An Overview of Search Capacity in Carrier Games

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When we played **White Ensign/Rising Sun**, we found that it seemed near impossible for either side to detect the other's ships. It seemed obvious that something was wrong with the search system. The question was how to describe the problem. A measurement that naturally suggested itself was to examine the sea area covered by a typical search plane when looking for an enemy task force. Since a number without a basis for comparison is of little use, I decided to take a look not only at **WE/RS**, but also at some of the other carrier games around, and compare results. On the way I discovered that this is actually an excellent vehicle to compare how the search systems for such games work even if the games themselves are at wildly different scales and levels of abstraction. The idea arose in email discussion with Brian McCue (not only a wargamer, but also involved with search in a professional fashion), who made some important suggestions.

The search plane chosen for examination was the PBY Catalina, for two reasons. First, it was the mainstay of the Allied land-based search forces, and is present in every carrier game. Second, the PBY's in **WE/RS** are the RAF/RN's most long ranged search asset, so their performance in the game can be assumed to be highly relevant to the **WE/RS** search problem. Assuming correct mapping of the plane's capabilities between the various games, a similar comparison could of course be made for the Japanese side's main search planes, the H8K (Emily) and H6K (Mavis) flying boats and the G4M (Betty) medium bombers, but ultimately I do not expect the results to be much different. Comparing the performance of a shorter ranged search plane (e.g., the USN's SBD scout planes) would be very interesting in its own right and I may do it at a later date.

Basically, two types of numbers were computed for each game. The first is the search area covered by a max-range PBY search flight on each game's map (measured in terms of the area of the hexes covered). However this only tells part of the story. Many games also have additional rules that deal with the external parameters of the search - weather, crew attention, communications. Brian suggested to me to simply use the prorated search area, i.e., the actual search area multiplied by the chance of finding a task force in the hex, and that's what I did. For example, if an aircraft can search a 1,200 square mile hex in a one-hour turn, but then has to roll a 5 or a 6 to see anything that's there, it's fair to consider this a 1200 * 1/3 = 400 square mile per hour search rate. As Brian wrote, "This sweeps under the rug the operational fact that searches are not strictly additive, because searchers cannot fully coordinate their efforts, but probably most games ignore this as well, so it's OK for a 'first cut' at the problem."

I first examined the top four games in the table below and then took a look at some others that were more unusual or harder to analyze.

Game	hex diameter	turn length
Flat Top (Avalon Hill)	20 miles	1 hour
Indian Ocean Adventure (GDW)	33 nm	6 hours
Solomon Sea (Simulations Workshop)	100 nm	3.5 hours
White Ensign/Rising Sun (MiH)	55 nm	8 hours
Carrier Battles (Rising Sun Simulations)	13.5 nm	1 hour
Carrier Battles Basic Game	54 nm	4 hours
Carrier Strike (3W)	80 nm	4 hours
Midway (AH ’65)	50 nm	2 hours
Scratch One Flat Top (3W)	40 nm	2 hours
Smithsonian Guadalcanal (Avalon Hill)	70 nm	4 hours
Victory at Midway (XTR)	100 nm	3.5 hours

I computed the hex area for each game, and examined the area searched for a typical flight and number of aircraft based on the game's unit scale. "Typical flight" here means a full length search mission. Plane readying time, even if explicitly handled, generally doesn't enter into this since PBY's can only really fly one such mission per day, for which they can spend up to 14 hours searching. More, in theory but daylight doesn’t last that long near the equator. See the Appendix for a closer look at the numbers.

Overall Results

For the first four games I got the following:

Game	Area (nm^2)	Comments
Flat Top, 9 planes, 12 hours:	162,000 "average"	135K or 215K depending on weather
Sol Sea, 9 planes, 14 hours	194,000 or 170,520	depending on weather.
	155,900 or 136,416	with comm delay optional rule.
I.O.A., 8 planes, 12 hours	180,000	
WE/RS, 12 planes, 16 hours	10,524	

Looking at this table, one gets an immediate explanation for the search problems in **WE/RS**: its search coverage sits at the bottom of the well, far below the other games.

Apart from **WE/RS** the others are remarkably close. It should be noted that the "average" (50-50 clear-clouds) case in **Flat Top** is not really typical, since less than half the map will be clouds typically. This would bring **Flat Top** into the upper range of these games, which fits my intuition - I always thought it was a bit easy to find the enemy in non-refereed **Flat Top**. The "raw" **Solomon Sea** numbers bracket the **Indian Ocean Adventure** numbers. **Solomon Sea** also has a special rule representing the problems both sides experienced with delayed search aircraft reports (which due to complex communication channels often became available only after their usefulness had passed). When using this (recommended) rule, the values are somewhat smaller than in the other games that do not model this problem explicitly.

Normalizing the Results

Brian suggested simply computing from the above the area searched by one real-world plane in one hour. This quotient, called *Q* below, makes it fairly easy to compare the games, and I added the other games, resulting in the following table.

Game	*Q* (nm^2/plane/hour)	Remarks
Carrier Strike	~3000 avg.	1600-6000 depending on range/concentration;
Smithsonian Guadalcanal	3197	
	2840	measured across one day with patrol rule
	2131	across 12 hours with patrol rule including readying time
	1599	across one day without patrol rule
Midway	2800	assuming 12 planes are searching
Victory at Midway	2175	
Carrier Battles	2020 avg.	2536/1521 clear/clouds
	2281 avg.	flying alone, 3042/1521 clear/clouds
Indian Ocean Adventure	1875	
Flat Top	1500 avg.	1990 clear /1250 clouds
Solomon Sea	1450 avg.	1539 good weather/1352 hazy
	1160 avg.	with comm delay, 1237 good weather/1082 hazy
Midway	1400	assuming 24 planes are searching
Basic Carrier Battles	1268	
Scratch One Flat Top[1]	764	search 7 hexes in clear weather
	652	search 7 hexes in 50% clear/50% clouds
	194	search 1 hex in clouds
White Ensign/Rising Sun	73	

[1] … selected set of representative choices only

Analysis

There is a solid center group, comprising the two most detailed games (**Flat Top** and **Carrier Battles**) as well as **Indian Ocean Adventure**, **Solomon Sea**, and Basic **Carrier Battles**. "Above" the center group, **Carrier Strike** and **Smithsonian Guadalcanal** make search very easy (this seems to fit in with the "make it interesting for kids" approach of **Smithsonian Guadalcanal**: quick action, extremely bloody combat, game over quickly). **Midway** '65 is in the "center" or "easy" group depending on the assumed search plane number. **Victory at Midway** is the link between this group and the center group.

Below the center group, **Scratch One Flat Top (SOFT)** makes search very hard (probably too hard, especially given the ferocious rate of search plane attrition in that game), although not quite as badly as as **WE/RS**. **WE/RS** still sits at the bottom, even more noticeably than before.

It is probably safe to say that (ignoring other factors such as search planning and plane handling) the games in the **CB/FT/SS/IOA** group provide a reasonably accurate estimate of historical search coverages. To confirm this, Brian mentioned that 750 nm^2/plane/hour was considered a standard value when searching submarines in daylight, and therefore up to twice that value would not be unreasonable for sighting entire task forces of larger ships.

A quick fix for White Ensign/Rising Sun

We started out wondering about search in **WE/RS**. We now know that it is too ineffective by a factor of ten compared to the closest other game, but more like a factor of 20 when taking the "center group" as a yardstick. Thankfully, since we now can quantify things, we also can do something about them. The easiest change in **WE/RS** is not to let a plane search just two hexes. Instead, use the following:

1. Each plane chooses four center hexes for search.

2. One center hex can be chosen at any distance up to one less than maximum range. The other center hex must be exactly three hexes closer to the base than the first. The plane searches the center hexes and for each center hex the six hexes directly adjacent to it.

3. Repeat paragraph 2, once.

This produces a search area roughly fourteen times the original one, i.e., a *Q* of about 1000 nm^2/plane/hour. It also restrains the player from placing searches in completely arbitrary patterns, which gives too much flexibility. Let's see if they can find each other now...

Appendix: Setting up the games for comparison

First group:

In **Flat Top**, a PBY can move for 6 hexes per turn for at most 20 turns. For simplification, I assumed that each hex moved means that a slice of hexes perpendicular to flight direction is searched (i.e., units discovered "ahead" will be not counted double but are counted when the search path sweeps over them). In clear weather, that slice is 5 hexes wide, in clouds 3 hexes. Search is initially prorated by 2/3 (since planes don't search on roll of 5,6). I assumed an additional 10% reduction for a certain overlap of search zones when using multiple counters (e.g., 3 factors = 9 planes) for searching.

I computed the prorated areas for searching in clouds and assumed a 50-50 clear weather/cloud mixture (this is still pessimistic, so in actually playing **Flat Top**, search will be slightly more effective than indicated by the numbers).

In GDW's **Indian Ocean Adventure**, 2 PBY planes (1 element counter) search 18 hexes per turn, with nothing overlooked in a searched hex. If I read the rules correctly they only search on the outward trip and are simply teleported back at the end of the 6-hour turn. The same system was also used for GDW's **Midway** and **Coral Sea** games.

In **Solomon Sea**, 9 PBY's (one counter) will cover 7 hexes in one turn, 14 hexes in 7h (2 turns), 28 hexes in 14h (4 turns). I examined the two most frequent situations: good if slightly hazy or cloudy weather (a 0.8 chance of sighting what's in a hex since a searching unit misses a TF on a roll of 1-2 on 1d10), and cloudy weather (0.7 chance of finding something that's there). The optional communications delay rule for land-based search represents search reports that were delayed until no longer relevant. It simply adds another factor of 0.8. (No search reports are received by land based planes if a separate die roll result in a 1 or 2).

In **White Ensign/Rising Sun**, 12 PBY's are based at Koggala RNAS, and over the course of an 8-hour turn can search two hexes, yielding a total area of 5262 nm^2 (exactly twice that, 10524, over 16 hours).

Second group:

Carrier Battles has 54nm hexes. In the basic game (4 hour turns), a 3-plane counter searches 6 hexes. In the Advanced game (1 hour turns), a plane unit flies 3 hexes/turn. Two sets of numbers are given because it's the only game where counters can be broken down to single planes to cover even larger

areas, but with higher probability of missing any individual task force in the searched area. I haven't actually seen the latter option used in play and it doesn't seem to fit historical practice.

Carrier Strike: The rules give hex size as varying between 70 and 90 miles depending on where you are on the map (I assumed an average value of 80). A plane unit represents 6 planes. This game has a very unusual system. The map hexes are grouped into non-overlapping 7-hex "megahexes". You search in megahexes and choose a desired search density for the different megahexes (usually higher for megahexes that are further away). This tells you how many planes to use (with closer megahexes requiring additional planes, i.e., they are not searched "on the way out"). As a result there are even more cases than with **SOFT**, below. In addition there is a "something in the megahex" result just as in **SOFT**, too. The extreme *Q* value is 6000 for close in search at 100% density; 75% density has 4500, 50% has 3000, and 25% has 0. Going out farther drops this drastically, 2 megahexes out at 100% is 3000, and 1600 at 3 megahexes out. These figures are again without considering the "something there" case (otherwise chances would all rise by 1/6 again).

My guess is the figures are so high here because (as in the **Smithsonian Guadalcanal** case below) searches ignore flight times and search all of the area every four hours. If one includes readying time, the numbers drop to 50% and become more reasonable, although we still have to live with the fact that search planes travel much too fast.

AH **Midway**: this has 50nm sized square boxes, and the US side has three searches of nine boxes per turn (67500 nm^2/2h). The search scale is not clear; most sources agree that about 24 PBYs were on Midway at the time. About half would be used in a single sweep.

AH **Smithsonian Guadalcanal** (same system as **Smithsonian Midway**): The scale is 70miles/hex, scouts are 3 planes per counter and search each hex they move through, with sightings in a hex being certain. This makes for a slightly narrower swath searched per 3-plane group than **Flat Top**, but the most important factor is that the planes zoom out to 630 miles and back to base in a single turn (which would give them 300 mph cruising speed instead of 100-150). There is an optional rule that spreads patrol plane flights across two turns instead of one, resulting in slightly longer though still very short flight times (still a whopping cruising speed of 200 miles), but also unrealistically increasing the search radius by half (only by half since using either variant the planes still have a separate return stage to fly back to their base in which they do not search). Using *Q* for distinction now breaks down since the game uses a second inaccuracy to balance the first. Without patrol rule, we get 9 hexes searched by a PBY counter in a one-turn flight, and the patrol rule results in 18 hexes searched in a two-turn flight, giving a monstrously high *Q* value of 3197 nm^2/p/h both times. If we use the patrol rule and include the subsequent readying time (which we don't have to do for other games since there the planes always have to fly so long to cover their whole search distance that they can only land late in the afternoon), we end up with $Q = 2131$ nm^2/p/h averaged over 12 hours, which is not bad (but note that due to the blinding speed of the search planes findings can be made earlier and further out than with most other games since the third turn is "rest"). The 12 hour choice is a bit arbitrary though. Consider the game's full four-turn day (where the planes can search for two turns, ready and launch a second time in one day) and this again drives the value up to 2840. Ironically playing with the basic one-turn flight rule results in a more realistic *Q* of about 1600 when measured across the whole day, at the cost of early findings and the most explicitly unrealistic plane operations of all the games here.

Scratch One Flattop: This game has 40 mile hexes. One PBY counter seems to be 3 planes. The system is slightly strange since a PBY can fly 5 hexes per turn for 10 turns, but if it flies the full 5 hexes, it never looks at two of these since searches are limited to hexes adjacent to the final position. How many of the latter are searched is up to the owner (more hexes covered means higher chances of missing something in each hex). Also, there's a search result "something seen" which does not tell in which of the searched hexes something was found. I've taken that as "no sighting" for now since it requires a later search, but obviously that is a restrictive assumption. (All ratings should be increased by 1/6 to approximate the effect of the "something" case.) This search system results in a wide spread of effectiveness depending on the strategy chosen.

Victory at Midway: There are 3 searches per daylight turn representing the 24 PBY's on Midway (this matches the scale of air units in the game which is about 7-9 aircraft per counter). Each search covers seven hexes and sightings are 100% certain. (If we assume only 12 PBY's are searching, the value given in the table is doubled, which would place **VaM** near the top of the list, similar to **Smithsonian Guadalcanal** without the patrol rule.)

(I wonder if anyone really reads through all this, but if I left it out I'm sure someone would complain.)