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**SORTIE-RATE MODEL**

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This appendix describes the method used to calculate aircraft sortie rates. Based on earlier unpublished work by former RAND colleague Lawrence Hollett,<sup>1</sup> the method was chosen to facilitate a simple and fast spreadsheet analysis of USAF aircraft sortie rates under a variety of assumptions about range to target, aircraft speed, and basing options. This analysis is based on historical F-15 and F-16 maintenance data and statistical analysis conducted by the Boeing Corporation on the relationship between maintenance time, sorties, and sortie duration for Boeing 737 airliners.

The use of airliner data to explore the relationship between maintenance requirements, sorties, and sortie duration may seem strange. However, using these data helps us understand and represent the influence on sortie rates of two very distinct classes of aircraft system failures: those that are a function of *cycling*—turning a component on and off—and those that are a function of aggregate time in use. Avionics components, for example, tend to produce cycle-related failures, whereas hydraulic pumps fail in relation to the hours of use that they have accumulated.

The model presented here relies on a recent study of F-15 and F-16 maintenance data<sup>2</sup> to help predict the relationship between sortie duration (or distance to target) and maximum sortie rates for USAF

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<sup>1</sup>J. Lawrence Hollett, “USAF Responses to Weapons of Mass Destruction Use: Standoff Tactical Airpower Projection Option,” unpublished RAND research.

<sup>2</sup>Craig Sherbroke, *Using Sorties vs. Flying Hours to Predict Aircraft Spares Demand*, McLean, Va.: Logistics Management Institute, April 1997.

units. The model reproduces sortie rates achieved by USAF fighters operating from Saudi bases during Operation Desert Storm,  $\pm 10$  percent. While our simple aircraft-sortie-generation model does not generate absolutely precise estimates of USAF sortie-generation potential, it provides estimates that are close enough to what could be achieved to allow us to estimate the costs and benefits of various adversary base-attack strategies and USAF responses.

Our model takes as its starting point the simple observation that, at any given time, an aircraft must be either in the air or on the ground. Time spent in the air is denoted  $FT$  (flight time), and time spent on the ground is denoted  $GT$  (ground time). Therefore, sortie rate ( $SR$ ) is a function of  $FT$  and  $GT$ :

$$SR = \frac{24 \text{ hours}}{FT + GT} \quad (\text{B.1})$$

Ground time can be divided into the time to accomplish routine actions required before a perfectly operating aircraft can accomplish its next mission, and those actions required to repair or replace malfunctioning systems. The former we refer to as *turnaround time* ( $TAT$ ) and the latter as *maintenance time* ( $MT$ ). Since  $GT = TAT + MT$ , we get the following equation by substitution:

$$SR = \frac{24 \text{ hours}}{FT + TAT + MT} \quad (\text{B.2})$$

Table B .1 summarizes the average time required for various routine TAT tasks and shows the basis for our 180-minute (3-hour) constant TAT.

*Flight time* is the distance from an aircraft's base to the target and back, divided by the average cruise speed:

$$FT = 2 \times \frac{\text{distance to target}}{\text{average cruise speed}} \quad (\text{B.3})$$

**Table B.1**  
**Average Time Required for Various Turnaround-Time Tasks**

Turnaround Time (TAT) Major Actions	Average Time Required (minutes)
Land and Taxi	10
Make Aircraft Safe for Ground Ops	5
Shut Down Systems	2
Conduct Post-Flight Inspection/Debrief	15
Re-arm	50
Service	20
Refuel	30
Conduct Pre-Flight Inspection	15
Start Engine	5
Perform Final Systems Check	5
Arm	5
Taxi	10
Wait in Queue	5
Take Off	3
<b>TOTAL</b>	<b>180</b>

NOTE: These turnaround times represent typical performance of USAF maintenance personnel in force-employment exercises conducted during the late 1980s and early 1990s, as determined through interviews of senior F-15 and F-16 maintenance personnel by J. Lawrence Hollett in 1995. While it may appear that substantial time could be saved by performing the post-flight inspection, re-arming, service, and refueling operations in parallel, safety considerations prevent doing so. When refueling or re-arming operations are in progress, only fuels and munitions personnel are permitted near an aircraft.

Recent analysis of the relationship between sorties, sortie duration, and maintenance requirements for F-15 and F-16 aircraft revealed that there is a constant average of 3.4 hours of maintenance time per sortie and an additional 0.64 hour of maintenance time for every hour the aircraft is in the air.<sup>3</sup> This relationship yields the following formula for maintenance time:

$$MT = 3.4 \text{ hours} + 0.68FT \quad (B.4)$$

<sup>3</sup>Author's conversation with Craig Sherbroke of the Logistics Management Institute, McLean, Va.

So, for a 24-hour aircraft flying a mission against a target 500 nautical miles (nmi) from its base with a cruise speed of 500 knots, the sortie rate would be

$$\begin{aligned}
 SR &= 24 \text{ hours} / (1.68FT + TAT + 3.4) \\
 &= 24 \text{ hours} / \left[ 1,000 \text{ nmi} / (500 \text{ nmi/hour}) \right] + 3 \text{ hours} \\
 &\quad + 3.4 \text{ hours} + \left[ 0.68 \times 1,000 \text{ nmi} / (500 \text{ nmi/hour}) \right] \quad (B.5) \\
 &= 24 \text{ hours} / (2 \text{ hours} + 3 \text{ hours} + 3.4 \text{ hours} + 1.36 \text{ hours}) \\
 &= 24 \text{ hours} / (9.76 \text{ hours}) \\
 &= 2.45 \text{ sorties per day}
 \end{aligned}$$

For 12-hour, “day or night only” aircraft (such as F-117s or A-10s), sortie rates are rounded down to the integer number of sorties an aircraft could fly in a 14-hour period.<sup>4</sup> Using the same cruise speed and distance to target from the above example gives a day-or-night sortie rate of 2, because an aircraft flies a sortie and is ready for relaunch in 9.76 hours. Its second sortie requires 2 hours, for a total of 11.76 hours. There is not enough time to complete the 7.76-hour average ground cycle before darkness or light makes further operations impractical for the particular aircraft type, so only 2 sorties can be flown.

Note that, as the distance between an aircraft’s base and its target increases, sortie rate decreases, because of two factors. The first and most obvious is that flight time has increased. However, in this model, the increase in flight time also leads to an increase in maintenance on those systems sensitive to sortie duration. So, not only do maintenance personnel have less time to work on a given aircraft as sortie duration increases (the more time it spends in the air, the less it spends on the ground), but they also have more work to do. As a result, sortie rate is *not* a linear function of distance to target.

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<sup>4</sup>This assumes an average 12-hour night with 30 minutes each of twilight at dawn and dusk and 30 minutes of transit in darkness or daylight over friendly territory at both dawn and dusk.