C-5 ISOCHRONAL INSPECTION PROCESS MODELING

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ABSTRACT

United States Air Mobility Command (AMC) has a limited number of C-5 aircraft, and so opportunities to either preserve or increase aircraft availability are of interest to them. In an attempt to reduce inspection costs and promote inspection scheduling predictability, the Air Force is reducing the number of C-5 Isochronal inspection (ISO) sites from five to three. C-5 ISOs require at least two weeks and involve an exhaustive inspection of the entire aircraft. AMC headquarters staff asked us to model the new ISO process to help them understand how the reduced number of ISO locations will affect inspection timeliness. We used the problem as the class project for a graduate discrete event simulation course at the Air Force Institute of Technology. We review our process and results, and present some insights on conducting simulation research as a class assignment.

1 INTRODUCTION

United States Air Mobility Command (AMC) has a limited number of C-5 aircraft at its disposal, and the aircraft are considered a high demand system. Opportunities to increase aircraft availability are of high interest to AMC. C-5 Isochronal inspections (ISOs) are required 420 days after the completion of the previous ISO. ISO involves a detailed inspection of the entire aircraft, where aircraft maintainers look for and repair problems in every aircraft system, from nose to tail and from wingtip to wingtip.

In an attempt to decrease costs and increase aircraft availability, the Air Force is reducing the number of C-5 ISO sites ("docks") from five to three. The intent is simple. "C-5 availability will increase due to centrally scheduling the inspection from a fleet-wide perspective and reducing flow days (the number of days it takes to complete one C-5 ISO) to a consistent number across the fleet," said Brig. Gen. Robert McMahon, AMC Director of Logistics (2006).

With the reduction to three ISO locations, the Air Force will need each C-5 to complete its ISO within an estimated 14.25 days. Any inspection that lasts longer than this will impact the timeliness of every C-5 inspection from that point on. However, the current process is requiring in excess of 18 days, significantly impacting C-5 fleet availability for worldwide airlift missions. Timeliness of the inspections is paramount; every C-5 is an airlift asset that AMC and USTRANSCOM cannot do without. AMC needs to shorten the existing process and understand the impact that reducing ISO locations from five to three will have on inspection timeliness.

In December 2007, personnel in AMC Headquarter's Directorate of Logistics contacted us with the ISO problem, and asked for research to be conducted as soon as possible. Coincidentally, the lead author (Johnson) was scheduled to teach an introductory graduate course in discrete event simulation during the Air Force Institute of Technology's (AFIT's) normal 10-week winter quarter, starting in early January 2008. This course requires the students to perform a capstone simulation project, which can either be a problem of the student's choosing or a "canned scenario" provided by the instructor. The project is usually worth between 30 and 40 percent of the course grade, and is expected to be conducted throughout the quarter. The project is intended to help the student comprehend and integrate the various steps associated with a typical simulation study, such as outlined by Banks et al (2005). This particular class had only five students enrolled: Glasscock, Little, Muha, O'Malley and Bennett—all pursuing Systems Engineering MS degrees. The small

class size and reasonably relevant student backgrounds (two fighter pilots, a C-130 navigator, a communications/information systems officer and a civilian systems engineer) led us to believe that we could use the ISO problem to both satisfy the class requirement and provide some initial insights for AMC. Johnson sought approval from the sponsoring AMC/A4XM office (aka "customer") for this strategy in late December and they concurred.

We addressed two research questions:

- If current ISO times are not in line with the 14.25 day requirement, what top-level steps can be taken immediately to improve ISO timelines?
- How does the ISO timeline impact other aircraft potentially waiting for their respective inspections?

A limitation is that our work doesn't try to optimize each current ISO subprocess. We lacked the time to travel on-site and gather necessary time and motion data on the existing process. Instead, we sought to describe process behavior for the customer with respect to ISO queue times and total time in ISO. However, we did build critical path sub-process detail into our models, should the additional data become available. The sub-process detail also let us examine the payoff for enabling two aircraft ISOs to simultaneously occur, by overlapping particular ISO processes.

2 METHODOLOGY

To conduct our ISO study, we implemented a bi-weekly teleconference with the customer. We used the first conference call to establish the study's overall objective and research questions. Subsequent calls were used to clarify various inspection processes and seek agreement on our study assumptions. For the first two teleconferences, Johnson met with the students before the call to review the call's objective and planned questions. Later calls were planned and led by the students without input from Johnson. Johnson discouraged email traffic from the students to the customer, in order to avoid burdening the customer by consolidating our dialog with them to a single period each week. Conference calls also enabled more people to participate simultaneously, and allowed immediate follow-up by both the students and the customer to clarify issues that arose. We completed the study in the last week of class by first emailing them the project report and briefing slides, and then conducting the briefing via a final teleconference.

The students developed an Arena 10.0 simulation model designed to mimic both the ISO process itself and the flow of C-5 aircraft to and from ISO. The simulation estimates ISO process queue times and total time in the ISO process. The model also provides the capability to conduct "what-if" scenarios to estimate process behavior if the control parameters are modified.

2.1 Data Collection

The customer provided all data used in our analysis. This data consisted of three sets of ISO timing data and workflow sequencing information. First, we used the Inspection Standardized Work Sequence (aka "Deterministic") data as the timing for an ideal-situation ISO. The second set was "14.25 day Standard" data that was based on the requirement to get all 111 C-5 aircraft through ISO within 420 days. It provides the current target for ISO completion timing. The third set involved "Modeled" data extracted from the customer-provided Hot Wash slides containing flowtime data for 17 recent C-5 ISO inspections.

2.2 Model Formulation

2.2.1 Assumptions

- C-5A and C-5B aircraft are treated identically except for differences in their Depot overhaul timing.
- A C-5 that has less than 270 days until its next Depot overhaul is due when it becomes due for ISO will have the ISO requirement waived. That C-5 will receive home-station maintenance and fly the remainder of its time until due for Depot without affecting the ISO docks.
- All ISO docks are equal; estimates and processes are modeled after the Dover AFB Facility.
- Depot overhaul requires 160 days for Deterministic and 14.25 day Standard data models.
- Depot overhaul requires an average of 190 days (exponentially distributed) for Modeled data models.
- Depot can handle a maximum of 12 jets simultaneously.
- ISO task sub-processes are serially completed without overlap, except in the case of the "Next C-5 enters ISO after Repanel" models.

2.2.2 Model Description

1. The models create 111 individual C-5 aircraft (62 C-5A, and 49 C-5B)
   a. Each is assigned a random time until next depot required (0-5 years for C-5A, 0-7 years for C-5B)
   b. The aircraft are sequenced into the model at a constant rate of one every 3.784 (420/111) days to simulate arrival at ISO.

2. As each C-5 approaches its next ISO, it determines if it has < 270 or ≥ 270 days until its next depot overhaul.
    a. If it has ≥270 days until its next depot, it goes into the ISO process
    b. If it has < 270 days until depot, it is recorded as an overfly (and the number of 90-day increments it overflies by) and flies until depot is due without affecting the ISO process
3. If the C-5 is going to ISO, it enters the ISO queue and waits until one of the ISO docks becomes available
    a. All ISO docks are represented as an "ISO Dock" resource that is used as necessary by the C-5s for their inspections
    b. The C-5 moves through ISO based on the assigned timing of the model set for "ISO complete before next C-5 enters" models, the dock is made available when the backline sub-process is completed
    c. For "Next C-5 enters after Repanel" models, the dock is made available when the Repanel sub-process is completed
4. Upon completion of ISO, the C-5 determines if it has ≥ 420 days until its next depot is due
    a. If so, it flies 420 days and goes back to step 4
    b. If not, it flies until it is due for Depot
5. Once a C-5 has flown its last day prior to Depot, it enters the Depot overhaul process.
    a. The depot process is set at 160 days for the Deterministic and 14.25 day Standard data
    b. For the Modeled data, an exponential function with an average of 190 days was used; the mean time was based on customer input
    c. After depot is complete, the C-5A's are assigned 5 years until next Depot and the C-5B's are assigned 7 years until next Depot
    d. The newly Depot-complete jet then enters the 420 days until ISO cycle
6. A timer is used to make each ISO dock unavailable for 14 days out of every 182.5 days
    a. A timer is generated every 182.5/(number of docks) days. This timer seizes the next available dock for 14 days.

2.3 Input Analysis

Our C-5 ISO process model used two methods to develop input models for the simulations. The first method modeled the entire ISO process deterministically. The schedule was based on the Isochronal Inspection Standardized Work Sequence. We decomposed the ISO process Critical Path into seven sub-processes that roughly correspond to the seven sub-processes provided in the Hot Wash data. The Critical Path sub-processes and their associated standard

times are shown below. These times sum up to 302 hours or 12.6 days:

- Wash/Depanel - 31 hours
- Inspection - 57 hours
- Repair - 72 hours
- MOC - 7 hours
- Repanel - 25 hours
- Fuel Cell - 26 hours
- Backline - 56 hours

Our customer could not determine which specific steps of the Critical Path were used to determine the timing of the seven processes in the Hot Wash data. Due to the limitations on determining the exact Critical Path items that constituted the timing in the 14.25 day Standard and Hot Wash data, the actual model times may not correlate well to either of those time paths. The MOC sub-process, in particular, does not match up well. It is only seven hours in the Critical Path, but one day in the AMC Standard. Because our models aim to improve the ISO process as a whole (and not study each individual sub-process), the inconsistency can safely be ignored.

The second method derived random variate input models from the provided Hot Wash data for each of the seven major ISO sub-processes. We used the Arena 10.0 Input Analyzer to fit a theoretical distribution to each sub-process data set. Hot Wash data for 17 aircraft ISO inspections were provided by the customer, but due to data aberrations the customer advised that two sets of data points be deleted. Because the resulting data set is small, Input Analyzer reported several different "good" ($p > 0.1$) distribution fits for each of the 7 modeled ISO sub-processes. We used Input Analyzer's default least squares ranking to select the best-fit cdf for each ISO sub-process time. The results are shown in Table 1.

Table 1: ISO Process Input Models

Sub-process	Input Model Results
Wash/depanel	Lognormal (1.21, 0.852)
Repair	Uniform (2.53, 5.72)
Repanel	Triangle (0.31, 1.03, 1.34)
MOC	0.14 + 4.32 * Beta (0.639, 1.92)
Inspection	Triangle (1, 3.73, 4.83)
Fuel Cell	1 + Lognormal (1.79, 2.9)
Backline	1 + Expo (3.28)

2.4 Experiments

To allow for comparison of real-world data to theoretical data, six (three sets of two) models were created.

- The Deterministic (D) model set uses data pulled from the customer-provided critical path spreadsheet and input into the seven sub-processes.

- The 14.25 day Standard (14.25) set is also deterministic in nature, and uses the time standard information from the Hot Wash data.
- The Modeled (M) set uses the random variates estimated from the Hot Wash data to model the time required for each of the seven subprocesses.

Each model set consists of two models.
- The "Not Released" (NR) model does not allow a subsequent C-5 to start ISO until the current ISO is complete (aircraft is signed off and ready for pickup).
- The "Released" (R) model allows the subsequent C-5 to enter the ISO process as soon as the current ISO has been Repaneled (moved to Backline).

An additional group of four models were created that used four ISO docks instead of the three that AMC is planning to have. The 14.25 day Standard times were not considered in this group of models, as this standard would not apply. Table 2 depicts our 10 experiment treatments.

Table 2: Experiment Plan

ISO Times Experiments	D (determ.)	14.25 (determ.)	M (random)
3 ISO Docks, NR	X	X	X
3 ISO Docks, R	X	X	X
4 ISO Docks, NR	X		X
4 ISO Docks, R	X		X

Each treatment was simulated for a total of 30 replications. Each replication consisted two 4,200 day periods. The first 4,200 day period was used to ensure the model had reached steady-state, minimizing any effects generated by start-up variable values; no data was collected during this warm-up period. The second 4,200 day period was used to generate the data used in Section 3, Results. We assumed 24 hour operations during each replication. The 4,200 day replication is equivalent to 11.5 years and, on average, 10 isochronal inspection cycles per aircraft.

2.5 Output Data

During each run, the model gathered specific statistical data on the following :
- Number of aircraft due an ISO within 270 days of an associated Depot overhaul
  - Those aircraft within 90 days, within 90 to 180 days, and within 180 to 270 days

- The total length of time an aircraft is at an ISO facility queue
- The length of time an aircraft is waiting at the ISO facility queue.
- The number of aircraft waiting at an ISO facility to start the inspection
- The Depot overhaul flow time
- A breakdown of the seven ISO steps (as described in Section 2.3)

2.6 Verification

Several iterations of the model with increasing complexity were developed. We used each model to verify the functionality of a small subset of the planned final model. The earliest iteration just tested the recording of the total time in the ISO process. The second model added the depot process (without preventing <420 day over flight of depot due date), the two different C-5 models and sequencing the aircraft into the system. The third model tested the ability to remove the ISO docks from service for facilities maintenance.

We used the fourth model to determine an effective system for ensuring the C-5 aircraft did not fly past their depot due date, but allowed aircraft to enter depot <180 days early. The fifth model incorporated better data for dealing with aircraft that are nearing their depot due date (Flying every aircraft until it is due for depot, incorporating the <9 months waiver of ISO when Depot is coming due). The sixth model incorporated counting the number of aircraft that overfly their ISO on the way to Depot. It was also the first model to break the single process ISO into the seven separate sub-processes. The sixth model became our baseline model for the collection of simulation output data.

2.7 Validation

We used the bi-weekly teleconferences with the customer to confirm the model's results with their personal experiences and actual data. In each case, the customer reported the simulation results to be reasonable and accurate. In addition, we compared the Hot Wash data to our Modeled and Deterministic data input models. Table 3 steps through the ISO process and reflects the respective mean output for each sub-process with 95% confidence intervals. The deterministic data is directly from the ISO Critical Path spreadsheet provided by the customer. There is no variance in the deterministic data, as it shows a "perfect world" and the model treated it as a constant flow.

The modeled data, however, represents the data provided from the "hot wash" slides and reviewed as part of the input analysis. Although the Wash Time is 0.07 days (1.7 hours) shorter and the Repanel Time is 0.146 days (3.5 hours) quicker, the modeled data reflects an isochronal in-

spection length that averages 5.182 days longer than the optimum critical path expected length. Inspection time, Repair time, and MOC time are each taking almost a day longer than expected. Fuel cell time is taking more than a half day longer and the backline time is taking almost two days longer than the expected on average.

Table 3: ISO Subprocesses in Days, 95% CI on Means

Experi-ments	Hot Wash Data from Customer (days)	Modeled Data (days)	Deterministic Data (days)
Wash Time	1.29 $\pm$ 1.37	1.22 $\pm$ 0.0119	1.29
Inspection Time	3.19 $\pm$ 0.9	3.19 $\pm$ 0.0105	2.38
Repair Time	4.11 $\pm$ 0.88	4.13 $\pm$ 0.0146	3.0
MOC Time	1.22 $\pm$ 0.99	1.22 $\pm$ 0.0157	0.29
Repanel Time	0.86 $\pm$ 0.26	0.894 $\pm$ 0.00296	1.04
Fuel Cell Time	2.8 $\pm$ 2.16	2.8 $\pm$ 0.052	2.25
Backline Time	4.27 $\pm$ 2.84	4.31 $\pm$ 0.0483	2.33
Total Mean Time	17.74	17.76	12.58

3 RESULTS

Arena 10.0 deposited the data from the 30 replications into more than 1,000 pages of output. In order to make the data more manageable, key metrics from the output data were condensed into the Arena 10.0 Output Analyzer.

Tables 4 and 5 display data for the total time each aircraft spends at the ISO facility and then breaks down that number into the time the aircraft spends waiting to begin the inspection and the time actually completing the inspection. The tables show data for both the three dock model and the four dock model. They add additional information regarding the hypothetical 14.25 day ISO timing goal that AMC is pursuing. In each case, the Time in ISO column is the difference of the Total Time at ISO and Time Waiting for ISO columns (both Arena-developed mean data at a 95% confidence interval).

Table 6 reports the percent decrease in total ISO time considering the fourth ISO dock versus using three. In all cases, the fourth dock does make a positive impact on the overall ISO time. The impact, however, is variable and as high as near 80% and as low as 3.1%.

Table 4: ISO Length in Days, 95% confidence interval on the mean.

3 ISO Docks			
Experiment	Tot. Time at ISO	Time Waiting for ISO Dock	Time in ISO
D, NR	17.5 $\pm$ 0.325	4.93 $\pm$ 0.322	12.57
D, R	13.1 $\pm$ 0.041	0.565 $\pm$ 0.040	12.54
M, NR	126.0 $\pm$ 4.27	109.0 $\pm$ 4.24	17.0
M, R	20.1 $\pm$ 0.196	2.38 $\pm$ 0.178	17.72
14.25, NR	29.7 $\pm$ 0.927	15.5 $\pm$ 0.929	14.2
14.25, R	15.7 $\pm$ 0.113	1.42 $\pm$ 0.112	14.28

Table 5: ISO Length in Days, 95% confidence interval on the mean.

4 ISO Docks			
Experiment	Tot. Time at ISO	Time Waiting for ISO Dock	Time in ISO
D, NR	13.5 $\pm$ 0.082	0.92 $\pm$ 0.081	12.58
D, R	12.7 $\pm$ 0.019	0.14 $\pm$ 0.019	12.56
M, NR	25.3 $\pm$ 0.576	7.61 $\pm$ 0.556	17.69
M, R	18.3 $\pm$ 0.085	0.59 $\pm$ 0.050	17.71

Table 6: Total ISO time reduction, using four docks vs. three.

Experiment	Percent Time Reduction
D, NR	22.9%
D, R	3.1%
M, NR	79.9%
M, R	9.0%

Considering the deterministic data and its roughly 12.5 day ISO process, aircraft are only backed up and waiting for the dock to be available when the dock is not released (4.93 days). The current ISO, however, is taking much longer (nearly 18 days). Only in the Released dock, four ISOs available case is there no wait. Releasing the dock with three ISOs available still has each C-5 waiting more than 2 days (2.38 days) before the facility is available to begin the inspection process.

Interestingly enough, AMC's reported goal of a 14.25 day ISO length still does not solve the problem of waiting aircraft. The average length of the 14.25 day ISO is almost 16 days with each aircraft waiting one and a half days at the facility before commencing the inspection. This information indicates that the goal of 14.25 days per ISO may not be sufficient with only three facilities.

Table 7 displays the information from the Depot overhaul. The reported goal of 162 days is represented in the deterministic data. Actual current total time averages, however, are running significantly longer (between 198 and 209 days depending on the model run). Although beyond the scope of this research project and developed simulation models, further analysis and investigation may be required to increase the predictability of the Depot process as well.

Table 7: Depot overhaul time: 95% confidence interval on the mean.

Experiment	3 ISO Docks (Days)	4 ISO Docks (Days)
D, NR	162 + 0.813	162 + 0.813
D, R	162 + 0.813	162 + 0.813
M, NR	198 + 6.31	204 + 8.51
M, R	209 + 8.45	209 + 8.44

Tables 8-12 depict the output data regarding those aircraft that are due for an ISO within 270 days of their next Depot overhaul. Each of the tables reflect the mean value from Arena's Output Analyzer at a 95% confidence interval. The Output Analyzer values were given across the entire 4,200 day replication. As a result, the data in the tables are corrected to represent numbers of C-5s per year. In the model, these aircraft did not revisit the ISO dock for their scheduled inspection. Instead, their inspections were "bridged" until the next Depot overhaul.

The model was built to capture the number of aircraft that were within 90 days, between 90 and 180 days and between 180 and 270 days. The intent is to help AMC better predict those aircraft that require a waiver (within 90 days), an HSC inspection (90 to 180 days) or a Contingency ISO / HSC+ Inspection (180 to 270 days). In each of these cases, the impact of the inspections are realized entirely by home units and do not impact the ISO facilities.

Table 8: Number of C-5s bridged to depot overhaul per year. Deterministic data, dock Not Released: 95% confidence interval on the mean.

	3 ISO Docks (C-5s)	4 ISO Docks (C-5s)
90 days or less	4.35 + 0.41	0.13 + 0.06
90 to 180 days	7.27 + 0.42	11.47 + 0.08
180 to 270 days	0	0

Table 9: Number of C-5s bridged to depot overhaul per year. Deterministic data, dock Released: 95% Confidence interval on the mean.

	3 ISO Docks (C-5s)	4 ISO Docks (C-5s)
90 days or less	0.01 + 0.01	0
90 to 180 days	11.56 + 0.07	11.65 + 0.06
180 to 270 days	0	0

Table 10: Number of C-5s bridged to depot overhaul per year. Modeled data, dock Not Released: 95% confidence interval on the mean.

	3 ISO Docks (C-5s)	4 ISO Docks (C-5s)
90 days or less	1.16 + 0.34	9.99 + 0.17
90 to 180 days	0.32 + 0.21	1.29 + 0.16
180 to 270 days	2.62 + 0.36	0.01 + 0.01

Table 11: Number of C-5s bridged to depot overhaul per year. Modeled data, dock Released: 95% confidence interval on the mean.

	3 ISO Docks (C-5s)	4 ISO Docks (C-5s)
90 days or less	7.32 + 0.27	4.98 + 0.26
90 to 180 days	3.82 + 0.25	6.17 + 0.28
180 to 270 days	0	0

Table 12: Number of C-5s bridged to depot overhaul per year. 14.25 day inspection length, 3 docks: 95% confidence interval on the mean.

	Docks NR (C-5s)	Docks R (C-5s)
90 days or less	10.86 + 0.17	1.02 + 0.21
90 to 180 days	0.62 + 0.17	10.60 + 0.21
180 to 270 days	0.02 + 0.02	0

Tables 8-12 permit analysis against each of the modeled variables (Deterministic data versus Modeled data, dock Release versus Not Released, and three versus four

docks). Because of the unique natures of each of the models alters the amount of days each ISO takes to complete, there is no parallel among the different tables for each of the periods. The data does not permit a broad assumption to numbers of aircraft in each category. Instead, it permits planners to select a specific model that best represents an expected state and use the respective table's data.

4   CONCLUSIONS

4.1   Research Findings

The 14.25 day ISO Standard is insufficient. Even with the best case scenario with dock release, the ISO process (including wait time) still takes 15.7 days and has each C-5 waiting on the ramp for almost a day and a half before entering the inspection. Across 111 C-5s, one and a half days per aircraft will start to add up and negatively impact airlift availability. The logic behind the 14.25 day requirement is well understood: given a 420 day ISO cycle and 111 C-5 aircraft, each C-5 must complete its ISO in 14.25 days for the next to start on-time. This logic, however, misses a key ingredient: waiting time in queue.

In models where the ISO dock is not released, aircraft develop an excessive queue wait time prior to entering the ISO process. This wait time precludes additional flying hours without adding a benefit. Starting the next ISO after the current ISO's Repanel sub-process is complete permits greater throughput.

4.2   ISO Recommendations

Continuing today's trend of almost 18 days to complete an ISO inspection will not be possible if only three ISO facilities are available for use. The process time must be reduced before such a reduction in ISO facilities can continue. As a result, AMC should focus on two main goals:

- Avoid process queue back-up by minimizing the time each aircraft waits to enter the ISO inspection after arriving at the facility.
- Reduce the ISO inspection time from the current 17.764 days closer to the critical path minimum time (not necessarily the 14.25 day AMC requirement).

In order to meet those two goals, AMC could:

- Release the dock. When releasing the dock (on critical path), there is a half day wait prior to a 12.5 day ISO. The result is a 13.1 day total at ISO, giving almost a day and a half of schedule flexibility before the 14.25 day requirement begins to make an impact. It can be done with three docks.

- Maintain four ISO locations for the foreseeable future. Almost two days of waiting can be saved with four docks and the total time at ISO is now only dependent on the process itself.
- Shift the mindset from a 14.25 day ISO length goal to a total flowtime goal that includes queue time. Once the entire ISO process has been reduced to 14.25 days, the fourth dock can be safely closed.
- Investigate moving some ISO inspections to the field, to reduce the time commitment at ISO and rapidly move the total time down from 17.746 days.
- Change the 420-day ISO requirement from timing after the date completed to 435 days from the date the inspection began. Such a change will provide the needed predictability the ISO scheduling process desires and increase AMC's ability to plan critical airlift missions based on known, not expected, long term C-5 availability.

Simulation data clearly identifies a problem with AMC's current plan and schedule to reduce ISO availability to three facilities. It also provides options for maintaining the availability of C-5 aircraft for worldwide airlift missions. Within certain specific constraints, the eventual plan to only operate three ISO locations is possible. Those constraints, however, indicate that such a reduction should not be attempted right away.

4.3   Recommendations for Further Research

We assumed all three ISO docks were identical. If the second and third ISO docks cannot produce aircraft inspections at the same rate as Dover AFB, then more research is required to model each ISO location separately.

If the Air National Guard, Air Force Reserve and active duty Air Force all do their own ISOs on their own aircraft at their own locations, then another study will be required to assess individual assigned aircraft and associated ISO location capabilities.

The excessive difference between the expected length of the Depot Inspection (160 days) and the modeled mean (between 198 and 209 days depending on the simulation run) indicates an area that could benefit from additional simulation and modeling. Improving the predictability of the Depot process will only help long range programming of C-5 inspection throughput.

Time and motion studies, and Lean process analysis should be conducted on the ISO sub-processes.

4.4   Classroom Insights

Three key factors helped this study to succeed: first, the class size was small. The instructor could focus his time

on only a single project team—multiple teams could have stimulated competition, but would have created an instructor span of control problem. Second, the students were mostly mid-career Air Force officers handpicked to attend AFIT full-time in residence—they were uniformly talented and highly motivated people. Third, the principal AMC customer was himself a graduate of an AFIT masters degree program. He was familiar with our processes, had a good idea what was needed, and was able to provide the data we required at the project start.

The "real world" nature of this problem really helped to make the course material relevant and proved to be a huge motivational tool. It also illustrated the challenges of doing simulation research: data were messy, the problem ill-defined, and the customer's desired outcome sometimes became fluid from week to week.

Grading individual effort proved somewhat difficult. To get a sense of individual contributions, Johnson informally separately questioned each of the students. He also had them individually present their portion of the project in a "dry run" briefing prior to the customer presentation. Five students on a single project seems a reasonable upper bound. For larger class sizes, we would likely split the class into multiple groups. This, however, could become burdensome to the customers, unless provisions are made for control group access to them.

DISCLAIMER

The views are those of the authors, and do not represent the official views of the Air Force, Department of Defense, or United States Government.

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