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USING SIMULATION TO INFLUENCE FOREIGN POLICY

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ABSTRACT

The United States Air Force's Air Mobility Command operates airlift missions that service the United States Navy's Pacific Fleet in the Indian Ocean. All of these missions travel through Singapore's airport, which has very restrictive operating hours. This paper discusses the use of simulation to assess the cycle time impacts of changing Singapore and Fujairah's operating hours and aircraft ground times.

1 INTRODUCTION

The United States Air Force's (USAF) Air Mobility Command (AMC) operates airlift missions that service the United States Navy's Pacific Fleet in the Indian Ocean. These missions operate on a regularly scheduled basis, departing Japan once per day Sunday through Thursday. The Tanker Airlift Control Center (TACC) at Scott Air Force Base, Illinois is ultimately responsible for the operational control of these missions and for keeping these missions on schedule.

Singapore is a bottleneck for all Indian Ocean missions because each mission must transit it at least once and because it has very restrictive operating hours. Singapore's airport is open for operations 11 hours each day. Therefore, any delays due to maintenance, etc. by an aircraft attempting to depart for Singapore or depart from Singapore can force the aircraft to remain over night (RON) at Singapore. This lengthens the cycle time substantially because it delays the mission for at least 18 hours for a mandatory crew rest. In addition, Singapore does not have the facilities for crews to stay overnight.

Previous attempts by the TACC to adjust Singapore's operating hours have failed due to lack of quantifiable evidence that extending the operating hours would improve operations. Realizing the value and insight that simulation could provide they turned to the Air Force Studies and Analyses Agency for modeling support.

2 PROBLEM

AMC operates three types of aircraft (C-17, KC-10 and DC-8) through five bases (Yokota, Japan; Paya Lebar, Singapore; Diego Garcia, Chagos Archipelago; Fujairah, United Arab Emirates; and U-Tapao, Thailand) in support of the Indian Ocean Channel Network. There are five different route-aircraft type combinations that fly once per day every Sunday through Thursday. Table 1 displays the day of departure, the route, and aircraft type that flies the mission. One constraint is that no missions are cancelled and no bases are skipped on a route.

Table 1: Departure Day, Route, and Aircraft Type

Day	Route	Aircraft
Sunday	Yokota-Singapore-Diego Garcia-Fujairah-Diego Garcia-Singapore-Yokota	DC-8
Monday	Yokota-Singapore-Diego Garcia-Singapore-Yokota	C-17
Tuesday	Yokota-Singapore-Diego Garcia-Fujairah-Diego Garcia-U-Tapao-Yokota	C-17
Wednesday	Yokota-Singapore-Diego Garcia-Singapore-Yokota	KC-10
Thursday	Yokota-Singapore-Diego Garcia-Fujairah-Diego Garcia-Singapore-Yokota	C-17

Aircrews are also a constraint. Each aircraft type has different limits for the maximum number of hours that a crew may operate in a given day. Once this limit is reached the crew must enter crew rest which also varies by aircraft type. In addition, we assume that all crews are flying augmented. This means that the crew duty day is 24 hours in duration. A crew may RON at any base if necessary; however, it is preferred that crews only RON at Diego Garcia because it has the facilities to accommodate more crews.

The most restrictive constraint for this scenario is the base operating hours. Table 2 displays the operating hours at each base in military Greenwich Mean Time.

Table 2: Base Operating Hours

Base	Operating Hours (GMT)
Yokota	2100 - 1300
Singapore	0001 - 1100
Diego Garcia	24 hour operations
Fujairah	0330 - 1500
U-Tapao	0100 - 1100

Each base has a limit for the number of aircraft that can be serviced simultaneously and each aircraft type has a different service time once the aircraft enters service.

Historical data is available for the following: departure reliability by base by aircraft type, departure delays by base by aircraft type, and flying times by base pair by aircraft type. Seasonal winds impact aircraft flying times depending on the direction of the route.

The TACC wanted to test the cycle time impacts of changing the operating hours at Singapore and Fujairah. In addition, they wanted to experiment with changing the ground times by aircraft type by base because these factors are under their immediate control.

After the TACC defined the problem statement and provided the historical data, AFSAA developed process maps of Indian Ocean channel missions and then implemented that design in a simulation model.

2 APPROACH

Through an iterative process, AFSAA and the TACC came to agreement on how the Indian Ocean channel process operates. This is documented through process maps developed using Visio®. Figure 1 displays an example of the process maps.

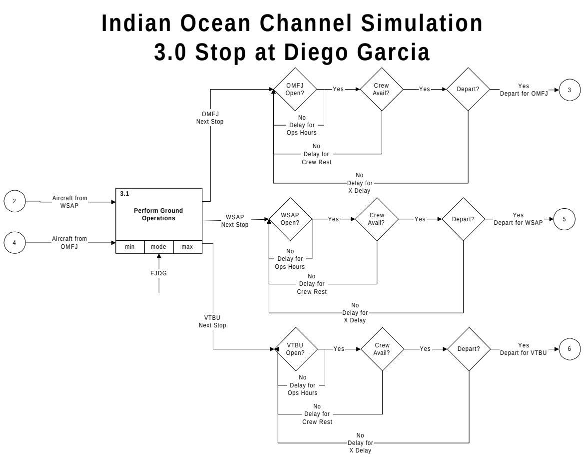

Figure 1: Process Map Sample

AFSAA translated the process model into a simulation model with Arena®. The animation view is displayed in Figure 2. The model was deterministically verified based on published route schedules. Trace reports demonstrated that for each route, the aircraft were within 1 minute of the scheduled departure and arrival times.

Trace reports also highlighted areas for model improvements. Subsequent modifications allow changes to Fujairah's operating hours and restrict aircraft RONs from non-RON bases.

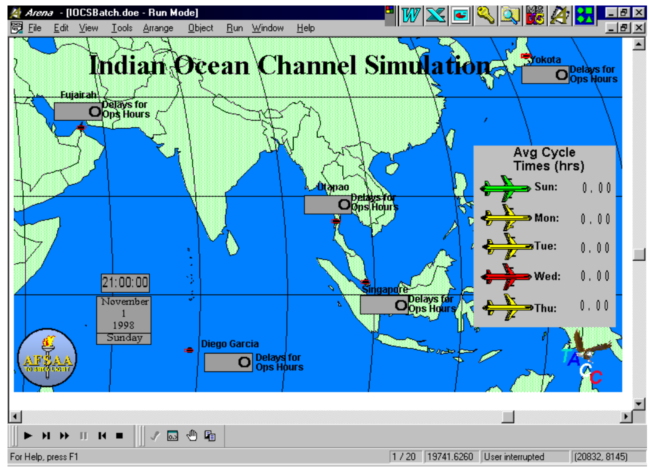

Figure 2: Indian Ocean Channel Simulation Animation

The model was statistically validated based on historical cycle time data. Once the warm-up period and minimum number of replications required were determined, the verified and validated model was then given to the TACC to use for experimentation. A graphical user interface (GUI) is also included that facilitates experimentation using the model. The GUI is displayed in Figure 3.

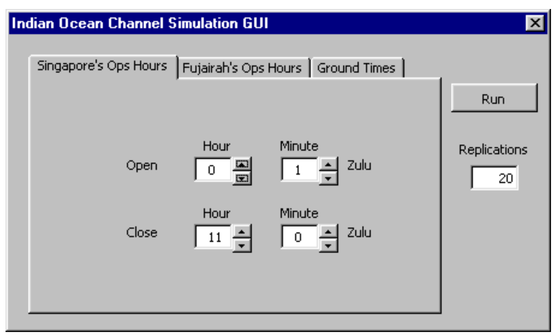

Figure 3: Graphical User Interface

3 RESULTS

Our original analysis was based upon a simulation, which only incorporated Singaporean changes. Opening and Closing times are the two factors evaluated in this Design of Experiments. Five levels for each factor and five replications for each combination made a total of 125 replications. An F test of the interaction between these two variables showed no significant interaction. The interaction-plot in Figure 4 indicates the same since the lines are roughly parallel to one another.

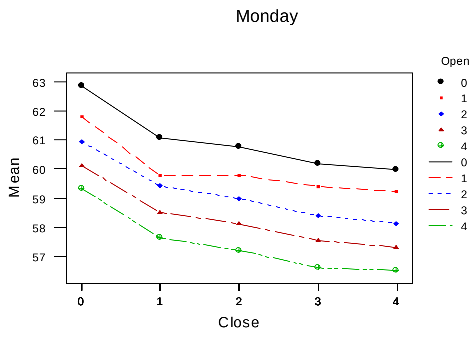

Figure 4: Interaction Plot

In this case the Opening and Closing time has a statistically significant impact on the Cycle Time, which is our key performance. For the following route, which transits Singapore one time, only the Closing time had a significant impact on Cycle Time. This is depicted in Figure 5.

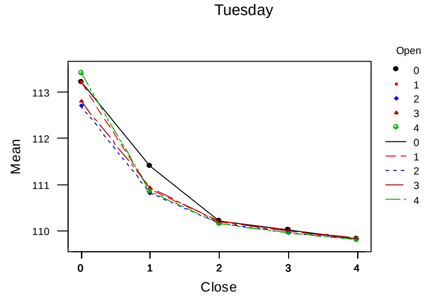

Figure 5: Closing Time Impacts at Singapore

Based upon this initial study we suggested that the station at Singapore open two hours earlier and close two later. This change reduces total cycle time by 10 hours per week. If aircraft are used for this time versus setting idle, the Air Force can generate approximately $50,000 per week in revenue generating flights.

In the second analysis we used the enhanced simulation. The model allows changes in operating hours at two locations and changes in the standard ground time for each aircraft. The experiment incorporated three variables set at the levels shown in Table 3.

Table 3: Second Experiment

	Level 1	Level 2
Singapore	0001z-1100z	2200z-1300z
Fujairah	0330z-1500z	0300z-1530z
C-17 ground time	3.25 hrs	2.25 hrs

Note: From this point on, the altered factor and its level will be referred to as factor(level). For example, Fujairah at level 2 is referenced as Fujairah(2).

Our analysis of the data from this experiment indicated that the biggest gains in performance would come through Fujairah(2). Fujairah(1) defined the normal operating time for Fujairah. On certain routes the variables had strong interaction with one another. For instance, the Thursday route, which is flown on a C-17, showed significant improvement using Fujairah(2) alone. On average, the cycle time was reduced by 16 hours. However, if we used Fujairah(2) and C-17(2), we saw a 24-hour reduction in cycle time. Interestingly, using a reduced C-17 standard ground time, C-17(2), alone had no or little impact. The histogram in Figure 6 shows by example the difference in cycle time distribution between Fujairah(1) and C-17(1) vs. Fujairah(2) and C-17(2). The only other route flown by a C-17 that transits Fujairah (Tuesday) showed the same interaction.

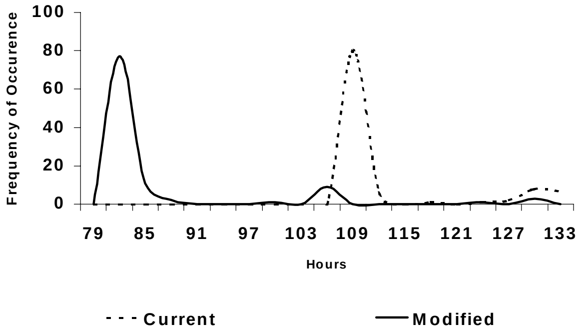

Figure 6: Histogram

When making recommendations to the Indian Ocean Network Manager (XOG) we cautioned them about these interactions. We explained that adjusting only one of the two variables would not likely produce the desired performance increase. At publishing time the XOG was still heeding our warning. We recommended Fujairah(2) for three routes which transited Fujairah, C-17(2) for those routes using the C-17, and Singapore(2) for the Monday and Wednesday Routes. We also noted that if the customer could only make one change, it should probably be a change to Fujairah's operating hours. These recommended changes increase the potential to fly an additional 70 hours of revenue generating flights valued at $350,000 per week.

Simulation, Design of Experiments, and Analysis of Variance work very well together for this type of problem. We need independent and identically distributed outcomes from our experiment to properly use Analysis of Variance. Using the averages from each replication of our simulation provided both of these. Analysis of Variance provides a concise way to evaluate each variable separately and also all together. Also, the interaction plots, which are a by-product of the Analysis of Variance, provide an excellent visual inspection tool.

4 CONCLUSIONS

We have developed a verified and validated model of the Indian Ocean Channel Network that is being used to change the way AMC operates in the Indian Ocean. Just prior to submitting this paper the TACC used the model to justify closing Fujairah's 2.5 hours later.

AUTHOR BIOGRAPHIES

MICHAEL CARTER is the Chief of Joint Mobility in the Air Force Studies and Analyses Agency. He has over 1 year of simulation experience. He earned his B.S. in Physics at Montana State University in 1977, a B.S. in Aeronautical Engineering at Air Force Institute of Technology in 1982, and a M.S. in Nuclear Engineering at Air Force Institute of Technology in 1989.

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