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A SIMULATION APPROACH TO ESTIMATING AIRCRAFT MISSION CAPABLE RATES FOR THE UNITED STATES AIR FORCE

Harold S. Balaban

Institute for Defense Analyses
1801 N. Beauregard Street
Alexandria, VA 22311-1772, U.S.A.

Robert T. Brigantic
Samuel A. Wright
Anthony F. Papatyi

HQ Air Mobility Command, Studies and Analysis Flight
402 Scott Drive, Unit 3L3
Scott AFB, IL 62225-5307, U.S.A.

ABSTRACT

This paper presents the results of a simulation model designed to estimate aircraft Mission Capable Rates (MCR) for the United States Air Force. This simulation model originated out of the need to estimate the MCR for different modernization schemes to be implemented on the Air Force C-5 Galaxy aircraft. Assigned to the Air Mobility Command (AMC), the C-5 is one of our nation's only two strategic airlift aircraft that can carry large outsize cargo (e.g., helicopters and tanks). The other outsize capable strategic airlift aircraft is the C-17 Globemaster III. At the same time, the C-5 is one of the Air Force's least reliable aircraft. This means that AMC has a deficiency in meeting all of its wartime cargo airlift missions. To address this problem, AMC embarked on a year-long Analysis of Alternatives (AoA) study in 1999 to determine the best value solution for the Air Force to meet its cargo airlift requirements. Integral to this analysis is the aforementioned simulation model used to estimate C-5 MCR. This paper reviews the different alternatives examined in the AoA and presents the details of the simulation effort to estimate the MCR for these different options.

1 BACKGROUND

The fundamental mission of the Air Mobility Command is to provide this nation with rapid global mobility through military airlift and air refueling forces. A key component of this mission is cargo airlift—the airlift of supplies and equipment whose urgency or nature cannot wait for surface transportation. AMC has a critical deficiency in its ability to meet this tasking due to the poor reliability of the C-5 fleet, consisting of 76 C-5A models and 50 C-5B models.

The C-5 fleet is expected to provide half of our nation's outsize and oversize strategic airlift capability, but the C-5 has AMC's lowest mission capable rate. A substandard mission capable rate reduces the number of available C-5 aircraft and the total airlift capability of our nation. As a result, AMC has difficulty meeting wartime mission requirements. Specifically, as established by the 1994 Mobility Requirements Study Bottom Up Review Update (MRS BURU), AMC's wartime cargo airlift requirement is 49.7 Million Ton Miles per Day (MTM/D). MTM/D is a capacity measure that relates how much cargo can be moved a certain distance, or conversely, how far a certain amount of cargo can be carried. AMC's ability to meet this wartime cargo airlift requirement, at a moderate level of risk, is based on an expected C-5 MCR of 75%. A C-5 fleet MCR less than this equates to a high-risk warfighting assessment. The current C-5 fleet MCR is roughly 60%.

2 AIRCRAFT CONFIGURATIONS

To correct AMC's cargo airlift deficiency, three different C-5 aircraft configurations were considered in this study—baseline, partial upgrade, and a full upgrade. None of these actually exist today, although the baseline is a programmed C-5 configuration that will exist by 2005 and is closest to the current C-5. The other two are possible upgrade extensions of the baseline configuration. A graphical depiction of these configurations and what they entail is shown in Figure 1, followed by a brief description of each.

2.1 Baseline C-5

The baseline C-5 configuration is the one that will exist after presently funded C-5 programs are fully implemented. This will occur by the year 2005. The most significant improvements over the current C-5 will be in the Avionics Modernization Program (AMP), the installation of high-pressure turbine inserts (HT-90 program) to improve TF-39 engine reliability, and a full overhaul of all engine thrust reversers.

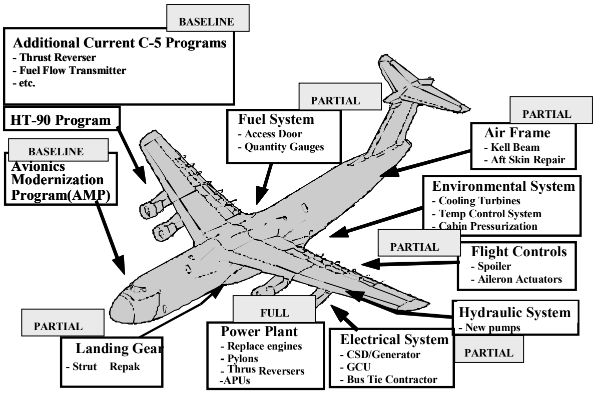

Figure 1: C-5 Configurations Analyzed

2.2 Partial Upgrade C-5

The partial upgrade C-5 configuration would build on the presently funded improvements in the baseline and add specified improvements to the landing gear, the fuel system, flight controls, airframe, environmental system, hydraulic systems and the electrical systems. A 1996 Lockheed-Martin study identified the replacement of these systems as essential for improving the mission capable rate. The partial upgrade does not include re-engining, but retains the baseline TF-39 engines with HT-90 and the thrust reverser overhaul. The reason for considering a partial upgrade is to introduce an alternative configuration to the baseline but at lower acquisition cost relative to the full upgrade for which the engine costs dominate. It helps address the question of whether re-engining is cost-effective.

2.3 Full Upgrade C-5

The full upgrade includes all improvements in the partial upgrade as well as more capable new engines to replace the TF-39 engines. This was also a recommendation of the 1996 Lockheed Martin study that noted the low reliability of current TF-39 engines.

The current TF-39 engine produces approximately 40,000 lb. of thrust at sea level. The C-5 wing is designed to handle up to 50,000 lb. thrust. The prevailing view within the USAF is that if re-engining is pursued, the new engines should take advantage of the availability of higher thrust engines and the inherent C-5 wing strength. There are 60,000 lb. thrust engines in commercial use that can be de-rated to 50,000 lb. There are also improved 40,000 lb. class commercial and military engines (e.g., the C-17 uses 40,000 lb. engines). If the de-rated 60,000 lb. thrust engines were used on the C-5, the extra thrust would permit shorter take-offs, if needed, and access to higher altitude trans-oceanic tracks. New 50,000 lb. thrust engines are also coming on the market.

For this study we used a generic 60,000 lb. thrust engine. It is not meant to represent any specific commercial engine, but represents a suitable engine from that class. The new engines would be obtained through a competition, capitalizing on commercial engine experience instead of introducing a unique military design.

2.4 Aircraft Configuration Summary

Table 1 summarizes the C-5 configurations considered in this study.

Table 1: Aircraft Configuration Summary

Aircraft Configurations	Short Descriptions
Baseline	The Baseline represents the configuration of the C-5 in 2005, including currently programmed upgrades.
Partial Upgrade	The partial C-5 upgrade includes non-propulsion items that Lockheed Martin recommended replacing, as well as a few AMC-added improvements. The partial upgrade is not one of the final AoA configurations and is included as an excursion.
Full Upgrade	The full C-5 upgrade includes the partial upgrade and adds replacement of the baseline propulsion system – engine, pylon, nacelle and associated components.

3 MISSION CAPABLE RATES (MCR) APPROACH

Aircraft MCR is used by the Air Force to describe the operational readiness of its aircraft fleets. The Air Force has three primary levels of readiness—fully mission capable (FMC), partially mission capable (PMC), and not mission capable (NMC). An aircraft is mission capable if it is either FMC or PMC. The Air Force's Minimum Essential Subsystems List (MESL) defines the systems and subsystems that must be operational for the aircraft to do its assigned missions.

The aircraft to which the MCR metric applies are those in the Air Force's Primary Aircraft Inventory (PAI)—aircraft that are available to go to war. Such aircraft are said to be "possessed" by operational Air Force units. This excludes the Backup Aircraft Inventory (BAI), those aircraft currently "owned" by maintenance activities to perform scheduled or unscheduled maintenance, modifications, inspections or repair. Thus, aircraft undergoing Programmed Depot Maintenance (PDM) or major modification using a depot field team are BAI and not possessed.

Mission capable rate combines failure frequency with repair efficiency, and thus is dependent on reliability, maintainability, and supply. For example, if a part needed to repair a failed component is not available, then the resulting logistics or supply delay adds to the down time, over and above the time needed to replace the component once available. Therefore, component or subsystem repair times alone are not sufficient for modeling down time due to failure of the item.

No trouble found (NTF) actions (i.e., a problem is reported, but it cannot be replicated) do not generally trigger the supply system, but do result in a NMC status if the item is considered to be mission essential. Scheduled maintenance activities on possessed aircraft also result in a NMC status. Typically, the C-5 aircraft undergoes periodic Home Station (HS) checks and isochronal inspections. Since the aircraft remains in a possessed status during such scheduled maintenance, it is recorded as NMC over the maintenance period.

3.1 NMC Categories

As indicated above, an aircraft can be in NMC status for a number of causes. Listed below are the NMC categories used in this study.

3.1.1 Failures

This category represents the downtime resulting from failures of critical components or subsystems. It is the primary cause of not mission capable times and is the NMC rate component for which the simulation model was developed.

3.1.2 Isochronal Inspections

This is a scheduled maintenance activity performed at the operating base approximately every 400 days. These inspections are designed to keep the aircraft healthy and safe.

3.1.3 Home Station Checks

This is also a scheduled maintenance activity performed at the operating base every 90 days to ensure the aircraft is healthy and safe.

3.1.4 Other Non-Corrective Maintenance

These are generally inspections and maintenance activities performed to meet special conditions or emergencies and which have not been included in the other non-corrective maintenance schedules. An example might be the discovery of a serious safety problem such as a crack in a plane resulting in a directive to inspect all aircraft that may be subject to the same problem.

3.1.5 Refurbishment

These are activities performed at the operating base to maintain the aircraft in an operable state. This includes such activities as washing, painting, and minor corrosion repair.

3.1.6 Cannibalization (CANN)

Typically, for the C-5 fleet there is a “CANN bird” at each major C-5 operating base. This CANN bird acts as a source of parts supply. A part needed to restore an aircraft to mission capable status after returning from a mission can borrow it from the CANN bird if it is not available through normal supply channels. When the part is received through the logistics supply chain at the base, it is used to replace the part removed from the CANN bird. Any time the CANN bird is missing critical parts, it is in NMC status.

3.2 MCR Simulation Model

Historical mission capable rates of the C-5 are known. The data are maintained in Air Force computer automated database systems (GO-81 and REMIS). However, for this study, AMC needed to estimate the reliabilities of aircraft that do not yet exist, namely the various upgraded versions of the C-5. To this end, we devised a simulation approach to estimating MCR from a consideration of the contributions of individual systems that are to be replaced.

The model explicitly takes into account the phenomenon that more than one failure can occur during a flight, although typically only one, the pacing item, is cited as the cause of failure. Figure 2 shows schematically the sequence of events modeled, including the potential for “masking” of one failure by the pacing item failure. By masking we mean a failure with a certain repair time conceals or masks simultaneous failures having shorter repair times. By calibrating the single parameter in the results to current C-5s, new configuration C-5 MCR may also be estimated once the particular parts and the associated reliabilities are substituted for current values. Flying hours play the dominant role in the failure rate estimates in Step 2. Specific items known to fail only on take-off and landing (landing gear, tires) are treated on a per-sortie basis.

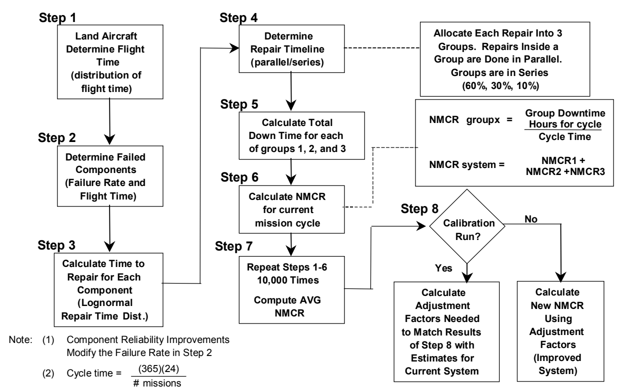

Figure 2: Approach to Estimating MCR for Aircraft

3.3 Model Specifics and Assumptions

Following are some assumptions and specific algorithmic details of the MCR Simulation Model.

3.3.1 Simulation Tool

The model uses the Crystal Ball computer simulation software which runs under Microsoft Excel. With Crystal Ball, cells in the spreadsheet can be designated as Assumption cells or Forecast cells. An Assumption cell is assigned a statistical distribution, which can be either continuous or discrete. A Forecast cell is one that is determined through Excel worksheet functions working on one or more Assumption cells. Crystal Ball then runs the simulation a user-designated number of times assigning Assumption cells values in accordance with the distributional assignments and keeps track of the resulting distributional statistics in the Forecast cells. As a very simple example, assume cell A1 is designated to be an Assumption cell with a normal distribution, mean = 10, standard deviation = 2; cell A2 is an Assumption cell with a uniform distribution over 3 to 6; and cell A3 is a Forecast cell equal to the sum of A1 and A2. After the simulation is run a number of times, one can have Crystal Ball display or print statistics based on cell A3, the addition of a normal to a uniform distribution. Statistics provided include mean, median, mode, variance, range, etc. Also, graphs of the results are provided. A number of other features are available, one important one being that the user can designate a degree of correlation between pairs of random variables.

3.3.2 Failure Distribution and Actions

For this analysis, we assumed that most components had an exponential failure distribution. Thus, if the mission was of length t, the probability that the component with failure rate λ fails during the mission is $1 - \exp(-\lambda\ t)$. For each component included in the MCR model, we generate a uniform random number between 0 and 1, and if this number is less than the failure probability, we assign a cell representing that component's status with a code indicating failure. Most components that fail during a single mission are then assigned to groups or repair "bins" in accordance with the binning distribution that is used. There are a small number of components for which binning or parallel repair is not be allowed. For example, if the fuel tank requires repair, the Air Force policy is to not allow work on other components at the same time. Such components are placed in their own special bins meaning that the component repair time is added directly to the aircraft down time without any masking. For non-time dependent items such as brakes and tires, we converted Air Force mean time between failure data to mission failure probabilities so that failures of such items were independent of the flight time and were modeled as a binomial distribution.

3.3.3 Repair Time Distribution and Actions

We analyzed Air Force data and determined that the repair times can be adequately represented by a lognormal distribution. Thus, for each Work Unit Code included in the model, we calculated a lognormal mean and variance which formed the basis of the repair times of the individual components that failed during the mission. Since the detailed component repair data at our disposal were man-hours and not calendar time, we relied on the calibration exercise to make the appropriate adjustment. The calibration factor we calculated was used only to adjust the man-hour times to represent repair times, though it may also have been influenced by other factors for which the model was not truly reflective of actual operations. The repair times generated by Crystal Ball for the set of failures that occur during a mission are placed in their respective repair bins in accordance with the bin probability distribution. The repair or down time of the bin is the maximum of the repair times in that bin, and the repair or down time for the aircraft is then the sum of the bin repair times.

3.3.4 Sortie Duration and Mission Cycle Time

Three years of data were analyzed to develop average peacetime sortie duration and mission cycle time. The former is the length of a mission, and the latter is the average time from mission start to mission start. Together they represent how much flying will be done and thus how many failures will occur. For the C-5A we used a 3.71 hours sortie length, and for the C-5B it was 4.37 hours. While we might have used distributions for each of these parameters we chose not to do so since trial runs on a subset of components indicated that the information gained would not be worth the additional development and run time. For the wartime simulations, we assumed that the sortie length would increase and have two possible values, 6.0 and 6.5 hours with the former having a probability of 0.75.

3.3.5 Non-Failure Related Causes of Not Mission Capable Rate (NMCR)

The simulation model only treats directly those causes of not-mission-capable status that result directly from component failures. As indicated earlier, a number of other causes for down time exist, such as cannibalization, home station checks, refurbishment, etc. Thus, in developing the final MCR for an upgraded C-5 aircraft, we ran the model to first calibrate repair times so that the model provides a close estimate to current failure-caused NMCR for the baseline aircraft. We then adjusted downward the failure rates of the improved components and ran the model again to determine the NMCR of the upgraded aircraft. To the upgraded aircraft NMCR, we added the NMCRs due to the non-failure related causes, some of which may have changed from the baseline values because of revised logistics and maintenance policies. An example of the latter is the potential for using a "letter-check" form of annual maintenance, which replaces programmed depot maintenance (PDM), refurbishments, and isochronal inspections. Since the definition of MCR applies only to aircraft that are considered "possessed" by the operational command, aircraft undergoing PDM are not included in the MCR calculation but aircraft down because of isochronal inspection or refurbishment are generally included. Since aircraft in letter-check are not to be considered possessed, improvement in MCR as a result of letter-check is partially a result of the current bookkeeping practice for calculating MCR, which does not truly reflect aircraft availability.

3.3.6 Data Requirements and Sources

Table 2 summarizes the sources of the data used in constructing contributions to MCR for the model. The primary types of data needed are:

(1) the number of flying hours per year for the C-5A and C-5B models and the size of the fleet possessed during that year;
(2) component-level reliability and failure rates;
(3) maintainability in terms of hours required to replace failed components;
(4) the number of type 6 actions recorded (i.e., events in which no problem could be found but for which the aircraft was grounded anyway);
(5) the extent to which multiple repairs can be conducted simultaneously or sequentially.

We do not model every single C-5 component, only the items listed in MESL. To estimate the increase in MCR by replacing system components in the different C-5 configurations, we generally used Lockheed Martin engineering estimates of failure rates at the 3-digit work unit code level. When necessary, we used our own failure rate improvement estimates based on previous reliability modeling experience. We did not change maintenance times for components, once they fail. In this regard, we feel that the reported MCR improvements are somewhat conservative as we expect decreased repair times for new components.

Table 2: MCR Contribution Data Sources

Type of Data	Primary Source	Description	Period	Use
Flying Hour and Fleet Sizes	AMC - Flying hour program and actual experience captured in C-5 historical data bases.	Number of TAI and PAA and total number of flying hours per year by aircraft type and component	1996-1998	Develop sortie duration and mission cycle parameters
Reliability	G0-81/REMIS and C-5 Historical data bases	Failure rates at the 3 digit work unit code (WUC) level	1996-1998	Determines failure probability of subsystems
Maintainability	G0-81/REMIS and C-5 Historical data bases	Maintenance man-hours per action at the three digit WUC level	1996-1998	Determines down time after adjustment to reflect mean time to repair
Type 6 Actions	G0-81/REMIS	Frequency of No Trouble Found actions	1996-1998	Adjusts reliability improvements to reflect various types of maintenance activities
Parallel/Sequential Repair Probability	AMC/LGAA	The probability that a component in the failure group cannot be repaired while other repairs are taking place	NA	Adjusts binning (parallel repair) operations

4 RESULTS

Table 3 summarizes the MCR results for the various C-5 configurations and the C-17 for the sake of comparison. Note that three columns of results are shown: Peacetime MCR, Surge MCR, and Sustained MCR. Peacetime represents normal, day-to-day AMC operations. Surge MCR is normally associated with the first 30 days of a war. Sustained MCR is associated with continued wartime operations after the surge period.

The most significant result is that by upgrading the C-5 through the full upgrade initiative, the MCR of the C-5 Galaxy fleet can achieve its expected 75% wartime requirement. This would eliminate the current high-risk warfighting assessment for our nation. Moreover, the results indicate that the Air Force would effectively have access to approximately 10 more C-5 tails in wartime compared to the baseline configuration—a significant improvement in capability.

Table 3: Summary of Mission Capable Rate Results

Configuration	Aircraft	Peacetime	Surge	Sustain
Current	C-5A	57.7%	66.6%	59.7%
	C-5B	68.4%	76.0%	70.4%
	Fleet Avg	61.9%	70.3%	63.9%
Baseline (2005)	C-5A	57.8%	66.7%	59.8%
	C-5B	68.7%	76.1%	70.5%
	Fleet Avg	62.1%	70.4%	64.0%
Partial Upgrade	C-5A	66.9%	72.1%	69.7%
	C-5B	76.1%	79.2%	76.2%
	Fleet Avg	70.6%	74.9%	72.3%
Full Upgrade	C-5A	70.1%	75.8%	73.4%
	C-5B	78.8%	81.9%	78.9%
	Fleet Avg	73.5%	78.2%	75.6%
C-17	Fleet Avg	85.0%	90.0%	87.5%

4.1 MCR Model Verification and Validation and Sensitivity Analyses

The verification and validation of the model was performed by a series of executions of the MCR model using different parameter values. Due to the huge number of combinations of parameters and corresponding values, the testing was not exhaustive. The purpose of the testing was to (1) ensure that sufficient iterations had been conducted for stability in the solutions, (2) determine if the model behaves as expected when parameters are changed, and (3) to test the sensitivity of the results to some of the more arbitrary parameter values.

Any assumption of the model will influence the fidelity of the results to some degree. Therefore, the implicit and explicit assumptions of the model, as well as any implied constraints that are a consequence of these assumptions were also examined as part of the verification and validation process.

We also conducted sensitivity analyses as part of a validation procedure for the MCR model. The analyses exercised the MCR model to test its behavior and its sensitivity to different assumptions than those made here. The model behaved as expected throughout its parameter space and gave nearly identical results for different sets of assumptions. This suggests that the expected MCR improvements are robust.

4.2 Number of Trials

For the MCR model, there is a tradeoff between the accuracy of the simulation and the required computational time. Therefore, the effect of the number of Monte Carlo trials on the MCR model results was investigated in order to determine the number of trials required for an accurate simulation. Figure 3 shows the results of this assessment for two different C-5 configurations considered. This figure shows NMCR versus the number of trials. From Figure 3 we conclude that 10,000 iterations are sufficient to achieve a stable solution. There is no advantage in proceeding to 25,000, but at least 10,000 are needed for confidence in the results. All results described in this paper use 10,000 Monte Carlo replications.

4.3 Effect of Assumptions on Repair Bin Probability

As noted in Figure 2, the model treats multiple repairs in terms of separate groups or "bins." A bin represents a set of repairs that are worked on concurrently. The time to finish all repairs in a bin is the time required to repair the pacing item—the one with longest repair time. When multiple failures occur, manpower and facility constraints dictate that some repairs will be done serially in separate sequential repair bins rather than concurrently. Based on past reliability experience and consultation with AMC logisticians, the model assumes that in peacetime, there are three bins where 60% of the failures are repaired concurrently in bin 1, 30% in bin 2, and 10% in bin 3. During surge situations, the MCR model uses two repair bins with a probability of 90% and 10%. The bin where a failed part is repaired is determined by a random draw for each Monte Carlo iteration.

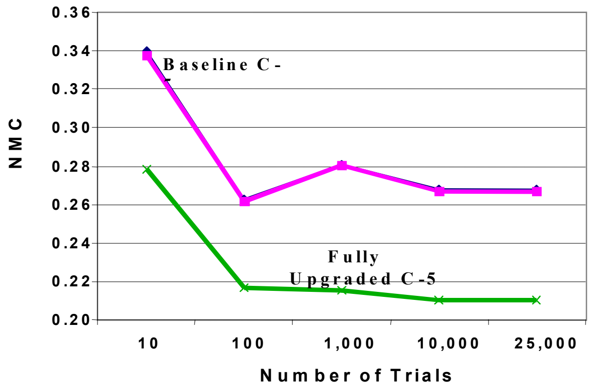

Figure 3: Monte Carlo Trials vs. NMCR

The question arises as to the sensitivity of the results to different sorting assumptions. Does the MCR depend on the binning assumption? Fortunately, the answer turns out to be *no*. As long as the model results are calibrated against current data for a given assumption about the relative percent of actions in the bins, the results for upgraded aircraft are relatively insensitive to the allocation assumptions. Calibration restores integrity to the problem.

Figure 4 shows NMCR versus different bin 1 probabilities for the surge case when the model is separately calibrated to the current system NMCR for each selected bin 1 probability (5 bin 1 values were used - 0.5, 0.6, 0.8, 0.95, 1.0). The "Current C-5" line is a constant by construction, since this case is calibrated to give a result matching the current fleet's NMCR. The baseline C-5 with AMP and HT-90 programmed improvements, is essentially identical to the current C-5 in these calculations. The different calibration factors obtained from this exercise are applied for the appropriate binning assumption to the other configurations. Figure 4 illustrates that there is little change in the model NMCR results over a large range of binning assumptions. This indicates that as long as the model is calibrated to historical data, the relative impact of modernization to the C-5 NMCR is insensitive to the bin probabilities (except for end effects with probability nearing unity), and therefore this parameter is not a major driver of the model results.

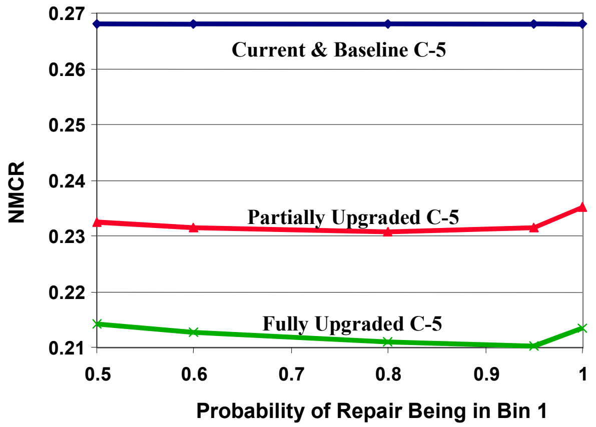

Figure 4: Repair Bin Probability vs. NMCR

4.4 Effect of Type 6 Repair Rates

The GO-81 database lists the type and number of failures for each part of the C-5. The failures are categorized into 6 types. A type 6 failure occurs when the pilot suspects a failure or the diagnostic electronics indicate that a part needs repair. Discussions with USAF personnel indicated that the type 6 repair rate may be overstated. Thus there is some uncertainty about the correctness of the class 6 reports. For that reason we examine how sensitive results are to changes in assumption about type 6 failures.

For our basic assumption we assume that one-half of the reported type 6 failures result in a repair action. The other half fall into the "no fault found" category. We have varied the probability that a type 6 report results in an actual repair action as a sensitivity excursion. We refer to the probability that a reported type 6 failure results in a down time and repair as the "type 6 repair weight." As expected, Figures 5 and 6 illustrate that as the type 6 repair weight increases, the number of failures and NMCR increase in a nearly linear fashion. This shows the model performs as expected when a parameter is changed. In these figures, the basic assumption of 0.5 is shown for reference purposes.

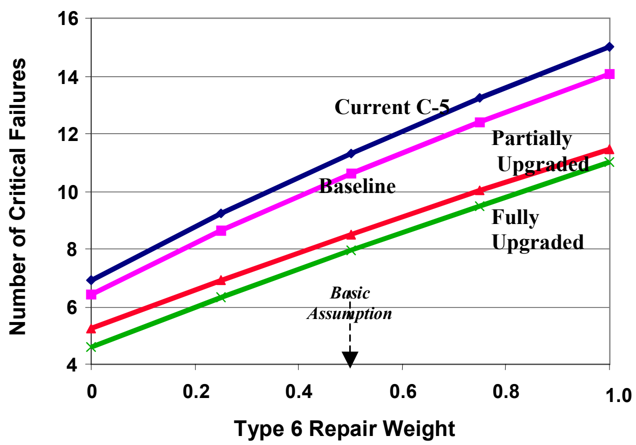

Figure 5: Type 6 Repair Weight vs. Critical Failures

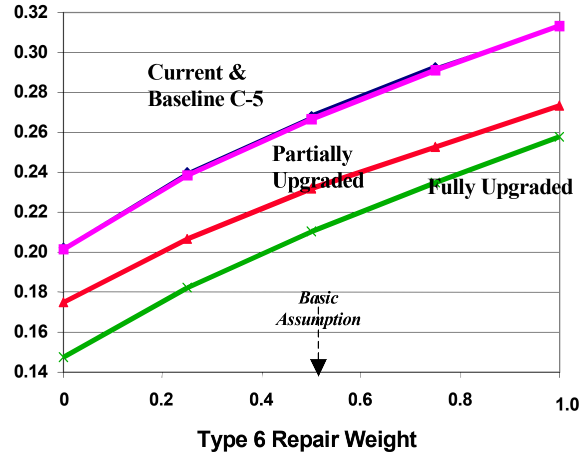

Figure 6: Type 6 Repair Weight vs. NMCR

If the model is calibrated for the current C-5 for each separate repair weight, Figure 7 illustrates that there is little change in the results of the MCR model. This indicates again that as long as the model is calibrated to historical data for current aircraft, the relative impact of modernization to the C-5 NMCR is fairly insensitive to the type 6 repair weight. Therefore, this parameter is not a major driver of the model results.

We conclude from these analyses that the MCR model behaves as expected and provides results that are not strongly dependent on certain of the more arbitrary assumptions. This provides greater confidence in the model outcomes.

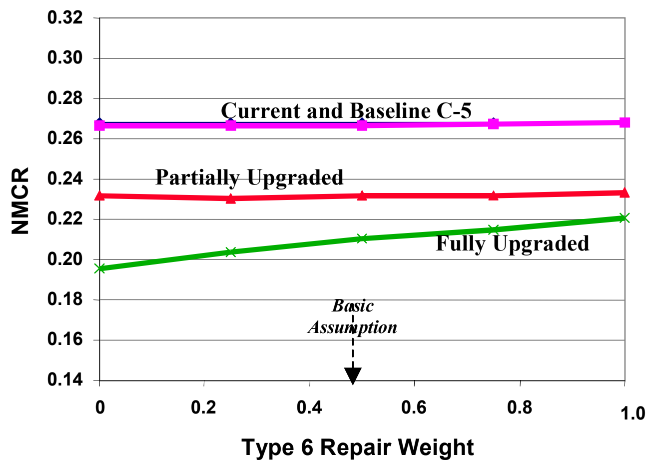

Figure 7: Type 6 Repair Weight vs. Calibrated NMCR

4.5 Additional MCR Improvements

Is the set of improvements proposed by Lockheed Martin and incorporated in the full upgrade for the C-5 all that the USAF might want to consider? The MCR model was used to determine additional potential items for improvement beyond those listed in the full upgrade configuration. The top 10 items that were identified are shown in Table 4. The item making the most significant reduction in NMCR is ranked number 1: the fuel tank, which is part of the fuel system. The next most important items to replace in NMCR reduction rank order are the flaps, which are part of the flight controls system, etc.

Table 4: Additional Modernization Items to Improve MCR

Rank	Part	System	Description
1	46A	Fuel System	Fuel Tank
2	14J	Flight Controls	Flaps
3	46B	Fuel System	Fuel Pump
4	14L	Flight Controls	Slat Assembly
5	11B	Air Frame	Visor Door
6	13L	Landing Gear	Wheel and Tires
7	14A	Flight Controls	Aileron and Flt Spoilers
8	41A	Aircon, Pressuriz, Deice	Aircon, Pressuriz, Deice
9	46H	Fuel System	Fueling/Defueling Sys
10	13B	Landing Gear	Nose Landing Gear

To make an estimate for the impact to be felt from further modernization, we reduced the failure rate of the modernized part by 90% but kept the repair time the same. The relative reduction of NMCR for each part being modernized is shown in Figure 8. The results are cumulative, in the sense that each improvement included all improvements to its left. MCR model results indicate that if all 10 items were modernized, the C-5 NMCR can be reduced by as much as 24% below that achievable in the full upgrade.

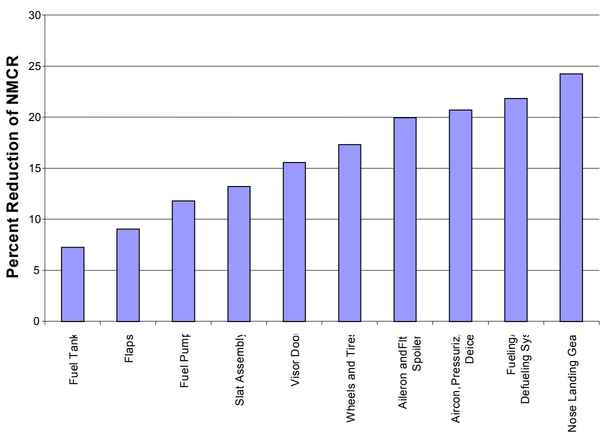

Figure 8: Impact of Additional Modernization on NMCR

5 CONCLUSIONS

This MCR model was shown to provide realistic results and behaves as expected across a wide set of assumptions. This model was used by AMC to refine different aircraft fleet configurations and to carry forward the best value recommendation to senior Air Force and DoD decision makers. In short, the model shows that the C-5 can attain its expected 75% mission capable rate through implementing the full upgrade initiatives. Further, the model can easily be extended to different Air Force aircraft and possibly commercial aircraft through appropriate data sources and assumptions.

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AUTHOR BIOGRAPHIES

HAROLD S. BALABAN is on the Adjunct Research Staff of the Institute for Defense Analyses in the Cost Analysis and Research Division. He received his B.B.A. in Statistics from the City College of New York, his M.A. in Statistics from the American University and his Ph.D. in Statistics from the George Washington University. Prior to his present position, Dr. Balaban was Director of Advanced Analysis at ARINC Research Corporation, Annapolis, MD. His research interests are in the fields of reliability, maintainability and logistics support. His email address is <`hbalaban@ida.org`>.

ROBERT T. BRIGANTIC is Mobility Analyst at the Headquarters Air Mobility Command, Scott AFB, IL. He received a Ph.D. in Operations Research and a M.S. in Space Operations from the Air Force Institute of Technology in 1997 and 1988 respectively. He received a B.S. in Chemical Engineering from Oregon State University in 1983. His research interests include applied statistics and digital imaging. He is a member of Tau Beta Pi. His email address is <`robert.brigantic@scott.af.mil`>.

SAMUEL A. WRIGHT is a Mobility Analyst at the Headquarters Air Mobility Command, Scott AFB, IL and a Ph.D. candidate in the Department of Operational Sciences at the Air Force Institute of Technology. He received a B.S. degree in Astronautical Engineering from the United States Air Force Academy in 1989, and a M.S. degree in Operations Research from the Air Force Institute of Technology in 1995. His research interests include applied statistics and simulation modeling. He is a member of Tau Beta Pi. His email address is <`sam.wright@scott.af.mil`>.

ANTHONY F. PAPATYI received a B.S. degree in Engineering from the Southern Illinois University at Carbondale in 1988, a MBA from Chapman University in 1993, and a M.S. degree in Operations Research from the Air Force Institute of Technology in 1997. His research interests include decision analysis and simulation modeling. His email address is <`anthony.papatyi@peterson.af.mil`>.