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THE SORTIE GENERATION RATE MODEL

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ABSTRACT

This paper presents a sortie generation rate (SGR) model and describes how to use it as a commander's tool. The SGR model was initially developed to generate published sortie rates, but proved to be an expedient commander's tool for planning options. Previously, developing sortie rates required three models, Regional Conflict Model (RCM), Logistics Composite Model (LCOM), and Flyer. Each model required its own input data and they were located in different agencies of the Air Force. The RCM model is no longer supported, LCOM requires large amounts of input data, and Flyer uses output of LCOM as part of its input. The SGR model requires little data and it is a one step process, which runs on a laptop computer. The SGR model uses constraints and events to capture the sortie rate process from a macro level without significantly detailed input.

1 INTRODUCTION

The current day and near future United States Air Force (USAF) is a responsive, expeditionary Global Reach and Global Power force. Thus, the USAF needs timely planning capability so the USAF can determine the appropriate force structure abroad and at home to protect and defend the United States (US) against all enemies. As a superpower, the US must proactively know its alternative munitions deliverability and support capability when threats arise. At a minimum, commanders must know the mix of aircraft, aircrews, and maintenance capability needed to yield a sortie capability for a desired level of munitions deliverability and support missions. If commanders are confronted with changing conditions, alternative sortie rates would allow commanders the flexibility to choose or change plans. Computing the sortie rates for alternatives may need quick turnaround. Most tools that compute sortie rates are designed either for in depth studies of base operations, or chemical and biological effects on sortie rates. A generic tool which is responsive, requires little input data, and provides alternative sortie rates for a variety of conditions would give commanders a tool they could use to develop alternatives quickly. The SGR model provides quick turnaround results for a variety of scenarios, using input from operational experience or specific information about the sortie. Abundant research into logistics or maintenance details is not needed for the SGR model. The results can be presented as sortie rates (cumulative daily sorties/day number/number of aircraft), cumulative daily sorties, daily sorties, or utilization rates based on cumulative daily sorties per aircraft.

2 THE SORTIE GENERATION PROCESS

The complexity of computing sortie rates is more than a mere spreadsheet task, and to collect an abundance of data for large models reduces the commander's flexibility, responsiveness, and ability to create alternative options. Thus, a requirement for a generic sortie model with simple operational input and quick turnaround will help the entire Air Force and contribute significant operational insights that add realism to the planning process. This was the motivation for developing a generic SGR model.

The initial concepts for the sortie process were first collected through interviews with several pilots, navigators, and maintenance personnel, who either flew or were familiar with different aircraft types. Their operational insights were transformed into a sortie rate model. As the model grew more sophisticated the author consulted with individuals, who had different experiences for more diverse details, which helped develop the SGR model to a greater resolution.

2.1 Parameters Constraining Sortie Rates

Many constraints can influence the number of sorties, but it was the intent to keep the constraints simple and provide more resolution by modifying input values. In the SGR model, some constraints address campaign level details, other constraints address mission details, and more detailed information may come from daily life of aircrews. From a campaign level, the parameters that govern the number of sorties are: number of days sorties will be flown; number of aircraft; number of aircrews; crew duty day length; pre-briefing and post briefing time; aircraft maintenance time; number of aircraft maintainers or number of aircraft that can be maintained simultaneously; sortie duration; aircrew rest; and limits on aircrew cumulative flying hours over 30 and 90 consecutive days. Some of the input parameters involving mission constraints on sorties are flight sizes, when two or more aircraft fly sorties together, and "hot turns" during a surge period. A "hot turn" is when an aircrew flies a sortie, returns, waits while the aircraft is rearmed and refueled, and flies a subsequent sortie with the same aircraft. Both flight sizes and "hot turns" can vary during a campaign. In the early stages of a campaign, the SGR model can address the surge (an early period in the campaign where aircrews fly "hot turns"), which may be required to dominate the air and reduce the ground threat. After a surge period, aircraft and aircrews can fly sustained sorties, which may not be as intense as the surge period to reduce the ground threat and allow friendly ground forces to advance. Thus, operations can drive the mixture of number of aircraft flying sorties together and their turnaround time. Other constraints, which can impact sortie rates, are ground and air aborted missions, aircrews on leave or sick, and flying windows. When a ground abort occurs, a sortie is not flown; but for air aborts, aircrews fly sorties for a reduced time. Aircrews that are on leave or become sick reduce the number of available aircrews to fly sorties. Flying windows deliberately restrict flying times that sorties may be flown for several reasons. For example, stealth sorties, flown during dark hours, or commanders may restrict flying sorties during certain times over areas governed by treaties. Other constraints can be included, but the idea was to develop a model using the most prominent constraints that gave the necessary resolution.

Secondary constraints result from operational timing such as queues for aircrews waiting for available aircraft, aircraft waiting for an available maintenance crew, aircrews waiting for the other aircrews to become available to form a flight. Aircrews on rest, leave, or illness are constraining factors that interact with the available aircraft and flight sizes. These constraints temporarily reduce the number of available aircrews which impact the number of sorties. Although they are fundamentally identified by the parameters previously discussed, it is important to identify the constraints resulting from interactive processes.

2.2 Event Times that Constrain Sorties

In the SGR model the event times are lengths of time for pre-brief, post brief, maintenance time, and sortie duration. Event times are dependent on operations of interest, types of aircraft, and mission types. However, the SGR model is generic, so it is not necessary to identified event times with specific aircraft or missions. Most often the actual time of these events is not known a priori; however, familiarity with the operations and types of aircraft allow planners to know approximate event times in terms of the minimum time, maximum time and the most likely time. The most likely time may be the most difficult to guess, but planners can quickly approximate event time. The SGR model uses triangular distributions to address subjectively estimating input data (Law and Kelton 1991) for the event times in the absence of accurate data.

2.3 Sortie Rates Used for Planning.

The current method of determining sortie rates is for planners to use published sortie rates over various time intervals. The sortie rates are computed based on historical operations, but sortie rates may not be a perfect geographical match for certain operations. Operational conditions and requirements can vary between theaters and with the various small-scale contingencies. The conditions published sortie rates were developed under may vary tremendously from the actual conditions that sortie may fly. Launching and recovering airbases may have unique characteristics that impact maintenance, sortie duration, and launch rates that were not included in published sortie rates. The differences between the actual operational conditions, geographical conditions, and other conditions provide some planning difficulties. It would be difficult to collect all the base information necessary to feed into LCOM to generate an ATO and run Flyer for accurate sortie rates in a short time. Consequently, a simple model that uses approximate operational input and can turnaround quick, relatively accurate sortie rates would be helpful for a commander to have nearby.

2.4 The Requirement for a Simple Sortie Model

A requirement for a generic sortie model with simple operational input and quick turnaround will help accurately compute sortie rates under a complex set of constraints and help the entire Air Force by contributing significant operational insights that add realism to the planning process.

3 SIMULATING THE SORTIE PROCESS

Operational information was first obtained by working with various Air Force commands; later, aviators, navigators, and maintainers provided additional information that helped to create the first model. The call for applications from various commands, since the first model developed added insight on how to use the model effectively when developing sortie rates for different aircraft.

The model was developed using Arena® Version 5.0, a copyright software product of Rockwell Software on a laptop computer. Figure 1 displays a macro level flow of the process. Each block contains details that enhance the process resolution. The output screen in Figure 2 is a run-time visual output that analysts can monitor. Model development was done and checked using the animation features of Arena in the networks similar to the one displayed in Figure 1 and the output in Figure 2.

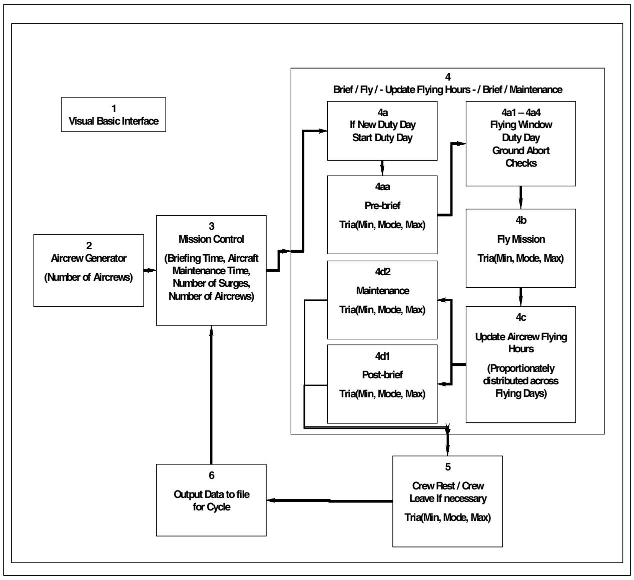

Figure 1: Macro Level Model Structure

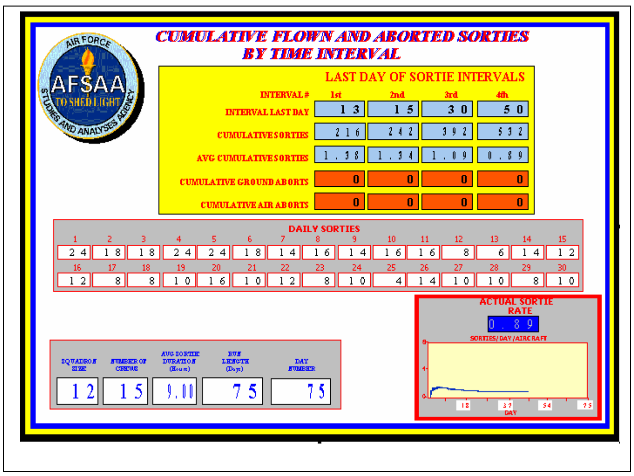

Figure 2: SGR Digital and Graphical Output

In Figure 3, the graphical user interface shows the only data fields required, which can be changed with ease so the model can be quickly rerun.

3.1 Verification

The SGR model was developed over the course of nine months as a part time project. Consulting with various operational personnel to assure we captured the correct details using the correct methodology allowed accurate model verification. The first verification was done in

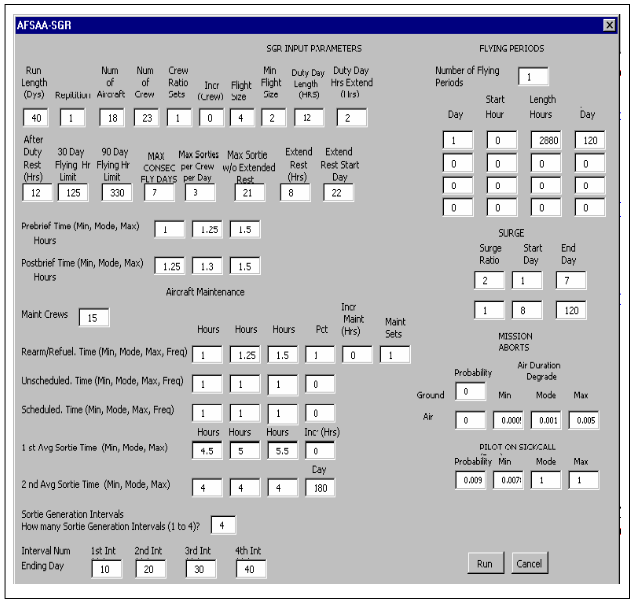

Figure 3: Graphical User Interface

March 2001 in a study involving fighters. The model was adjusted slightly to capture some refined effects for aircrew duty day extension. In an exercise the SGR model was used to determine sortie rates for primary and secondary sortie duration. Additional verification was accomplished during the Quadrennial Defense Review (QDR) when sortie requirements for different airframes were generated to propose ideas and a variety of sortie rates under different conditions. The SGR model has not been validated for cargo carriers that fly scheduled circuits because a scheduling model would be more appropriate. The SGR model does address sortie rates for cargo carriers flying single sorties from an airbase to a single location and returning to the same airbase.

3.2 Validation

The desired validation for a computer model is to have it replicate reality. This occurred in several instances where the model generated sortie rates that matched the actual number of daily sorties flown. The SGR model also matched the utilization rates for several aircraft over the first thirty days. Statistical validation of the SGR model was accomplished using sortie rates from a previous Crew Warrior III.2 study done using LCOM and Flyer, which computes the number of crews necessary to achieve a defined sortie rate. Crew Warrior presented the number of aircrews for four sets of combined pre-brief – post brief times, namely two, three, four, and five hours. The numbers of aircraft for each pre-brief – post brief combination were 12, 18, and 24. Crew Warrior used 15 sortie durations and 12 different sortie rates to generate 180 different crew numbers for each number of aircraft. Thus, in the Crew Warrior study, each combined pre-brief – post brief time had 540 aircrew/aircraft sets. To validate the SGR model a 3^2 design was used for each combined pre-brief – post brief time and number of aircraft. A low, intermediate, and high sortie duration (1.7 hrs, 3.8 hrs, 5.9 hrs) combined with a low, intermediate, and high number of aircrews associated with sortie rate inputs (0.80, 1.6, 2.8) were chosen to test the difference between the sortie rates generated by the SGR model. A paired "t- test" was used to successfully compare the differences between sortie rates of the SGR model and those used as input for Flyer. All samples tested good for a 95% confidence interval.

4 SENSITIVITY TESTS AND ANALYSIS

Varying four input parameters tested the model sensitivity. Table 1 lists the parameters changed for sensitivity tests and the values used.

Table 1: Parameters Changed for Sensitivity Tests

Parameters Changed During Sensitivity Tests	
Number of Aircrews: 23, 27, 32	
Aircrew Duty Day (Hours)	
Length	Extension
12	6
15	3
18	0
30 Consecutive Day Flying Hour Limit:	125, 130, 135, 140

Aircrew duty day length is the number of hours aircrews must be on duty to fly or perform other duties. Aircrew duty day extension is the maximum amount of time a commander is willing to extend the duty day for a single additional sortie. If one additional sortie cannot be flown with the duty day extension, the extension is not allowed. In this analysis the 30 consecutive day cumulative flying hours limit, governed by Air Force Instruction, controls the maximum number of cumulative flying hours over the 30 consecutive days before aircrews must have crew rest. Aircrew duty day length and the duty day extensions were paired. Crew ratio is the ratio of aircrews to aircraft. After aircrews go on rest and their 30-day cumulative flying hours reduces below the limit, they return to flight duty. Table 2 lists other input parameters that are fixed during the sensitivity tests. Using the SGR model, the objective is to quickly generate sortie rates and display as many options as possible to aid commander's decisions. The model will generate sortie data to calculate sortie rates for 100 scenarios, with five repetitions per scenario in approximately three hours with post processing.

Table 2: Fixed Parameters

Fixed Parameters	Values
Number of Aircraft	18
Days of Campaign	60
First flight Size	4
Second Flight Size (Hot Turns only)	2
Max Sorties per Day per Aircrew	2
Sortie Duration Time (Hours)	Trian(2, 2.5, 3)
End of Duty Day Mandatory Crew Rest (Hours)	12
Extended Crew Rest (Hours) After Ten Consecutive Flying Days Or 20 Consecutive Sorties without Extended Rest	12

4.1 Simple Analytical Methodology

A simple graphical method can identify scenarios producing the most sorties with the least impact on crew rest and aircrews. In the scenarios plotted in Figures 4 and 5 the aircraft utilization rates, which are cumulative sorties over ten consecutive days, are plotted on the vertical axis. The 30-day cumulative flying hours limits are plotted on the horizontal axis.

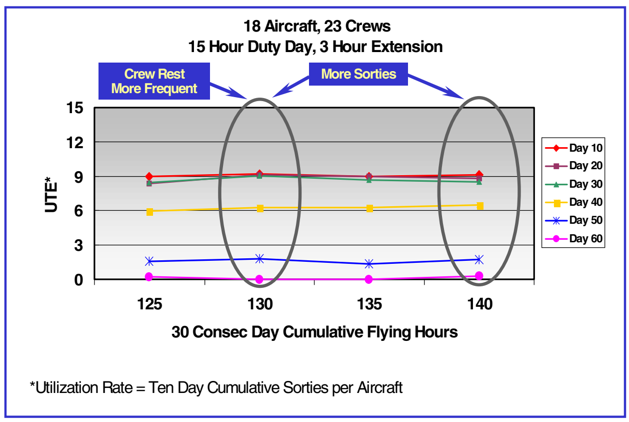

Figure 4: Utilization Rates, 15-Hour Duty Day, 3-Hour Extension, 1.25 Crew Ratio

In both scenarios the crew ratio is 1.25. In Figure 4, aircrew duty day is 15 hours long with a 3-hour extension. In Figure 5, aircrew duty day is 18 hours long and no extension. In Figure 6, the crew ratio is 1.75, and the duty day is 12 hours long with a 6-hour extension.

4.2 Results

Comparison of the UTE rates plotted in Figure 4 show that for a 1.25 crew ratio the best combination of duty day length and cumulative flying hours is the fifteen hour duty day with a three hour extension and 130 cumulative flying

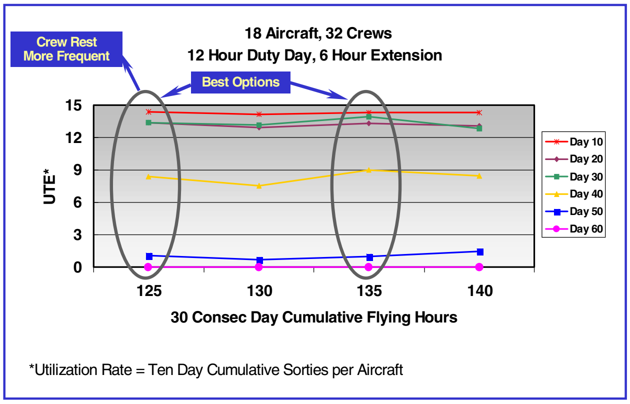

Figure 5: Utilization Rates, 18-Hour Duty Day, 0-Hour Extension, 1.25 Crew Ratio

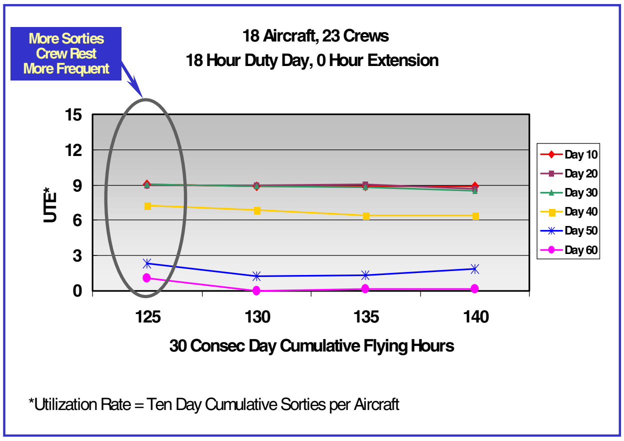

Figure 6: Utilization Rates, 12-Hour Duty Day, 6-Hour Extension, 1.25 Crew Ratio

hour limit over 30 days. Figure 4 presents two candidate scenarios, the scenario for flying hour limit of 130 hours and 140 hours. Each produce approximate the same number of cumulative sorties in each interval, but by using the 130 flying hour limit aircrews go to crew rest more frequently, which is good because it allows aircrews to maintain their edge under stressful conditions. In Figure 5, the scenario using the 125 flying hour limit provides the most sorties and the greatest frequency for aircrews to go on crew rest. These analytically simple methods are quick and useful when used with the sortie generation model. The last scenario, presented in Figure 6, demonstrates the model's sensitivity for a crew ratio of 1.75 and a twelve-hour duty day with a six-hour extension. Figure 6 has two candidate scenarios that offer good options, one using a 125 flying hour limit and the other using a 140 flying hour limit. Both have approximately the same number of sorties and UTE rate, but the scenario for the 125 cumulative flying hour limit allows aircrews to rest more frequently.

5 CONCLUSIONS

The SGR model is a quick, flexible tool that allows a commander to obtain alternatives easier than other methods. Simple graphical methods allow the analyst to observe the effects of several variables with simple graphical tools. The portability of the SGR model requires a laptop and a curious mind. Planners can effortlessly obtain input from operationally intuitive personnel and use it in the SGR model, rather than spending time collecting data.

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AUTHOR BIOGRAPHY

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