

4.4 Overview of JADIS

The MAAF simulation developed for this requirements definition and proof-of-concept effort is based on extensions to the JADIS architecture [7]. JADIS stands for *Java-based Architecture for Developing Interactive Simulations.* JADIS was developed in large part at Wright State University under the direction of Dr. S. Narayanan and sponsored by the Human Effectiveness Directorate of the Air Force Research Laboratory. An overview of the JADIS architecture and key components is provided below.

There are four basic components to JADIS, including the Basic Simulation, Basic Interface, Communication Infrastructure, and Modeling Infrastructure components. The Basic Simulation component include fundamental simulation elements (objects in the case of JADIS) such as the simulation clock, random number generators, random variate generation capabilities, and various queue objects. The Modeling Infrastructure includes those objects used to build models based on a particular domain of interest, and the supporting domain analysis upon which the simulation model is constructed. These Basic Simulation and Modeling Infrastructure components were of particular interest and value to the MAAF simulation development. The Basic Interface component contains objects useful for building the graphical user interfaces necessary for visual information systems (VIS). The Communication Infrastructure contains objects employed to accommodate information passing between a simulation model and the interface. Neither of these components are used extensively in the MAAF simulation.

The focus in the initial design and development of JADIS was on modeling the logistics resources of a single airbase supporting fighter aircraft flight operations using various generic approaches to determining fighter missions, or sorties. This particular implementation of the JADIS architecture for provided for a baseline simulation model and engine that was subsequently extended as part of the MAAF research effort to support the MAAF proof-of-concept demonstration.

4.5 Extensions of JADIS for MAAF

The MAAF domain is different than the fighter domain modeled in the past using JADIS. Fighter missions typically involve aircraft leaving and returning to their home base, usually within a smaller time window (for instance the same day). Mobility aircraft missions can span several days and involve stops at multiple bases or enroute locations throughout the mission. This is in contrast to fighter aircraft that in a single mission, depart and return to their home station and generally have the requisite maintenance resources with which to accomplish repairs. Mobility aircraft may land at enroute locations possessing a minimal support infrastructure and lacking in requisite maintenance capabilities for anything but possibly routine maintenance. These primary differences, and other more subtle differences, led to the definition, design, and implementation of extensions to the JADIS architecture to support the development of the prototype MAAF simulation model.

The basic aircraft object was extended to provide the aircraft knowledge of

- it's current mission;
- the current leg executing on the mission;
- current status of the aircraft with respect to function systems (i.e., full or partially mission capable); and
- minor repairs awaiting action upon return to home station.

The airbase object was extended to accept transient aircraft objects in addition to the return of home station assets. The airbase object was also extended to model personnel on duty (per shifts) by maintenance specialty code, and to generate missions that either originate at the home station or are required for the next leg of some transient aircraft mission. Additionally, the airbase object was extended to accommodate multiple types of aircraft both in terms of similar missions (cargo or fighter) and in terms of system (C-5 or C-17).

The maintenance activity model was extended to consider the availability of base resources versus the resources required by the maintenance action. In past simulations, when an object is unable to acquire resources needed to proceed along some activity (e.g., maintenance), the object stayed within the resource queue indefinitely. In the MAAF concept demonstration, the lack of required resources at a base triggers a pre-defined delay that is intended to represent the real-world AMC action of sending a maintenance response team to the site to conduct the repair. This extended resource consideration also considered the criticality of the maintenance action. In mobility operations, a minor repair can be postponed during the execution of a mission provided that the repair is not critical to the accomplishment of the remaining legs of the mission. The resulting PMC aircraft status is maintained until the minor repair is accomplished upon return to home station. This modeling capability is a novel concept realized by the MAAF simulation.

MAAF simulation airbase objects must accommodate home station and transient aircraft. In the mobility domain, capturing this capability in a simulation is important. When aircraft objects take-off from a base to commence some leg of a mission (leave current location), the aircraft object will "fly" a direct route to the destination base or location (destination for the current leg of the mission). The destination airbase accepts the transient aircraft, performs requisite thru-flight activities including unscheduled maintenance (depending on the type failure and maintenance capabilities), and then prepares and launches the aircraft to continue onto the next leg of its mission. The Coordinator object methods were extended from JADIS to comprehend and accommodate home station versus transient aircraft considerations.

5.0 Task 3 – MAAF Concept Demonstration

The MAAF concept demonstration is intended to convey the utility of MAAF, and showcase the key features of an OO-based simulation model that AMC logistics planners and analysts can use as a decision support tool to better predict aircraft availability, as well as to assess the impact of policy and resource changes on aircraft availability. In designing and developing the concept demonstration the focus was on breadth, not depth, of functionality. In essence, to be able to show users how they might use MAAF to create a simulation project, define an experiment, run a simulation, and assess model results. Therefore, the functionality supporting each of these capabilities is confined to supporting the important characteristics outlined in the MAAF scenario and use cases described earlier in this report (e.g., modeling a channel mission that traverses multiple locations).

5.1 Project Setup and Demonstration Data

To support the development and testing of the concept demonstration, a MAAF project was created to model both the baseline and "what-if" use cases defined in the MAAF demonstration scenario. The project includes the locations identified scenario – namely Dover AFB, Ramstein AB, Sigonella IAP, and Kuwait City IAP. For each location, we coordinated with and obtained data from HQ AMC/A44Q on the type and number of maintenance personnel and aircraft assigned to each of these locations. Since no other resource types were addressed in the concept demonstration, no data was collected for resources such as support equipment, spares, facilities, etc.

In addition to defining an initial set of personnel for each location, historical R&M data was also obtained from both G081 and REMIS for both C-17 and C-5 aircraft. This information was used to derive Mean Time Between Failure (MTBF) and Mean Time to Repair (MTTR) statistics for each of the top 25 subsystems or components for the C-5 and C-17. The top 25 list is based on a rank-ordering of MTBF values from G081 and are the only subsystems/components currently included in the MAAF demonstration project (see Appendix 5). LCOM data was obtained from HQ AMC/XPMRL to help derive AFSC and crew size requirements for each of the subsystems/components on the top 25 list.

For purposes of the demonstration, we focused on modeling a single type of channel mission for both the C-5 and C-17. The C-17 mission is addressed in the baseline use case, and the C-5 is addressed in the "what-if" use case. To support the description of these missions in MAAF, we obtained estimates from AMC CAMPS program personnel on the average flying times between each of the locations specified in the scenario.

The final type of data collected to support the MAAF demonstration project involved aircraft scheduled inspections and maintenance, as well as ground handling and servicing activities. For the demonstration, our intent was to model a subset of these type activities to support the processing of aircraft for mission and to show the potential impact of aircraft scheduled inspections/maintenance on aircraft availability. For scheduled inspections/maintenance, we focused on collecting data to model C-5 and C-17 aircraft preflight, thru-flight, postflight, and isochronal inspections, as well as home station checks, and aircraft washes. For each of these activities, we collected estimates on the average duration and AFSC crew composition and included this in the MAAF demonstration project. The estimates are based on data obtained from AMC/A44Q and LCOM scenarios for selected ground handling, scheduled inspection/maintenance, and servicing activities.

5.2 Mission Event Processing Cycle

The MAAF simulation is defined by the particular locations, resources, etc., defined in our MAAF project supporting the concept demonstration. The next significant part of the demonstration development effort centered on defining the logic for simulating the aircraft channel missions in our scenario. For concept demonstration purposes, we developed and coordinated with AMC, a very scaled-down "sequence of events" to represent what we refer to as the "mission event processing cycle". This sequence of events represents the logic that is currently used in the MAAF demonstration to process an aircraft through the complete mission cycle including maintenance, transportation, and sortie tasks. It is important to note that the actual sequence of events for a specific AMC aircraft and mission is much more detailed in terms of the actual number of tasks that occur, their specific sequencing, duration, etc.

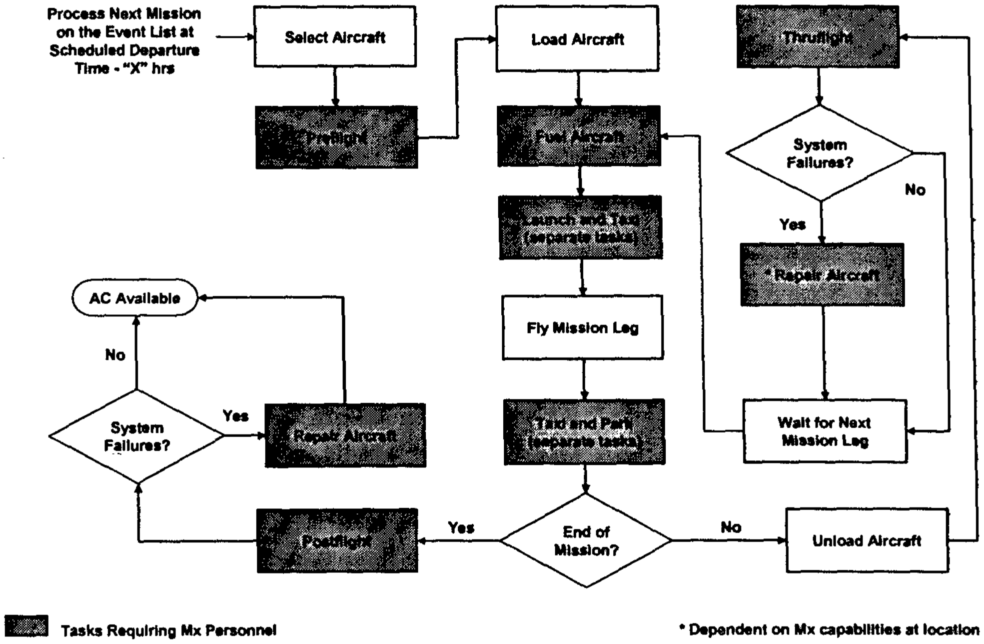

Figure 6. MAAF Demonstration – Mission Event Processing Cycle

Figure 6 portrays the sequencing of the specific tasks that are currently modeled in the MAAF demonstration. This sequence includes tasks that consume time and/or resources (e.g., aircraft "Preflight"), and model *special* tasks that do not consume time and/or resources, but rather encapsulate the intrinsic business rules or logic in MAAF that control the processing of events in the simulation. For instance, "Select Aircraft" is a special task that incorporates the logic or business rules associated with the selection of aircraft for a particular mission (e.g., aircraft in an NMC state are not available for mission selection). In addition, not all the tasks in the sequence of events shown in Figure 6 involve maintenance resources, but are included to demonstrate the future flexibility of MAAF for defining and modeling other types of tasks including tasks that accrue time, but do not involve personnel (e.g., "Aircraft Taxi"), and tasks primarily performed by other types of personnel such as transportation (e.g.,. "Load Aircraft" and "Unload Aircraft").

Referring to Figure 6, the key components of the MAAF mission event processing cycle include the 1) selection of aircraft, 2) pre-mission processing, 3) flying a mission leg, and 4) enroute and post-mission processing.

a. Selection of Aircraft. In a MAAF simulation, the processing cycle for a mission begins when a mission appears as the next event on the event list (actually at some preset time before the scheduled departure time to allow time for aircraft preflight, servicing, and launch activities, etc.). For purposes of the demonstration, this task occurs 12 hours prior to the scheduled departure of a mission. Based on the mission information specified by the user in the MAAF project, the model determines the type and quantity of aircraft required, type mission, mission routing, scheduled departure and arrival times, etc. When evaluating an aircraft for mission assignment or selection at home station, the model considers the MESL requirements for the type mission to be flown, and compares these requirements against the current status of a candidate aircraft. If the required systems/components on the aircraft being examined are functional (or meet MESL requirements), then the model selects the aircraft and assigns it to the mission, otherwise it looks at the next available aircraft. For demonstration purposes, only aircraft in an FMC status are considered candidates for mission selection. Aircraft in a PMC or NMC status are not considered by MAAF for mission selection.

b. Pre-Mission Processing. Once an aircraft is selected for a mission, it undergoes a preflight inspection, loading, servicing (fueling), and launch processing, and then departs at its scheduled departure time on the first leg of the mission. Ground aborts and unscheduled maintenance are not currently addressed in pre-mission maintenance processing.

c. Flying a Mission Leg. Upon completion of the aircraft "taxi" task, the model considers the aircraft as flying and starts the accrual of flying time and other essential information during this portion of the mission (mission segment). Air aborts, weather diverts, etc., are not currently addressed in the model.

d. Enroute and Post-Mission Processing. Once a mission leg is completed and the aircraft lands, the accrual of flying time stops and the aircraft taxis to a parking location, where it is parked by maintenance personnel. There are two cases (at least) to consider at this point.

- **End of Mission.** If this was the final leg or segment of the mission, then is assumed that the aircraft is back at home station (although in reality the mission may terminate at another location, and through "flight following", begin a new mission). At home station, the aircraft receives a post-flight inspection, and the MAAF model checks for system failures, and updates aircraft status (if necessary). If there are any system/component failures, the model schedules the repair of ***all*** failures and once maintenance is complete, the model returns the aircraft in an FMC status to the available pool of aircraft for mission assignment.

- **End of Mission Segment.** If this leg of the mission is not the termination point for a mission (i.e., the aircraft is at an enroute location), then the aircraft receives a thru-flight inspection and the MAAF model checks for system failures. If there are system failures, the model updates the aircraft status based on the MESL, and checks to see if the location possesses the maintenance personnel required to perform repairs. If the personnel required are assigned to the location, then the model schedules and accomplishes the necessary repairs. If the personnel required to accomplish the repair of a system(s) are not assigned to the location, then the model delays the aircraft for 12 hours to simulate the time involved in deploying a mission ready technician (MRT) to the location and performing repairs. Once all repairs are complete at the enroute location, the aircraft status is changed to FMC and the aircraft is re-fueled and continues (at its scheduled departure time) on the next leg of the mission.

6.0 MAAF Output Reports and Analysis

The MAAF model supports the generation of summary level and detailed reports on key statistics to support the assessment of mission accomplishment, MC rates, logistics departure reliability, aircraft availability, and repair cycle times. These statistics can be viewed by type aircraft, type mission, and/or location basis to support an assessment of model performance at home station and enroute locations. The summary level report generated by MAAF is intended to provide a user with a quick overview of key simulation statistics aggregated over the time period of the simulation (e.g., overall MC rate). The detailed reports generated by MAAF for key statistics can be displayed in both graphical and tabular formats and allows a user to view the trend of statistics on daily basis over the period of a simulation. This is particularly helpful in assessing statistics related to aircraft availability and mission accomplishment. In addition to providing reports for individual simulation experiment runs, MAAF also supports the comparison and analysis of key from multiple experiments. This is particularly useful in assessing the impact of a policy change (e.g., changing the frequency of an aircraft scheduled activity) or parametric change (e.g., changing the reliability of an aircraft system) against a baseline experiment to evaluate the potential impact of such a change to key operational and logistics metrics. Appendix 6 includes a sample summary level and detailed report generated from the MAAF reports module for a single experiment. Appendix 7 provides a sample summary and detailed report from the MAAF analysis module to support the comparison of key statistics for multiple MAAF experiments.

7.0 Conclusions

One of the main objectives of the MAAF research effort was to explore and demonstrate the feasibility of using object-oriented simulation technologies and concepts to develop a modeling tool that can assist AMC logistics analysts in predicting and assessing the availability of AMC aircraft under different operational scenarios. While the MAAF demonstration model represents only a subset of the functionality that would be required in an operational MAAF model or application, we assert that the demonstration achieves this objective by highlighting the core functions necessary for constructing a MAAF model, executing simulation runs, and evaluating simulation outputs. In particular, we think that MAAF could be a useful tool for helping analysts gain better and quicker insight into questions related to aircraft availability, resource shortfalls, potential home station and enroute location bottlenecks, etc. The feedback from AMC personnel during the final review of the MAAF research effort and demonstration model would also seem to support these assertions.

However, as discussed earlier in this report, we feel that the success of any potential follow-on efforts to transition and deploy MAAF will hinge on defining the "right" of model fidelity commensurate with the overall goals and objectives of a MAAF modeling tool and user requirements. Based on our research, we conclude that in addressing the MAAF model fidelity question, it will be important to investigate the following in more detail:

- Representation of the aircraft MESL and the business rules associated with changing the status of aircraft. The current MAAF demonstration model incorporates a simplified representation of the MESL and associated business rules. These rules will need to be expanded to more accurately address the tracking and changing of aircraft status mission requirements and aircraft R&M factors.
- User interface requirements to support the intuitive setup, execution, and analysis of MAAF simulation experiments by AMC logistics analysts. This is probably one of the more challenging tasks since the modeling and assessment of resource and scheduling issues at multiple locations is a complex task that will need to be supported by a more robust MAAF analysis module that can provide an appropriate level of feedback to an analyst to help identify problem areas in the simulation and suggest alternative courses of action.
- Input data sources for aircraft R&M parameters, resource levels at various AMC operating locations, and mission scheduling information. The MAAF research effort investigated

various data sources that could be leveraged in a follow-on effort to address these inputs, including G081 for aircraft reliability parameters, LCOM for maintenance repair and personnel requirements, and CAMPS for mission planning and scheduling information. Although, the demonstration model does not directly interface with these sources, data and information from these sources were utilized in the design and development of the MAAF demonstration model.

These are a few of the more important topics we recommend should be addressed in any potential follow-on research and transition efforts. Working closely with AMC personnel, we feel these topics can be addressed to the level of detail necessary to ensure the right level of model fidelity.

8.0 References

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9.0 Glossary

AATS	Aircrew / Aircraft Tasking System (AATS)
AMC	Air Mobility Command
BSL	Basic Systems List
CAMPS	Consolidated Air Mobility Planning System
FMC	Fully-Mission Capable
FSL	Full Systems List

LCOM	Logistics Composite Model
JADIS	Java-based Architecture for Developing Interactive Simulations
MAAF	Mobility Aircraft Availability Forecasting Model
MC	Mission Capable
MEL	Minimum Equipment List
MESL	Minimum Essential Subsystem List
NMC	Not Mission Capable
OO	Object-Oriented
PDM	Programmed Depot Maintenance
PMC	Partially Mission Capable
PMCB	Partially Mission Capable Both
PMCM	Partially Mission Capable Maintenance
PMCS	Partially Mission Capable Supply
TACC	Tanker Airlift Control Center
WIC	Weapons Instructor Course

Appendix 1. MAAF Project Team Members

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Appendix 2. MAAF Model Requirements Definition Questionnaire

Name ______________________________________

ORGANIZATION ______________________________________

POSITION/TITLE ______________________________________

COMM. PHONE ______________________________________

E-Mail ______________________________________

The MAAF Model Research Team is beginning the process of defining the functional and technical requirements for the MAAF model. While most of this work will be accomplished in greater detail in conjunction with the MAAF conference scheduled for later in August, we are interested in trying to get some general questions answered in advance of this meeting to help make the upcoming meeting and requirements work more productive and focused. Your participation is greatly appreciated.

"REMARKS" ARE STRONGLY ENCOURAGED WHERE APPLICABLE BELOW

1. The AMC Logistics Directorate does not possess a capability to 1) quickly and accurately forecast aircraft availability, 2) assess and evaluate the impact of policy changes or limiting factors on aircraft availability, and 3) perform "what-if" type analyses of alternative strategies (e.g., resource allocation) or policies impacting aircraft availability to determine "best" solutions.

   Agree Disagree Neither Agree/Disagree

   Remarks:

2. The AMC/LG staff routinely gets tasked to assess the potential logistics impact of near/long term ***operational taskings***. These taskings may include predicting the impact to aircraft

availability, assessing resource shortfalls at locations that will be impacted by operational taskings, etc.

Agree Disagree Neither Agree/Disagree

Remarks:

3. If you responded “Agree” to the previous question, can you describe in general how such an assessment is currently performed?

4. The AMC/LG staff routinely gets tasked to assess the future logistics impact of potential ***policy changes*** related to training, maintenance, etc. as well as potential organizational realignments affecting AMC units or bases. These types of taskings may include assessing the impact to aircraft availability and/or mission capability, as well as potential resource shortfalls at locations affected by the respective policy change or organizational realignment.

Agree Disagree Neither Agree/Disagree

Remarks:

5. If you responded “Agree” to the previous question, can you describe in general how such an assessment is currently performed?

6. Per the “AMC Metrics Handbook for Mobility Air Forces (1st Edition, July 2003)”. AMC measures *“Fleet Availability”* by the metric *“Mission Capable Rate”*, which is the percentage of possessed hours that an aircraft is partially or fully mission capable. The MC Rate is computed as follows:

$$\frac{\text{FMC Hours} + \text{PMCB Hours} + \text{PMCM Hours} + \text{PMCS Hours} \;\; \text{X} \; 100}{\text{Possessed Hours}}$$

Hence, one of the primary goals for the MAAF model will be to derive predictions of future *"Fleet Availability"* according to this computation, including modeling or tracking each of the component parameters of the MC rate formula (e.g., tracking possessed hours).

Agree Disagree Neither Agree/Disagree

7. If you responded "Agree" to the previous question, are the data sources and business rules readily available and clearly defined for deriving each of the component parameters used in the MC rate calculation (e.g., possessed hours, PMCM hours, etc.)? Can you identify some of the key data sources?

8. In your opinion, what do you feel are the top three factors (availability of spare parts, training, etc.) that impact aircraft availability"?

   a.
   b.
   c.

9. In your opinion, who are the potential target users (organization / specialty) of the MAAF model (e.g., HQ AMC/LGMQA / Maintenance Analyst)?

   a.
   b.
   c.

10. Is there <u>one</u> predominant user in particular from the target group above that we would want to focus on during the MAAF research effort? Why?

11. Describe a tasking or problem from <u>your</u> daily work experiences that you would want to be able to address using the MAAF model? How do you perform this tasking or address this problem now?

12. What features of a MAAF model could help you perform your work more effectively ("doing the right things") and/or efficiently ("doing things right")?

13. Is there one specific tasking that the MAAF model should be particularly focused on helping an AMC staff analyst or action officer address?

14. What types of information (reports, statistics, etc.) would you expect the MAAF model to produce and output?

15. What do you foresee are the key systems or data sources that the MAAF model may need to interface with in the future (e.g., mission data from GDSS)? For each system or data source, please provide a short description of the type of data or information that might be provided to the MAAF model.

Appendix 3. MAAF Demonstration Scenario and Use Cases

The purpose of the demonstration scenario and summary use case description that follow is to provide a situational context that supports the process of thinking about, identifying and defining some of the core capabilities (e.g., modeling a multi-leg mission) and key features that would be needed in a MAAF modeling application. The scenario and use case components provide a setting for the MAAF proof-of-concept demonstration that will highlight a subset of these capabilities and features, and provide a means for explaining how a MAAF application might be used by logistics analysts at AMC to model and predict aircraft availability.

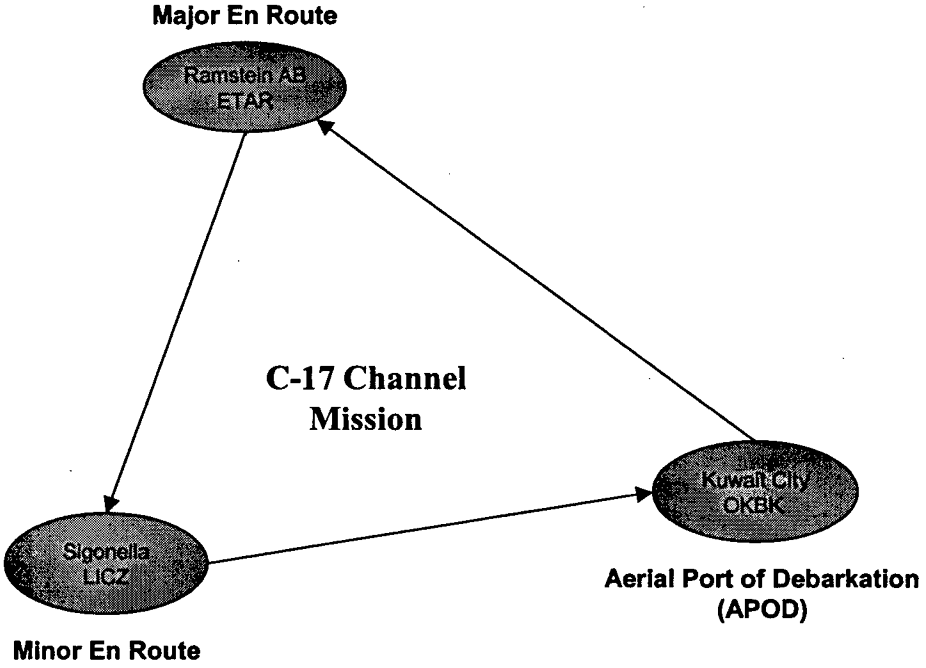


Figure 1. Demonstration Scenario - "Baseline"

The demonstration scenario has two use case components that we've arbitrarily labeled *"baseline"* and *"what-if"* (Figures 1 and 2 respectively). The intent of the baseline use case is to provide an operational setting that emulates a "normal" mission that, on any given day, might occur at a major enroute location like Ramstein AB. The baseline scenario portrayed Figure 1 looks at a notional channel mission that involves the movement and delivery of 150 short tons (ST) of cargo a day from Ramstein AB to Sigonella AB and Kuwait City IAP (75ST/ea). The cargo will be transported on a daily basis to these locations by C-17 aircraft based at Ramstein AB. We will assume that there are no aircraft based at Sigonella AB or Kuwait City IAP.

The “what-if” use case component of our demonstration scenario shown in Figure 2 expands on the “baseline” described above to look at the application of the MAAF model for assessing the potential operational and logistics impacts associated with supporting a notional humanitarian relief operation that would involve the flow and distribution of an additional 100 ST/day of cargo through Ramstein AB to Sigonella AB and Kuwait City IAP. In support of this notional operation, C-5s based at Dover AFB will transport 100ST of cargo daily from Dover AFB to Ramstein AB. At Ramstein AB, the cargo will be off-loaded from the C-5s (which will return to Dover AFB) and transported on a daily basis by C-17s based at Ramstein AB to Sigonella AB and Kuwait City IAP. We will assume the C-17 missions associated with this new tasking will be accomplished without the addition of any resources, and in addition to the current C-17 channel mission described in our baseline scenario. In essence, supporting this notional operation will represent an additional workload for the C-17s, maintenance personnel, and other resources already based at Ramstein AB. The goal is to transport the 100 STs/day arriving at Ramstein AB to Sigonella AB and Kuwait City IAP (50ST/ea). The TACC is predicting that this operation would continue for up to 60 days.

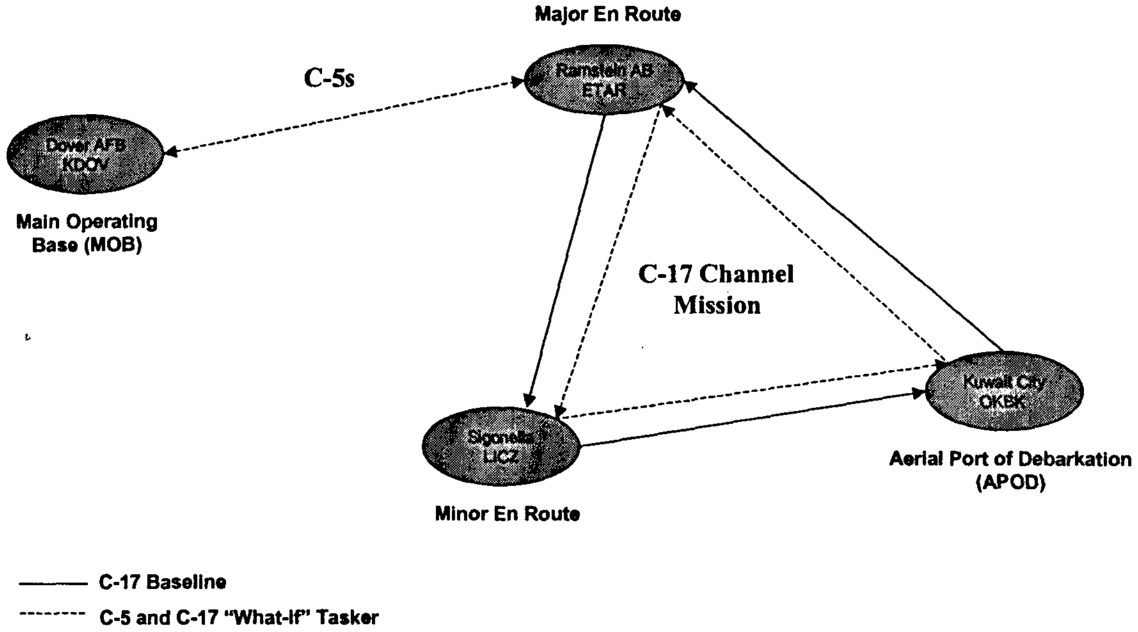


Figure 2. Demonstration Scenario - “What-If”

Some sample questions related to the demonstration scenario that an analyst might use the MAAF model to help answer:

1. Can the C-17s currently based at Ramstein AB support the additional channel missions required to support the humanitarian relief operation without additional C-17s? If not, how many additional “taskable” C-17 aircraft would be needed at Ramstein?

2. How long can the C-17s currently based at Ramstein AB support the additional channel missions before more aircraft will be required?

3. How does additional flow of transient C-5 aircraft from Dover to Ramstein AB impact Ramstein’s ability to generate “taskable” C-17 aircraft?

4. Can the maintenance manpower already in-place at Ramstein AB, Sigonella AB, and Kuwait City IAP support this new tasking for 60 days? If not, how many additional maintenance personnel would be needed at each location?

Some of the key MAAF design challenges exposed by the scenario include the following:

1. Modeling AMC mobility missions that involve multiple segments (legs) and "accurately" tracking aircraft status.
2. Modeling the logic associated with selecting an aircraft for mission assignment based on aircraft status (e.g., FMC, PMC, NMC).
3. Modeling maintenance capabilities for various types of AMC bases and enroute locations.
4. Providing an intuitive capability for functional analysts (non-programmers) to create simulation objects representing a base or location, aircraft, personnel, etc. This includes defining the attributes, methods, and business rules associated with a particular simulation object.
5. Providing an intuitive capability for functional analysts (non-programmers) to define both mission and non-mission events that "drive" the simulation.

Appendix 4. MAAF Rules for Changing Aircraft Status (Demonstration Only)

1. At the beginning of any MAAF simulation run, assume all aircraft are in an FMC status (state).

2. Assume that for aircraft undergoing a scheduled maintenance activity (e.g., isochronal inspection, home station check, or wash), the aircraft status is changed to NMC upon entering the activity.

3. For unscheduled maintenance, the MAAF demonstration will align to the rules identified below when checking system failures, assessing changes to aircraft status, and performing repairs.

C-5 MESL Column References (for the MAAF demonstration only "B" and "C" apply)

A: Local Trainer Departing Home Station (not applicable in demonstration)
B: Mission Departure From Home Station
C: Departure at Enroute Locations

C-17 MESL Column References (for the MAAF demonstration only "A"applies)

A: Airland
B: Evacuation
C: Tactical
D: Air Refueling

Aircraft Status and Repair Rules:

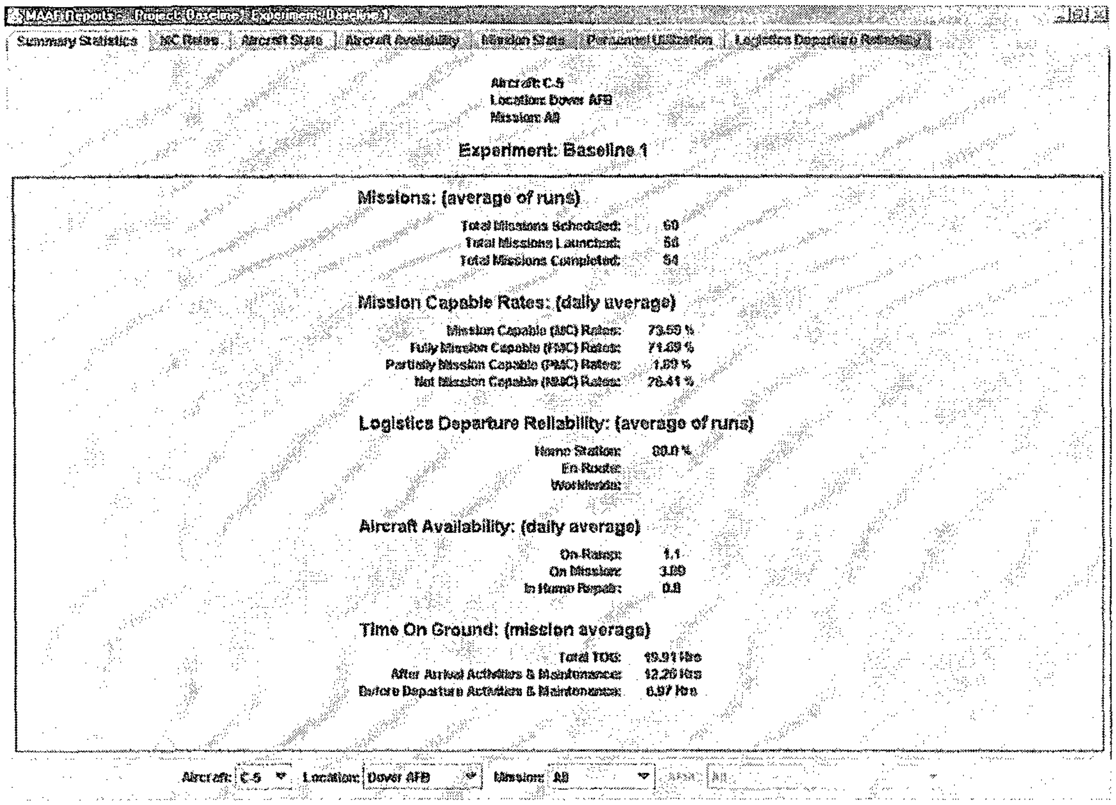
Question	Response	Action	Remarks
A. Does a failure exist on a system, subsystem, or component specified in the MESL?	Yes No	Go to "B" FMC	
B. Are all columns of the MESL checked for the failed system, subsystem, or component specified in the MESL?	Yes No	NMC, Go to "C" PMC, Go to "C"	
C. Is the aircraft at home station or an enroute location?	Home Station Enroute		Schedule repair of aircraft. Schedule repair of aircraft if resources are available at the enroute location, else delay aircraft for 12 hours to simulate repair of the aircraft by a maintenance recovery team.

Appendix 5. MAAF Top 25 R&M Data – C-5 and C-17

		C5	MTBF	MTTR
	WUC	ITEM/SUBSYSTEM	(hrs)	(hrs)
1	11XPR	SK APU INS DR PNL L	5.62	1.38
2	23EAL	COWL DOOR (OPEN/CLOSE)	12.71	2.00
3	11XJD	SK APU INS DR PNL R	14.43	1.29
4	23000	TURBOFAM PWR PLT SYS	15.76	2.85
5	11000	AIRFRAME	18.87	5.42
6	13AA4	ROLL PIN LOCK TAB	21.19	2.90
7	41JA0	BLEED AIR SYS GENERAL	21.82	2.57
8	65BCH	TRANSPONDER COMPUTER	23.31	0.98
9	65BA0	MODE S (IFF R/T APX-100) TRANSCEIVER	25.02	1.30
10	11TUE	STRUCTURAL ASSY PYLON #1	25.58	6.02
11	12JCD	SEAT 3 MAN AFT F BL	26.14	1.40
12	12CAF	CARGO CMPT FLOOR	27.03	4.13
13	14JCV	GRBX TEE OTBD=1 LH	30.23	0.99
14	12AAP	SEAT ASSY PILOT	31.89	1.59
15	23EA0	NACELLE STRUCT GENERAL GR 1	33.71	5.21
16	23EAE	COWL ENGINE INLET	33.72	3.98
17	45LAA	MTR AIR TURB SYS	36.61	3.62
18	12CA0	CARGO COMP FRNSHGS GENERAL GRP 1	36.71	6.20
19	64AA0	INTERCOM SYS GENERAL	40.54	2.96
20	52EA0	COMPUTER, GAAS	41.52	2.93
21	49C00	FIRE SUPPRESSION SUBSYS	41.62	2.09
22	13AAM	BOGIE ASSY MLG	42.00	3.49
23	51AFA	IND HORIZ SITUATION	42.82	3.12
24	23EAK	COWL DOOR LH	44.80	3.37
25	72HD0	BATTERY UNIT	45.39	2.03

		C17	MTBF	MTTR
	REFDES	ITEM/SUBSYSTEM	(hrs)	(hrs)
1	7200	ENGINE ASSEMBLY	408.5	6.53
2	4910	POWERPLANT	1177.0	9.19
3	3210	MAIN GEAR	1541.7	3.25
4	2580	ARMOR PROTECTION	1985.2	3.72
5	3130	RECORDERS	2163.7	2.12
6	2210	ELECTRONIC FLIGHT CONTROL	2728.8	6.05
7	2310	SPEECH COMMUNICATIONS	3393.5	3.39
8	2780	SLATS	3763.4	3.73
9	3340	EXTERIOR	3836.1	2.31
10	3442	RADAR ALTIMETER	4436.2	4.14
11	2750	FLAPS	5258.8	3.94
12	2710	AILERON	5293.8	6.68
13	3310	FLIGHT COMPARTMENT	5592.1	2.61
14	3900	ELECTRICAL/ELECTRONIC	5592.1	4.02
15	2230	AUTO THROTTLE	5672.0	3.72
16	3133	Signal Data Recorder	5733.4	1.95
17	5230	CARGO/RAMP	5882.0	2.78
18	3220	NOSE GEAR	5896.6	3.00
19	2510	FLIGHT COMPARTMENT	6252.6	1.80
20	9312	MISSILE WARNING SYSTEM	6411.8	6.50
21	4000	SYSTEM INTEGRATION	6965.6	4.10
22	3240	WHEELS AND BRAKES	7262.9	3.12
23	2840	INDICATING	7635.3	6.51
24	3443	INERTIAL REFERENCE	7706.6	3.83
25	2550	CARGO COMPARTMENT	8136.0	1.20

Appendix 6. MAAF Reports Module – Sample Summary Level and Detailed Report



Aircraft: C-5
Location: Dover AFB
Mission: AB

Experiment: Baseline 1

Missions: (average of runs)

Total Missions Scheduled: 60
Total Missions Launched: 58
Total Missions Completed: 54

Mission Capable Rates: (daily average)

Mission Capable (MC) Rates: 73.59 %
Fully Mission Capable (FMC) Rates: 71.69 %
Partially Mission Capable (PMC) Rates: 1.89 %
Not Mission Capable (NMC) Rates: 26.41 %

Logistics Departure Reliability: (average of runs)

Home Station: 80.0 %
En Route:
Worldwide:

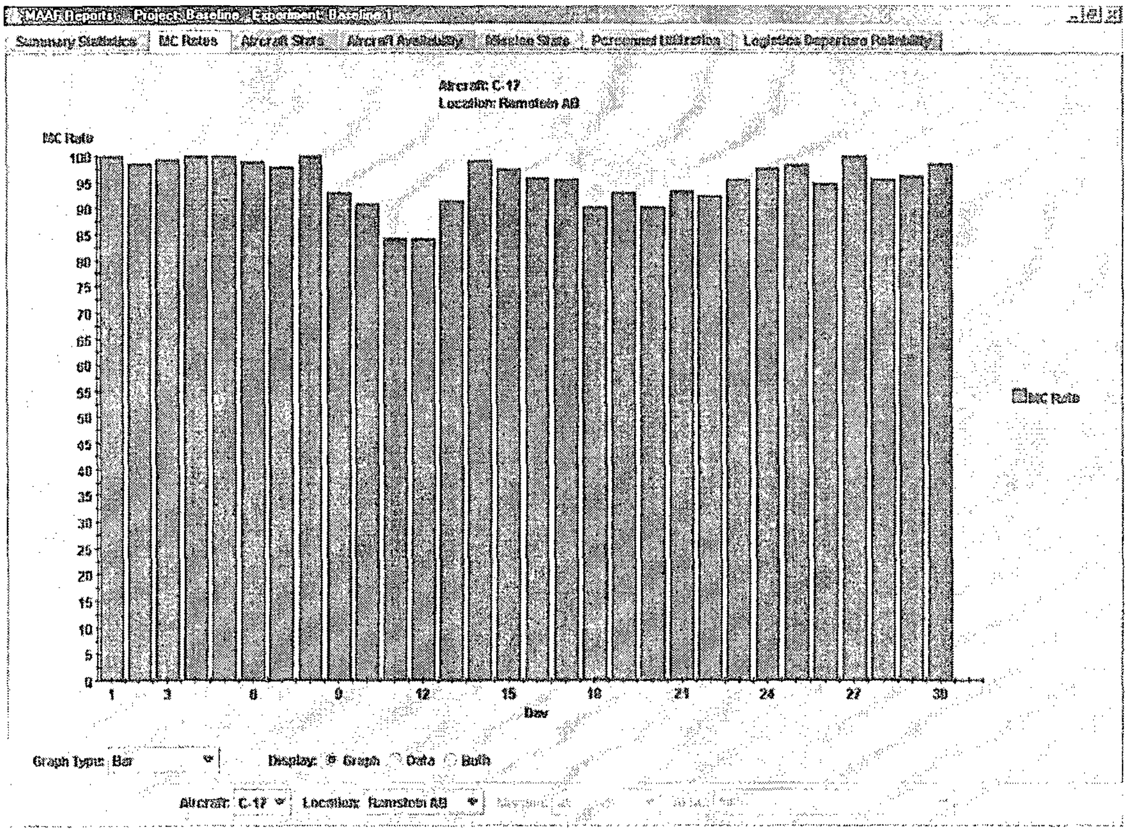
Aircraft Availability: (daily average)

On Ramp: 1.1
On Mission: 3.89
In Home Repair: 0.8

Time On Ground: (mission average)

Total TOG: 19.91 Hrs
After Arrival Activities & Maintenance: 12.26 Hrs
Before Departure Activities & Maintenance: 6.97 Hrs

Aircraft: C-5
Location: Dover AFB
Mission: AB



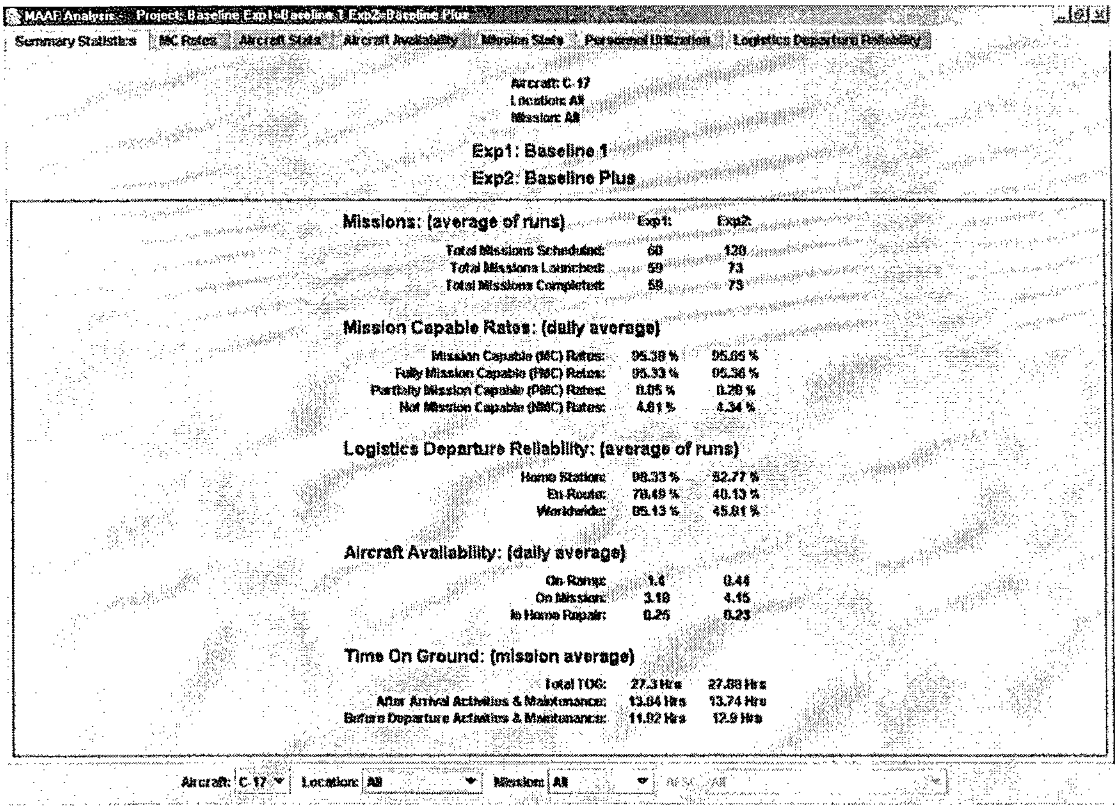
Aircraft: C-17
Location: Ramstein AB

Graph Type: Bar

Display: ● Graph ○ Data ○ Both

Aircraft: C-17
Location: Ramstein AB

Appendix 7. MAAF Analysis Module – Sample Summary Level and Detailed Report

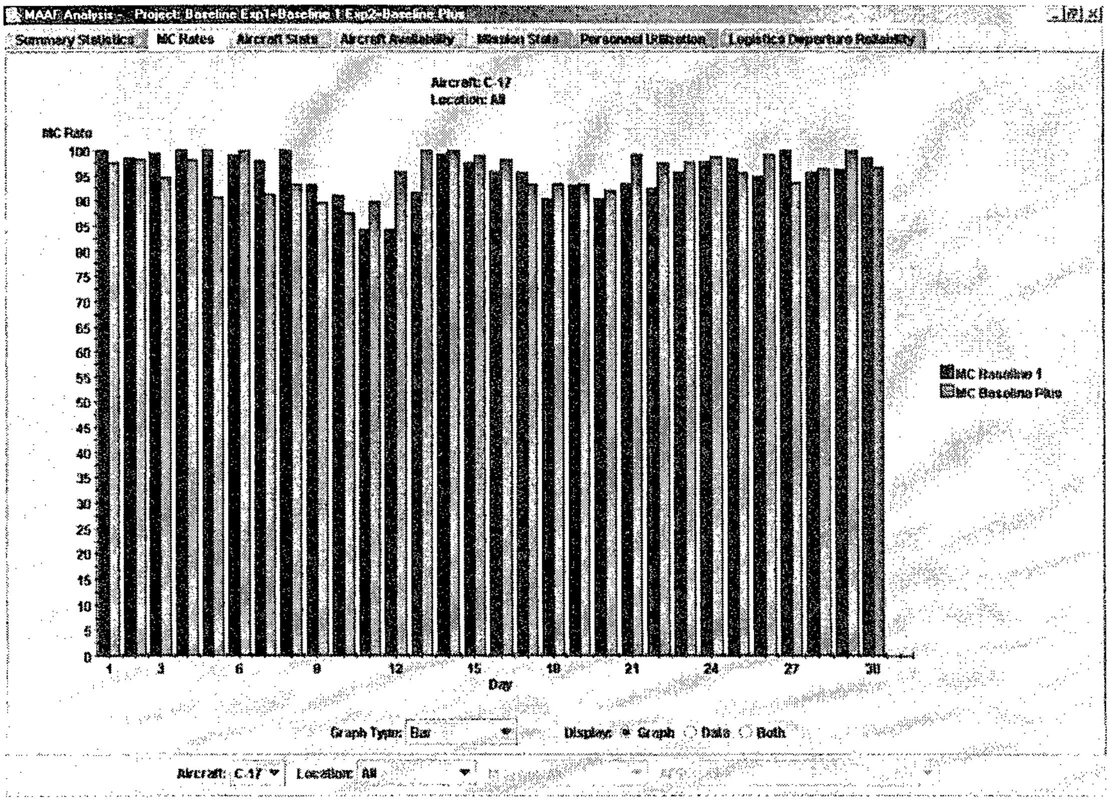


Aircraft: C-17
Location: All
Mission: All

Exp1: Baseline 1
Exp2: Baseline Plus

Missions: (average of runs)	Exp1:	Exp2:
Total Missions Scheduled:	60	120
Total Missions Launched:	59	73
Total Missions Completed:	59	73
Mission Capable Rates: (daily average)		
Mission Capable (MC) Rates:	95.38 %	95.65 %
Fully Mission Capable (FMC) Rates:	95.33 %	95.36 %
Partially Mission Capable (PMC) Rates:	0.05 %	0.29 %
Not Mission Capable (NMC) Rates:	4.61 %	4.34 %
Logistics Departure Reliability: (average of runs)		
Home Station:	98.33 %	52.77 %
En-Route:	78.49 %	40.13 %
Worldwide:	85.13 %	45.81 %
Aircraft Availability: (daily average)		
On Ramp:	1.4	0.44
On Mission:	3.18	4.15
In Home Repair:	0.25	0.23
Time On Ground: (mission average)		
Total TOG:	27.3 Hrs	27.88 Hrs
After Arrival Activities & Maintenance:	13.84 Hrs	13.74 Hrs
Before Departure Activities & Maintenance:	11.92 Hrs	12.9 Hrs

Aircraft: C-17 Location: All Mission: All AFSC: All



Graph Type: Bar Display: ● Graph ○ Data ○ Both

Aircraft: C-17 Location: All