Aircraft Carrier Defense in the Pacific War:
The Carrier Battles of 1942

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November 8, 2014

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Introduction

In the years before World War II, aircraft carriers were often thought of as "eggshells armed with hammers," ships with a very potent offense, but a very weak defense.[1] Pre-war thinking on carrier warfare tended to focus in three areas: how to maximize the carrier's offensive potential, how to devise strategies that would make the best use of carriers before they were sunk or put out of action, and, lastly, how perhaps to make carriers a bit less vulnerable. The major operators of carriers – the British, the Americans, and the Japanese – all developed their own approaches to these issues. This study focuses on the United States Navy and the Imperial Japanese Navy, and on how they tried to protect their carriers.

Specifically, this study looks at the aerial threats to aircraft carriers in the first year of the Pacific War, and the means used to combat those threats. It examines the material and doctrines of the IJN and the USN, looks at how those doctrines were implemented and with what results, and tries to draw some conclusions about the relative effectiveness of each navy's approach to carrier protection.

Killing Carriers: Ways and Means

Why were aircraft carriers thought to be so vulnerable? They were certainly not without advantages. They were fast enough to keep away from most major warships, and their aircraft gave them an offensive weapon that far out-ranged any gun-ship. Tactically, both the Japanese and the Americans envisioned carriers being employed well distant from the gun-line formed by capital ships.

Carriers' vulnerabilities stemmed directly from their offensive powers. They were inherently floating bombs. They needed to be if they were to field a powerful offense. Aircraft needed bombs, torpedoes and gasoline to be effective, and carriers had to

[1] Said by Hector Bywater, a British naval commentator and novelist, of the heavily armed and lightly armored heavy cruisers engendered by the 1922 Washington Treaty limiting naval armaments, but perhaps even more appropriately applied to aircraft carriers in the inter-war years. Thomas Hone and Trent Hone, *Battle Line: The United States Navy 1919-1939* (Annapolis, Maryland: Naval Institute Press, 2006).

carry large quantities of all of these things; they were, in effect, highly concentrated airfields. Due to the irreducible logic of warship design, IJN and USN carriers were also lightly protected. The carriers needed high speed, great range, and extensive facilities for aircraft. With designers working to the limits of treaties and budgets, armor had to be sacrificed for other qualities that had higher priorities.[2]

The offensive capabilities of carriers made them vulnerable in another more direct way. In the Pacific War, carriers were the worst enemies of carriers.[3] Even the smallest fleet-sized carriers could put 18 dive bombers and 18 torpedo bombers in the air.[4] It seemed that just a few hits from the dive bombers could put a carrier out of action; just a few torpedoes could do even worse. It was logical to think that each carrier committed could sink its enemy counterpart, even before the threat of land-based aircraft was considered.

That leads to a more detailed look at the air threats that aircraft carriers faced. These came in a variety of forms, and each form of air attack posed its own challenges to defensive efforts.

Level Bombing

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[2] The Royal Navy did take a different tack here, designing their carriers with considerably more armor protection than did the Japanese or the Americans. The result was carriers that were hard to sink but that had very limited aircraft capacities.

[3] Carrier aircraft accounted for nine fleet carriers outright (*Lexington*, *Kaga*, *Akagi*, *Soryu*, *Hiryu*, *Hornet*, *Hiyo*, *Zuikaku*, and *Amagi*) and shared one sinking with a submarine (*Yorktown*). Submarines were the second most potent carrier killer in the Pacific War, accounting for *Wasp*, *Shokaku*, *Taiho*, *Shinano*, and *Unryu*.

[4] Most USN fleet carriers started the war with air groups that nominally contained 36 dive bombers and 18 torpedo bombers. Because the USN was transitioning from one type of torpedo bomber to another at the start of the war, its torpedo squadrons tended to be understrength. The smallest IJN fleet carriers carried air groups with 18 dive bombers and 18 torpedo bombers, with some carrier air groups fielding as many as 27 dive bombers and 27 torpedo bombers. In this study, the term “fleet carriers” refers to carriers designed to operate as the main carrier striking force. These ships typically displaced more than 15,000 tons. They were far more capable units that the smaller light and escort carriers that the navies of the time operated. In this study, “tons” refers to long tons of 2,240 pounds.

First off, carriers would face attacks by level bombers. In the main, this threat came from shore-based multi-engine aircraft. The term "level bomber" is a fair description of how these aircraft attacked; they dropped their bombs while in level flight, often in formation and generally from altitudes of 10,000 feet or more. A single aircraft might drop four to six bombs, meaning that a nine plane formation might salvo up to 54 bombs in a bombing run. Not all the bombs would be expected to hit, but just a few hits could wreak havoc. Coming down from high altitude, the bombs would pick up considerable velocity and so have the potential to penetrate armored decks before exploding deep within a target ship. Even bombs exploding high in a carrier's deck structure would have the potential to wreck flight decks and hanger areas, touch off gasoline fires, and cook off the carrier's own stores of bombs and torpedoes.

A key unknown in level bombing was the ability of level bombers bombing from high altitude to actually get bombs onto a ship. The IJN practiced formation bombing extensively, while the US Army Air Force trumpeted the marvels of its precision Norden bombsights.[5] Early Royal Navy experiences with the German Luftwaffe and the Italian Regia Aeronautica were mixed, but suggested that bombing a ship from a lofty height was no easy thing.

The main level bombers attacking aircraft carriers in the first year of the Pacific War were, for the Americans, the B-17 "Flying Fortress," and, for the Japanese, the G3M "Nell" and the G4M "Betty."[6] The American bomber differed greatly from its Japanese counterparts.

The B-17 was a large and sturdy four engine bomber, built to pummel an enemy's industries and installations. But the pre-war United States had a strong isolationist undercurrent, and so the B-17 was positioned with the public as a defender of

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[5] Mark R. Peattie, *Sunburst: The Rise of Japanese Naval Air Power, 1909-1941* (Annapolis, Maryland: Naval Institute Press, 2001), 138-9. Robin Neillands, *The Bomber War* (Woodstock, New York: The Overlook Press, 2001), 23-4

[6] These were not the only level bombers that operated against enemy shipping, but they accounted for most of attacks on carriers by land-based aircraft during the period. In this study, I will use the alpha-numeric designators for both US and Japanese aircraft, rather than their popular names, Allied code names, or year and model designators.

America's coasts from foreign enemies. A number of the planes were flown to the Philippines just before the Japanese attack on Pearl Harbor, where it was hoped that they would deter the Japanese from attacking, or failing that, attack Japanese bases in Formosa. They did neither of those things. They were instead pressed into service as coastal defense aircraft, the precise role that pre-war propaganda had spun for them, but a role in which they accomplished little.

The Japanese paid more attention to level bombing as a means of attacking ships. Their twin-engine G3Ms and G4Ms were operated by the IJN, which meant that they were designed and operated with an emphasis on their anti-shipping role rather than strategic bombing. Proof of concept came early in the war, when level bombing attacks against the Royal Navy's *Prince of Wales* and *Repulse* played an important role in the combined bombing and torpedo attacks that sank the ships.[7] Stressing medium altitude attacks by good-sized formations of aircraft, land-based IJN level bombers quickly emerged as a serious threat to Allied ships. They lacked the B-17's payload, precision bombsight and defensive abilities, but the IJN bombers had good range and many of their crews had good anti-ship training, making them more of a threat than the US Army bombers that occasionally threatened Japanese ships.

Some carrier-based aircraft could also level bomb. The Japanese B5N "Kate" could serve in a level bombing role in addition to serving both as a torpedo bomber and as the primary carrier-based search aircraft. It generally attacked as a level bomber when its targets could not be reached with torpedo attacks, most famously when Kates bombed the inner row of USN battleships during the Pearl Harbor attack. The USN equivalents – the TBD "Devastator" and its successor the TBF "Avenger" – could also carry bombs for level bombing attacks in lieu of torpedoes. But as with the Kate, torpedoes were usually their preferred attack weapon.

Dive Bombing

[7] Arthur J. Marder, *Old Friends, New Enemies: The Royal Navy and the Imperial Japanese Navy: Strategic Illusions 1936-1941* (Oxford: Clarendon Press, 1981), 467-74.

While the threat posed by level bombers was open to debate, there was little doubt about the efficacy of dive bombing.[8] Developed first as a technique for the close support of ground forces, then as an anti-ship technique, the pre-war assessment of dive bombing was that it would be a very potent ship-killer. The idea was a simple one. The dive bomber would typically approach its target at an altitude of 10,000 feet or higher, using the sun and any available cloud cover to mask its approach. Once over the target, the dive bomber would nose down at anywhere from an angle of 60 degrees to nearly vertical, opening dive brakes to slow and stabilize its descent. In essence, the dive bomber became its own bombsight, with the pilot using the aircraft to aim its bomb as it dove in at 200 to 300 knots. The bomb would be released at about 1,000 to 2,000 feet of altitude and the bomber would pull out low over the water.

Pre-war exercises showed that dive bombing attacks were likely to be highly accurate and hard to counter. Early war experience confirmed this. Both the Japanese and the Americans bought into dive bombing well before the start of the Pacific War, with the Americans pioneering the concept and the Japanese entering the field by building a licensed version of a German biplane dive bomber. But the two navies thought differently about the tactical uses of dive bombers.

The principal IJN dive bomber at the start of the Pacific War was the D3A "Val." It was an elliptical-winged monoplane with fixed, spatted landing gear. It was reasonably fast and quite long-ranged, and was armed with two 7.7 mm machine guns firing forward through its propeller arc and a third flexible 7.7 mm machine gun bearing to the rear. Being a dive bomber, the D3A's airframe was robust. But it was devoid of any armor or protection for its gas tanks.

The main point about the D3A, however, was its payload. In combat, it carried no more than 250 kilograms (about 551 pounds), generally in the form of single bomb carried under its fuselage. A 551 pound payload was not insignificant, and proved quite capable of sinking ships as large as a heavy cruiser. However, it was a bit light to

[8] Friedman, *Naval Anti-Aircraft Guns and Gunnery* (Annapolis, Maryland: Naval Institute Press, 2013), 30-5.

deal with a fleet carrier, and in fact D3As never managed to sink or cripple a fleet carrier unaided. The IJN armed its dive bombers with a mix of high explosive and semi-armor piercing bombs. The HE bombs were meant to explode on contact, hopefully destroying or suppressing the ship's antiaircraft fire by blast and fragments. The SAP bombs were meant to penetrate a bit deeper before detonating, although their relatively low velocity (due to their having been released at a relatively low altitude) meant that they were unlikely to penetrate more than the lightest armor.

The USN viewed the dive bomber as much more of a potential ship-killer. Its main dive bomber at the start of the war was the famous SBD "Dauntless." The SBD differed from the D3A in a number of ways, but two stand out. First and foremost, the SBD could carry almost more than double the load of the D3A – a 1,600 bomb in overload condition and a 1,000 pound bomb for a normal strike. Even SBDs assigned to search missions each usually carried 500 pound bombs to attack targets of opportunity. This reflects a difference in emphasis in the USN, where dive bombers were regarded not just as a way to soften carriers up for other attackers, but as carrier wreckers all on their own.[9] When attacking carriers, the SBDs carried high explosive bombs that were fused to penetrate flight decks and explode in the vulnerable hanger spaces underneath.

There was a less apparent difference between the SBD and the D3A. The SBD was a far more rugged aircraft than the D3A. Empty, but fully stressed for the rigors of dive bombing, the D3A1 weighed in at 5,309 pounds. The same figure for the SBD-3, the most common model of the SBD during the first year of the war, was 6,345 pounds.[10] Both aircraft had engines rated for 1,000 horsepower at take-off; the higher weight for the SBD reflected a deliberate decision to build in toughness at the price of some

[9] Thomas C. Hone, Norman Friedman, and Mark D. Mandeles, *American and British Aircraft Carrier Development 1919-1941* (Annapolis, Maryland: Naval Institute Press, 1999), 63.

[10] The D3A1 was the standard model of D3A in use at the start of the Pacific War. By late 1942 it had been largely replaced with the D3A2, an up-engined model with the same payload and lack of protection. The SBD-3 model was the standard USN carrier dive bomber throughout 1942, although some earlier SBD-2s fought through the first half of the year. Sources vary as to the armor and fuel tank protection of SBD-2s, but it is likely that some of these aircraft at least had armor and self-sealing fuel tanks retrofitted.

performance. This toughness took the form of armor and self-sealing fuel tanks. The latter were a relatively new technology, taking the form of a rubber bladder inside a metal tank. The idea was that the bladder would seal itself behind any bullet penetrating the metal tank, thus preventing a fuel leak and potential fire. Armor was heavy and self-sealing tanks cut down on the maximum potential fuel load that an aircraft could carry. The USN was willing to accept the range and performance penalties that went along with these features in order to get a more rugged aircraft. The IJN preferred performance and range to protection, and apparently even to maximum bomb load.[11]

SBDs were also more heavily armed than their IJN equivalents. SBD-3s sported a brace of .50 caliber machine guns firing forward through the nose. Dash 3s from the factory had a single flexible .30 caliber machine gun facing to the rear, but this was generally modified to a twin gun mount in the field.

Torpedo Bombing

From their inception, torpedoes were seen as the slingshots that small craft Davids could use to slay battleship Goliaths. Once aircraft were powerful enough to carry a torpedo aloft, it was a logical step to send them against large ship targets. The first torpedo bomber attacks took place in World War I, and torpedo bombers were recognized early on as a potent way to project air power against ships.

The IJN developed an excellent torpedo bomber in the B5N "Kate." The B5N2 model which equipped the IJN's fleet carriers in the first year of the war was fast and long-legged. It also had a maximum ceiling that allowed it to travel in close company with D3As, easing the problems of coordinating attacks between the two types of aircraft. Its gun armament was limited to a single flexible 7.7 mm machine gun firing to the rear. Like the D3A, the B5N completely lacked armor or fuel tank protection.

[11] Rene J. Francillon, *Japanese Aircraft of the Pacific War* (Annapolis, Maryland: Naval Institute Press, 1979), 275-6. Barrett Tillman, *The Dauntless Dive Bomber of World War II* (Annapolis, Maryland: Naval Institute Press, 1976), 8-9, 217.

The B5N was paired with an excellent torpedo weapon – the Type 91 aerial torpedo. This weapon permitted the B5Ns to make effective torpedo drops at airspeeds of up to 260 knots and altitudes of 1000 feet.[12] These were far faster and higher drops than the USN aerial torpedo could handle. Once in the water, Type 91s ran at between 41 and 43 knots.[13]

The USN equivalent of the B5N at the start of the Pacific War was the TBD "Devastator." The TBD began fleet service in the fall of 1937 as the first monoplane to be operated from USN carriers. It was slightly ahead of the B5N in entering fleet service, but far behind it in performance. The TBD was slower than the B5N, with a much shorter range and a much lower ceiling. While, as with the SBD, the TBD significantly outweighed its IJN counterpart, it lacked the self-sealing fuel tanks and armor that contributed to the SBD's ruggedness. Nor did it have the SBD's gun armament, with a single .30 caliber machine gun firing though the propeller and another in a flexible mount firing to the rear. And its 900 horsepower engine strained to lift it with a full load, in contrast to the 1,000 power plant of the B5N2. Numbers tell the tale: the B5N2's horsepower to weight ratio was 1.35 times better than the TBD-1 at full load.

Worse, the TBD's torpedo armament was a disaster. The Mk 13 Mod 1 in use at the start of the Pacific War had failure rates of up to 90% and required drop parameters of 50 feet or less and 110 knots or slower.[14] This condemned the already vulnerable TBD to making its attack approach low and slow. Further, the torpedo's relatively low speed (30.5 to 33.5 knots) meant that the TBDs had to hold out for extremely favorable target angles to have any chance of a hit. The faster Japanese fleet carriers could literally outrun the torpedo if it was launched astern of them.

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[12] Parshall and Tully, 574n36. Altitudes of 330 feet or less and speeds of 162 knots or less were preferred. Peattie, 144-5.

[13] John Campbell, *Naval Weapons of World War II* (Annapolis, Maryland: Naval Institute Press, 1985), 209.

[14] *Ibid.* Barrett Tillman, *TBD Devastator Units of the US Navy* (Oxford: Osprey Publishing, 2000), 45. The deficiencies of the Mark 13 aerial torpedo may well have stemmed from USN thinking in the early 1930s that torpedo bombers were irremediably vulnerable and that the dive bombers was the wave of the future. Norman Friedman, *U.S. Aircraft Carriers, an Illustrated Design History* (Annapolis, Maryland: Naval Institute Press, 1983), 75.

June of 1942 saw the first combat for TBD's successor, the TBF "Avenger," although the TBF did not see carrier combat use until later in the year. The TBF was a different proposition entirely from the TBD: a big, fast, rugged airplane with a .50 caliber machine gun in a powered turret, a flexible .30 caliber machine gun firing below and behind the aircraft, and a fixed .30 caliber gun firing forward. It was still burdened by a poorly performing torpedo, but it weighed as much empty as a TBD at full load, and was faster than the B5N2.[15] Hampered by its bad torpedoes, the TBF was often pressed into an anti-shipping role as a level bomber or glide bomber, with a usual armament of four 500 pound bombs.

Glide Bombing

This brings us to the final method of aerial attack that USN and IJN carriers faced in 1942: glide bombing. This was mild form of dive bombing, typically undertaken by aircraft not equipped or aircrews not trained for bomb delivery from near vertical dives. Level bombers such as the G3M and the TBF could make glide bombing attacks, while dive bombers might resort to the same form of attack if their crews were inexperienced or low cloud ceilings precluded dive bombing.

Glide bombers attacked in shallow dives, generally from lower altitudes than would be the case for level bombing. As one would expect, glide bombing lacked the pinpoint accuracy of dive bombing, but was more likely to hit the target than level bombing. Relatively low altitude bomb releases meant that level bombing was potentially much more effective at punching bombs through armor than was glide bombing, if hits could be gotten. Glide bombing was the poor relation of true dive bombing or tightly controlled level bombing, but it did see use in the period under study here.

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[15] Gordon Swanborough and Peter M. Bowers, *United States Navy Aircraft since 1911* (London: Putman Aeronautical Books, 1990), 233. The USN ultimately developed the Mark 13 aerial torpedo into a potent and reliable weapon, but it is not clear whether any improved models found their way to the fighting squadrons in 1942. The absence of the improved model may explain why the TBF was at times used as a level or glide bomber when it could have been armed with torpedoes.

Protecting Carriers

Having reviewed the means of killing carriers, let us turn to the ways of protecting them. I have identified six ways in which the IJN and the USN tried to protect their aircraft carriers from aerial attack. Both navies used means such as armor and damage control systems to limit the damage that aerial attacks could cause. Both navies equipped their carriers (and supporting ships) with antiaircraft guns. Both navies considered whether keeping carriers separated from each other would increase the chances of some surviving even if others were taken out of action, or whether groups of multiple carriers operating together were better. Both navies used individual ship maneuvers to try to throw off an attacker's aim or to force an attacker to attack from a disadvantageous position. Both navies tried to use the fighters in the carrier air groups to intercept strike aircraft, in a practice known generally as "combat air patrol." Finally, the IJN extended its generally policy of trying to out-range its opponents' weapons to carrier aircraft. I consider these different efforts in reverse order below.

Out-ranging

Out-ranging is perhaps the most subtle of the protections available to aircraft carriers. It sounds simple in theory: just have carrier aircraft with longer ranges that your opponents' so that you can strike them when they cannot strike you. In practice, out-ranging was far harder to apply. Limits on search effectiveness, strike navigation and strike preparation all meant that it was hard to detect the enemy, launch a strike, and hit them while beyond their range.

The idea of out-ranging was a logical extension of the IJN's surface warfare tactics. Faced with the fact that any war against the USN would be fought against a far more numerous opponent, the IJN hit on the idea of concentrating as much long range firepower as possible in its ships. This, it hoped, would overcome its numerical inferiority in an IJN-USN showdown.[16]

[16] Peattie, 74-5. David C. Evans and Mark R. Peattie, *Kaigun: Strategy, Tactics, and Technology in the Imperial Japanese Navy 1887-1941* (Annapolis, Maryland: Naval Institute Press, 1997), 238-98, and especially 282-3.

The IJN realized that a considerable margin in range – its estimate in 1934 was 150 miles – was needed to conclusively out-range enemy carriers.[17] The hampering factors mentioned above – the need to search and find the enemy, the difficulties of a strike navigating a long distance to find the enemy, particularly if it lacked updated contact information, and the operational cycle times needed to ready and launch strikes – all conspired to prevent this sort of straightforward out-ranging except in the relatively limited cases of land-based attack aircraft and of carrier aircraft shuttling from carriers to bases located closer to the enemy.

While only a single land-based attack during 1942 saw this pure form of out-ranging applied in practice, striving for longer strike ranges than the enemy had more subtle advantages. Technology in 1942 was not such that strikes could always fly directly to their targets. Search reports were often mistaken as to the positions of enemy forces. Even if the reported positions were accurate, they might be hours out of date before the strike force arrived at the last known position of the enemy. And the strike forces themselves were subject to navigational errors. All of these issues grew in significance as the distance to the enemy increased.

Thus, it was entirely possible for a strike to miss its target. It happened to the USN at the Battle of Midway and to the IJN at the Battle of the Eastern Solomons, in conditions that certainly did not preclude a strike from finding the target task force.[18] Air staff took the possibility into account when calculating effective ranges; a strike flying to maximum range might carry a lighter payload or even be delayed in launching while the strike's carriers tried to close the range. This was particularly true for the USN; SBDs could fly further with 500 pound bombs than with 1,000 pounders, and TBDs lugging torpedoes had ranges much shorter than those of the SBDs.

This meant that there was an advantage to having longer ranged aircraft even when operating within the maximum range of the enemy. Longer ranges meant greater

[17] In this study, "miles" refers to nautical miles.

[18] It also happened to the IJN in the preliminary stages of the Coral Sea battle, but in conditions that made it unlikely that any but the most precisely directed strike could have found its target.

endurance, and this translated to more opportunities to find targets and more time to coordinate strikes on targets once found. The advantage was a subtle one, and the ability to capitalize on it was by no means guaranteed, but it was potentially an undeniable advantage nonetheless.

Concentration and Separation

Should fleet carriers be concentrated together in one task force or employed singly in separate task forces? The question could not be answered without taking a view on the uses and vulnerabilities of aircraft carriers.

From the perspective of offense, it was clear that concentrating carriers would enhance striking power. Operating carriers in close proximity would allow aircraft from two or more carriers to be combined into a single powerful strike, potentially capable of overwhelming defenses and so more potent than a series of uncoordinated strikes delivered by single carrier air groups.

Defensively, operating carriers together would in theory permit them to pool CAP fighters and perhaps antiaircraft guns for common defense. But that would only be worthwhile if the defensive assets were effective.

Some numbers demonstrate this issue. Assume that one IJN carrier faces two USN carriers operating together. Each USN carrier can launch a two-wave strike, each wave of which has a 75% chance of sinking the IJN carrier. The IJN carrier can also launch a two wave strike, but assume that due to more effective combined Allied defenses, each wave has only a 60% chance of sinking a carrier. On average, the IJN comes out ahead in the exchange. The USN carriers have a better than 99% chance of sinking the IJN carrier, but the IJN carrier has a 48% chance of killing one USN carrier and a 36% chance of killing two. Playing the odds, the USN would have been further ahead if it had sent only one carrier against its IJN opponent, as that would have limited USN potential losses to the single ship risked.

In the example above, the chance of an IJN strike wave sinking a USN carrier would have to drop below 50% before it would make statistical sense for the USN to commit more than one carrier to the battle. And that underscores the point of the exercise – the pre-war tacticians lacked the ability to know with certainty just how grouping carriers together would make either their offenses or defenses more potent.[19]

The IJN ultimately opted for multi-carrier formations, which gave it the ability to launch coordinated multi-carrier strikes.[20] In each of the four battles that this study examines – Coral Sea, Midway, Eastern Solomons, and Santa Cruz – most or all of the IJN fleet carriers were grouped together in this way. That said, the exigencies of air operations, which often required aircraft carriers to maneuver away from their formation base course to launch or land planes, and tactical maneuvering often spread these formations out to the point that an approaching strike would be unable to see all of the carriers in the formation.

The USN apparently came at the problem from the other direction, favoring separation of carriers but occasionally operating them together regardless. Thus, two carriers operated together at Coral Sea and two operated together with one operating separately at Midway. At Eastern Solomons and Santa Cruz, the two carriers engaged operated in separate task forces, but within such close proximity of each other that any concept of separation was largely compromised. What was clear was that operating carriers together in 1942 generally did not allow the USN to assemble concentrated multi-carrier air strikes. It was not a concept that the USN had developed pre-war. To the extent that USN carriers operated together, the only real tactical effect of concentration was some concentration of defensive resources.

Maneuver

[19] Of course, this is before the consideration of whether an attack against multiple carriers could be spread efficiently among them, or whether a single carrier formation was less likely to be spotted than several carriers each in a separate task force. These just add to the hard-to-ponder variables inherent in the issue.

[20] Peattie, 147-9.

Unlike other bombing targets, ships move. And by moving, they could generate a potent defense against bombers. There were both advantages and disadvantages to violent maneuver as a means of defense.

The clear benefit of maneuver was making enemy bombers miss. Maneuver was very effective against level bombers, which were generally attacking by flying to a pre-determined bomb release point that had been set based on the target's estimated course and speed. Giving level bombers a maneuvering target made calculation of the release point much harder, reducing level bombing to a shotgun affair in which the bombers could only hope to catch their target in a large pattern of bombs.

Compounding level bombers' problems was the fact that their bombs took a considerable time to fall. A bomb dropped from 20,000 feet might take almost half a minute to reach sea level – enough time for the target ship to make a meaningful course change between the time of the drop and the time of arrival.[21] Faced with level bombers, carriers waited until the bombs left the planes, then changed course.

Maneuvering against bombs only worked when the targets saw the bombers. It proved to be relatively easy to spot level bombers, which tended to be large planes operating in tight formations, but much harder to see dive bombers. Dive bombers tended to be smaller and to attack in less compact formations. The relative flexibility of their method of attack meant that they could more easily use sun or clouds to mask their approach. Once in the attack, dive bombers could more easily follow a target's twists and turns. And, of course, the target had much less time to maneuver between bomb drop and arrival.

Nonetheless, carriers could maneuver against dive bombing attacks. Hard turns could through off at least the first few bombers, at least until the target carrier steadied into a constant radius turn. Turning into a dive bombing attack could force the bombers to steepen their dive and potentially botch their attack. Turning away would cause the bombers to dive more shallowly, giving anti-aircraft guns more time to engage them.

[21] Most bombs in World War II had terminal velocities of less than 1,000 feet per second. I leave it to the reader to calculate how quickly a bomb could attain its terminal velocity.

Maneuvering to force attacks into a cross-wind was an effective way to reduce dive bombers accuracy. Maneuvering to force the bombers to attack from a target ship's beam rather that from ahead or astern also decreased the likelihood of a hit. But, to return to the point of the previous paragraph, all this required the target carrier to spot the attacking dive bombers in enough time to react.

Maneuver could also be effective against torpedo bombers. Recognizing this, a standard torpedo bomber tactic had the attacking torpedo bombers split into two groups. Both groups would try to attack from ahead of the target, with each group on one side of the target's bow. The effect of such an "anvil" attack was that turning away from one prong of the attack exposed the target to the other prong.

When torpedo bombers were spotted at a distance, the standard tactic was to show them the stern and run away. This complicated efforts to set up an anvil attack and gave anti-aircraft guns and CAP fighters a longer time to engage the bombers. Once torpedoes were in the water, the target carrier tried to weave its way among the torpedo wakes without being hit.

The major disadvantage of maneuver was its effect on anti-aircraft gunnery. Larger anti-aircraft guns in particular lost accuracy when their platform was maneuvering radically, and even smaller guns were affected to a degree. Anti-aircraft formations, designed to allow other ships to combine their anti-aircraft fire with the carrier under attack, could come apart under the stress of a carrier's evasive maneuvers. The USN relied more on anti-aircraft fire than did the IJN, thus making this more of an issue for its carriers. From the outset, the IJN used loose ship formations and encouraged their carriers to maneuver to the maximum. The USN tried to give carriers the freedom to maneuver, but not at the expense of disrupting the anti-aircraft support being given by other ships in close formation.

Armor and Damage Control

One obvious way to protect aircraft carriers was to limit the damage that hits could cause. The Royal Navy took this furthest, but only by accepting small air groups and

relatively slow aircraft operating tempos. Both the IJN and the USN wanted larger air groups and quicker operating cycles, which meant that they had to accept limits on the amount of protection that they could provide.

Protection for carriers came in three basic forms. Perhaps most obviously, aircraft carriers could be designed with armor that would stop at least some bombs, shells, and blasts from penetrating to their vitals. Defense against torpedoes took the form of bulges built into a carrier's sides. Torpedoes would detonate on the outer wall of the bulge, but space between the outer wall and the inner hull would prevent or lessen flooding from the explosion. Finally, damage control systems and procedures could minimize and repair damage from hits that were not stopped by armor and bulges. For example, USN carriers could flood their aviation gas supply lines with carbon dioxide, thus reducing the risks of gas fired from fractured piping. Other examples of damage control measures included extensive pumps and main lines for fire-fighting and pumps and water-tight subdivision to limit flooding.

Both the USN and the IJN used armor to protect their fleet carriers. Their fleet carriers typically carried deck armor, which protected against bombs or shells plunging down vertically, and belt armor, which was primarily effective against shells arriving horizontally. The term "deck armor" requires some explanation. In both USN and IJN carrier designs, carriers equipped with deck armor carried that armor below the level of the carrier flight deck and hangers. The armor was meant to protect the ship's propulsion spaces and her magazines. It provided no protection for her flight deck or hanger spaces. Positioning the deck armor in this way sacrificed the flight deck and hangers to bomb damage, but protected the carrier's ability to steam and survive.

Almost all USN and IJN carriers carried some deck armor, the only exceptions being *Junyo* and *Hiyo*, which the IJN converted from merchant liners while the hulls were under construction. The *Shokaku* and *Zuikaku* carried the most armor: 6.7 inches in multiple decks. In contrast, the *Hiryu* and *Soryu* carried only an inch of armor over their engineering spaces and 2.2 inches over their magazines. Deck armor on USN

carriers varied from 2 inches for the *Lexington* and *Saratoga* to 1.25 inches for the *Wasp*.[22]

Even relatively light deck armor could be effective against bombs dropped from dive bombers. These bombs hit at relatively low velocities, and so had relatively little kinetic penetrating power. The explosive force of bombs detonating on armor plate tended to be directed up and away from the armored deck. In recognition of this, dive bombers often carried high explosive bombs that were designed to maximize blast effects in unarmored areas of a ship rather than to penetrate armor.

As stated above, during this period IJN dive bombers carried either high explosive bombs that were fused to explode on impact, or "semi armor piercing" bombs with delay fuses. The two types had distinctly different purposes. The HE bombs were meant to sweep exposed carrier decks with blast and fragments, wreaking havoc with AA guns and command areas. The SAP bombs carried less explosive but had a thicker casing, hopefully enabling them to penetrate deck armor and detonate in the target's vitals. Ideally, the first D3As to attack would be armed with HE bombs. The SAP armed bombers would then follow up the initial attacks.

Judging from the damage caused, USN dive bombers carriers high explosive bombs fused to explode after a slight delay. Early on, they also carried smaller bombs for AA suppression, but these had little effect. Delayed action HE bombs were meant crash into a carrier's hanger deck before detonating, rather than detonating on the flight deck. At least in 1942, USN dive bombers apparently did not carry armor piercing bombs against carrier targets. Certainly, none of their bombs penetrated a carrier's deck armor.

Bombs dropped from higher altitude could penetrate a considerable amount of armor – particularly if they were heavy bombs specifically designed for the task – but carrier designers generally elected not to try to armor their ships against such bombs.

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[22] Peattie, 230-43. Friedman, *U.S. Aircraft Carriers*, 109, 390-3. Another source gives the *Shokaku* class deck armor as 3.9 inches over machinery and 5.1 inches over magazines. Roger Chesneau, ed., *Conway's All the Worlds Fighting Ships 1922-1946* (Annapolis, Maryland: Naval Institute Press, 1980), 181.

Battleship designers did, and this is reflected in the fact that battleships designed in the immediate pre-war period typically had more than 7 inches of deck armor, often in more than one deck.

Both navies tried to give their fleet carriers bulge protection against torpedoes as well. The *Akagi*, *Kaga* and the *Lexington* class all had bulges as a legacy of their origins as battlecruisers, or, in the case of *Kaga*, as a battleship hull. The *Shokaku* and *Yorktown* classes had bulges by design. The *Wasp* was too small to have that protection, and I have been unable to determine the degree to which the *Hiryu* and *Soryu* carried anti-torpedo protection.

It is in the area of damage control systems that the USN and IJN most diverged. The IJN certainly did not ignore the issue, but the USN studied damage control more deeply and provided damage control systems far more lavishly.[23] USN damage control was not perfect and IJN damage control was not completely lacking, but USN damage control practices and equipment could deal with damage that would overwhelm an IJN carrier. A USN carrier had advantages of more trained damage control parties better distributed throughout the ship able to use more redundant systems and better equipment to combat battle damage as it occurred.

Anti-aircraft Guns

Now we come to the first means of defense meant to do harm to the attacker. Anti-aircraft gunnery got its start in the First World War, but was far from perfected by the Second. In 1942, anti-aircraft guns were of two basic types: larger guns that fired a time-fused shell and had to be manually reloaded after each shot and smaller rapid-fire guns that fired either a solid projectile or an impact-fused shell, typically from a belt, clip, or magazine. The larger guns tried to bring down aircraft by bursting shells close enough to them to let the shell fragments knock them down. The smaller guns depended on getting direct hits on the opposing aircraft, and so tried to put many projectiles in the air as quickly as possible. Larger guns might open fire in earnest at

[23] Parshall and Tully, 276-8.

12,000 yards range while smaller guns had effective ranges of from 1,000 to 3,000 yards.[24]

Anti-aircraft fire posed difficult problems in fire control. Compared to ship targets, aircraft were smaller, faster, at varying elevations, and capable of movement up and down as well as from side to side and towards and away from the firer. It took time for the big guns to get on target, and time was very much of the essence when aircraft attacked. Time fuses had to be set based on a host of factors, including the time it took load and fire the shell after the fuse setting had been communicated to the gun. Aircraft maneuvers could easily upset a fire control solution even if it could be established in the first place. All of these difficulties sometimes caused the big guns to engage in "barrage" firing – a technique that abandoned trying to predict the precise course of attacking aircraft in favor of putting up a wall of shells through which the attackers (hopefully) would have to fly.

Despite these complications, both the IJN and the USN worked hard to develop effective large anti-aircraft guns paired with sophisticated fire control systems. The principal large IJN anti-aircraft gun of the era was a 5 inch 40 caliber weapon that gave good service. The USN used a 5 inch 25 caliber gun optimized for anti-aircraft work and a superb 5 inch 38 caliber piece that was designed for use against surface or aerial targets. The USN's 5"/38 gun equipped ships from battleships down to destroyers, with even the destroyers being given gun directors fully capable of controlling anti-aircraft fire. In 1942, the IJN's 5"/40 weapon was found on ships of cruiser size or larger. IJN destroyers carried different 5 inch 50 caliber guns that, while theoretically capable of engaging aerial targets, were much hampered by their fire control and gun loading arrangements.[25] The best IJN and USN optical gun directors were roughly equivalent, although the USN emerged with a distinct advantage as its directors received fire control radars. These radars were being installed throughout 1942.[26]

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[24] Friedman, *Naval Anti-Aircraft*, 232.

[25] Friedman, *Naval Anti-Aircraft*, 146-7.

[26] Friedman, *Naval Anti-Aircraft*, 145, 252-3.

When they worked (and they became more reliable over time), they greatly aided in range measurement and fire control solutions.

Both navies recognized that large anti-aircraft guns were best used against large formations of aircraft flying on relatively straight and level courses over a significant period of time. This of course describes level bombers attacking. Pre-war, the USN was certainly aware of the limitations that the big guns would have in engaging dive bombers.[27] Given its approach to anti-aircraft armament, the IJN seems to have reached the same conclusions. Dive bombers were much harder to spot and much less likely to fly on a steady course and at the same altitude, even before diving to attack. Automatic machine gun and cannon fire seemed to be the best way to deal with these attackers.[28]

These lighter weapons varied in size from .30 caliber machine guns up through 40 mm autocannon. The USN began development of a 1.1 inch autocannon in the pre-war period, but looked to .50 caliber machine guns as a stop-gap measure until the autocannon were available. When the Pacific War began, many ships still mounted these .50 cal. guns. As the 1.1 inch guns were only available in large quadruple mountings and were not as reliable as hoped, the USN also began to mount 20 mm autocannon in many ships. These were licensed versions of the famous Swiss Oerlikon gun. They were relatively light, could be mounted in various nooks and crannies without no need for power hook-ups, and proved accurate, reliable, and easy to operate in action. The USN had begun to install them in numbers in 1941, and accelerated the process when the Pacific War started.

As the war went on, the USN became convinced that it needed a better heavy autocannon than the 1.1 inch gun. It found its answer in a water-cooled and power-mounted version of the 40 mm Swedish Bofors gun. That gun made its appearance in

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[27] Friedman, *Naval Anti-Aircraft*, 130.

[28] I view torpedo bombers as being an intermediate case between level bombers and dive bombers. They were not as constrained as level bombers in attacking in formation and flying on straight and level courses, but they were easier to spot and engage than dive bombers. They were also vulnerable to machine gun and autocannon fire, as their idea torpedo drop range was within 1,000 yards of their target.

the Pacific carrier battles at the end of 1942. The USN developed effective directors for both the 1.1 inch and the 40 mm guns, ultimately permitting them to engage aircraft not attacking the ship in which they were mounted. This concept of ships using their light anti-aircraft batteries to support other ships was a key one in USN thinking.[29]

The IJN roughly paralleled the USN in these developments. Its principal light anti-aircraft weapons in the Pacific War were a 13.2 mm machine gun and a 25 mm autocannon. The 25 mm gun was the most widely used, often appearing in twin and triple gun mounts. At least some of the 25 mm guns were director-controlled, although the IJN directors were less effective than the directors used by the USN.[30]

Below are some comparisons of IJN and USN anti-aircraft weapons.[31]

Weapon	Ceiling	Rounds per Second	Weight of Projectile	Pounds per Second
.50 caliber M2 machine gun	15,000 ft.	10	0.1 lb.	1
20 mm Oerlikon	10,000 ft.	7.5	0.2741 lb.	2
1.1 inch Mark 1/1	19,000 ft.	2.5	0.917 lb.	2.3
40 mm Bofors	22,800 ft.	2.5	1.985 lb.	5
13.2 mm Type 93	13,060 ft.	7.5	0.1143 lb.	0.9
25mm Type 96	18,040 ft.	3.5	0.5513 lb.	2

Some of these numbers seem a bit fanciful, but the general trends should be right. I doubt that the Oerlikon had a lower ceiling than the .50 caliber and 13.2 mm machine guns. I suspect that the ceiling for the .50 caliber machine gun may be exaggerated. Rounds per second is the rate of firing for a short burst from the gun. None of the guns could sustain these rates of fire over long periods. Water-cooled guns such as the

[29] Friedman, *Naval Anti-Aircraft*, 121.

[30] Friedman, *Naval Anti-Aircraft*, 148-9.

[31] Campbell, 75, 147-54, 200-2.

.50 caliber machine gun and the 40 mm Bofors could come closer to their theoretical maximums that the other guns, which were air-cooled. The need to replenish the guns' ammunition supplies also slowed the rate of fire. The 25 mm Type 96 was probably the worst in this regard due to its 15 round magazine. The Bofors was the best, as it permitted additional clips of ammunition to be dropped into its feed mechanism while it was firing. Overall, the numbers for the 20 mm and 40 mm guns show why they were outstanding AA weapons, with the Oerlikon matching the weight of fire from the IJN's 25 mm weapon and the Bofors more than doubling it.

In terms of numbers of guns, IJN carriers tended to mount more heavy guns and fewer light guns than their USN counterparts. For example, the *Hiryu* at the time of her loss in 1942 mounted 12 5"/40 guns in six twin mounts and 33 28 mm guns.[32] The larger *Yorktown* at the same time mounted 8 5"/38 guns in single mounts, 16 1.1 inch guns in quad mounts, and 24 20 mm guns.[33] While the USN 5" single mounts would have been more efficient than the IJN 5" twins, *Hiryu* still had an edge in heavy anti-aircraft gun firepower.[34] Conversely, *Yorktown* held the edge in light anti-aircraft firepower, being able to putting 85 pounds of metal in the air each second as opposed to 66 pounds for the *Hiryu*.

Looking at the numbers in a different way, *Hiryu* devoted about 187 tons to anti-aircraft guns while *Yorktown* devoted about 156 tons.[35] But the ratio of weight devoted to heavy guns versus light guns was about 3.1 to 1 for *Yorktown* and 8.9 to 1 for *Hiryu*. With fewer heavy guns, *Enterprise* invested less weight in anti-aircraft guns overall, but almost twice as much weight as *Hiryu* did in light guns. I do not think that this is mere coincidence. Rather, it reflects the IJN concentrating on guns that could engage level

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[32] Parshall and Tully, 471.

[33] Friedman, *U.S. Aircraft Carriers*, 97. Data on light anti-aircraft outfits can be contradictory. The outfits given here were those planned by the USN and IJN, and reflect their thinking about the threats to be countered. The *Yorktown's* light anti-aircraft was upgraded after the start of the war, but the plans for the upgrade had been approved four months before the war began.

[34] The edge went to *Yorktown* when fire control is considered, but this exercise is focusing on the guns.

[35] This includes the weight of guns and mountings, but not of off-mount directors, ammunition hoists, etc.

and torpedo bombers at long range, while the USN was concentrating on close range firepower to combat dive bombers and torpedo bombers nearing their drop points.

This was perhaps a case of each navy concentrating on protecting against the threats that they were most able to project against an enemy. The IJN emphasized torpedo bombing and level bombing in mass formations, and built up their anti-aircraft defenses to counter those threats. The USN focused on building potent dive bombers, almost to the point of abandoning torpedo bombing, and equipped their ships to counter that threat.

One last point should be made about anti-aircraft fire before leaving the subject. I doubt that either the IJN or the USN expected that anti-aircraft fire would sweep the skies of enemy aircraft. Pre-war exercises and the war-time experiences of other navies suggested just the opposite.[36] Despite this, anti-aircraft fire could still play two important roles. First, it could blunt an attack through its morale effects. Shells bursting up close and tracers from automatic fire whizzing by could distract pilots, causing hasty attacks and making precise aiming more difficult. Second, even if anti-aircraft fire could not prevent an aircraft from attacking, it might damage the plane so severely that it would be unable to fly again. That would not save the target of the plane's attack, but it could save the next ship that the plane would have attacked if it could have flown.

Combat Air Patrols

Both the IJN and the USN saw combat air patrols by fighter aircraft as an important part of carrier defense. Both navies made fighter aircraft a significant part of their carrier air groups; for both navies, one-quarter or more of all aircraft in each carrier's

[36] This was particularly true of the USN. Friedman, *Naval Anti-Aircraft*, 140-1. There is some evidence that the IJN somewhat over-estimated the effectiveness of naval anti-aircraft fire. Its naval war game rules provided for losses from six to 15 torpedo bombers shot down before attacking and the same number range of losses after attacking. The number range for level bombers was two to 10. Arthur J. Marder, *Old Friends, New Enemies: The Royal Navy and the Imperial Japanese Navy, Strategic Illusions 1936-1941* (Oxford: Oxford University Press, 1981), 516.

air group were fighters.[37] Both navies developed potent ship-board fighters. Both emphasized the role of fighters as escorts for their strike aircraft, which certainly suggested that they believed that strikes could be effectively intercepted. However, the USN held two definite advantages over the IJN; it had radar and it had insights into the Royal Navy's experiences with radar-guided interceptions.

For the USN, the aircraft that performed most combat air patrol duties was the F4F "Wildcat." While the SBD was used on occasion as a low-altitude CAP versus IJN torpedo planes, the F4F shouldered the brunt of combat air patrol duties. The USN used three different models of F4F in 1942. Until June, the USN carriers in the Pacific operated the F4F-3 and F4F-3A. The main variant was the F4F-3, a tubby but rugged mid-wing monoplane with a supercharged 1,200 horsepower engine and four .50 caliber machine guns. F4Fs were not initially equipped with self-sealing fuel tanks or armor, but received both early in the war.[38] The -3's .50 caliber machine guns had 450 rounds per gun, enough for more than 30 seconds of firing.

In late May of 1942, F4F-4s replaced the -3s in the fighting squadrons. These had six .50 caliber machine guns rather than four and self-sealing tanks and armor installed at the factory. Perhaps more importantly, they had folding wings that allowed carrier air groups to increase their fighter complement from 18 to 27 and then to 36 aircraft. The improvements came at a cost: less range, a slower rate of climb, a lower ceiling, and only 18 seconds of ammunition for the guns.[39]

The IJN counterpart to the F4F was the A6M fighter – in the period under study, the A6M2 "Zeke." The A6M2 was a sleek, agile fighter with a high rate of climb and long range, but neither armor protection nor self-sealing fuel tanks. It was lightly built, weighing only 3,704 pounds empty as opposed to 5,785 pounds for an empty F4F-4.

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[37] For IJN carriers, the proportions varied from 18 to 27 out of an air group of from 54 to 72 aircraft. For USN carriers, 18 fighters were carried at the start of the war.

[38] John B. Lundstrom, *The First Team: Pacific Naval Air Combat from Pearl Harbor to Midway* (Annapolis, Maryland: Naval Institute Press, 1984), 12-14. The -3A had a different engine than the -3, with slightly lower performance.

[39] Lundstrom, *First Team*, 140.

Power was provided by a 950 horsepower engine with a single speed supercharger that gave poorer high altitude performance than the power plants in the F4F-3 and F4F-4. The A6M2 sported a mixed armament of two 7.7 mm machine guns and two short-barreled 20 mm cannon, with more than 30 seconds of fire for each machine gun but less than 7 seconds for each cannon.[40] Up against sturdy USN strike aircraft with full crew and fuel protection, the light machine guns of the A6M2s would prove relatively ineffective.

Effective defense through combat air patrols required much more than capable fighters. It also needed a reliable way of spotting incoming air strikes and a workable means of directing the fighters on patrol to intercept strikes as they were spotted. The British were the pioneers in this, first with the land-based system that the Royal Air Force used in the Battle of Britain and then with sea-based systems used to by the Royal Navy carriers. The foundation of the British systems was of course radar, in which the USN had a considerable lead over the IJN.

Radar was extremely useful in combat air patrols, but it was not a panacea. Radar in 1942 could be temperamental and fluky. Because of its method of operation, raids might be detected at a distance and then lost when they drew closer. Height estimation using radar was more a black art than a science. Most importantly, radar only made a difference if it was backed by an organization that put it to effective use. Enemy raids and friendly air formations had to be identified and tracked, radar information had to be collated and shared, decisions about interceptions had to be made promptly and correctly, and an effective communications network had to permit fighter controllers to vector the defending fighters into interception positions.[41]

The USN was fortunate in having access to the Royal Navy's experiences and techniques in fighter direction. This guided USN thinking and allowed it to capitalize

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[40] Lundstrom, *First Team*, 185-6. Francillon, 366-7, 376. Allied code names for the various models of A6M varied, but eventually the code name "Zeke" was applied to all A6M models. Despite this, the fighter was generally referred to as the "Zero," after the year of its introduction: 1940 in the Western calendar, 2600 in the Japanese calendar.

[41] Lundstrom, *First Team*, 89-91.

more fully on its radar advantage than would have otherwise have been the case. That said, USN CAP doctrine and procedures at the start of the Pacific War were very much works in progress.

The IJN, by contrast, labored under several disadvantages. Lack of radar meant that it had to rely on visual spotting of incoming strikes. The IJN could have dispersed its fighters aloft to provide advance warning of incoming strikes, but that would have made it harder to concentrate the CAP against a strike. The IJN preferred to concentrate its CAP assets closer to the ships being defended. With the fighters kept in close, the IJN located its screening ships well out from the carriers in the hope that they would see an incoming strike in enough time for the combat air patrol to respond. As one would anticipate, the screening ships were good at spotting torpedo planes coming in at low level, and even large formations of level bombers at high level. But dive bombers – small aircraft dodging from cloud to cloud or arriving from up-sun, were much harder to see.

Getting the CAP to respond to sightings gets to the second major issue that the IJN faced – poor communications. The radios carried by the A6Ms were unreliable, short-ranged and hard to use. The carriers lacked the facilities on USN carriers to collate information and communicate it efficiently to the CAP. The IJN tried to surmount these difficulties by having the screening ships make smoke and fire their main batteries as strikes were spotted. Hopefully, the CAP would see the smoke and shell splashes and respond.

Against these disadvantages the IJN could set one significant advantage: the A6M. The main IJN fighter was fast in level flight and unmatched in a climb. Its pilots could respond to threats quickly, even if they were spotted late. In contrast, the F4F was a slow climber that needed ample notice to intercept an enemy positioned above it. The A6M's long range meant that it could remain on CAP for a long time, simplifying the task of always keeping some CAP fighters over a task force. Its main drawbacks were its vulnerability and its limited amount of 20 mm cannon ammunition. Against the

rugged aircraft of the USN, the A6M would discover that it was hard to get kills without getting cannon rounds on the target.[42]

Despite the limitations and drawbacks of CAP abilities in 1942, both navies considered defending fighters a real threat to attacking forces. Both IJN and USN doctrine emphasized the importance of escorting fighters to strike forces. Had they though that the strikes could simply slip past the defenders, there would be no need for escorts.

Carrier Protection in Action – Early Engagements

The USN quickly got an opportunity to try out its aircraft carrier protection doctrines under combat conditions. From the period immediately after the start of the Pacific War, USN carrier task forces carried out a series of raids against IJN bases in the Central and Southern Pacific. These raids were generally carried out by task forces organized around a single carrier, although more than one task force might act in concert. The raids did not meet with opposition from IJN carriers, but land-based IJN bomber raids precipitated four actions over USN carriers.

The Marshalls Raid

Early February of 1942 saw the USN carrier *Enterprise* raiding IJN bases in the Marshall Islands. The first IJN strike on a USN carrier took the form of five G3M twin-engined bombers approaching the carrier task force through scattered clouds. Seven F4Fs were on CAP with a further six SBDs were committed to anti-torpedo plane patrols. It is unclear whether the raid was spotted by radar, as the USN aircraft were not yet equipped with the electronic IFF equipment that would allow a radar operator to distinguish them from enemy aircraft. With the radar scope cluttered by friendly aircraft, the raid may have been missed on radar.

Even if the raid was not detected by radar, it was seen early enough to permit the F4F CAP to intercept it at about 15 miles from the carrier. The G3Ms were first intercepted

[42] Parshall and Tully, 136-7.

at 10,000 feet, but quickly nosed down to 6,000 feet to begin a glide bombing attack on the *Enterprise*. Jammed guns kept the F4Fs from being fully effective while the task force's anti-aircraft fire was behind the bombers. All of the G3Ms survived to bomb from 3,000 feet and recovered at about 1,500 feet, but missed as *Enterprise* maneuvered violently. Immediately after the attack one of the G3Ms, damaged by the F4Fs, tried to crash the *Enterprise*. It struck the carrier a glancing blow, probably thrown off by the carrier's anti-aircraft fire.

The first action was hardly an overwhelming success. To some degree, the G3Ms owed their relatively light losses to the speed they picked up in their attack dives. But the CAP's effective was blunted by gun failures, radar had not played much of a role (if any), and the anti-aircraft fire was ineffective until one of the bombers tried to crash *Enterprise*. The score stood at one G3M shared between the F4Fs and the AA guns, shot down after attacking.

A second raid of two G3Ms approached *Enterprise* about two hours after the first raid. This raid was detected 25 miles from the task force, but the 9 F4Fs aloft failed to engage the bombers before the AA guns opened up. The G3Ms made a level bombing attack from 14,000 feet, again with no hits. One was damaged by AA fire and the other was downed by the CAP, but only after attacking. Again, *Enterprise's* evasive maneuvers were its most effective defense.

Again, this was not a promising start for CAP and AA. At least the AA guns managed to damage one aircraft and the CAP to down the other, but both had been able to attack.[43] Still, it was early days, and there was certainly potential to improve the performance of both the CAP and the AA. While results from fighter interceptions and the AA guns were not impressive, the IJN failed to score any hits against the radically maneuvering *Enterprise*.

One bright spot for the CAP was its success in shooting down an IJN search plane that was snooping the task force. Consistent with the Royal Navy's experience in the Mediterranean, it was easier for the CAP to track down these snoopers than to

[43] Lundstrom, *First Team*, 73-5.

intercept a raid. The snoopers provided a single, uncluttered radar image, were often large easy to spot four-engine flying boats, and by the nature of their mission were forced to linger in the vicinity of the task force. Some snoopers eluded detection or destruction, but a key advantage of radar controlled CAP proved to be its ability to track down opposing reconnaissance aircraft.

The Rabaul Raid

Later in February, a task force built around the carrier *Lexington* attempted to raid the newly captured Japanese base at Rabaul. The raid was called off when the task force was spotted by a Japanese reconnaissance aircraft well short of its destination, but not before the IJN was able to send out a strike of 17 bomb-carrying G4Ms to strike the task force. The strike split into two groups to search for the USN ships. Both groups found the *Lexington*, with one attacking about 40 minutes after the other.

Lexington's radar spotted the first group of nine G4Ms while they were still 75 miles from the task force. The strike group spotted the task force through light cloud about four minutes after the strike itself had been spotted, and headed in to attack. The radar sighting caught six F4F-3 CAP aircraft about to launch and another six low on fuel and about to land. All 12 CAP fighters headed out to intercept the attackers, but all were handicapped by starting at low altitude while the strikers were headed in at about 11,500 feet. The first CAP attacks took place 19 minutes after the first radar sighting, about 10 miles from the task force. Ten F4Fs from the CAP shot five of the bombers out of formation, leaving only four to attack *Lexington*. These four G4Ms conducted a level bombing attack on *Lexington*, but all the bombs missed as the carrier evaded. Shortly after the bombing attack, one of the G4Ms knocked out of formation by the CAP attempted to crash *Lexington* but was finished off by her anti-aircraft fire.

Lexington's air group was not yet done with this wave of attackers. The carrier launched another four F4Fs just before the bombing attack. Two of these plus two laggards from the original CAP fighters joined in the fight as the G4Ms attempted to withdraw. Two of the F4Fs were lost to the G4Ms' defensive fire, but another three G4Ms went down, leaving only one still flying. The final G4M was lost to an SBD

returning from a search mission, while another SBD claimed two crippled G4Ms found at low level.

From the USN's perspective, this was a far more successful fight. The CAP had been caught at a disadvantage when the raid was first spotted, but radar gave warning far enough in advance for the CAP to recover. More than half of the attacking force was taken out of action before it could attack. CAP accounted for five bombers outright and shared the destruction of one with AA and two others with an SBD. The strikers scored no hits. But a second wave of G4Ms was inbound.[44]

Radar spotted the second group of eight G4Ms about 30 miles distant from the task force.[45] The raid was identified while the CAP was still engaged with the first wave. Two F4Fs were orbiting *Lexington*, having been held back from the four that launched just before the first bombing attack. A destroyer detached from the task force saw the second wave about seven minutes after the radar sighting, with the wave sighting the *Lexington* about 11 minutes after the radar sighting and the *Lexington* seeing the raid about 2 minutes later. The two unengaged F4Fs met the raid a few miles from the task force, about 16 minutes after the initial radar sighting.

Of the two F4Fs intercepting, one had all of its guns jam. The other F4F killed two of the G4Ms outright, caused one to abort, knocked a fourth out of formation and damaged a fifth.[46] Four G4Ms managed to bomb, but without success. The bomber knocked out of formation tried to crash *Lexington*, but was downed by her AA. The CAP that had fought the first wave downed another G4M as the raiders withdrew. Two more G4Ms ditched on the way back to Rabaul. Only two returned to base, both damaged.[47]

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[44] Lundstrom, *First Team*, 97-101.

[45] I suspect that the raid was on the radar scopes before this, but the fighter direction personnel were fully occupied with the first wave of attackers.

[46] This was Lieutenant Edward H. "Butch" O'Hare, in the fight that would earn him the Medal of Honor.

[47] Lundstrom, *First Team*, 101-5.

Again, this was far more promising than the fights in the Marshalls. While the CAP was again caught off-balance, half of the attackers were downed or knocked out before they could drop their bombs. CAP attacks throughout the raids' bombing runs and evasive maneuvering by *Lexington* helped the carrier avoid any damage. Of the entire force of attacking G4Ms, only two survived and they were both damaged. In exchange for 15 downed bombers, two F4Fs were lost.

For the USN the results were good, but questions remained. So far, they had faced no dive or torpedo bombers. How would they fare against these more dangerous foes. They had also faced limited numbers of attackers. A two carrier IJN task force could be expected to put 54 or more strike aircraft in the air. How would a task force's defenses handle that many attackers? And none of the attacking strike had a fighter escort. How would throwing escort fighters into the mix affect the CAP's effectiveness?

Indian Ocean Adventure

While the USN carriers were dealing with four waves of aerial attackers, the IJN carrier force went through the first four months of the Pacific War without seeing a single incoming strike. The first attack on the IJN carriers took place in April, when the IJN was savaging the Royal Navy in the Indian Ocean. Nine Blenheim bombers of the RAF surprised the IJN carriers with a level bombing raid, but scored no hits and lost five of their number to the CAP when withdrawing. This was not an encouraging start for IJN carrier defense, but the IJN had fed on such a constant diet of victory over the past four months that it might be forgiven for not thinking too much about failing to see the raid before it attacked.[48]

Battle of Coral Sea

[48] Arthur J. Marder, Mark Jacobsen, and John Horsfield, *Old Friends, New Enemies: The Royal Navy and the Imperial Japanese Navy, The Pacific War 1942-45* (Oxford: Oxford University Press, 1990), 134-5.

May of 1942 saw the Japanese mount an invasion attempt directed at Port Moresby, on the southeastern coast of New Guinea. Light carrier *Shoho* and big new fleet carriers *Shokaku* and *Zuikaku* covered the assault, while the USN sent carriers *Yorktown* and *Lexington* to contest this and other Japanese landings in the Southwest Pacific. Neither side was sure of the other's location or order of battle, bringing on a game of blind man's bluff compounded by squally weather in the battle area.

In broad outline, the battle began on 7 May, when the USN found and sank the *Shoho*. After a series of misadventures, the *Shokaku* and *Zuikaku* launched a dusk strike that failed to locate the USN carriers. The carrier forces found each other on 8 May, exchanging strikes. The IJN strike damaged *Yorktown* and mortally wounded *Lexington*; the USN strike put three 1,000 pound bombs into *Shokaku*, knocking her out of the war for two months. Although unscathed, *Zuikaku* found that her air group had taken heavy losses. Both sides then withdrew, with the Japanese calling off the Port Moresby landings in the absence of carrier air to support the invasion force against Allied land-based air.

Coral Sea: the USN Experience

The USN CAP got its first workout on May 7, when it intercepted a late afternoon strike from *Shokaku* and *Zuikaku*. Conditions were not promising: dusk and overcast. The strike was spotted about 48 miles out from the USN task force, which at the time consisted of both carriers and their screens operating together. The strike consisted of a dozen D3As and 15 B5Ns; CAP at the time of sighting was 12 F4Fs, all low on fuel. Four of the airborne F4Fs were sent to attack the strike while another seven F4Fs were scrambled for an intercept. The first four F4Fs found the B5Ns, shooting five down and seriously damaging another. One of the F4Fs was lost when its target exploded. The first interception took place about 17 minutes after the first sighting. The F4Fs were certainly hindered by the poor visibility, but helped by an accurate assessment from the radar sighting that the IJN aircraft were at low altitude.

Of the F4Fs scrambled to intercept, two found another B5N formation, downing two of the planes and damaging a third. One F4F was lost, either to defensive fire or to

navigational difficulties in the murk. The other five scrambled F4Fs bounced the D3As, killing one before the formation broke apart. Scattered and hurt, the IJN strike aircraft jettisoned their ordnance and headed back to their carriers. Only then did some of them spot the USN ships. One final F4F was lost when it could not find its way back to the USN task force.

This was the best CAP performance of 1942. In poor visibility, all of the CAP fighters committed to the engagement found the enemy. The IJN lost seven B5Ns and one D3A outright, with two more B5Ns damaged and one of those ditching on return to its carrier. The action accounted for a quarter of the IJN torpedo bomber strength with nothing to show in return. Only the loss of three F4Fs was any cause for concern, particularly given the relatively small size of the carrier fighter squadrons at that time.[49]

May 8 brought the most severe test of USN carrier defenses to date, when a combined strike from the Shokaku and Zuikaku was detected 68 miles from the USN task force. *Yorktown* and *Lexington* were still operating in a combined task force, although both would maneuver independently once attacked. The IJN strike was 69 aircraft strong: 18 A6M escorting 18 B5N and 33 D3A.

At the time that the incoming strike was detected, the USN CAP consisted of eight F4F-3s running low on fuel with a mix of 18 SBD-2s and -3s at low altitude for anti-torpedo plane CAP. The *Lexington* launched five more F4Fs and five more SBDs for CAP five minutes after the initial raid sighting. *Yorktown* lofted four additional F4Fs three minutes after that. Two minutes later, the strike force spotted the USN task force, about 35 miles distant. The strike bored in with the D3As at 14,000 feet, the B5Ns starting at 10,000 feet but easing down to 4,000 feet to begin their torpedo attacks, and the A6Ms following the B5Ns.

Altitude was the first problem for the CAP. The fighter direction officer controlling the CAP either assumed that the both components of the incoming strike where at much lower altitudes than they were, or mistakenly thought that the F4Fs could easily climb

[49] Lundstrom, *First Team*, 210-4.

to make interceptions. The FDO may well have been thrown off by the fact that IJN torpedo bombers began their run-ins and attacks from much higher altitudes than the USN's TBDs, but it is difficult to understand why he would send CAP against the dive bombers without having them climb to altitudes at least consistent with USN dive bomber attacks.

Whatever the reasons, the FDO sent the nine recently launched (and fully fueled) F4Fs out to intercept the raid, with three of the F4Fs climbing to 10,000 feet and the other six low. The six low CAP completely missed the B5Ns and their escorts. The IJN strike aircraft were well above them and hidden by the moderate cloud cover then prevailing. The high CAP spotted the D3As about 20 miles from the task force 14 minutes after the initial sighting, but were too low to intercept. One of the high CAP did spot the B5Ns about 4 miles from the task force. The F4F dove in to splash one B5N before being driven off by the escorts. By then, 21 minutes had elapsed from first sighting of the raid.

The A6M escorts next busied themselves with the SBDs on low CAP. The *Yorktown* SBDs were too low and slow to intercept the B5Ns as they dove by. Powerless to intervene, they at least distracted the escorting A6Ms, which shot down four of them. *Lexington's* SBDs were better positioned and less bothered by the IJN escorts. They shot down two of the B5Ns as the IJN strikers flashed by, then pursued and shared a third victory with the task force AA.

The clock now stood at 26 minutes after the initial sighting of raid. Time had run out for CAP as the B5Ns began their torpedo runs on the two USN carriers. Three minutes after that, the D3As began their dives on the *Lexington*. And two minutes after that, the D3As lined up on the *Yorktown*. Most of the D3As dove in unopposed by fighters, as the six F4Fs that ultimately attempted to intercept the dive bombers before their attack were in turn intercepted by nine A6Ms diverted from the B5N escort. Two CAP F4Fs unsuccessfully attacked the D3As diving on the *Yorktown*, while one F4F returning from the USN raid downed one of the D3As attacking *Yorktown* while it was still in its dive.

With the strike attacking, the bloody day quickly got bloodier. Four B5Ns dropped torpedoes on *Yorktown*, losing two of their number to AA.[50] As with previous attacks, *Yorktown*'*s* maneuvers saved her. Nine B5Ns mouse-trapped *Lexington*, losing a B5N to the combined attentions of AA and a *Lexington* SBD before it could attack, but scoring two hits on the carrier out of eight torpedoes dropped. This was just too many attacks from too many directions for the *Lexington* to dodge them all. Two more B5Ns attacked a heavy cruiser without result. Of the 18 torpedo bombers in the strike, 14 survived to drop on their targets. The dive bombers did still better, with all 33 apparently diving on the two carriers – 17 on *Lexington* and 16 on *Yorktown*. One was lost to AA and two to F4Fs (one before bombing), but they scored a total of three hits and three damaging near misses: two hits and a near miss on *Lexington* and the balance on *Yorktown*.

There then ensued a chaotic scramble as the IJN strike aircraft and their escorts withdrew from the task force. Three F4Fs were lost in combat with the A6Ms, while one A6M ditched on the way back to its carrier. The SBDs continued to take toll on the withdrawing B5Ns, downing two more of the torpedo bombers and two D3As but losing two of their number to damage inflicted by A6Ms and (in one case) friendly AA.[51] In addition to tangling with the IJN escorts, F4Fs accounted for one D3A as the strike withdrew.

A single semi-armor piercing bomb hit *Yorktown*, failing to penetrate her armored deck but starting fires and causing the temporary shutdown of some of her propulsion spaces. The near misses peppered her with bomb fragments and opened one of her fuel bunkers to the sea. In all, she was not badly hurt and easily able to deal with her damage.

Lexington was another matter. The two bomb hits on her were apparently high explosive bombs. One wiped out the crew of a five-inch gun; the other burst on her

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[50] While all four attacking B5Ns were seen to drop their torpedoes, one drop may have been forced by AA damage. The B5N crashed in flames immediately after dropping.

[51] Apportioning the SBD victories is arbitrary on my part, but is based on total losses reported by the Japanese sources. The SBD pilots claimed more torpedo bombers and few if any dive bombers.

stack, killing and wounding many of the men manning her AA machine guns. The near miss flooded some compartments. As with *Yorktown*, *Lexington*'*s* bomb damage was not serious. But one of the two torpedo hits was. One torpedo forced the shutdown of three firerooms, opened a fuel bunker to the sea, and caused a slight list – serious damage, but controllable. The other torpedo hit ultimately doomed the ship. It jammed her flight deck elevators in place, but its main effect was to fracture her aviation gas fueling system and start volatile gas fumes seeping through the ship. Three explosions ensued over the next five hours, with the third blast causing the hanger fire curtains to fail. With firing sweeping the ship, the order to abandon was give about eight hours after the strike. The *Lexington* was ablaze from stem to stern when she was finally scuttled.

What were the lessons from the main IJN strike?

It seemed to validate IJN escort doctrine, as the A6Ms were largely successful in preventing the CAP from disrupting the strike. The escorts showed flexibility in shifting from the torpedo bombers to the dive bombers when the CAP finally climbed high enough to threaten the D3As. The escorts could be faulted for concentrating too much on the first group of SBDs that it encountered, but there were so many SBDs in the air that it was unreasonable to think that the A6Ms would be able to deal with all of them. The escorts effectiveness also waned as the strike withdrew, although again it would have been very difficult for them to cover all of the scattered strike elements as they made their escape.

The coordination of the strike was a bit off, as ideally the D3As would have attacked just before the B5Ns. This would have permitted the dive bombers to distract the target carriers and hopefully suppress anti-aircraft fire with their high explosive bombs. That said, the B5Ns did not seem to suffer too much for the timing lapse.

Over-claiming by the Japanese flyers – the inevitable result of the chaos of combat – may have masked the relative ineffectiveness of the dive bombers. While both USN carriers were hit, neither sustained bomb damage that would have knocked it out of the fight. Japanese claims were ten bomb hits on *Lexington* and eight to ten hits on

Yorktown, which led the Japanese to believe that they had inflicted far more severe bomb damage.[52]

It is not clear if the strike underlined the value of torpedo bombers attacking a target in numbers and from multiple directions. Three or four drops on the *Yorktown* achieved nothing, but eight drops on the *Lexington* finished her. The IJN aircrews claimed two hits on *Yorktown* and nine on *Lexington*, so the right conclusion might have been draw despite the over-claiming. In subsequent battles, the IJN torpedo bombers continued to try for attacks as close together in time and as widely separated in bearing as possible, suggesting that Coral Sea at least did nothing to discourage these tactics.

One lesson that the IJN could not do much about in the short run was the vulnerability of its strike aircraft. Most of the strike planes fell to SBDs with half the firepower of F4Fs, certainly solid performers but nothing that would ever be mistaken for fighter aircraft. Later models of IJN aircraft would have armor and self-sealing tanks, but the IJN's aircrews would have to carry on through 1942 with the aircraft at hand.[53]

The USN saw CAP performance drop from sterling (in the dusk battle) to dismal, with only three of 17 CAP F4Fs engaging strike aircraft before the strike finished its attacks. The main culprit was altitude. The F4Fs simply did not have enough of it to deal with either the D3As or the B5Ns. The CAP was fortunate in the dusk battle; the IJN strikers were traveling at cruise speed and at low altitude, trying to spot the USN task force through the murk. The CAP had neither advantage in the main battle. The CAP's difficulties with the A6M escorts stemmed from the same issue. Without altitude, the CAP was unable to dive past the escorts and into the formations of strikers. Instead, the CAP was forced either to engage the escorts or to dive out and lose the chance to hit the strikers. In the process, two F4Fs were lost to the A6Ms with only one A6M lost in return.

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[52] The number of hits claimed was not preposterous. In April, 53 D3As attacked two Royal Navy cruisers in near-perfect conditions. They scored 31 direct hits and all of the rest near misses, sinking one of the cruisers in eight minutes and the other in 15 minutes. Marder, Jacobsen, and Horsfield, 129-31.

[53] Lundstrom, *First Team*, 243-68.

The only consolation for the CAP was the effectiveness of the SBDs on anti-torpedo plane patrol. Even this was a mixed blessing, with only 15 of the 23 patrolling SBDs engaging (seven before the B5Ns attacked), five of the SBDs lost to A6Ms outright and a sixth crippled by A6Ms and downed by AA. The bomber pilots may have appreciated the opportunity to shoot down some enemy aircraft, but I suspect that more senior leaders questioned the wisdom of holding back aircraft that could have been used to strike the enemy.[54] We will see that 23 SBDs carrying 1,000 pound bombs would have been likely to put an IJN carrier out of action.

Anti-aircraft fire proved relatively ineffective, accounting for two B5Ns and only one D3A, with credit for a third B5N shared with an SBD. Perhaps one of the two AA victories was a B5N going down before it could make an effective attack. The SBDs were far more effective, downing two B5Ns before they could attack (with shared credit for a third), plus two B5Ns and two D3As as the strike withdrew. F4F victories were relatively sparse: one D3A before attacking and one after, one B5N before attacking, one A6M after the strike had attacked.

Maneuver proved effective against limited numbers of torpedo bombers, but conferred no immunity against dive bombers or torpedo bombers executing an anvil attack. It helped to reduce the number of hits, but could not prevent them entirely.

Having the two carriers concentrated helped to concentrate the CAP and AA assets of the task force. Had the two carriers been separated, it is likely that one would have been sunk in any event. Concentration led to moderate damage to a second carrier, but a portion of the strike might have found and attacked the second carrier even it was not in the immediate area. The range of the strike was short enough that the IJN strikers could have taken the time to search for a second carrier had they wanted to do so. On balance, the jury was still out on the issue of concentration or separation.

[54] This is a higher kill rate than A6Ms were able to achieve against strike SBDs loaded down with bombs. I suspect that this was due to two factors: SBDs attempting to dogfight A6Ms, and some earlier SBD-2s in the mix without the armor or fuel tank protection of the -3s.

Armor and damage control showed both strengths and weaknesses. The *Yorktown*'*s* deck armor proved able to defeat the SAP bombs of the D3As, but the *Lexington*'*s* gasoline supply system proved vulnerable to the shock effects of an aerial torpedo hit. It was some slight consolation that the *Lexington*'*s* damage control systems could contain the resulting explosions and fires for a time, but the inability to deal with the gas vapor leaks causing the explosions ultimately doomed the ship.

Coral Sea: the IJN Experience

The first meeting between IJN carrier CAP and a USN strike was not auspicious for the IJN. The first clash took place on 7 May, when the IJN sent a large strike to sink IJN carrier *Shoho*. *Shoho* was not a fleet carrier. Her fighter group was a mix of A6Ms and older A5M4 aircraft.[55] She was a relatively small ship, unarmored and with a modest air group suited mainly to providing fighter and anti-submarine patrols. She was engaged in these prosaic pursuits on May 7 when the combined striking forces of *Yorktown* and *Lexington* swept down on her.

Lexington's strike forces were the first to see *Shoho*, about 40 miles distant under scattered cloud. The *Lexington's* strike group consisted of 28 SBDs and 12 TBDs, with 10 F4F-3s providing escorts. Four of the F4Fs escorted the torpedo bombers, four escorted the dive bomber squadrons, and two accompanied a command section of three SBDs. The TBDs traveled well below the SBD squadrons, with the SBD command section maintaining a link between the two.

The IJN look-outs spotted the USN aircraft about 10 minutes after the strike had sighted *Shoho*. At the time, *Shoho* had two A5Ms and one A6M aloft as CAP and was just landing four A6Ms and a B5N that had been patrolling over a nearby convoy. The IJN sighting gave the CAP about 20 minutes to intercept the USN formation before the strike began its attacks. In that time, the airborne CAP climbed to intercept the dive bombers while *Shoho* prepared to launch three more A6Ms. These were probably CAP

[55] The A5M was a graceful, diminutive low-wing monoplane armed with two 7.7 mm machine guns and totally unsuited to combat with the oncoming USN strike.

aircraft held ready on deck, rather than the patrol aircraft that just landed. *Shoho's* total fighter complement was eight A6Ms and four A5Ms.

The first three SBDs to dive (*Lexington's* command section) were not intercepted, but the CAP did try to shoot up the next squadron of 10 SBDs to dive. None of the first 13 dive bombers scored; neither did the CAP. *Shoho* maneuvered effectively to spoil the attacks, placing herself crosswise to the line of the bombers' dives. She was even able to launch her three readied A6Ms. But her luck ran out when the 15 SBDs of the *Lexington's* bombing squadron piled in.[56] They scored two hits with 1,000 pound bombs, igniting fires in the carrier's hangers. These two hits alone were in all likelihood fatal, but worse was to follow.

About nine minutes after the SBDs began their attack, the *Lexington* torpedo bombers arrived. They dove in from 4,000 feet in an anvil attack on *Shoho* that resulted in five hits.[57] Two A5Ms attempted to intervene as the TBDs dove in, but the low escorts kept them off the torpedo bombers. Now there could be no doubt as to *Shoho's* fate.

The bad news just kept coming, though. Six minutes after the torpedo bombers began their drops, *Enterprise's* dive bombers began to attack. Her strike consisted of 25 SBDs and 10 TBDs, with three F4F-3s escorting the SBDs and five F4F-3s with the TBDs.[58] Twenty-four SBDs dived on *Shoho*, now heading straight into the wind with her steering gear jammed.[59] They made an additional five to 11 hits, turning the carrier

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[56] Most USN fleet carriers carried two squadrons of SBDs, one designated a bombing squadron and the other a scouting squadron. Both squadrons were generally equipped identically, although any SBD-2s in the air group seemed to have been allocated to bombing squadrons while that version was still in service.

[57] This was the single most successful USN torpedo attack of the year. It was certainly helped by the fact that *Lexington's* torpedo squadron managed a successful anvil approach. I suspect that it was also helped by the two bomb hits, which were evidently scored just before the torpedo drops. These may have interfered with any effort by *Shoho* to dodge the slow USN aerial torpedoes.

[58] The intention had been to split the escort evenly, but one of the F4Fs detailed to protect the SBDs joined the TBD escort by mistake.

[59] The twenty-fifth SBD to dive bombed an escorting cruiser instead, but missed. One SBD of the 25 had inadvertently jettisoned its bomb before attacking. Another had failed to have its bomb release.

into junk. Conditions were close to ideal, marred only by three A6Ms following the SBDs into their dives and an increasing smoke pall that began to obscure the target.

The *Enterprise* TBDs then bored in for at least another two torpedo hits on *Shoho*. Their escort engaged A5Ms and then a lone A6M. They killed two A5Ms and the A6M for no loss.[60]

The main lesson for the USN from this strike was that escorting fighters could very effective in escorting torpedo bombers. They could not do much for the dive bombers once the bombers had begun to dive, but the CAP fighters apparently could not do much to harm the bombers at that point. The torpedo bombers had to go in low and slow, and that exposed them to effective CAP attacks unless the escorts could intervene.

A second lesson related to strike control. *Shoho* was clearly doomed after the *Lexington* air group had attacked, but only one plane from the *Yorktown* group switched to another target on the pilot's own initiative. There were four heavy cruisers in company with *Shoho*; a few 1,000 bombs on them would have been worth the effort.

For the IJN, the attack on the *Shoho* was a rout, but in circumstances in which any other result was very unlikely. But even in the dire circumstances, there were causes for disquiet. Even with 20 minutes warning, the CAP could only intercept the USN dive bombers in the midst of their dives. None of the highly vulnerable TBDs were brought down despite four A6Ms being present. Anti-aircraft fire caused the TBDs to take some evasive action, but scored no kills. Ship handling prolonged *Shoho's* life, but only by a few minutes – showing again that maneuvering could be overcome with sheer numbers. The strike was not a fair trial of IJN armor and damage control; the *Shoho* was unarmored and was probably doomed to a fiery end from the time that she took her second bomb hit.

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[60] Lundstrom, *First Team*, 197-205.

As with the USN, the main event for the IJN was a two-carrier strike mounted against IJN carriers *Shokaku* and *Zuikaku*. These were large, fast, well-armed, and modern ships. The morning of 8 May found them cruising under overcast, squally skies, operating in a single task force but occasionally separating as they launched and landed aircraft.

The strike that the IJN carriers had launched was first to give a warning, reporting the incoming USN strike as the two passed on the way to their respective targets. The *Yorktown's* SBDs sighted the IJN task force almost an hour later, but delayed their strike in an attempt to coordinate with her TBDs. The *Yorktown* strike was made up of 24 SBDs and nine TBDs, with four F4F-3s escorting the TBDs. Two F4F-3 had set out with the SBDs, but became separated in the heavy weather and proceeded to the IJN task force separately.

On CAP were five A6Ms high over the IJN task force, five more A6Ms low over the ships, and another six poised for take-off. The SBDs had the task force in sight for 23 minutes before the IJN lookouts and CAP simultaneously spotted the SBDs, but loitered in the area waiting for the lower, slower TBDs to arrive. The TBDs reported that they had the task force in sight about two minutes after the IJN sighting, prompting the SBDs to attack *Shokaku*. As with the *Shoho*, the SBDs would precede the TBDs in the attack by about five to ten minutes.

Diving in, the *Yorktown's* first squadron of SBDs encountered opposition from three A6Ms, but took no losses. They also made no hits, as their windscreens and bombsights fogged up in the humid air near the ocean surface. Four A6Ms newly launched from *Zuikaku* pursued them as they withdrew, but again without effect.

The 17 SBDs of *Yorktown's* second SBD squadron also encountered CAP fighters as they dove, in the form of two *Shokaku* A6Ms. This time the CAP scored, downing an SBD that nonetheless held its dive to the limit and made a hit on *Shokaku*. That plus another hit started serious fires but did not impair her ability to steam at top speed. Seven more A6Ms joined the fight as the SBDs withdrew, killing a second SBD.

The nine TBDs closed *Shokaku* as the SBDs withdrew. Their escorts again found work, engaging five A6Ms, shooting down two and seriously damaging a third. Three more A6Ms joined this fight from pursuing the SBDs, but neither side took any additional losses. The TBDs scored no hits for nine drops and had one of their number seriously damaged by AA fire.

The score from the *Yorktown* strike was two SBDs lost and a TBD seriously damaged to two A6Ms lost and one seriously damaged. *Shokaku* took two hits which hampered her ability to conduct air operations but did not appear mortal. Next in was the *Lexington* strike of 15 SBDs and 11 TBDs, with an escort of two F4F-3s with a command section of four SBDs and another four F4F-3s with the TBDs.[61] The command section spotted the task force about 15 miles off at the same time as the task force saw the strike. The first striker attacked about 10 minutes later, about 30 minutes after the last attack of the *Yorktown* strike. The *Lexington* strike faced 13 A6Ms on CAP: six high and seven low.

Luck now favored the Japanese, as the *Lexington's* SBD squadron failed to spot any ships of the task force. Short on fuel due to an administrative foul-up, the 11 SBD's turned for their own task force. The command group did find *Shokaku*, although the low cloud ceiling forced it into a low-level glide bombing attack. That probably put them under the high CAP; they were not intercepted until after they had attacked, although their escort tangled inconclusively with three A6Ms just before the SBDs dove in. Two more A6Ms found them as they withdrew with the result of one A6M badly damaged, one SBD badly shot up, and one F4F probably lost.[62] Another SBD from the group discovered that its bomb had not released. Returning to the IJN task force, it was not seen again and likely fell victim to the A6Ms.

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[61] An additional TBD turned back with engine trouble. Three additional F4Fs escorting the SBD squadron became separated and returned to the USN task force in time to fight the IJN strike.

[62] The F4F was engaged by the A6Ms and not seen again. It could have been a victim of navigational difficulties, but I credit it to the A6Ms.

The *Lexington* TBDs and their escorts had a harder time than their *Yorktown* counterparts. Four A6Ms fought the escort, downing two F4Fs. Three attacked the TBDs before they could drop their torpedoes, but the TBDs all survived. They began their attack on Shokaku a couple of minutes after the SBDs, scoring no hits for 11 drops.[63]

The end result of the double strike was three 1,000 pound bomb hits on *Shokaku*. She was out of the war for almost two months, but in no danger of sinking. Three SBDs and three F4Fs had been lost to the CAP, in exchange for two A6Ms down and two others seriously damaged.

The strike against the IJN task force underlined even more forcefully the value of fighter escorts for the torpedo bombers. The TBDs faced far more daunting opposition than they did in the attack on *Shoho*, but the escorts were able to keep most of the A6Ms away. The cost was steeper this time, although the escorts shot down as many aircraft as they lost. It was disturbing that a quarter of the dive bombers did not find a target, but that may not have been too alarming given the poor state of the weather over the IJN task force. Of course, the under-fuelling mistake was inexcusable, but there seemed no evident problem with strike navigation or search procedures.

More significantly, a post-strike comparison with the results obtained by the IJN could not have been comforting. Both strikes had approximately equal numbers of aircraft, but the IJN finished one carrier and damaged another while the USN strike had only removed one carrier for less than two months. This may have been laid to the USN problem of fogged bombsights, but that did not explain the inability of the torpedo planes to score. I would expect that the disparate results would have given the USN food for thought. Only a comparison of aircraft losses would have been encouraging, assuming that the USN could accurately boil the claims from the CAP, AA, and escorts into something close to the actual losses.[64]

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[63] Lundstrom, *First Team*, 228-42.

[64] One aspect of losses here were aircraft that returned to the IJN carriers but were ditched or jettisoned due to damage. By the time that the IJN strike returned, the *Shokaku* was out of business as a carrier. Twenty-two IJN aircraft went missing or ditched, against total likely

Defensively, the IJN tactic of out-ranging was not of much consequence. Bad weather over the IJN task force, helped by the SBD under-fuelling mistake did contribute to a quarter of the USN dive bombers failing to attack, but the IJN would have found the USN carriers even if its aircraft ranges were as short as the USN's. Concentration was a net help to the IJN, as the A6Ms from both carriers formed the combat air patrol while the weather hid one carrier from view. In essence, the weather gave the IJN the best of both worlds: the carriers could pool their fighter assets while not both being in view of the same attackers. IJN armor and damage control were effective, keeping the 1,000 pound bomb blasts from *Shokaku's* vitals and controlling the fires that the bomb blasts started.

CAP performance and anti-aircraft gunnery were another matter. *Shokaku* had more than five times the light anti-aircraft weapons as *Shoho*, but could manage only to damage one relatively vulnerable TBD. It was a performance that made the three and one-half victories credited to the USN AA look good. As for the CAP performance, it is interesting to note that IJN was able to put more fighters on the SBDs as they dove than the USN was able to manage against the D3As with clearer skies and radar. The real difference in CAP performance came in aircraft downed, not in interceptions made. This would have been hard for the IJN to see, given the usual over-claiming of aerial victories, but it is noteworthy that dive bombers were hard for CAP to handle, even with the advantage of radar.

Battle of Midway

The Battle of Midway was of course the decisive carrier battle of 1942, resulting in the sinking of four IJN fleet carriers and one USN fleet carrier. Even though the story is well known, it is still instructive to parse the different engagements that made up the battle.

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shoot-downs of 16. I am reluctant to credit all of the other six to the USN, given that some probably ditched as a result of damage to *Shokaku*. It is clear that the combination of shoot-downs, ditchings, aircraft battle damage, and *Shokaku's* inability to conduct air operations reduced the IJN air strike force to less than a quarter of its strength at the start of the day.

Unlike the Battle of the Coral Sea, Midway did not see all of the IJN and USN fleet carriers exchange airstrikes. Instead, aircraft from two of the three USN carriers engaged succeeded in knocking out three of the four IJN fleet carriers engaged, leaving only a single carrier – *Hiryu* – to strike back against the Americans. *Hiryu* launched two separate strikes against the USN carriers, the first of 18 D3A and 6 A6M and the second of 10 B5N and 6 A6M. Both of these strikes found and attacked carrier *Yorktown*, although carriers *Enterprise* and *Hornet* were operating in a separate task force in the same area.

Midway: the USN Experience

Hiryu's dive bomber strike was detected by radar about 32 miles from the *Yorktown*. The strike found the *Yorktown* about five minutes later, about 25 miles away. Their escort was down to four A6M, as two had been forced to abort after tangling with some SBDs returning from the USN strike.

Yorktown had just launched 12 F4F-4s as relief CAP when the strike was detected. The second USN carrier force, about 30 miles from *Yorktown*, had 19 F4F-4s on CAP. The fighter direction officer of the second force immediately send eight of its CAP fighters to assist *Yorktown*, although only six responded to his directions. Fortunately for the USN CAP, the incoming strike had been properly assessed as dive bombers. The just-launched F4Fs had to claw for altitude, but they knew that they were looking for D3As.[65] The CAP sent over from the second task force (Task Force 16) was already at 20,000 feet, ample altitude to engage the D3As, but with 30 miles of distance to close.

The *Yorktown* CAP struck first, about ten minutes after the strike was first reported. The initial attack by four F4Fs scattered the IJN dive bomber formation while it was 10 to 15 miles from *Yorktown*. This was an important result, as the time that the Japanese flyers needed to rebuilt their formation and organize their attack gave the American flyers more time to intercept the dive bombers before they could attack.

[65] Officially, a fully loaded F4F-4 could reach 10,000 feet in a little more than 5 1/2 minutes and 20,000 feet in about 12 1/2 minutes. Bureau of Aeronautics, Navy Department, *Airplane Characteristics & Performance: Model F4F-4* (July 1, 1943). In reality, the times were likely longer.

Seven of the ten *Yorktown* F4Fs that heard the fighter direction officer's directions to the raid combined to down eight D3As and an A6M. Two more D3As lost or jettisoned their bombs as a result of the *Yorktown* CAP attacks. One additional D3A then fell to the first four F4Fs to arrive from the TF 16 CAP, although one F4F from that group fell victim to either an A6M or AA fire. In response, the *Yorktown* CAP downed an A6M attacking the TF 16 CAP. One other A6M probably succumbed to the CAP as well.

Only seven D3As were left to attack *Yorktown*. They dove in about 19 minutes after the strike was first spotted. Two were splashed by AA, with one of the downed bombers bombing successfully and the other not. The other five bombers made two more hits and two damaging near misses, a remarkable performance in the face of such heavy opposition. At least one more D3A – probably one that had lost its bomb in the initial CAP attack – fell to the CAP as the IJN aircraft withdrew. Thirteen D3As failed to return from the mission, so it is possible that the CAP accounted for additional dive bombers as well.

The hits on *Yorktown* were serious but not fatal. The first had wiped out many of the crew manning her light AA guns. The second hit in the uptakes for the boiler rooms, causing all but one to be temporarily evacuated. This brought the ship's to a halt, but she was able to work back up to 19 knots in the next two and a half hours. The third bomb started fires that caused a magazine to be flooded as a precaution. It could have played havoc with the carrier aviation gas system, but did not because the system had been flooded with CO^2 gas. *Yorktown* was even able to resume operating fighters by the time that the second IJN strike arrived.[66]

The second strike took the form of 10 B5N torpedo bombers escorted by six A6Ms. They were first spotted by a cruiser in *Yorktown's* screen about 45 miles away, then spotted by *Yorktown* herself three minutes later and 33 miles out. The strike saw *Yorktown* at the same time and started to let down from 13,500 feet to attack.

[66] Lundstrom, *First Team*, 374-90.

At the time that the raid was spotted by the carrier, she had six F4Fs in the air and eight more on deck ready to launch. TF 16's CAP amounted to 15 F4Fs, of which 8 were committed to help *Yorktown*. At the time, distance from *Yorktown* to TF 16 had widened to 40 miles.

In the four minutes after the raid was first spotted, *Yorktown's* FDO sent out all six F4Fs to intercept. It seems that the differences between IJN torpedo attack techniques and USN torpedo attacks again baffled the FDO and the CAP, as the first four F4Fs to be committed overflew the diving B5Ns without spotting them.[67] The two F4Fs that did engage managed to splash a B5N, but both then fell victim to the escorting A6Ms.

The *Yorktown* began to launch her on-deck F4Fs just a minute before the B5Ns arrived to drop their torpedoes. They began their attacks about 14 minutes after they were first sighted, dividing into two sections to attempt a classic anvil attack. The first group (of four B5Ns) arrived before the second, to be greeted by four just-launched F4Fs. Two F4Fs each downed a B5N, while the third probably shared its B5N victory with AA fire. Of the three B5Ns downed, two went down after completing their attacks. Thus, the first group dropped three torpedoes on *Yorktown*. She managed to evade all three. In the melee, the four F4Fs that initially overflew the IJN strike returned, killing two A6Ms and causing a third A6M to abort. The single B5N from the first group of torpedo bombers to escape survived only long enough to meet three F4Fs from the TF 16 CAP, which shot it into the sea.

The second wave of five B5Ns had much more success. The last four of the eight F4Fs launched by *Yorktown* made much less of an impact, with one downed by AA fire and another by an A6M. The first group of just-launched F4Fs were too low and slow to set up on the second wave of B5Ns. The result was no losses for the torpedo bombers and two hits on *Yorktown* from the five torpedoes dropped. Both hitting on the same side, the torpedoes flooded many of her firerooms while the concussion from their blasts

[67] The B5Ns were correctly evaluated as being at 10,000 feet or higher. This led to the incorrect assumption that they were dive bombers.

shut down *Yorktown's* boilers and caused her to lose all power. She quickly took on a serious list from flooding. All of the second wave escaped both the CAP and AA fire.[68]

These two strikes make an interesting contrast. The CAP interception of the dive bomber strike hinged on the CAP getting altitude, and the CAP getting altitude hinged on the correct call that the strike consisted of dive bombers. That allowed the CAP to intercept the strike short of *Yorktown* and well in advance of the D3As attacking. The CAP interception was particularly effective for two reasons: first, because the initial attacks scattered the D3As, and second, because the IJN escorts failed to intervene effectively.

The scattering of the D3As gave the CAP more time to shoot up the dive bombers as they struggled to reform. It was (depending on one's point of view) a vicious or a virtuous circle. CAP firing runs and dive bomber losses disorganized the strike aircraft further, which delayed their attack, which gave the CAP more time for firing runs and so meant further losses. The disorganization is reflected in the time it took the D3As to attack: 19 minutes to cover 32 miles, as contrasted to the B5N attack taking 14 minutes to cover 45 miles.

The absence of effective action from the escort allowed the F4Fs to concentrate on shooting down the D3As. In contrast to the torpedo bomber strike, where the escorts intervened almost immediately, the escorts for the D3A strike did not make their presence felt until relatively late in the action.

The result was a massacre reminiscent of the dusk raid at Coral Sea. More than half of the attacking force was shot down or bombless before it was able to attack. The seven D3As that ultimately did bomb made an impressive three hits and two near misses, but that was not enough to inflict lasting serious damage on *Yorktown*. Once again, armor and damage control contained the damage that the IJN dive bombers could inflict. But double the damage might have been a different matter. As it was, *Yorktown* was lucky that more than two and a half hours separated the first raid from the second. Without that time to make repairs, she could have been a sitting duck for the torpedo bombers.

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[68] Lundstrom, *First Team*, 397-411.

The B5N attack was the opposite of the D3A strike. The FDOs were wrong in their estimate of how high the attackers would be when they crossed paths with the CAP, and that caused most of the CAP to miss making an interception away from *Yorktown*. The two CAP F4Fs that did make an early interception downed only one B5N before the escorts shot them down. The B5N attack developed swiftly, which meant that the TF 16 CAP (which was coming from further away) only arrived after the strikers had struck. And finally, the B5Ns' torpedoes again proved to be far more effective than the bombs of the D3As. The two torpedo hits that the B5Ns scored did not sink *Yorktown* outright, but they took her irretrievably out of the fight. The only saving grace for the CAP defense was that the F4Fs launched from *Yorktown*, although late to the fight, were at least in a position to intercept some of the B5Ns coming in at low altitude.

The toll exacted by the USN defenses on the torpedo bombers was still high – half the B5N force fell to CAP and AA fire – but only two B5Ns were downed before attacking. And the losses to escorts and CAP was almost inverted from the first raid to the second, with one F4F lost versus three A6M losses in the first raid and three F4Fs lost versus two A6Ms in the second raid.

To briefly consider the other aspects of defense, AA fire continued to be disappointing in terms of its material effect. It accounted for only two D3As and half credit for a B5N. The poor performance against torpedo bombers is particularly puzzling. One would expect them to be easier targets than the dive bombers, as seemed to be the case in the Coral Sea. *Yorktown's* damage may have interfered with her AA in the B5N attack, but it was still potent enough to down an F4F and the screen's AA was certainly unimpaired.

The jury was still out on separation versus concentration. Because the USN was facing raids from a single out-numbered carrier, IJN was unlikely to sink more than one carrier in any event. That made the perils of concentration moot, although the result might have been different had more IJN carriers survived to launch strikes against their USN counterparts. Concentration would have increased the number of CAP

fighters opposing the raids, although a 30 mile separation did not prevent TF 16's CAP from intervening effectively in the IJN dive bomber raid.

Midway: the IJN Experience

The IJN carrier task force at Midway faced eight separate raids: one by torpedo bombers based at Midway, one by Midway-based SBD-2s that coincided with a B-17 bombing attack, one by Midway-based SB2Us, one by *Hornet's* torpedo bomber squadron, one by *Enterprise's* TBD squadron, the climactic raid, involving *Enterprise's* SBD squadrons plus *Yorktown's* dive bombing and torpedo bombing squadrons, a carrier raid against the last surviving IJN carrier, the *Hiryu*, and a final raid by B-17s.[69] In response, the four carriers in the task force – *Akagi*, *Hiryu*, *Kaga*, and *Soryu* – mounted the second largest carrier CAP of 1942, with up to 42 A6Ms (out of a total complement of 72) committed to the CAP at its peak.[70] The CAP shot down 52 US aircraft, the deadliest CAP toll of all of the 1942 carrier battles, but failed utterly to prevent the loss of all four IJN carriers engaged.

The action began with a series of three raids by Midway-based aircraft over a period of about one and one-half hours. The first raid of four B-26 and six TBF torpedo bombers was spotted in enough time for at least 16 A6Ms to engage before the bombers reached their drop points. Three TBFs and two B-26s went into the water before they could drop their torpedoes. Two B-26s dropped on *Hiryu* while two TBFs attacked carrier *Akagi* and one went after a light cruiser. None of the torpedoes hit. The A6Ms killed one more B-26 and two more TBFs after they had attacked, with the B-26 attempting unsuccessfully to crash *Akagi*.[71] At least 29 A6Ms fought in the later stages of the attack, losing two of their number to the bombers.[72]

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[69] The SB2U was a predecessor to the SBD in USN scout bomber service.

[70] The USN CAP at the Battle of the Eastern Solomons was larger by 10 fighters, counting seven F4Fs that were diverted from strike escort to CAP duties.

[71] AA fire may have contributed to the demise of this bomber.

[72] Parshall and Tully, 149-52.

The second raid from Midway was really two raids, one by 16 Marine SBD-2s and another, arriving at the same time, of 15 Army Air Force B-17Es. The SBDs were spotted first and the B-17s were spotted a minute later. At the time, the CAP only had 9 A6Ms aloft. All of the fighters intercepted the SBD-2s, downing six before they attacked for the loss of one A6M.

The SBDs approached at 9,500 feet and then let down into relatively shallow dives for a glide bombing attack on *Hiryu*. They attacked about 15 minutes after they were first spotted. None of them hit the target. In addition to the six SBDs lost over the task force, two more failed to return to Midway.

The 15 B-17s droned over the IJN task force at high altitude, bombing here and there over a 20 minute period that began before the glide bombing attack and extended after it. They had been spotted about six minutes before their first attack. Nine A6Ms returning from a strike intercepted the B-17s, as did three CAP A6Ms, but without losses to either side. Nor did the bombers score any hits on the IJN ships twisting far below.[73]

The final land-based attack of the morning arrived in the form of 11 SB2U-3s, obsolescent dive bombers manned by Marines. They bombed a battleship at the edge of the task force rather than a carrier, but missed. Seventeen CAP A6Ms were on patrol when the SB2Us were spotted, although only 11 may have intercepted them. The interception took place before the dive bombers attacked, but the only losses over the task force – two dive bombers – took place after the bombers had attacked. Two more SB2Us ditched on the way back to Midway. It was a relatively poor performance by the CAP, compared to the results that a smaller group of CAP fighters managed against the SBD-2s. The SB2Us should have been slower, easier targets. Perhaps the intercepting fighters had been low on cannon ammo, or perhaps they had less time to attack before the SB2Us bombed.[74]

[73] Parshall and Tully, 176-80.

[74] Parshall and Tully, 185-6.

That concluded the land-based strikes for the time being. The IJN task force would not encounter another land-based air attack until the end of the day. The next four attacks came from the aircraft of the three USN carriers in the battle: *Enterprise*, *Hornet*, and *Yorktown*.

First to attack was the *Hornet's* torpedo bomber squadron, which had separated from the rest of the *Hornet* strike and managed to fly almost directly to the IJN task force. Unfortunately, this left the 15 TBDs of the squadron alone and unsupported by the any dive bombers or escorting fighters. The IJN look-outs sighted the TBDs almost an hour after the SB2U raid was spotted: ample time for the CAP to replenish itself. They gave the alarm while the TBDs were 20 miles from the task force: ample time for the A6Ms to intercept them long before they were in a position to attack. The CAP began with 18 A6Ms aloft; an additional 11 were launched in time to intercept the torpedo planes. With the carriers headed away from the lumbering TBDs, the torpedo squadron took a least 12 minutes from the initial sighting position to reach attack positions. Only one TBD did so; 21 intercepting A6Ms blew the rest into the water. The lone TBD to reach its drop point dropped on *Soryu* but its torpedo missed. It was splashed shortly thereafter.[75]

The next carrier squadron to attack was *Enterprise's* TBD squadron. This strike was sighted while the *Hornet's* TBDs were in the midst of their attack, between 25 and 30 miles distant. Again, the TBDs were unescorted and unsupported. Again, they faced long runs to reach their attack positions, with the attacks taking place 22 minutes after the first sighting report. The only break the *Enterprise* got was that the CAP was low on cannon ammo and in the midst of savaging the *Hornet's* TBDs. The CAP amounted to 30 A6Ms as the *Enterprise* squadron started in, with another nine A6Ms launched before and during the attack.

The results were bad for the USN, but not as bad as the massacre of the *Hornet's* torpedo bombers. Nine of the TBDs went down and one ditched on the way back to its

[75] Parshall and Tully, 205-9.

carrier. Five TBDs survived to drop on *Kaga*, but again without result. The CAP lost one A6M, with the bulk of its victories scored by fighters that had just launched.[76]

The next USN strike was really two strikes attacking at the same time. The *Enterprise* dive bombers had spotted the IJN task force about 35 miles distant at 1000, just as the *Enterprise* torpedo squadron was attacking. The 32 SBDs of the strike began to maneuver into attack position. Three minutes after the *Enterprise* sighing, the *Yorktown's* strike saw the smoke from the IJN task force. This was the only cohesive USN strike of the day: 17 SBDs, 12 TBDs, and 6 F4F-4 escorts for the TBDs. Unfortunately, glitches in the SBD bomb arming gear meant that only 13 of the *Yorktown* SBDs still carried their bombs.

Akagi raised the alarm at 1006, but only as to the TBDs, which it saw about 25 miles distant. CAP at the time was 36 A6Ms, probably with 14 or 15 close to the carriers and another 21 or 22 chasing the remnants of the *Enterprise* torpedo bombers. At 1010, a screening heavy cruiser fired its big guns at the *Yorktown* TBDs, now about 14 miles out, to attract the attention of the CAP. In the absence of effective fighter direction by radio, this was a standard IJN practice for getting CAP onto incoming raids. It worked here, for the TBDs and their escorts were engulfed in A6Ms immediately afterwards.

A number of A6Ms engaged the six F4F escort. In a fight that stretched over 25 minutes, the F4Fs downed four A6Ms while the A6Ms killed an F4F and damaged two others. This combat marked the inauguration of the "Thach Weave," a multi-plane maneuver that three of the F4Fs used to neutralize the A6Ms' advantage in maneuverability. The F4F leader estimated that 15 to 20 of the CAP engaged them. While this fight was going on, the *Hiryu* and *Soryu* each added three A6Ms to the CAP, raising the total committed to 42.

The torpedo attack took 29 minutes to develop from first sighting by the IJN until first torpedo drop at 1035, with the first drop coming after the dive bomber attacks. Five of the 12 TBDs survived long enough to drop on *Hiryu* (for no hits), but four of those

[76] Lundstrom, *First Team*, 343. Parshall and Tully, 210-4.

five were lost after attacking. By then, the SBDs had attacked and three IJN carriers were in flames.

The SBDs began their attack about 1022, shortly after the TBDs reported that they were beginning their attack runs. The results were devastating. The SBDs were not spotted until just before they began their dives.[77] Twenty-eight SBDs attacked *Kaga*, scoring five hits (three or four from 500 pound bombs and one or two from 1,000 pounders) and five damaging near misses. Thirteen SBDs hit *Soryu* three times with 1,000 pounders. *Akagi* was attacked by only three SBDs, but they scored one hit and two damaging near misses.

These hits would have been devastating enough under normal circumstances, but circumstances were not normal. All of the IJN carriers had been readying a strike, with armed and gassed aircraft and ordnance packed in their hangers. As the bombs exploded among the strike planes the hangers became infernos.[78] Even the single bomb that hit *Akagi* was enough to doom her.[79]

None of the *Yorktown* SBDs were intercepted. Of the *Enterprise* SBDs only one-third reported being intercepted, all after they had attacked. SBD losses over the task force amounted to two or three, with *Kaga's* AA definitely splashing one and another

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[77] A *Hiryu* look-out spotted SBDs over *Kaga* at 1019.

[78] But for the readied aircraft, it is possible that all of the carriers would have survived. *Akagi*, with only a single hit, likely would have remained afloat although a near miss that ultimately caused her rudder control to fail would certainly have taken her out of action and could have prevented efforts to tow her clear. *Kaga* had received so many hits that she would certainly have been out of the action, but given that most of the hits were from 500 pound bombs, she could well have survived as well. *Soryu* might have been finished by her three 1,000 pound bomb hits; four hits did for her near-sister *Hiryu,* but *Shokaku* had survived three such hits and was later to survive four more. *Soryu* was a lighter ship with less armor, but it appears that the hits she took did not penetrate her magazines or propulsion spaces. Parshall and Tully make a convincing showing that the strike aircraft were still in the hangers and not on the flight deck ready to launch.

[79] Although even the near miss that caused her rudder to jam could also have doomed her even without fires and explosions from armed aircraft. Similar damage led to the *Bismarck* and the *Hiei* being lost.

accounted for by an A6M.[80] It appears that 10 A6Ms fell in combat with the *Yorktown* contingent and the *Enterprise* dive bombers, including the four that were downed by the TBDs' escorts. One additional A6M ditched due to battle damage and another was shot down by AA.[81]

The final raids took place in the late afternoon. Twenty-four SBDs from *Enterprise* sighted *Hiryu* about 40 miles off and maneuvered for position. They began their dives about 20 minutes later, with the IJN task force having spotted them only four minutes before they began their attacks. Thirteen or 14 A6Ms were on CAP duty, dispersed at three different altitude levels and in different sectors around *Hiryu*. They did manage to down one SBD before it could attack, but the 21 dive bombers scored four 1,000 pound bomb hits that finished *Hiryu*.[82] Two more SBDs fell to A6Ms as the dive bombers withdrew, the last successes of the IJN CAP. When 16 SBDs from *Hornet* arrived 15 minutes later, *Hiryu* was so clearly finished that they bombed escorting heavy cruisers instead. They were not intercepted, despite the fact that some CAP was still airborne. The final attack on the IJN carrier force – now devoid of functioning carriers – came shortly after the *Hornet* aircraft departed. A dozen B-17 bombed without result: six flying from Midway and another six from Hawaii, but both groups arriving coincidentally at the same time. No B-17s or CAP fighters were lost.[83]

To restate the obvious, the most striking thing about CAP performance is the disparity in the CAP's effectiveness against torpedo bombers and dive bombers. The IJN task force was attacked by 51 torpedo bombers in the course of the morning. The CAP accounted for 34 of these before they could attack, while CAP and AA shot down another seven after they attacked. Less than one-third of attacking torpedo bombers

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[80] Eighteen of the *Enterprise* SBDs failed to return, but many were likely lost to fuel starvation as they had searched to and beyond their maximum range. All of the *Yorktown's* SBDs returned.

[81] Lundstrom, *First Team*, 349-64. Parshall and Tully, 216-28, 232-43, 500-05.

[82] Two SBDs bombed a battleship, but missed. *Hiryu* may have had some armed and gassed strike planes in her hangers at the time of the attack, as she was planning a dusk strike on the USN carriers with the few strike aircraft remaining to her. If so, half the number hits would probably have finished her.

[83] Lundstrom, *First Team*, 411-5. Parshall and Tully, 323-7.

survived to drop on a target. Over the same time, 72 dive bombers attacked the task force. CAP killed only six of these before they could bomb (all SBD-2s) and only four or five afterwards. Even with 15 minutes warning, the CAP could only splash six out of sixteen SBD-2s of the Marine Air Group before they attacked, and those SBDs were at relatively low altitude conducting glide bombing attacks that should have been easier to intercept. Performance against the obsolescent Marine SB2Us was even worse, with none downed before they attacked despite their being intercepted.

Why such a discrepancy? There were a number of reasons, some more obvious, some less so.

First, dive bombers were far harder to spot than torpedo bombers. This can be seen in the performance of USN and IJN look-outs and fighters.[84] The USN had a hard time getting a visual spot on dive bombers at Coral Sea, and would again in other battles. Spotting torpedo bombers, particularly US torpedo bombers, required that a sharp look-out be kept on and just above the horizon. USN torpedo bombers had to make their approach runs from low altitude, simplifying the problem of where to look for them and keeping them under any cloud cover. They also had to make a slow approach to stay within the dropping parameters of the finicky Mk 13 Mod 1 torpedo, TBDs could not move much faster than the maximum dropping speed in any event. Either way, slower approaches meant more time for look-outs to spot the bombers before they could close.

By contrast, dive bombers approached at altitude. Spotting them required searching much more of the sky. They could also more easily use cloud and sun as cover for their approach. And they often attacked more quickly than torpedo bombers, giving less time for look-outs to spot them.

[84] As noted above, radar was no panacea here. The USN's air search radars in 1942 could give early warning of a dive bomber attack, when the bombers were miles out, but it could neither give precise altitude information or easily track high flyers as they got closer to the radar. Later in the war, the USN developed radars precisely to address shortcomings. Until then, dive bombers spotted on radar 30 or 40 miles from a task force might go unseen until they began to attack.

Attacking at altitude conferred other advantages on dive bombers. CAP fighters at low altitude could engage torpedo bombers more rapidly than they could dive bombers. The A6M2 was a ferocious climber, but still took more than seven and one-half minutes to climb to 20,000 feet. It could cover 20,000 feet horizontally in less than 45 seconds. Lower targets were almost always easier to engage than higher targets, which meant that there was a much greater chance that they would be engaged before they could attack, and that the CAP fighters would have more time to shoot down the strikers. The IJN tended to keep a portion of its CAP on deck until a strike was sighted. This exacerbated the differences in the CAP's ability to hit low targets versus high targets.

Altitude gave dive bombers yet another benefit. IJN CAP relied heavily on visual sighting by look-outs on the task force ships. When screen ships sighted incoming raids, they would make smoke or fire their guns in the direction of the raiders. The CAP was then supposed to see the smoke or shell splashes and use them to vector onto the attackers. These crude techniques were necessary because IJN aircraft radios were notoriously unreliable. They were much more effective in pointing the way to a torpedo bomber attack than they were in designating incoming dive bombers.

SBDs were also tougher targets than TBDs, the bulk of the torpedo planes that the IJN CAP faced. The SBD-3s carried self-sealing tanks and significant armor, and at least some of this protection may also have been retrofitted into the SBD-2s present at the battle. Some of the TBDs may have had some armor added in the field, but their fuel tanks were unprotected.[85] The TBDs were potentially vulnerable to even the 7.7 mm machine guns of the A6Ms, but the SBDs would have been much harder to bring down, likely requiring multiple 20 mm cannon strikes before falling. This would particularly have been a problem once the A6Ms ran low on cannon ammo, and we have seen that the A6Ms had less than seven seconds of fire for each cannon. Of the 40 A6Ms that records show were aloft for the big USN carrier strike, all but 12 had probably already engaged the *Enterprise's* torpedo bombers and many of those would have also fought

[85] I know of no such armor modifications, but they may have gone unreported. *Hornet's* TBD squadron did modify their TBDs to the extent of giving the rear gunner two .30 caliber machine guns rather than one.

the *Hornet's* TBDs and escorts. Low or no cannon ammo would have hampered the CAP's ability to down SBDs before they attacked. It also helps to account for the low casualty toll among the SBDs as they withdrew.[86]

Particularly suggestive of the A6M's relative impotence once it ran through its cannon ammo are the losses to the Enterprise's TBDs. The majority of the nine TBDs lost fell to nine newly launched A6Ms, while 30 (most of which had already fought) accounted for the remainder. This implies that A6Ms with cannon ammo were at least four times as effective versus vulnerable TBDs than those without.

One last point should be made about the CAP's effectiveness versus torpedo planes. Up to the Battle of Midway, the aerial torpedo had been the preeminent weapon in the war of aircraft versus ships. It had sunk the battlecruiser *Repulse* and the battleship *Prince of Wales* in the open sea, the battleships *Oklahoma, West Virginia*, *California,* and *Conti di Cavour* in harbor, had caused the beaching of the battleships *Littorio* and the *Caio Duillio*, and had doomed the battleship *Bismarck*. Dive bombing, on the other hand, had failed to sink a single battleship or fleet carrier. The IJN's aerial torpedo was a devastatingly effective weapon that had already accounted for one carrier and would cripple two others before 1942 was over. It should not be surprising, then, that the IJN was inclined to focus both operational doctrine and tactical decisions on countering torpedo bombers more than dive bombers. Not only were torpedo bombers easier to counter, the IJN likely thought them to be the more destructive and decisive force.

There were many reasons why the IJN CAP was as effective against torpedo bombers as it was ineffective against dive bombers. But even crediting the IJN CAP with

[86] I suspect that the A6M's limited supply of cannon ammo also played a role in the IJN doctrine of bringing at least some CAP back on board soon after it fought. For example, the *Kaga* fighter trio of Yamaguchi Hiroyuki, Toyoda Kazuyoshi, and Bando Masahi fought three times on 4 June. Their first mission overlapped the first torpedo plane attack, and lasted for 30 minutes. Their second mission coincided with the first Marine dive bomber and B-17 attacks, and lasted for 55 minutes. The third began as the main USN carrier strike was approaching, with Yamaguchi and Bando both being shot down and killed in that attack. An A6M had enough endurance to fly a three hour patrol easily. Considerations of controlling the CAP also played a role in keeping A6Ms on deck ready to launch, but it is logical to think that the need to re-arm CAP aircraft after engagements also played into the desire to cycle CAP fighters through their carriers after they fought.

performance equivalent to the USN CAP that day, the IJN was still in for a decisive defeat. We have seen that the USN committed 20 F4Fs to knock down or knock out 10 D3As before they could attack, in circumstances where the USN CAP did not have to worry about going after torpedo bombers at the same time. Granted that the IJN fighters intercepting the SBDs would not have to deal with escorts, but we have also seen that the escorts accompanying the D3As were almost entirely ineffective. This was an exceptional performance by the F4Fs.

Assume that the A6Ms did as well. Assume that they could shoot down SBDs as easily as F4Fs could shoot down the more fragile D3As. Assume that they would focus exclusively on the dive bombers and ignore the torpedo bombers attacking at the same time. Assume that they had as much time to pummel the SBDs as the F4Fs had to maul the D3As.[87] If 40 A6Ms had managed to engage, the toll would have been 20 SBDs down or aborted with damage. Twenty-five SBDs would have been left to bomb the IJN carriers. Historically, on this day one in five SBDs hit its carrier target solidly, with 12 of the 13 hits wrecking the carriers' hangers. That would leave about five bomb hits to spread among the three IJN carriers. Even if the distribution was four hits on one carrier and one on another, it seems very likely that both would have been lost. A distribution of hits across three carriers would still easily have resulted in the loss of all three, and would very likely have knocked out of action any carrier that managed to survive. Even in the best likely circumstances, the CAP had an impossible task in attempting to shield the carriers from substantial harm.

Why would a relatively few bomb hits still destroyed the IJN carriers? It was because the IJN carriers were as vulnerable as they possibly could be to the precise type of weapons that the SBDs were wielding, so vulnerable that a single hit could and did result in catastrophe. This was a result of the tactical situation in which the IJN found itself. When it had sent an early morning strike to pound Midway the carriers had reserved their remaining aircraft for an anti-shipping strike if any USN ships turned

[87] I do not seriously contend that all of these conditions could have applied. In the absence of radar and effective fighter direction, the IJN CAP could not have intercepted the SBDs with the time margin that the F4Fs had. Experience showed that SBDs were much harder to bring down than D3As, and, for that matter, that dive bomber defensive fire was much more effective against A6Ms than against F4Fs. Making all of these favorable assumptions demonstrates the point that the IJN CAP could not have saved the day.

up. When they did not, and the Midway strike force communicated the need for a second strike on Midway, the carrier began to rearm the strike aircraft in their hangers with ordnance to use against the Midway land base. The subsequent discovery of carrier *Yorktown* prompted the carriers to reverse course and switch their available strike aircraft back to anti-ship weapons. The task of readying these aircraft for a strike against *Yorktown* was largely complete when the USN carrier SBDs arrived overhead. At that moment, the hangers of the IJN carriers were crammed with fully armed and gassed strike aircraft, littered with discarded ordnance not yet stowed back into the bomb magazines, and lined with aviation gas fuelling systems still charged with aviation gas. At that moment, the SBDs were tipping over into an attack that would shower three of the IJN carriers with high explosive bombs primed to spread fire and shock waves through those hangers.[88] As the example of *Akagi* shows, even a single 1,000 pound bomb hit in these circumstances was enough to cause an uncontrollable conflagration. Even a controllable configuration in these circumstances would do enough damage to take a carrier out of action.

The status of the IJN carriers make a discussion of damage control largely irrelevant. All of the bombs detonated above the armor belt, leaving the propulsion spaces and the magazines initially unaffected, but the fires that were ignited would eventually have killed anyone in the propulsion spaces and detonated any magazine that was not flooded. Fire-fighting would have been an impossible task given the fuel for the fires. The example of the USN carrier *Franklin* is instructive here. Late in the war, *Franklin* took a 550 pound bomb in her hanger spaces while she had fueled and armed aircraft on deck and in her hanger. She had two aviation gas fuelling systems, one of which was active. Even with state-of-the-art damage control systems and processes, fire swept through the *Franklin*, killing hundreds of her crew. She survived, but only just, and was out of the war for good. The IJN carriers were in a worse material condition

[88] Based on their effects, USN high explosive bombs were probably fused so that they exploded shortly after impact. The brief delay would permit the bomb blast to penetrate the flight deck and detonate in the hanger deck below. See Parshall and Tully, 244-61 for particulars of the damage suffered by *Akagi*, *Kaga*, and *Soryu.* D3As carried a mix of high explosive and semi-armor piercing bombs. Their high explosive bombs were fused to explode immediately on impact, maximizing their effect against topside AA mounts. The semi-armor piercing bombs had delayed fuses and thicker bomb cases meant to let them punch through an armored deck before exploding. There is no evidence, however, that any of the SAP bombs actually penetrated the armored decks of the USN carriers.

than *Franklin* when she was hit, with more ordnance lying in more enclosed spaces and fewer damage control resources to draw on. With examples such as this, one can see why the IJN carriers were uniquely vulnerable.

Concentration was of no help to the IJN in the particular circumstances of the main USN carrier attack, but it clearly did help in the defeat of all earlier attacks through the concentration of the four carriers' fighters. It is harder to know whether dispersion would have been the better tactic in the face of the USN dive bomber attack. On the face of it, having three dive bomber squadrons attack only one carrier seems better than having them attack three, given that each squadron could destroy one carrier in an attack. Even with a chance that each of the squadrons found a separate one carrier task force to attack, the result would be no worse than three carriers sunk. But the situation rapidly gets more complicated, as two additional USN carrier squadrons sought the IJN carrier task forces but failed to find them. If increasing the number of task forces means increasing that chance that an individual dive bomber squadron would find a task force, then it becomes much less clear that dispersion was a better tactic.[89] Add to this the need to screen each task force against submarine attack and the desire to coordinate strikes from all the carriers, and the benefits from dispersion become more dubious. All this said, the IJN adopted in future battles a modified form of dispersion, placing a vanguard force in front of the main carrier force in the hope that it would divert USN strikes from the carriers.

Out-ranging was of some help, but obviously not decisive. A number of USN squadrons were operating at the limits of their endurance. The TBDs were flying to their maximum ranges, but they largely succeeded in finding the IJN carriers despite that. The SBDs were operating within greater margins, with two of five squadrons failing to contact the IJN carriers for the main attack and another two operating so far into their margin that some of their aircraft probably failed to return because of it. But

[89] Some math could be used to crunch this, but not by me. The Allied organization research groups did conclude, in a different context, that fewer larger convoys were better than more smaller ones in combating U-boats. That conclusion was based in large part on the greater chance that at least some of the smaller convoys would be spotted while one large convoy had a better chance of going undetected. W. J. R. Gardner, *Decoding History: The Battle of the Atlantic and Ultra* (Annapolis, Maryland: Naval Institute Press, 1999), 70-2.

three squadrons was enough to kill three IJN carriers and give the USN a decisive margin for the rest of the battle.

IJN anti-aircraft fire continued to have minimal physical effect on the enemy. Its morale effect was largely speculative. The IJN could point to a single clear success, when *Kaga* shot down an SBD before it could attack.[90] The lack of success against the TBDs is particularly notable. These were fairly large, fairly slow targets, forced into long predictable approaches and lacking the protection of self-sealing fuel tanks. The IJN should have (and likely did) expect better results than it got from its AA guns.

In summary, a great truth of the Midway battle was that IJN CAP and AA could not prevent dive bombers from scoring. Given enough dive bombers – and something between 18 and 45 was enough – some bombs would land on carriers. The question then became what the effect of those bombs would be. In the circumstances, the effect was catastrophic.

Battle of the Eastern Solomons

The Battle of the Eastern Solomons saw IJN carriers *Shokaku* and *Zuikaku* pitted against the USN carriers *Saratoga* and *Enterprise*. The main engagement took place on 24 August 1942. It had its origins in the Allied landing on Guadalcanal Island earlier in the month, and specifically in a Japanese attempt to take a convoy of reinforcements through to that island. Supporting the Japanese effort was light carrier *Ryujo*, which launched a desultory air strike on Henderson Field, the Allied airfield on Guadalcanal, with the meager forces at her disposal. As we will see, *Ryujo* operated apart from the two big fleet carriers.

The IJN fleet carriers did not get a good fix on their USN counterparts until late in the day, and then only by making the assumption that a search aircraft reporting fighter attacks had contacted the USN carriers and was just where it should have been at the

[90] This success was balanced by IJN AA downing a CAP A6M.

moment of the report.[91] For this battle, the IJN decided to send out two strikes each of 27 D3A dive bombers while holding the carriers' torpedo planes in reserve.[92] The first strike was escorted by 15 A6Ms, but five of the escort peeled off to engage SBDs snooping the IJN carrier force.

Eastern Solomons: the USN Experience

USN radars saw the raiders at 88 miles range and again 13 minutes later at 44 miles range. The strike saw the USN carrier task force about five minutes after the second radar sighting, 40 miles away under clear skies. Four of the A6Ms approached ahead of the main strike on a fighter sweep, while the other six stayed close to the D3As.

The IJN strike found the USN carriers with all of their F4F-4 fighters present. Seven had been detailed as escorts for a strike just in the process of departing, but all were made available for the CAP. At the time of the second radar sighting, the *Saratoga* and *Enterprise* had a combined CAP aloft of 42 F4Fs plus an additional 11 readied on the two carriers. Four of the aloft CAP were low on fuel and about to land. Eleven had already been sent out along the approximate bearing of the strike with 16 more following close behind. The carriers maneuvered independently, each with its own screen and with about 10 to 15 miles separating the carriers, but pooled their CAP. The IJN strike saw both carriers in the prevailing excellent visibility, 16,400 feet below. The strike leader decided to hit both carriers, allocating 18 D3As to the *Enterprise* (the closer target) and nine to the *Saratoga*. The old problem of altitude bedeviled at least eight of the CAP fighters. They were forced to watch the strike pass overhead, but one of them tempted an A6M of the fighter sweep into a fight and downed it. Four more F4Fs tried to intercept the strike before it could close on the carriers, but were jumped by the dive bomber escorts and lost one of their number.

[91] As mentioned above, radar was very effective at allowing fighter direction officers to vector CAP onto single snoopers.

[92] These were probably D3A2 models, with more powerful engines but less range, and still lacking protection or the ability to carry 1,000 pound bombs.

The D3As began their dives about 26 minutes after the second radar sighting, hotly pursued by another four F4Fs. These shot up the first three D3As to dive, downing one which missed with its bomb. AA shot down three D3As in their dives, with one of the downed aircraft hitting *Enterprise* with its bomb. Before the first nine D3As could finish their attack, four of the F4Fs that were originally passed by the strike got enough altitude to attack the second group of nine D3As waiting to dive in. These F4Fs lost one fighter to AA, but downed a D3A before it could bomb accurately.

Not all of the first wave of 18 D3As bombed *Enterprise*. Three of the group bombed an escorting battleship instead, a puzzling choice of target because the bombs that the D3As were carrying would have been extremely unlikely to do any real damage to such a ship. Perhaps they were attempting to suppress the fearsome AA that the battleship was producing, or perhaps they were pressed by the CAP and decided to attack the closest available target as quickly as they could. None of the IJN crews survived to say, as one D3A fell to AA, one to a combination of AA and a CAP F4F, and the third to CAP alone. All of the D3As bombed, but none hit.

The 13 D3As that managed accurate dives on the *Enterprise* did better. They scored three hits: two with HE bombs, one of which ignited ready ammunition in two of the five inch gun mounts, and one with a semi-armor piecing bomb that pierced no armor but did cause extensive damage below decks while disabling *Enterprise's* aftmost aircraft elevator.

The nine D3As detailed to attack *Saratoga* not only had further to travel, they had to make the journey without fighter escort. They were attacked by a fresh section of three F4Fs well short of their target. When one of the overflown F4F sections got altitude and added four more F4Fs to the fight, the formation leader decided that the better course was to attack *Enterprise*. A further four F4Fs tried to join the fight before the D3As could dive, but four escorting A6Ms arrived in time to disrupt further CAP attacks on the bombers. During this battle two D3As went down to the F4Fs while three F4Fs were lost to either the A6Ms or AA. The F4Fs may have accounted for an A6M as well.

All seven of the remaining D3As bombed targets, with three targeting *Enterprise* and another four her escorting battleship. None hit, with one of the D3As attacking the carrier shot down by the CAP after its attack.

Now the IJN strikers had to withdraw. Seventeen D3As and eight A6Ms started back to their carriers, but only nine D3As and four A6Ms would return to their carrier decks. An additional dozen F4Fs joined the fight at this time, some launched from *Saratoga*, some returning after having missed the IJN raid as it came in. They likely downed both A6Ms lost close to the USN task force and the bulk of the six D3As lost in the same area. Two more D3As succumbed to five CAP F4Fs when more distant from the USN carriers. These fighters had also missed the IJN strike on the way in but had continued out nearly 100 miles before reversing course. Two ditched A6Ms and two ditched D3As completed the losses for the IJN; two-thirds of the strike aircraft and half of the escorts failed to return.

The second IJN wave failed to find either USN task force. In a day in which both sides were plagued with communication failures, the leader of the second strike failed to copy sighting reports that would have sent the strike to the USN carriers. It was a good thing for the USN that no new attack materialized, as it likely would have arrived when the CAP was comparatively thin and the *Enterprise* was circling at low speed with a jammed rudder. It was a rare miss for an IJN carrier strike.[93]

The CAP response to the IJN strike was disappointing. The CAP had nothing like its success at Midway, where one D3A was taken out of action before bombing for every two F4Fs committed to the defense. In this battle, 49 F4Fs accounted for only four D3As before attacking. The main reason for the poor showing was a number of the CAP flights being too low to intercept the strike before it struck, although the escorts played a role as well. The only reason to keep the CAP low once the strike was spotted was to counter torpedo bombers; apparently the IJN was not alone in making a priority

[93] John B. Lundstrom, *The First Team and the Guadalcanal Campaign: Naval Fighter Combat from August to November 1942* (Annapolis, Maryland: Naval Institute Press, 1994), 129-57.

of defeating the torpedo bomber menace.[94] The poor performance led to a thorough review of USN CAP practices and procedures. All that said, the CAP did play an important role in forcing the IJN strike to settle for attacks on only one carrier, and likely also played a role in forcing some of the D3As to attack *Enterprise's* escorting battleship rather than the carrier herself.

USN anti-aircraft fire was showing signs of improvement even though it was not yet accounting for large numbers of attackers. *Enterprise* had both a battleship and an anti-aircraft cruiser in her screen, as well as six destroyers and a heavy cruiser. They put up a huge volume of AA fire, although it is hard to judge its effect. The D3As scored a higher percentage of hits than they did at Coral Sea, but lower than their performance at Midway, where early hits on *Yorktown* suppressed some of her AA guns and reduced her speed. And in addition to the heavy AA fire, a number of the dive bombers were harassed by CAP fighters when in their dives.

Concentration seemed vindicated in this fight. While pooling CAP resources did not lead to the IJN strike being defeated outright, it prevented the strike from attacking more than one carrier. The pooling of CAP resources that concentration allowed thus overcame the risks of putting carriers close together, while the additional losses inflicted by the combined CAP was a bonus in favor of concentration.

Armor and damage control was once again put to the test and passed with flying colors. None of her three bomb hits seriously threatened *Enterprise*. Her steering casualty was actually the result of her damage control efforts, when fire-fighting foam and water shorted out her electric steering motors. The steering failure was concerning, and could have been serious had the ship come under attack, but it was dealt with in fairly short order.

Eastern Solomons: the IJN Experience

[94] Prior to a strike being detected, CAP fighters might be kept low to conserve the pilots' oxygen supplies or the planes' fuel.

The USN carriers were unable to manage a strike at the IJN fleet carriers in the Battle of the Eastern Solomons.[95] Their main strike effort was directed at light carrier *Ryujo*, arriving about an hour before the IJN strike on the USN carriers. The strike consisted of 29 SBDs in two squadrons and 7 torpedo-armed TBFs, cruising with the SBDs at 15,000 feet and the TBFs 3,000 feet below. It attacked about 14 minutes after sighting *Ryujo* and her small group of escorts. Initially, the strike leader assigned one squadron to attack *Ryujo* and split the second squadron between *Ryujo* and an escorting heavy cruiser.

Ryujo saw the strike coming. Launching two A6Ms to raise her CAP to seven, but none of the CAP intercepted the SBDs on the way in to their attacks. Four A6Ms harassed the SBDs of the second squadron assigned to bomb *Ryujo*, but only after they had bombed. The part of the second squadron switched targets to *Ryujo* after the first SBDs to bomb failed to score against the twisting light carrier. The six SBDs making the switch reported attacks by four A6Ms before they attacked, probably aided by the time it took them to switch targets. Despite the CAP attacks, they scored hits on the carrier. *Ryujo* is estimated to have taken three 1,000 pound bomb hits and at least one damaging near miss. Even without armed aircraft on board, those three hits probably doomed *Ryujo.*

Her fate was sealed by the TBF attack. Flying a far different attack profile that the TBDs at Midway, the big TBFs dove in from 12,000 feet. *Ryujo's* CAP had previous splashed one two scouting TBFs that had attempted horizontal bombing runs on the carrier, but the three A6Ms that intercepted these attackers got no such result. Five of the torpedo bombers made an anvil attack on *Ryujo* that netted one hit, while two others attacked and missed her accompanying heavy cruiser. The USN strike retired without loss. The CAP took no losses either.[96]

The CAP effort here was a faint hope against the force arrayed against *Ryujo*. They were even less effective that could have been hoped, but even if they had been more

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[95] Two SBDs on search did dive bomb *Shokaku*, but missed. They escaped despite being intercepted by five A6Ms escorting a strike.

[96] Lundstrom, *First Team: Guadalcanal*, 119-22.

effective they had little chance of saving the carrier. AA fire was barely a factor. As with the *Shoho,* the *Ryujo's* best hope lay in maneuver, and that was unlikely to shield her given the sheer number of bombs that she had to dodge. Her small size and lack of armor meant that any hit could have been fatal, and the number of bomb and torpedo hits that she did take amounted to overkill. The only solace for the IJN was that the little carrier had drawn off forces that otherwise might have been used against the fleet carriers, thus providing a positive example of a modified form of dispersion. We will see this again.

Battle of Santa Cruz

The Battle of the Santa Cruz Islands was the last great carrier battle of 1942, and would be the last time that carriers fought carriers until 1944. It was also the greatest IJN offensive effort since Midway, and like Midway was planned to feature four fleet carriers and a light carrier in the battle area. The October operation was meant to cover a large troop and supply convoy to Guadalcanal, bombard Henderson Field into submission, and crush the retreating Allied forces once the Imperial Japanese Army took the airfield. *Shokaku*, *Zuikaku*, *Hiyo*, and *Junyo* were the four fleet carriers scheduled to participate, although *Hiyo* was forced to drop out due to an engine fire.[97] *Zuiho* was the light carrier, although in a different role than she had at Midway. Before, she provided aerial cover for the invasion forces. In this battle she would provide fighter cover and search capability for *Shokaku* and *Zuikaku* and steam together with them.

The USN was running out of operational carriers by this time. *Lexington* had gone at Coral Sea and *Yorktown* at Midway. *Wasp* had been sunk by an IJN submarine in September and *Saratoga* had been torpedoed and damaged in the same month. *Ranger* was considered too small, too slow, and too lightly protected for service in the Pacific. That left only *Hornet* and *Enterprise* on the front lines. *Hornet* was in the area as the IJN efforts began, while *Enterprise* came out from Pearl Harbor to join her.

[97] Hiyo and Junyo were poor fleet carriers. They were merchant liner hulls converted to carriers while on the ways. They lacked speed and protection and carried truncated air groups.

Carrier air group composition had changed for both the IJN and USN carriers. At the time of the battle, *Shokaku* and *Zuikaku* had 38 operational A6Ms, 43 operational D3As, and 44 B5Ns ready for operations. That was fewer aircraft overall than the two carriers had at Eastern Solomons, but a higher proportion of B5Ns. *Junyo* had 20 A6Ms, 17 D3As and 7 B5Ns ready for duty. The *Enterprise* and *Hornet* had 64 F4F-4s, 47 SBD-3s and 26 TBF-1s available, reflecting increases in USN carrier fighter complements.[98]

After several days of bombardments, air strikes from and against Henderson Field, postponed IJA assaults and failed IJA assaults, the opposing carrier forces squared off for their fight on 26 October. The IJN carriers battered the USN carriers with a series of strikes.

Santa Cruz: the USN Experience

The first IJN strike was the largest IJN effort in any of the carrier battles since Coral Sea. The *Shokaku*, *Zuikaku*, and *Zuiho* sent 64 aircraft winging towards the *Enterprise* and the *Hornet*: 21 D3As, 22 B5Ns (two as unarmed search and contact aircraft), and 21 escorting A6Ms. By the time the strike approached the USN carriers, nine of the A6Ms had peeled off to engage a USN strike that they had seen headed in the opposite direction. That left four A6Ms with the torpedo bombers and eight with the dive bombers.

The weather over the USN carriers was partly cloudy but thickening. The two carriers cruised in separate task forces about 10 miles apart. *Hornet* was operating 15 CAP F4F-4s as the strike approached, and *Enterprise* had another 22 F4Fs aloft. The *Enterprise* CAP was at 10,000 feet to conserve oxygen in the belief that radar would

[98] Lundstrom says that the USN carriers had 74 F4Fs and 72 SBDs available, but only operated the numbers shown during the battle. Apparently, some aircraft and crews were held in reserve. Lundstrom, *First Team: Guadalcanal*, 348.

give them enough time to climb to attack altitudes, and it appears that the *Hornet* CAP was also below the altitude of the IJN strike.[99]

Unfortunately for the USN, radar and communications failures resulted in much less notice of the IJN strike than had been anticipated. While a heavy cruiser's radar saw the IJN strike about 70 miles out, word of this did not reach the carriers. Their first notice of the raid came from a *Hornet* sighting report that put the strike about 35 miles away. The strike had actually seen *Hornet's* task force two minutes before *Hornet's* radar saw it. The strike had been cruising with the B5Ns at 14,000 feet, the D3As at 17,000 feet and the high escort at 21,000 feet, but it quickly began to descend as it went into the attack.

The *Hornet's* FDO sent eight fighters to intercept the strike, followed shortly by the remainder of *Hornet's* CAP. Almost all of the Hornet's CAP intercepted the D3As, climbing as the D3As dove down to their attack altitude of 12,000 feet. Twelve of the 15 actually fought, accounting for four D3As before they could bomb, damaging a fifth that later crashed before bombing, and causing a sixth to abort. The toll was four F4Fs to the eight escorting A6Ms and, remarkably, one F4F to a D3A.

While the *Hornet's* CAP was taking on the dive bombers, 21 of the 22 *Enterprise* CAP entered the fray. At first, they concentrated on the torpedo bombers, splashing one before it could attack, but they also engaged the D3As during and after their attacks.

The D3As and B5Ns managed a coordinated attack on *Hornet* starting about 15 minutes after the *Hornet's* radar reported the strike. In fact, a photo from the strike actually shows a D3A and a B5N in the same frame during their attacks. The dive bombers attacked in three groups. Of the first group, six survived to begin their dives but only four bombed. One was lost to AA fire before bombing, one apparently to

[99] Officially, it would take an F4F-4 about seven minutes to climb from 10,000 feet to 20,000 feet. In practice, it probably took longer. An altitude of 20,000 feet should give the fighters a comfortable margin for attacking IJN strike aircraft, but might still put them under the strike's escorts. By contrast, an unladen SBD-3 would take almost twice as long to make the same climb – hence limiting its occasional fighter role to low level interceptions.

damage from the F4Fs before it could bomb, and one was nailed by AA fire after it bombed. Three of the four bombs hit *Hornet*.

Four bombers from the second group managed to bomb *Hornet*. At least one of their original number fell to *Enterprise* CAP before diving, but that aircraft may have already been damaged by *Hornet* fighters. None of the bombers bombed successfully; one did crash *Hornet* in flames but without its bomb detonating.

The third group of D3As began bombing about four minutes after the first. The delay allowed the *Enterprise* CAP to intercept them just before they bombed. The CAP killed one D3A before it could attack; the remaining four survivors all bombed *Hornet* for no hits. Two of them fell to *Enterprise* CAP while withdrawing, while a D3A crashed *Hornet* shortly after the dive bombers have finished their attacks.

The torpedo-armed B5Ns bored in while the first group of D3As was attacking, causing *Hornet* and her screen to divide their AA fire. The B5Ns split into two groups to execute an anvil attack on *Hornet*, with 11 on one side and nine on the other.

The larger group had the most success. As their four fighter escorts fought F4Fs, losing one of their number, nine of the 11 B5Ns headed for *Hornet*. Of these nine two were downed by AA before they could drop and AA claimed two after attacking, but the seven that did drop scored two hits. Two B5Ns opted for a heavy cruiser after failing to get a good attack angle on *Hornet* due to her maneuvers. One of these two was tagged by AA before it could drop. The other missed. A fifth B5N from this group of 11 was downed by a SBD as it tried to withdraw.

The second group of nine B5Ns lost one of their number to the *Enterprise* CAP, as recounted above, and had another abort with damage from a *Hornet* fighter. A third B5N aborted with damage from the *Enterprise* CAP. A fourth crashed from a combination of AA fire and damage from the same *Hornet* fighter. A fifth was a victim of AA before its drop. The remaining four all dropped on *Hornet*, but none hit. Shortly after the attack, a B5N attempted to crash-dive the carrier, but fell into the sea short of its target.

In the midst of all the fighting, eight A6Ms fought a mixed *Hornet-Enterprise* group of seven F4Fs. Two F4Fs and two A6Ms were shot down. The only other IJN fighter loss in the strike was one A6M lost from the torpedo bomber escort. This brought total IJN losses to 11 D3As, 10 B5Ns and three A6Ms. Thirty-six F4Fs were committed to the defense of the *Hornet*. All 15 of the *Hornet* fighters fought, while 17 of the 21 *Enterprise* fighters committed to the fight shot at an enemy. AA fire was a particularly potent force in this engagement, accounting for seven of the B5Ns (counting two half-victories shared with the fighters) and two of the D3As.

The one HE and two semi-armor piercing and bomb hits on *Hornet* caused heavy casualties among the AA and damage control parties, but did the ship no serious damage. Once again, the SAP bombs did not penetrate the carrier's armored deck, and the HE bomb was only capable of causing local damage. The two D3As that crashed the *Hornet* caused fires, but these could be controlled. The two torpedo hits, however, caused grave damage. Both torpedoes hit on *Hornet's* starboard side, flooding propulsion spaces and causing the carrier to glide to a halt without power.[100] Unless *Hornet* could get moving again, she would be a sitting duck for the next IJN strike.

The next strike was not long in coming, being spotted less than 15 minutes after the last attacks from the first strike. This strike actually came on as two waves, the first of 19 D3As and five A6Ms and the second of 16 torpedo-armed B5Ns, one B5N search and contact plane, and a four A6M escort. With these strike aircraft, *Shokaku* and *Zuikaku* had shot their bolt. The strike was first spotted by a heavy cruiser and battleship, but *Enterprise's* radar picked up the first wave only about 45 miles from her task force.

The second strike's objective was the undamaged USN carrier. The first wave saw *Hornet*, obviously crippled, just as *Enterprise's* radar spotted the raid. The D3As pressed on, spotting *Enterprise's* task force about seven minutes after her radar sighting of the raid. The dive bomber raid found *Enterprise* with eight F4Fs at altitude over the carrier and another 13 low. Altitude issues again plagued the CAP. The D3As were coming it at 17,000 feet, while the high CAP was apparently at 10,000 feet. Four

[100] Lundstrom, *First Team: Guadalcanal*, 386-407.

of the CAP were dispatched to make a distant intercept but missed the raid. Two of them managed to return in time to catch the D3As, downing one. But most of the CAP was well under the dive bombers and clawing for altitude when the D3As tipped over, about 15 minutes after *Enterprise's* radar first saw them.

What the CAP lacked, the AA fire from *Enterprise* and her screen supplied. The carrier had just been refitted with 16 extremely potent 40 mm automatic AA cannon, and these immediately proved their worth. AA fire downed the first four of the first seven D3As to dive, while none of the seven scored any hits. Three F4Fs that had climbed up from low altitude joined the fray as the D3As continued to dive in, dropping another D3A before it could attack and one more after attacking. AA fire continued to prove its worth, killing another three D3As in their dives. But the D3As also began to score, making two hits and a damaging near miss.[101]

The A6Ms apparently never engaged and the F4Fs did not pursue the departing D3As. The strike left 10 of its dive bombers behind: three down to the CAP and seven to the AA. One of the bomb hits passed through the bow structure of the *Enterprise* before exploding, doing little damage. The second hit was potentially much more serious, detonating in the ship's hanger were aircraft were being armed and fuelled. While the hit started fires, the hanger crews were able to jettison any aircraft in danger of adding to the flames. In this they were aided by *Enterprise's* open hanger structure, which permitted the crews to roll aircraft over the edge of the hanger deck and directly into the sea. The hit also had the more lasting effects, jamming the forward elevator in its up position.[102]

Enterprise's radar detected the B5N wave of the second strike about 20 minutes after the last of the D3As had attacked, although it took another five minutes for the radar plot to confirm that the sighting was an incoming strike. The CAP fighters were now

[101] It is difficult to judge the effect that the AA fire had on the D3As, other than to think that it was not positive. None of the D3As downed by AA scored hits, but all apparently were seen to drop bombs. It is unclear how many of these D3As were jettisoning their bombs *in extremis* rather than making normal attacks. Overall accuracy was worse than at Eastern Solomons but better than Coral Sea.

[102] Lundstrom, *First Team: Guadalcanal*, 408-16.

running low on both fuel and ammunition. It seems that none of them had landed since the first raid, when all but five had fought. Five had also fought in the second raid, with at least one of those five having fought both raids.[103] As the B5Ns swept in, *Enterprise* had 11 F4Fs climbing over her and another 14 orbiting close by at low altitude. Weather favored the raid, as it would be attacking through a squall quickly making up to the northwest of the *Enterprise* task force. It formed into two sections of eight B5Ns each before diving through the squall.

Eight of the CAP headed out to try to intercept the raid. Six of fighters (one without ammo) managed to contact one group of eight B5Ns and their A6M escorts, downing one B5N and crippling another before the four escorting A6Ms intervened. The A6Ms and the F4Fs dueled for a time, but neither side scored against the other. The B5Ns pressed on, with the crippled aircraft crashing a screen destroyer, one other B5N killed by *Enterprise* AA as it attacked from dead astern, and five others dropping on *Enterprise's* port quarter. The carrier managed to dodge all of their torpedoes, which had begun dropping less than 15 minutes after the raid was first seen on radar.

A low F4F and AA combined to splash a B5N from the other group of eight B5Ns. Two of the group attacked a battleship, with one of them being downed by AA before it could make an effective drop.[104] Five attacked *Enterprise*, with one killed by AA after attacking and two more falling to F4Fs while trying to withdraw. None scored any hits on *Enterprise*, although three of their torpedoes dudded against a screening heavy cruiser at the end of their runs.[105]

As with the other raids, the torpedo plane raid resulted in about half the strike planes lost over the USN task force. In this case, one B5N crash-dived a destroyer after damage, one was shared by CAP and AA, three went down to CAP, and three to AA

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[103] In addition to the obvious point that combat uses up ammunition, combat flying also consumes fuel at a rapid rate.

[104] This pattern of the last two torpedo planes in a large attack going for a screening vessel occurred in all but the smallest of four IJN torpedo attacks. It may be that the pilots were trained to go after screening ships if they could not get good attack angles on the primary target, and that a good angle got progressively harder to get as aircraft after aircraft attacked.

[105] Lundstrom, *First Team: Guadalcanal*, 416-26.

alone. No fighters were lost on either side, although six F4Fs and four A6Ms did tangle. But the headline to the last effort is that no torpedoes scored. Even one torpedo hit on *Enterprise* could have been an extremely bad result for the USN, depriving them of their last operational carrier in the Pacific.

While *Shokaku* and *Zuikaku* were done for the morning, *Junyo* also had an strike card to play. This took the form of 17 D3As and 12 A6Ms, which appeared on *Enterprise's* radar about 15 minutes after the last B5N of the previous strike left the immediate area of her task force. The radar sighting had the strike only 20 miles away, with the first D3As diving in only about six minutes after the radar sighting. Earlier warning would have made little difference, as most of the CAP was now very low on fuel and with little or no ammo.

None of the D3As were intercepted before they attacked, but all had to deal with low cloud cover that made target selection difficult and resulted in shallow dives through holes in the overcast. The first eight D3As to attack did manage to find *Enterprise* through a hole in the murk, but none of their bombs struck home. One damaging near miss opened some seams and caused some minor flooding. AA downed three of the D3As in their dives. None of the remaining nine dive bombers targeted *Enterprise*; four dove against a battleship for one hit while five dove against an antiaircraft cruiser for one hit (which passed right though the ship before exploding under her keel) and one damaging near miss. All nine attacked out of a low overcast that blunted the effectiveness of AA fire.

The D3As had a rougher time withdrawing at low level, where they were attacked by both CAP fighters and F4Fs returning from strike escort duties, and even SBDs and TBFs. Five D3As fell in the withdrawal. While it is hard to apportion credit for these victories, it is likely that most of the dive bombers fell to four returning escort F4Fs, as these aircraft had the most ammo remaining. The escort A6Ms had their own victories at this time, downing one F4F and one TBF. Another F4F was lost to AA.[106]

[106] Lundstrom, *First Team: Guadalcanal*, 429-38.

Once again the IJN lost about half of its strike aircraft for little gain. Eight of 17 D3As went down close to the task force; three more would ditch before they could regain their carrier.

That concluded the strikes against the *Enterprise*, as the ship withdrew from the battle area and was not spotted again. More IJN strikes pounded the *Hornet* and sealed her fate. Six B5Ns from the *Junyo* put another torpedo into her at the cost of two B5Ns down to AA. That was followed by a dive bombing attack from two D3As that scored a damaging near miss and resulted in a decision to abandon ship. Six B5Ns from *Zuikaku* followed that up with a level bombing attack from 8,000 feet that results in one hit and a series of misses astern.[107] The final attack by four *Junyo* D3As resulted in yet another hit that sparked a large fire. The Americans attempted to scuttle the battered ship, but although five inch gunfire set her on fire from stem to stern she refused to sink. The IJN completed the job the following day, as IJN forces swept south to exploit their victory.[108]

Looking at the entire series of strikes, once again the CAP seemed hobbled by altitude issues. At least the CAP was high enough to intercept torpedo bombers; at Coral Sea, even those interceptions were hampered by an apparent assumption that IJN torpedo bombers would come in low and slow. But getting to the dive bombers before they were able to attack was still a problem. Part of the issue was telling dive bombers from torpedo bombers. Height finding with the search radars of the day was notoriously difficult, and IJN torpedo bombers and dive bombers cruised at close to the same altitude in any event. Also, I suspect that FDOs were naturally biased towards guarding against the deadlier torpedo bombers. Experience showed that if a choice had to be made, two or three 250 kg bomb hits were far preferable than hits

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[107] I have seen no explanation of why these aircraft were armed with bombs rather than much more deadly torpedoes. By this time, *Shokaku* and *Zuiho* were both out of action. Perhaps *Zuikaku* did not have six torpedoes left in her magazines. Or perhaps the big bombs were felt to be a better choice against a badly damaged and likely stationary target. Five of the B5Ns in the strike were search aircraft from *Zuiho,* which would have come aboard *Zuikaku* without the adapter mounts needed to carry torpedoes. Perhaps the *Zuikaku* armorers did not take the time to transfer the adapters from returning strike aircraft to the *Zuiho* planes but instead used bomb adapter mounts available from the ship's supply. See Parshall and Tully, 131.

[108] Lundstrom, *First Team: Guadalcanal*, 439-40, 446-9.

from two or three torpedoes. The result of all these factors was that once again the CAP was forced to watch the D3As fly by above them. The FDOs were also not helped by the relatively short distances at which the carriers' radars detected the incoming strikes. Nor were they aided by the generally poor radio reception conditions that plagued both sides during the battle.

All that said, the CAP did markedly better than at Eastern Solomons, with 36 F4Fs accounting for at least seven D3As before they could attack. But they were still short of the Midway gold standard of 20 F4Fs taking out 10 D3As before they could attack. The CAP's performance in the later strikes can be attributed to fuel and ammo shortages.

The CAP also did not fare particularly well against the B5Ns. They made interceptions of both the first two torpedo attacks, but were hampered in the first case by the B5Ns attacking in tandem with the D3As and in the second attack by low fuel and ammo. With those factors considered, perhaps it is not surprising that the CAP did no better than the CAP performance at Midway. It also seems that torpedo bombers were particularly tough targets for the CAP. CAP victories against dive bombers were often achieved as the dive bombers were forming up or waiting to dive. By contrast, IJN torpedo bombers simply shook out into a loose line abreast from their cruising formation and dove in from there. The torpedo bombers were vulnerable if intercepted early in their attacks, but harder to deal with if bounced only just before they were about to drop their torpedoes.

While the CAP achieved no breakthrough performances at Santa Cruz, the anti-aircraft guns did. They accounted for 21.5 victories, more than one-quarter of the 79 IJN strike aircraft attacks on USN ships that day.[109] And this count includes 18 attacks on the crippled *Hornet*, which with her AA screen accounted for only two of those 18 attackers. Without them in the mix, the number rises to almost one-third. At Eastern Solomons, the next best AA performance, AA accounted for a bit more than one in five attacking dive bombers – five down of 23 that dove. The combined total at Midway was 2.5 AA victories for 16 attackers – about one in six.

[109] I credit half victories where AA and CAP shared a kill.

Enterprise's new 40 mm AA battery accounts for some but not all of this. Screening ships took a considerable toll on attacking torpedo bombers. And the *Hornet's* AA batteries also did damage. This generally increased effectiveness added another dimension to defensive power. While it is difficult to say to what degree the intense AA fire degraded the strikers' accuracy, it does seem that it at least inflicted damage and caused hurried or bad weapon drops. At least two of the IJN strike aircrew spoke of the unusually heavy AA fire. It also played a role in hamstringing the IJN carriers' abilities to continue in action. Even if the carriers were not damaged, their air groups evaporated rapidly. Even if an AA-damaged aircraft managed to stagger back to its carrier, it might be so shot up that it was unusable.

It is hard to judge the number of IJN aircraft that returned damaged, as a number of *Shokaku* and *Zuikaku* strike aircraft were forced to ditch either because they did not located a functioning IJN carrier or because the carrier that they did locate was so congested that they could not land before running out of fuel. But some measure of this effect might be given by *Junyo's* dive bombers. Seventeen D3As attacked the *Enterprise* task force. Eight went down over the task force and three ditched later, leaving six to return to *Junyo*. Only four were available to fly again that day. The heavy casualties that the IJN strikes experienced from CAP and AA made each strike very close to a one-shot affair.

Maneuvering still played an important role in avoiding or minimizing hits, but it still had its limits in the face of numerous attackers. The combination of maneuver plus effective defense from the screen showed that the USN was able to combine the two. This continued a trend begun at Eastern Solomons, where battleships and anti-aircraft cruisers were incorporated in to a screen close enough to the screened carrier that even 20 mm guns on the screening ships could effectively engage raiders. The performance of Enterprise and her screen was a particularly good example of effective maneuver combined with an effective anti-aircraft screen.

USN protection and damage control was very good versus the (relatively) small bombs being dropped by the D3As. *Enterprise* was able to absorb two bomb hits and continue

operating aircraft, while the first three hits on *Hornet* did not seriously threaten her. Torpedo damage was once again the Achilles heel of USN carriers. This was not a glaring design flaw – it proved hard for all navies to build effective torpedo protection into their ships.

Santa Cruz: the IJN Experience

The IJN had four carriers to protect at Santa Cruz: two powerful fleet carriers – *Shokaku* and *Zuikaku*, one mediocre fleet carrier – *Junyo*, and a light carrier – *Zuiho*. Sensibly, the IJN positioned *Junyo* relatively far from the expected action and *Shokaku* and *Zuikaku* closer to it. *Zuiho* accompanied the two big fleet carriers to provide CAP and escort fighters and search aircraft. She was much more vulnerable than her big companions, but also much more expendable if it came to absorbing USN strike attacks – probably not a reassuring thought for the crew of *Zuiho*. In a refinement of the dispersion concept, the IJN stationed other ships in between the three IJN carriers and the expected position of the USN carriers. The hope here was that these ships would also absorb some strikes that would otherwise fall on the carriers.

First blood for the USN was drawn by search aircraft. Unlike IJN search aircraft, USN carrier search aircraft were normally armed with 500 pound bombs.[110] They would put those bombs to good use in this battle. Searching in pairs, ten of the SBDs found the main IJN carrier force or the advance force. Two bombed a heavy cruiser in the advance force, but without success. Four of the six that found the carriers were intercepted by CAP, but no SBDs and no A6Ms went down. USN carrier planes generally searched at low altitude, which meant that the searchers had to climb to attack altitude before diving on their targets. This lengthened their time in the vicinity of the IJN ships and so made them more vulnerable to interception. Despite this handicap, the last two search SBDs to find the main IJN carrier force exploited cloud cover to take *Zuiho* by surprise. They managed one 500 pound hit on her stern, which

[110] Single bombs for the SBDs, up to four bombs for the TBFs. PBY flying boats sometimes carried torpedoes in lieu of bombs, but were generally armed only when searching at night. It was tempting fate enough just to search for IJN carriers in a big, clumsy PBY in broad daylight, let alone try to attack them.

started a fire and wrecked her arrestor gear. She would land no more planes during the battle.

The USN launched three strikes, all of which crossed IJN strikes in the air. The first USN strike saw the first IJN strike but neither strike made any move to engage the other. The USN strike consisted of 29 *Hornet* aircraft: 15 SBD-3s escorted by four F4F-4s at high altitude and six torpedo-armed TBF-1s escorted by another four F4F-4s at low altitude.

Radar installed in *Shokaku* picked up the *Hornet* strike about 78 miles distant – a good performance by any measure. It is unclear, however, whether the IJN had built up the equipment and procedures needed to exploit radar sightings. It is clear that its aerial radio equipment had not improved. The main carrier task force had 20 A6Ms close to the carriers at two different altitudes, plus three more headed south to protect the vanguard force of battleships, cruisers and destroyers. The vanguard force had been closing the range to the USN carriers, but the IJN carriers had been steaming away from them.

The *Hornet* strike passed over two separate elements of the vanguard force. As it did so, the three A6Ms over the vanguard force attacked the SBD escort and the TBF escort in succession. They shot down one F4F from the SBD escort and one from the TBF escort while losing two A6Ms. The surviving F4Fs were separated from the strike aircraft, with two from the SBD escort aborting. The SBDs turned off their base course to avoid the A6Ms, heading for some clouds, but the TBFs continued straight on.

The turn by the SBDs took them right to *Shokaku* and *Zuiho*, although *Zuikaku* had separated to launch her contribution to the second IJN strike and so was not spotted. The SBDs saw the IJN carriers about 35 minutes after IJN radar had seen the strike. While the SBDs were now headed towards their prime target, the TBFs did not hear their radio transmissions and never turned to follow them.

Within five minutes of sighting the carriers, the SBDs were under attack from the CAP. A6Ms from *Shokaku*, *Zuikaku*, and *Zuiho* all joined in the attack, with the engaged CAP

totaling 11 before the SBDs bombed and at least two more after. The A6Ms killed two SBDs and caused two more to abort. They lost one A6M to the SBDs' fire, one to a mid-air structural failure, and one damaged and later ditched.[111] Five of the CAP remained at low level to guard against torpedo planes, while two guarded *Zuikaku*.

Ten SBDs bombed *Shokaku*, starting about 43 minutes after *Shokaku's* radar had sighted the strike. The SBDs made at least three 1,000 pound bomb hits in the big carrier's hanger and on her AA guns. She was out of the battle with serious fires, but her strike aircraft had already left and her ability to steam was unimpeded. The eleventh SBD bombed a screening destroyer. The SBDs were attacked by more A6Ms as they withdrew, but without losses to either side. Fourteen A6Ms had attacked the SBDs and their F4F escort before they could dive, downing two SBDs and an F4F, causing another two SBDs and an F4F to abort with damage. Five A6Ms were lost. Thus ended the only USN strike to find carriers that day.

The six TBFs from the *Hornet* strike searched in vain for the IJN carriers and finally, running low on fuel, attacked a heavy cruiser in the vanguard group. Only five of the six torpedoes dropped; none hit.

The second strike launched from the USN carriers came from the *Enterprise*. It consisted of eight torpedo-armed TBF-1s, the air group commanders in an unarmed TBF, three SBD-3s, and eight escorting F4F-4s. The small number of SBDs in the *Enterprise* strike reflects the fact that many of the *Enterprise* had been detailed to conduct the morning search. The strike was at 6,000 feet and slowly climbing when the first IJN strike spotted it a bit more than 60 miles out from the USN carriers. The opportunity proved too much for the IJN strike escort to resist, and nine A6Ms peeled off the ambush the USN strike.

The result was a bloody brawl. Two TBFs and three F4Fs went down, as did four A6Ms. Two more TBFs and an F4F were forced to abort. All of the surviving A6Ms returned to their carriers rather than rejoining their strike, with one severely damaged. Their

[111] Based on Lundstrom's account of this action, I estimate that the A6Ms first hit the SBDs about five minutes before the SBDs began their dives. That implies an interception about 10 miles from the IJN carriers.

decision to leave their strike was "strongly questioned," but they probably had intended to return to it until the fight became extended.[112]

In addition to the aircraft downed and aborted, the A6M ambush also caused the escort F4Fs to shed their drop tanks prematurely. The F4F-4 had a significantly shorter combat range than the SBD-3 or the TBF-1. The fighters relied on auxiliary fuel drop tanks to stay with the strike aircraft. With the escorts' drop tanks gone before the fuel in them had been fully used, the strike leader had to decide whether to press on without the escorts or turn back when the escorts had to. The decision was for the latter, with the result that the strike did not search long or far enough to locate the IJN carriers.

As with *Hornet's* torpedo bombers, the *Enterprise* strike attacked the IJN vanguard force. The SBDs dive-bombed a heavy cruiser already hit by the second Hornet strike, managing a damaging near miss, while the four TBFs with torpedoes tried for another heavy cruiser. One torpedo refused to be dropped, the other three missed. The only CAP opposition was encountered by the SBDs, which were attacked by three A6M without result.

The last USN strike of the day flew from *Hornet*. It consisted of nine SBD-3s, nine bomb-armed TBF-1s, one unarmed TBF with the air group commander, and seven F4F-4s for escort.[113] This raid seems to have copied a spoof IJN transmission that the lead raid had reported finding no carriers.[114] Discouraged by this, *Hornet* SBDs selected

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[112] Lundstrom, *First Team: Guadalcanal,* 369. If, roughly speaking, two A6M escorts neutralized one F4F capper, and one F4F capper accounted for one-half of a strike aircraft, the additional nine A6Ms would have saved two strike aircraft. It is an open question whether it was better to down two TBFs and abort two more than save two D3As or B5Ns. In hindsight, the TBFs were not much of a threat, but the IJN could not have known that at the time of battle.

[113] I suspect that USN commanders were still very suspicious of the ability of the TBFs to score with Mk. 13 torpedoes. As I wrote above, I could not determine whether the faults in this weapon were cured by October 1942. It is reasonable to think that many in the USN would be suspicious of assurances that the weapons were working until that had clearly been proven in action. TBFs did have some success with these torpedoes in the Eastern Solomons battle, but that may not have been enough to overcome all doubts.

[114] An irony that, given that so many valid radio transmissions went unheard on that day.

targets from among the vanguard forces. They attacked the same heavy cruiser that later took the near miss from the *Enterprise*, scoring two hits and wrecking the cruiser's bridge. The TBFs and their escort continued to search for a while further, but turned back to bomb the same heavy cruiser attacked by the SBDs of the Enterprise and second Hornet strikes. Nine TBFs executed a glide bombing attack, dropping 36 500 pound bombs for one hit. The TBFs were intercepted by two A6Ms before attacking, but escorting F4Fs ended the threat by killing one before they could score against the strike planes. The USN air effort for the Battle of Santa Cruz was over.[115]

The battle left each navy's carrier forces exhausted. For the USN, only the damaged *Enterprise* remained in the Pacific. For the IJN, only the *Junyo* remained, as the *Zuikaku* air group had taken so many casualties that the carrier returned to Japan. The naval battle for Guadalcanal would go on, but it would be fought mainly with surface forces and land-based air.

IJN defensive performance in the Battle of Santa Cruz shows some interesting contrasts. The IJN managed deliberately to combine the concepts of dispersion and outranging – aided by weather – to provide an effective defense to its carrier force. This was not the classic concept of dispersing carriers into separate task forces, but instead the concept of putting some attractive but less vital (or more heavily protected) targets in harm's way. The vanguard force served that purpose well, absorbing almost half of the SBD sorties and all of the TBF sorties.[116] Out-ranging intensified this by limiting the time that the USN strikes had to find and attack targets. The IJN strikes had to search for targets as well, and in no better weather than the USN strikes faced, but had sufficient range to carry out their searches.

Armor and protection also held up well for the IJN. Losing *Zuiho's* services to a single 500 bomb had to be disappointing, but at least she did not sink. There was no hope

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[115] Lundstrom, *First Team: Guadalcanal*, 360-84.

[116] The IJN might have felt differently if the attacks on the vanguard force had fallen on battleships rather than heavy cruisers, but probably not. Carriers were more important than battleships at that moment, and the damage actually taken by the cruisers in the vanguard force would have sent a battleship to the dockyards but not sunk it. Given that the IJN forced the USN to withdraw at the end of the battle, even a crippled battleship would have stood a good chance of being saved.

than Shokaku would continue after eating three or more 1,000 pound bombs, but she would be repaired and training a new air group in five months. The IJN took care to prepare and launch strikes as quickly as possible, minimizing the chances that the carriers would be caught with armed and gassed planes in their hangers. This sacrificed some offensive punch – in this case splitting the second strike into a dive bombing strike followed by a torpedo bombing strike – but helped to assure that one well-placed bomb would not spark an inferno and the loss of a carrier.

As in previous battles, IJN anti-aircraft fire was not a factor in knocking down strikers. As the USN flyers became more used to the relative impotency of the AA, it may well have been losing any psychological effect as well, becoming merely distracting rather than threatening.

If anything, the performance of the IJN CAP validated the IJN's development of dispersion and outranging strategies as the primary means of IJN carrier protection. This is not because the CAP performed poorly; it is because the CAP performed well.

The *Shokaku*, *Zuikaku* and *Zuiho* had 23 A6Ms on CAP when the *Hornet* strike arrived. Three of the CAP disposed of all the escorts, leaving the field open for another 11 IJN fighters to hammer the strike planes before they could attack. They were able to concentrate on the SBDs in the strike, as the TBFs had failed to spot the carrier task force. The A6Ms had some time to attack the SBDs before they could reach their tip over points. All but one or two of the A6Ms should have had a full complement of ammo. Yet they only downed two of the 15 SBDs and knocked another two out of the fight. Ten of the remaining 11 SBDs hit *Shokaku* at least three times, taking her out of the battle. And the SBDs got away cleanly, despite being attacked during their withdrawal.

At the time of the *Hornet* SBD attack, the IJN carriers had committed 30 fighters to escort duties. Adding them to the CAP might have swamped this one small USN strike, but only at the expense of denuding the IJN strikes of protection against the USN CAP. The IJN escorts had a discernable effect in keeping CAP from concentrating on the strike planes, so it would have been hard for the IJN to dispense with them entirely.

All this leads to the conclusion that when faced with the best CAP conditions that the IJN could reasonably expect, SBDs would always get through, and probably in sufficient numbers to take an IJN carrier out of the battle. The IJN was inherently offensive-minded anyway; the results of the 1942 carrier battles led it to rely more on indirect means of defense, such as out-ranging and dispersion, rather than direct means such as AA and CAP.

Summary

To begin, let me define some terms for the sake of brevity and clarity. When this summary section speaks of a "carrier," it means a fleet carrier rather than a light carrier. When this section speaks of aircraft "striking," it refers to aircraft that were part of an airstrike that spotted and attacked a carrier. Aircraft "attacking" are aircraft in a strike that actually bombed or launched a torpedo at a target. The term excludes (where it is possible to exclude), aircraft jettisoning ordnance in the vicinity of a target or aircraft shot down before they could finish an attack that they had begun. A "crippled" carrier is one that is dead in the water or capable of only extremely limited movement. A "disabled" carrier is one that due to battle damage in incapable of operating aircraft until repaired in a dockyard. A "damaged" carrier is one that has taken significant battle damage but retains or regains most of its ability to steam and operate aircraft.

The great carrier battles of 1942 were a crucible for carrier defense. Both the IJN and the USN got extensive experience in trying to defend their carriers from the others' air strikes. The battles certainly highlighted the difficulties of carrier defense. The battles saw 20 instances of carriers on the front lines.[117] Four IJN and two USN carriers were scuttled as the direct result of carrier strikes.[118] Another USN carrier was sunk by a

[117] *Lexington*, *Yorktown*, *Shokaku* and *Zuikaku* at Coral Sea; *Enterprise*, *Hornet*, *Yorktown*, *Akagi*, *Kaga*, *Hiryu*, and *Soryu* at Midway; *Saratoga*, *Enterprise*, *Shokaku*, and *Zuikaku* at Eastern Solomons; *Enterprise*, *Hornet*, *Junyo*, *Shokaku*, and *Zuikaku* at Santa Cruz.

[118] *Lexington*, *Akagi*, *Kaga*, *Hiryu*, *Soryu*, *Hornet*. Technically speaking, no carrier aircraft in 1942 sank an enemy carrier, although these six carriers were so severely wrecked that they were scuttled. There is some question as to whether *Kaga* and *Soryu* were scuttled or sank, but Parshall and Tully make a good case that they were in fact scuttled by the IJN. Parshall and Tully, 334-9.

submarine while seriously damaged by a carrier strike.[119] In two instances, an IJN carrier was disabled.[120] There were three instances of USN carriers being damaged but being able to continue operating aircraft.[121] In total almost two-thirds of the appearances made by carriers in these battles resulted in the carrier being at least damaged. In more than one-third, the carrier was scuttled or sunk. The USN accounted for no IJN carriers other than the four at Midway, which were scuttled by IJN forces after being gutted by fires. IJN successes were spread throughout the battles, with one USN carrier scuttled or sunk in every battle except Eastern Solomons.

The two sides were evenly matched in the numbers of strike aircraft that they threw at each other's carrier defenses. The US managed 86 sorties by torpedo bombers and 146 by dive bombers. The IJN managed 85 torpedo bomber sorties and 147 dive bomber sorties. These numbers include the IJN dusk strike at Coral Sea and the USMC and USAAF strikes from Midway Island, all of which were intercepted by CAP fighters guarding carriers. They do not include the second *Hornet* strike at Santa Cruz, no part of which ever sighted carriers and which attacked cruisers instead. Nor do they include any IJN strikes at Santa Cruz beyond the B5N strike from *Junyo* that finished *Hornet* when she had no CAP.[122]

It took the IJN about 28 torpedo bomber strikers to cripple a USN carrier, while the USN torpedo bombers never hit an IJN carrier.[123] About 24 IJN dive bomber strikers sufficed to damage a USN carrier. About the same number of USN dive bombers would on average disable an IJN carrier, with the damage resulting in the carrier being

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[119] *Yorktown*.

[120] Unlucky *Shokaku* at Coral Sea and Santa Cruz.

[121] *Yorktown* at Coral Sea, *Enterprise* at Eastern Solomons and Santa Cruz. Each instance resulted in some dockside repairs before the carrier was again committed to action – in the first two cases with the repairs done at Pearl Harbor, in the third with the repairs done at Noumea in the South Pacific theater. None prevented the carrier from operating its aircraft.

[122] The USN mounted more carrier strike sorties against all types of IJN carriers when the strikes against light carriers *Shoho* and *Ryujo* are included.

[123] USN torpedo bombers did succeed in torpedoing light carriers *Shoho* and *Ryujo*, in both cases after they had taken hits from dive bombers.

scuttled in two-thirds of the cases. IJN torpedo bombers were almost as productive as USN dive bombers in crippling carriers, even without the advantage of attacking targets with hangers full of armed and gassed aircraft (as the USN was able to do at Midway).

Midway does complicate comparisons, as it provides the only example in 1942 of USN carrier aircraft so wrecking IJN carriers that they were scuttled. Clearly, USN dive bombers could cripple IJN carriers even if the carriers did not have large quantities of gassed and armed aircraft on board; they did precisely that to *Hiryu* at Midway.[124] Equally clearly, USN dive bombers struggled to kill large, well-protected carriers such as *Shokaku*. Venturing uncertainly into the realm of what-if, I would score the results at Midway without armed aircraft in the IJN hangers as *Akagi* disabled and, for *Soryu* and *Kaga*, one of them disabled and the other crippled.[125] With that scoring, the ratios of carriers sunk versus carriers disabled from USN dive bomber attacks reverse: an expected two carriers ultimately sunk and four carriers disabled.

Looking at the numbers leads to some general conclusions about the relative effectiveness of USN and IJN attacks on carriers.[126] As noted above, it took about 28

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[124] I wish I knew how many armed and gassed aircraft had on board *Hiryu* when she was bombed. She was preparing a strike of 5 D3As and 4 B5Ns with a launch scheduled for about an hour after she was bombed. That suggests that she had at least some armed and gassed aircraft in her hangers. But all of the bombs hit in her forward hanger, which was said to contain 19 A6Ms with no mention made of armed strike aircraft. That suggests that any armed strike aircraft she had on board were in her aft hanger. The evidence is that she had none on her flight deck. She was able to steam for more than four hours after she was hit, and her fires seem to have been concentrated forward. In all, I suspect that the presence of some readied strike aircraft contributed to her loss but were not the primary cause of it. Parshall and Tully, 323, 326, 341.

[125] *Kaga* rates as unable to conduct air operations because a 1,000 pounder near miss badly jammed her rudder. The hit put her in no danger of sinking, but she could not have launched or landed aircraft. I consider the hit to be more than a fluke – the mining effect of a 1,000 pound bomb exploding close alongside was considerable.

[126] For these numbers, I have used the following actions: the main IJN strike at Coral Sea, the *Hiryu's* two strikes at Midway, the first IJN strike at Eastern Solomons, the IJN strikes at Santa Cruz up through the second strike from *Junyo*, the main USN strike at Coral Sea, the USN carrier SBDs strikes at Midway except for *Hornet's*, and the USN strike at the main IJN carrier force at Santa Cruz. I excluded strikes that did not make contact with their targets and the USN strikes on *Shoho* and *Ryujo*.

B5Ns in a strike to cripple a USN carrier.[127] That number is based on an average of 17 B5Ns surviving to make good attacks. For SBDs, the numbers are 24 in a strike disabling an IJN carrier, with 22 surviving to make good attacks.[128]

The usual B5N strength of an IJN carrier was 18 aircraft, although the number could be as high as 27.[129] If it had not faced active defenses, the usual torpedo plane group of an IJN carrier would have been sufficient, on average, to cripple one USN carrier. Because it did face defenses, a carrier air group with 18 B5Ns actually had, on average, about a two-thirds chance of crippling a USN carrier. This assumes that none of the carrier's B5Ns were being used for searching. The IJN tried to avoid using them for this, relying instead on floatplanes, land-based searchers, and search aircraft from light carriers.

For the USN, the situation was different. Twenty-two attacking SBDs would on average disable an IJN carrier. Because losses to SBDs were so low, 24 in a strike would (again, on average) suffice to allow 22 to attack a target. Most USN carriers carried 36 SBDs apiece, although in a group of two carriers 18 SBDs from one carrier would typically be employed in search and other duties, so a two carrier group would in theory have 54 SBDs available to strike. Again looking at averages, this should have been more than enough to disable two IJN carriers if all of the SBD were carrying 1,000 pound bombs.

How many SBDs armed with 1,000 pound bombs could a USN carrier launch? SBDs with these bombs required longer take-off rolls, which resulted in some carrier strikes being made up of a mix of SBDs with 500 pound bombs and SBDs with the heavier weapons. *Enterprise's* first strike at Midway was an example of this. Despite this,

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[127] This includes the last IJN torpedo bomber attack at Santa Cruz, which put a third torpedo into *Hornet* that was might be argued to be superfluous. Without that strike, the numbers are 26 B5N striking and 15 attacking.

[128] These numbers exclude attacks by land-based SBD-2s and SB2U-3s. For comparison purposes, they treat *Akagi* as only moderately damaged. Were she treated as disabled, due to her steering damage, the distinction here would be 20 striking for 18 actually attacking.

[129] The following IJN carriers had 18 B5Ns in their torpedo plane groups: *Shokaku* and *Zuikaku* at Coral Sea, all except *Kaga* at Midway, *Shokaku* and *Zuikaku* at Eastern Solomons. The *Kaga* had 27 on her roster at Midway, while *Shokaku* and *Zuikaku* carried a combined total of 44 at Santa Cruz (although only 36 were used as strike aircraft) and *Junyo* would have been authorized nine.

there is good evidence that USN carriers could operate at least 24 and perhaps as many as 30 SBDs armed with the bigger bombs. At Midway, the *Yorktown* launched a strike of 24 SBDs, all armed with 1,000 pound bombs. At the Battle of Eastern Solomons, the *Enterprise* armed a strike of 25 SBDs with 1,000 pound bombs, later switching some of the loads to 500 pound bombs for SBDs detailed to search missions. In the same battle, the 30 SBDs initially launched for *Saratoga's* strike against Ryujo were all apparently armed with 1,000 pound bombs.[130] *Saratoga* had a longer flight deck than *Enterprise*, but *Enterprise's* open hanger would have allowed her to warn up strike aircraft on both her flight deck and her hanger deck. This suggests that while not all of the 54 SBDs theoretically available for a USN two carrier strike might have been able to carry 1,000 pounders, anywhere from 42 to 48 of the aircraft could be armed with the larger bombs with the remaining 6 to 12 carrying 500 pounders.

On this analysis, carrier for carrier the USN was more effective at taking IJN carriers out of action. Even though SBDs required more attacks than B5Ns to disable a carrier, the relatively more effective USN active defenses – CAP and AA – reversed the margin of aircraft that had to be committed: 24 SBD or 28 B5N strikers. Combined with the fact that USN carriers typically carried twice as many SBDs as the IJN did B5Ns, this gave the USN carriers an edge.

The IJN did have an advantage in crippling carriers, factoring in the effects of carriers caught with armed and fueled aircraft on board. B5Ns left *Yorktown* dead in the water and set up for a fatal submarine attack, and caused *Lexington* and *Hornet* to be scuttled after the USN was forced to abandon them. Even without many armed and fueled aircraft on board, the USN did wreck *Hiryu* and would probably have hurt *Soryu* and *Kaga* badly enough for at least one of them to be scuttled. That was an advantage to the IJN of three to two, but in the context of the 1942 battles, a "mission kill" by the USN – taking a carrier out of action – was almost as good as a sinking. The United States was about to start bringing new carriers into service faster than Japan could

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[130] Lundstrom, *First Team*, 225. Lundstrom, *First Team: Guadalcanal*, 113-4, 119-22. John B. Lundstrom, *Black Shoe Carrier Admiral: Frank Jack Fletcher at Coral Sea, Midway, and Guadalcanal* (Annapolis, Maryland: Naval Institute Press, 2006), 440. Samuel Eliot Morison, *History of United States Naval Operations in World War II: The Struggle for Guadalcanal, August 1942-February 1943* (Boston: Little Brown, 1984), 90.

repair hers. And in the strategic settings of the battles, depriving the IJN of carrier support generally meant exposing her other naval forces to US land-based air. Without carrier-based air cover, IJN invasion or reinforcement convoys – the *raison d'être* of all four of the carrier actions – were either recalled or pounded.

CAP Effectiveness

Combat air patrol was the dominant means of active carrier defense in the 1942 battles. For the IJN, CAP accounted for almost all downed USN aircraft. For the USN, CAP accounted on average for two-thirds of the kills and anti-aircraft fire for one-third, with the proportion of AA kills rising throughout the period. Here are some numbers on CAP performance.

CAP Effectiveness Measures – Based on Strikes Launched at Fleet Carriers[131]

Measure	**F4F CAP**	**A6M CAP**
Number of CAP Instances[132]	290	300
Number of Engagement Instances	179	220
Total CAP Victories	90	80.5
Victories versus Escorts	13	16
Victories versus Torpedo Bombers	21	44.5
Victories versus Dive Bombers	43.5	20
Victories versus Level Bombers	12.5	0
Losses from Escorts	16	12
Losses from Strike Aircraft	4	9
Losses from Friendly AA	4	1
CAP Engaging Torpedo Bombers	37	122
CAP Engaging Dive Bombers	93	67
Torpedo Bombers in Strikes Opposed by CAP	79	86
Dive Bombers in Strikes Opposed by CAP	147	146
Torpedo Bombers Surviving to Attack	50	42
Dive Bombers Surviving to Attack[133]	103	128

[131]Unless otherwise noted, this table includes all strikes versus light or fleet carriers in the Pacific in 1942.

[132] In this table, an "Instance" refers to one CAP fighter opposing one strike. The number of CAP fighters would be less than this number, as the same fighters fought more than one strike. Likewise, the number of CAP fighter sorties would also be less, as a CAP fighter may not have landed and relaunched in between fighting separate strikes.

[133] Includes losses from AA and CAP other than A6Ms and F4Fs.

Percent of CAP Engaging	62%	73%
Percent of CAP Engaging Torpedo Bombers	21%	55%
Percent of CAP Engaging Dive Bombers	52%	30%
Strike Aircraft Downed per CAP Instance	0.27	0.22
Strike Aircraft Downed Before Attacking per CAP Instance	0.17	0.16
Strike Aircraft Downed per Instance of Engaged CAP	0.43	0.30
Torpedo Bomber Downed per CAP Engaging Torpedo Bombers	0.57	0.36
Dive Bomber Downed per CAP Engaging Dive Bombers	0.47	0.27
Percent of CAP Torpedo Bomber Victories before Torpedo Bomber Attacked	79%	85%
Percent of CAP Dive Bomber Victories before Dive Bomber Attacked	55%	55%
Chance of Torpedo Bomber Attacking[134]	59%	49%
Chance of Torpedo Bomber Surviving	51%	47%
Chance of Dive Bomber Attacking	70%	88%
Chance of Dive Bomber Surviving	56%	86%

Despite the USN advantage of radar, the IJN managed to get a higher proportion of its CAP fighters into combat. Almost three-quarters of IJN CAP fighters aloft or ready for take-off at the time of a US strike managed to engage strike aircraft. For the USN, the number was 62%. This is a reflection of three things: the USN struggling with making radar-directed CAP effective, the ability of the A6M to get to where it was needed quickly, and the fact that some of the USN CAP was initially located over task forces some distance from the carrier being attacked. For CAP at altitude over the task force being attacked – CAP that would be more likely to target dive bombers – the honors were even at about 55% of CAP engaging. That reflects a USN advantage in radar offset by an IJN advantage in fighter aircraft performance.

Looking at the effects of the interception, F4Fs and A6Ms were closely matched in terms of carrier strike aircraft shot down before attacking. On average, each F4F on CAP accounted for 0.17 attacking carrier strike aircraft before the strike aircraft was able to attack, while the number for A6Ms was 0.16. Looking at all carrier strike aircraft downed, each CAP F4F accounted for 0.27 carrier strike aircraft while each CAP

[134] This and the following three categories include losses from all causes, including AA and CAP other than A6Ms or F4Fs. They disregard strikes on IJN light carriers.

A6M accounted for 0.22 aircraft. [135] The balance tips further to the USN, however, when one considers the kill rates of CAP fighters that engaged strike aircraft. Comparing CAP F4Fs engaging versus CAP A6Ms engaging, the respective numbers are 0.43 to 0.30 aircraft downed per CAP fighter. In other words, plane for plane the A6Ms were only about two-thirds as effective as F4Fs when attacking carrier strike aircraft.

Two-thirds of F4F CAP victories versus carrier strike aircraft were against D3As (43.5 victories) and one-third was against B5Ns (21 victories). Slightly more than one-third of all carrier strike aircraft in the IJN strikes were B5Ns and slightly less than two-thirds were D3As, so the losses to F4Fs were fairly proportionately split between the two types. B5N losses become disproportionately larger when the contributions of SBDs and AA are included. SBDs accounted for five and one-half B5Ns and only two D3As, while AA finished 15 1/2 B5Ns and 18 1/2 D3As. Almost 80% of the F4F victories against B5Ns came before the torpedo bombers could make effective attacks. For D3A victories, the number was about 55%, reflecting the struggle to intercept dive bombers before they could deliver their payloads.

For IJN CAP, the proportion of dive bombers to torpedo bombers in the attacking strikes was almost exactly the same, but the proportion of kills was reversed. More than two-thirds of the victories (44.5 in total) came against TBDs and TBFs and less than one-third (20 victories) against SBDs and SB2Us. This reflected how the IJN CAP was committed, with two-thirds of the CAP fighting torpedo bombers and one-third fighting dive bombers. The pattern of IJN CAP commitment in turn reflected both the belief that the torpedo bomber was more of a threat than the dive bomber and the fact that the IJN's CAP procedures made it far easier to intercept torpedo bombers than dive bombers.

IJN CAP was much more effective against torpedo bombers that it was against dive bombers. For the IJN, the proportion of torpedo bombers downed before attacking was even higher than the USN percentage – 85% of all victories occurring before the

[135] The USN accounted for 0.27 level bomber per F4F CAP and 0.34 level bomber per F4F CAP engaging, while the IJN, faced with the formidable but ineffective B-17, accounted for none. The numbers in the text include attacks by shore-based carrier aircraft types, namely the SBDs, SB2Us, and TBFs at Midway, as well as the Midway B-26s that attacked as torpedo bombers.

torpedo bombers could attack. But as with the USN, only 55% of all victories scored against dive bombers took place before the bombers bombed. An A6M engaging a torpedo bomber had a 36% chance of downing it, but only a 27% chance of downing a dive bomber.

Why the difference in kill rates between the two navies? Obviously, USN strike aircraft with self-sealing fuel tanks and armor protection were generally harder to shoot down than their IJN counterparts. And they were particularly hard to shoot down with A6Ms, which had only limited amounts of cannon ammo and relatively ineffectual light machine guns. The effect is even more striking when one considered that more than half of all victories by IJN CAP against strike aircraft were against TBDs: aircraft that lacked the protection of SBD-3s and later TBFs.

A modest math exercise sharpens the point. Thirty-four of the A6M CAP kills were TBDs, downed by about 86 attacking A6Ms. That gave the A6Ms a kill rate of 0.40 against the TBDs. Another 52 A6Ms engaged SBD-3s, downing 12 and giving them a kill rate of 0.23 SBD per A6M engaged. When it came to downing the sturdy SBD-3, A6Ms were about half as productive as F4Fs were in killing the more vulnerable D3As and B5Ns and two-thirds as productive as A6Ms fighting TBDs.[136]

More support for the proposition that the A6M was hampered when faced with a well-protected aircraft comes from the relative performance of the A6M and the F4F as escort fighters. As an escort fighter, each F4F accounted for 0.38 A6Ms, while each A6M escort only downed 0.18 F4Fs.[137] As the accounts of the battles show, A6M escorts engaged fewer CAP fighters with more escorts compared to their USN

[136] These numbers are subject to some argument, but I still think that they are valid support for the point. One could argue that the A6Ms were hampered in some SBD attacks by attacking the dive bombers in their dives. But then the sheer number of A6Ms fighting the TBDs probably resulted in overkill, with the result that the number of TBDs downed per A6M declined from its potential maximum.

[137] These numbers are based on the numbers of escorts that actually fought, versus those present with a strike. USN CAP downed A6M escorts at a rate of 0.05 escort per CAP fighter. IJN CAP downed USN escorts at a rate of 0.04 escort per CAP fighter.

counterparts.[138] But despite outnumbering their opponents, the IJN fighters had a harder time scoring kills.

A look at the numbers for dive and torpedo bomber attacks shows both the difficulties of intercepting dive bombers and the problem of bringing down the tough SBDs. Both the IJN and the USN torpedo bombers took high losses before attacking. About 60% of IJN torpedo bombers survived long enough to attack a target, and only about 50% of them survived the strike.[139] For the USN the numbers are worse, with less than 50% attacking and still fewer surviving. But dive bombers fared better, particularly in surviving to make an attack.[140] For the IJN, 70% of all dive bombers managed an attack, while 56% survived the strike.[141] For the USN, 88% of striking dive bombers attacked, while 86% escaped.[142] Looked at in terms of CAP victories before and after an attack, we have seen that the numbers become even more lopsided. CAP for both sides got more than 80% of their victories against torpedo bombers before the bombers attacked, but neither side managed more than 55% of their CAP victories against dive bombers before the dive bombers bombed.

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[138] Forty-eight A6M escorts engaged 43 F4F CAP, while 32 F4F escorts engaged between 38 and 43 A6M CAP.

[139] B5N pre-attack survival numbers ranged from 80% (*Hiryu's* strike at Midway) to 60% (the first strike at Santa Cruz), with strike survival numbers ranging from 56% (the main strike at Coral Sea) to 45% (the first strike at Santa Cruz). Of course, no B5Ns attacked in the Coral Sea dusk strike so it is not included among the survival statistics.

[140] I think the USN torpedo bomber loss rates are largely a matter of escorts. Where escorts could not keep the CAP off the torpedo bombers, fewer bombers survived to make an attack. Where the escorts were successful, torpedo bomber casualties were fairly low. Pre-attack survival rates were from 100% (a majority of strikes) to 7% (*Hornet's* torpedo squadron at Midway), with strike survival numbers of from 100% (again, most strikes) to 0% (again, *Hornet's* TBDs at Midway).

[141] Surviving to attack, from a high of 97% for the Coral Sea main strike to a low of 44% at Midway; surviving the strike, from a high of 82% for the Coral Sea main strike to a low of 28% at Midway. Again, no D3As attacked in the Coral Sea dusk strike.

[142] Surviving to attack, from a high of 100% (most strikes) to a low of 63% (for the USMC SBD strike at Midway), with the same numbers for survival. After the Midway strike, the strike with the lowest survive-to-attack number was the Hornet's strike at Santa Cruz, with the lowest survive-the-strike number being the small force of Lexington SBDs attacking at Coral Sea (75% surviving).

This was not just a matter of the USN CAP making interceptions that the IJN CAP failed to make. The IJN succeeded in intercepting at least some dive bombers before they could make their attacks in five of the seven dive bombing attacks made on IJN carriers. Adding the two strikes on IJN light carriers raises the proportion to seven of nine. Despite this, the IJN labored under the twin handicaps of not being able to intercept dive bombers at a distance and of struggling to kill USN dive bombers once they were intercepted. But even USN levels of effectiveness let more than two-thirds of IJN dive bombers attack.

All the analysis above speaks to the relative effectiveness of USN CAP and IJN CAP and the strengths and weaknesses of each. But the fundamental point is that CAP in 1942 was almost never able to prevent strike aircraft from attacking. It could shoot down strike aircraft, disorganize attacks, and discourage and distract attackers, but the bombers almost always got through.[143]

One interesting sidelight to CAP effectiveness was the effectiveness of escort fighters. Every fighter sent on escort duty was one less fighter for CAP. What balance between escort duty and CAP duty made sense? There is an element of *reductio ad absurdum* to this inquiry; if both sides used all their fighters as escorts, there would of course be none left to man the CAP. But with some practical considerations in mind, it is still an issue worth examining.

The USN flew fewer escort sorties than the IJN, even though the number of strike aircraft sorties was broadly comparable. For escorts that either accompanied strikes that contacted carriers plus escorts that fought enemy fighters attacking strike aircraft, the totals for 1942 were 32 escort sorties for the USN and 79 for the IJN.[144] Ninety-five A6Ms started on escort missions, but 16 left their strikes to attack USN aircraft encountered in route and never rejoined. Fifty-four F4Fs also started on carrier versus carrier escort sorties, but 22 failed to stay in contact with strike aircraft

[143] "Almost never" because the IJN dusk strike at Coral Sea resulted in no attacks on USN carriers, although the strikers were confounded by the weather as well as the CAP attacks. Even in the massacre of the *Hornet's* torpedo bombers at Midway, one TBD managed to attack a carrier.

[144] A further 18 F4Fs escorted strike aircraft on the strike against light carrier *Shoho.*

attacking enemy carriers. It appears that all 32 USN escorts that stayed with their strikes fought, but only 48 of the A6Ms did. Those 48 A6Ms fought 43 CAP F4Fs. The escorts did not keep all of those F4Fs from attacking bombers, but the CAP that fought escorts had strike aircraft kill rates of about half the USN average. The 32 USN escorts fared better, engaging between 38 and 43 A6Ms and holding the strike aircraft kill rate of those A6Ms to about 0.05, less than one-sixth of the average for A6Ms. While the A6M escorts more frequently took the initiative in starting combats, the F4Fs wound up attracting more A6M CAP and keeping more of them from making effective attacks on strike aircraft.

Crunching the numbers a bit further, the F4Fs that engaged strike aircraft without having to deal with escorts managed a kill rate of 0.55 strike aircraft per fighter. The 79 A6Ms devoted to escort may have reduced the kill rates of the 43 F4Fs they engaged from 0.55 to 0.23. If so, that would amount to roughly 14 strike aircraft saved to attack.

For the IJN, retaining 79 escorts as CAP fighters would theoretically resulted in roughly 13 USN carrier strike aircraft being downed, against 14 saved by the escorts. On the face of it, that suggests that escorts were just marginally a good bargain for the IJN, but the reality is more complex. That is because the relative impotence of both USN torpedo bombers and IJN dive bombers. Escorts allocated to D3As and CAP intercepting USN torpedo bombers were, past some point, wasted assets, as those strike aircraft were unlikely to inflict significant damage on the enemy. The fighters would have been better employed either escorting B5Ns or intercepting SBDs. And between those two choices, the relative ineffectiveness of A6Ms against SBDs suggests that the best choice was escorting B5Ns, the aircraft with the most potential to cripple and sink USN carriers. Saving 14 B5Ns to attack a USN carrier meant essentially an additional 80% chance of crippling the carrier. IJN CAP would have had to downed more than 17 SBDs before attacking to reduce the USN chances of disabling a carrier by 80%. That would have required far more than 79 additional A6Ms on CAP. Clearly then, escorting the B5Ns seems the better course. No doubt, some CAP should have been used against USN strike aircraft so that they could not attack entirely undisturbed, and some escorts should have been used with the D3As to at least

distract the USN CAP. But the way to maximize effectiveness was to send more A6Ms in with the B5Ns.

I do not suggest that the IJN was likely to make that determination in just this way in the course of 1942. To do so, it would have had to recognize that USN torpedo bombers were unlikely to hurt its carriers, that its D3As were unlikely to disable or cripple USN carriers, and that its A6Ms were unlikely to down or discourage attacking SBDs. That is a lot to ask of any process for analyzing the results of combat.

Similar calculations can be applied for USN escorts, but with some modification. The 32 F4F escorts mentioned above all fought the enemy, either because they accompanied strike aircraft all the way to their target or because they fought A6Ms before the strike reached its target. There were another 22 escorts that set out with their strikes but failed to engage the enemy. Unlike the 16 escort A6Ms that peeled off to attack USN aircraft, these 22 F4Fs accomplished nothing.[145] Counting in these additional 22 aircraft suggests that the 54 F4Fs allowed between 12 and 13 USN strike aircraft to survive to attack. The same 54 F4Fs put on CAP would (at average effectiveness) have downed about nine strike aircraft before they could attack, which suggests on the face of it that providing USN escorts was probably good value. The problem is that the USN escorts were mostly protecting torpedo planes. SBD-3s demonstrated that they did not need much in the way of escort protection, while the torpedo planes failed to accomplish anything against the IJN carriers despite their escorts. This was a double story of good men wasted: escort pilots risked to protect torpedo plane aircrews who had little chance of achieving any result against the enemy. The USN would have been further ahead shoving its torpedo planes overboard and committing its F4Fs to CAP defense.

Again, I do not seriously suggest that the USN was any more likely to take this approach than the IJN was to de-emphasize CAP attacks on torpedo bombers.

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[145] Twenty of these were *Enterprise* and *Hornet* escorts at Midway. Another two were *Lexington* escorts at Coral Sea. I do not count another three *Lexington* F4Fs at Coral Sea that became separated from their strike but returned in time to contribute to the defense of the USN task force.

Institutionally, it would have been hard to admit that its torpedo weapon was essentially worthless. Its torpedo planes did have some limited success against targets other than IJN fleet carriers while mistakenly claiming eight hits against *Shokaku* at Coral Sea. Midway left no doubt as to the shocking vulnerability of the TBD, but the advent of the TBF probably gave torpedo bombing advocates a second wind.

It was also hard for the people on the spot to evaluate the effectiveness of escorts. Particularly in the chaos of fighter on fighter combat, it is natural to over-estimate both the number of enemy aircraft engaged and the losses taken by the enemy. Targets and attackers were seen fleetingly, an aircraft shot at and then disappearing from view appeared to be shot down, different pilots shooting at the same aircraft both claimed it. The same problems afflict CAP combat, but at least much CAP combat took place over friendly ships that could count the aircraft falling into the water. Even that double-check was unavailable when evaluating escort combat. The natural tendency was for the escorts to over-report both the number of CAP fighters they had faced and the number of their victories. That would naturally lead to an over-estimation of both the need for escorts and their effectiveness.

AA Effectiveness

Analyzing AA effectiveness is more clear-cut than the ins and outs of CAP and escort combat, but is not without its issues. As I noted above, the physical effect of IJN AA was extremely limited, while USN AA accounted for about one-third of all IJN attack aircraft downed.[146] USN AA effectiveness grew throughout the period, reaching its peak at the Battle of Santa Cruz, when they almost equaled CAP victories. Santa Cruz accounted for more than two-thirds of AA victories during the four battles.

Anti-aircraft fire had a psychological effect as well, and that effect is much harder to judge. I believe that much of the psychological effect stemmed from the physical effect. AA fire deterred attacks because it could kill you. But I also believe that even if

[146] IJN AA downed very few aircraft, but did damage some in ways that could have affected their attacks. However, even that effect appears quite limited.

aircrew could have been assured that AA fire posed little real danger, flying through air-bursts and ribbons of tracer fire was still distracting.

Finally, to say that AA fire deterred attacks was not to say that it prevented attacks. There are few, if any, documented instances in these battles of aircraft turning away from an attack in the face of AA fire. Its effects were more subtle, causing weapon drops at greater than optimal ranges, causing attackers to accept less than optimal attack angles, and rushing the selection of targets. Those subtle effects on attacks make the overall effects of AA fire harder to quantify.

Santa Cruz provides some insight into this. In that battle, the IJN took the heaviest losses from AA. At least two IJN pilots remarked on the extreme weight of AA fire that was brought against them. But did their accuracy suffer?

From the numbers, it is not immediately obvious. The torpedo bombers scored fewer hits than average, dragged down by the torpedo attack against the Enterprise having gone hitless. But the dive bombers did a bit better than average, in terms of both hits and combined hits and damaging near misses. In terms of the averages, the torpedo bombers made three hits against an average expected number of a bit more than five based on all other IJN strikes, while the dive bombers made seven hits against an average result of less than six and 10 total hits and damaging near misses against an average of almost nine.[147] Adding all the numbers, the IJN Santa Cruz strikes made 13 hits and damaging near misses against an average result in the other strikes of 14. That is not overwhelming evidence that the heavier AA made that much difference to bombing effectiveness, although it suggest some slight degradation. It is a bit more suggestive that the greatest decrease in accuracy came from the torpedo bombers. They experienced the greatest increase in losses from AA compared to previous strikes, even though their AA losses were almost identical to losses taken by the D3As.[148] The increased losses were likely a reflection of increased AA intensity, which

[147] The averages for other strikes are the average number of hits for the number of aircraft attacking.

[148] 12 1/2 shot down for the B5Ns versus 12 down for the D3As. In previous strikes, B5Ns had taken only three losses from AA compared to 6 1/2 for D3As.

also resulted in a decrease in the quality of the attacks. If so (and I am inclined to think that it is so), then credit should go in large part to increased AA effectiveness from the USN screening ships, as these got a large portion of the AA victories over B5Ns at Santa Cruz.

One other aspect of AA complicates any assessment of its effectiveness. In many cases, it is hard to know whether AA killed a striker before it could score, or whether the kill was on a striker that had attacked and missed. The scenario is easy to picture. The dive bomber hurtles down while tracers rise to meet it. Its bomb falls free. The D3A bursts into flame, crashing close beside its target. Its bomb falls as close but misses. Did the AA score before the bomb was dropped? Was the crew dead or dying or the aircraft uncontrollable at the time of the bomb drop? It is impossible to know with certainty whether the AA saved the ship from a potential hit or merely downed an aircraft that had already attacked.

Hard it may be, but I have given it a try. By my calculations (which involve a few arbitrary classifications), almost two-thirds of the kills made by USN AA on IJN torpedo bombers were made before the bombers could make effective attacks. I estimate that to be about 27 kills, equal to one and one-half carriers saved. For D3As, the kills split almost evenly between before and after attacking, with a slight edge to before. But these numbers are also harder to evaluate for AA versus dive bombers, as the bulk of the AA fire would have happened as the dive bombers were diving.

To conclude, IJN AA had limited physical effects but probably had some psychological effects – at least when contrasted to the complete absence of AA fire. USN AA fire had increasing formidable physical effects as 1942 went on, and likely some increasing psychological effects as well.

One final point: by the end of 1942, the combined effects of USN CAP and AA fairly savaged the IJN carrier strikes sent against them. Of the 99 strike aircraft that attacked during the Battle of Santo Cruz, up through the *Junyo's* torpedo bomber

attack on *Hornet*, 51 were lost to CAP or AA.[149] The USN defenses essentially killed more than one carrier's striking power even without killing the carrier itself.

Maneuver

We have seen that maneuver was an important aspect of defense throughout 1942. Its only drawback was diminished AA effectiveness, as a twisting, turning gun platform complicated fire control solutions and a twisting turning carrier complicated the task of the ships attempting to screen it. Neither of these issues were of much moment to the IJN, as its AA was not much of a defense in any event and its screens were quite loose and distant by design. The USN concentrated on improving AA effectiveness even from radically maneuvering platforms – even if by sheer weight of fire – and by developing the tactics and teamwork necessary to operate screening ships in close circular formations around a radically maneuvering carrier.

Maneuver was most effective against small, uncoordinated torpedo attacks and least effective against well-coordinated "anvil" torpedo attacks. But that is a bit misleading, because maneuvering also made it harder to set up anvil attacks, particularly for the slow TBDs with their slow torpedoes. The IJN carriers at Midway are a prime example of this, as they showed their sterns to the TBDs and so made much harder the efforts of the torpedo bombers to set up coordinated attacks in the face of intense CAP opposition. The USN faced the greater torpedo threat, and the 1942 battles show both adroit ship handling used to avoid torpedoes and the difficulties the *Lexington*, *Yorktown*, and *Hornet* faced when trying to deal with many attackers coming from different directions.

It seemed that IJN anvil tactics were most effective when executed by from eight to ten aircraft. Fewer made it harder to trap the target, more seemed to overload the attack lanes and result in some of the torpedo bombers attacking secondary targets.

[149] These numbers do not include damaged aircraft or aircraft that ditched. At least some of the ditchings could be the result of the damage to *Shokaku*, and the crews of damaged aircraft could fly again even if the aircraft could not.

Maneuver was also effective against dive bombing, although the effect was less marked. Course changes could even make a target as large as a carrier difficult to hit, while heading towards or away from the dive bombers could force them to make dives that were steeper or shallower than optimum. Showing the dive bombers the width of the ship rather than its length was also fairly effective as it gave the pilots a harder target to hit. Forcing dive bombers to dive with the wind to one side or the other of their dives also impaired accuracy. But the key word here is "impaired;" none of these tactics allowed carriers to escape unscathed.

The 1942 battles saw 14 strikes with dive bomber attacks on carriers – six IJN attacks and eight USN – with all strikes but two scoring at least one hit. In some cases, the target's initial maneuvers seemed to baffle the first attackers and in others the target's maneuvers seemed more effective against later attackers, but in 12 of 14 cases the dive bombers still scored.[150] That leads to the next topic: how carriers stood up under the punishment they received.

Armor and Damage Control

Clearly, armor was quite effective in protecting carriers from dive bombing. None of the carriers lost in the 1942 battles was lost to a bomb penetrating deck armor to reach a vital area. Of course, that is not the end of the issue. Four carriers were lost to bombing despite their armor protection. In each case, the losses resulted from uncontrolled fires and explosions. In three of the four cases, the fires became uncontrollable due to the presence of many armed and fueled aircraft in the hangers of the bombed carriers.

All carriers proved vulnerable to fire and explosion. In addition to the four IJN carriers lost to these causes – *Akagi*, *Kaga*, *Hiryu*, and *Soryu* – *Lexington's* torpedo hits created the conditions for the explosions and fires that caused her loss. Having armed and fueled aircraft on board made the risks much worse, with *Akagi*, the best example of this, being lost to a single bomb hit. That said, being bombed was far from a sentence

[150] Of the two attacks that failed to score, one involved 14 D3As forced to glide bomb out of low cloud. They missed the carrier, but they hit a battleship and a light cruiser. The other was staged by USMC SBDs from Midway, and was also a glide bombing attack.

of death. On two occasions, *Shokaku* survived multiple 1,000 pound bomb hits. She was set on fire in each case, but in each case was able to steam at speed and to get the fires out. She needed dockyard repairs to return to combat, but return she did.

As to the IJN carriers lost to bombing, it is clear that they did not have the resources that USN carrier had to combat fire and explosions.[151] That said, it is far from clear whether better damage control would have saved the IJN carriers that were lost. I doubt that any level of World War II damage control could have saved *Kaga* and *Soryu* when they were caught with an armed strike in their hangers. *Akagi* possibly might have escaped being scuttled if her damage control had been better, but would almost certainly have taken heavy damage.[152] *Hiryu's* small size made her survival doubtful even with enhanced damage control resources.

USN damage control for bomb hits is a bit of the flip side of the IJN being overwhelmed by the scale of damage. In a sense, USN damage control was underwhelmed by the bomb damage that its carriers took. The USN carriers were fortunate to be caught without many armed aircraft on board in any of the battles.[153] The smaller scale of damage and the greater resources to combat it meant that USN damage control was largely able to concentrate on restoring bombed carriers to a battle-worthy condition rather than saving the ship for dockyard hands to fix.[154] And USN damage control managed just that, as no USN carrier in 1942 was knocked out of combat just because of bomb damage.

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[151] Parshall and Tully, 245-55.

[152] That assumes that her jammed rudder could have been freed. If it was not, I doubt that she could have been towed clear of the USN forces that would have pursued her.

[153] But not without any. At Santa Cruz, *Enterprise* had to jettison some armed and fuelled aircraft after an IJN bomb exploded in her hanger. An IJN carrier, with her closed hanger deck, could not have done the same. But if the *Enterprise* had had more armed aircraft in her hanger, her hanger crews would probably never had the chance to push the aircraft overboard. They would have been overwhelmed by a chain reaction of damage.

[154] USN carriers were hit by D3A bombs 15 times, with no carrier taking more than four hits in a battle and no more than three in rapid succession. The carriers also took at least eight damaging near misses. More hits in rapid succession might have overwhelmed the USN damage control teams, but massing enough bombers to get more hits in rapid succession would have been hard.

That is not to say that USN damage control had a cake walk. Some of the bomb hits scored by the IJN could have resulted in serious damage without prompt well-resourced, well-drilled damage control. One of the hits shut down *Yorktown's* powerplant, albeit temporarily. Another crashed into *Enterprise's* hanger when aircraft were being gassed and armed. But the damage control teams of both carriers had the resources and the expertise to deal with the damage.

Torpedoes, however, presented insurmountable problems to USN damage control. Only seven IJN torpedoes found their targets in the 1942 battles, but those hits sufficed to finish three carriers. *Lexington* was torpedoed twice, with the fatal hit rupturing her gasoline stowage and delivery systems and resulting in a chain of fires and explosions that effectively wrecked the ship. *Yorktown* also took two torpedoes, which knocked out her power plant and exposed her to the submarine attack that ultimately sank her. She might have been salvaged, but only after a tow to a dockyard. *Hornet* took three torpedo hits, which likewise ravaged her powerplant and left her dead in the water. She fell victim to a vicious circle; with *Hornet* out the battle the USN lacked the ability to contest the IJN advance that resulted in *Hornet* being abandoned and scuttled.

In sum, the inability of active defenses to stop attackers completely made protection and damage control important. Both IJN and USN damage control had their successes and failures. The USN was able to keep bombed ships in combat due to the effective of USN carrier protection and damage control. But the carriers were faced with relatively low numbers of hits by relatively small bombs. USN protection and damage control practices were less effective in the face of the damage caused by IJN torpedoes. The IJN had its successes in this arena as well, twice saving *Shokaku* from multiple 1,000 pound bomb hits. But four such hits overwhelmed *Hiryu*, while no practicable amount of damage control could have prevented severe damage or worse to the IJN carrier caught with more than just a few armed and gassed strike aircraft in their hangers.

Out-Ranging

Out-ranging was an IJN idea of gaining an advantage by being able to strike at an enemy while beyond the range of the enemy's weapons. In the context of carrier warfare, this meant building strike aircraft that could out-range the enemy's. Out-ranging was unlikely to confer an absolute advantage, as it was difficult to control the ranges at which a carrier battle would be fought. But even if the IJN carriers were within the range of the enemy carriers' air groups, superior range would give their strikes more time to locate and attack the enemy.

How did this work in practice? The proof of the concept would be instances in which IJN carriers were able to strike their USN counterparts while the USN carrier strikes were unable to find and strike the IJN units. Where a USN strike ran out of search time due to range limitations, and the IJN strike did not, the out-ranging concept would be vindicated.

With that as the test, there is not much evidence that out-ranging was as effective as the IJN might have hoped. In the period, only two USN strikes sent after IJN carriers failed to find any targets to attack. The first was the SBD portion of the *Lexington* strike at Coral Sea. These aircraft searched for the IJN carriers in poor visibility but ultimately returned due to fuel constraints. While this looks like a victory for out-ranging, it is actually a special case as the SBDs had – due to an administrative error – not been fully fueled before taking off. The second strike that failed to reach a target was the SBD portion of the *Hornet's* strike at Midway. However, these aircraft almost literally flew a ring around the IJN carriers without spotting them. One could argue that the SBDs could have done a few more orbits of the IJN carrier task group if they had more endurance, but it seems more sensible to regard this as due as much to the fortunes of war as to the out-ranging principal.

That conclusion is bolstered by the fact that the IJN also had strikes that missed their targets. Two strikes did so in this period: the dusk strike at Coral Sea and the second strike at Eastern Solomons. Out-ranging was clearly not a factor in these failures, as

they happened to the IJN. Instead, they demonstrate that missing the target was a risk that both navies ran, in about equal measure.[155]

That said, I believe that there was a more subtle way in which out-ranging did give the IJN a hard-to-quantify but nonetheless real advantage. That was when it worked in tandem with the evolving IJN conception of dispersion as a means of defense – a topic to which I now turn.

Concentration and Separation

Should carriers be concentrated together or separated? In theory, concentration permitted better coordination of offensive and defensive efforts and reduced the chance of a force being spotted, while separation prevented a single enemy strike from destroying more than one carrier and gave the enemy the opportunity to "overkill" one carrier with multiple strikes while inadvertently missing others.[156] This framed the terms of the debate at the start of the Pacific War, although the concepts would morph into different forms as the conflict progressed.

The IJN eschewed separation because its focus on offensive power mandated concentrated carrier assets. Only by concentrating could the IJN coordinate air strikes from multiple carriers. In fact, every carrier battle in which more than one IJN carrier launched a strike against USN carriers, the main IJN strikes included aircraft from more than one carrier. But despite being wedded to concentration for the sake of offensive power, the IJN devised an effective tactic that put a new twist on separation.

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[155] In terms of numbers, a total of 45 USN strike aircraft hunted carriers but failed to make any contact; for the IJN the number was 54 strike aircraft.

[156] In theory, the detection issue worked this way. Assume that a single task force had a 70% chance of being sighted. Be generous, and assume that two smaller task forces each had only a 60% chance of being spotted. There is an 84% chance of at least one of the smaller task forces being spotted, and a 36% chance that they both would be spotted. Concentration was the better course to maximize the chance of surprising the enemy and to attempt to defend all the carriers in the force rather than sacrifice one. If surprise was unimportant and the enemy was likely to respond to a sighting with the overwhelming force, then separation made more sense.

The USN pre-war was more inclined to separate carriers. As a result, it did not in 1942 perfect the art of launching and coordinating airstrikes from multiple carriers. Each carrier struck largely on its own, even if it was operating in company with another carrier. Carrier separation varied from battle to battle, with *Lexington* and *Yorktown* operating together at Coral Sea, *Hornet* and *Enterprise* operating together at Midway but with *Yorktown* 30 or 40 miles away, and the carriers at Eastern Solomons and Santa Cruz operating between 10 and 20 miles apart. Effective separation required as wide a dispersal as practical, and certainly more than 20 miles, while separation of more than 30 miles would make it hard for CAP from one task force to intercept strike aircraft before they could attack the other task force.

While USN CAP could not stop IJN strikes entirely, concentrating carriers and pooling carrier CAP resources clearly did the USN more good than harm. CAP killed IJN aircraft, and, even without more, killing off experienced IJN aircrews was valuable to the USN. With USN CAP assets combined, the IJN proved incapable of mounting a single strike that would – after attrition from the combined USN defenses – be likely to cripple more than one carrier, so putting two carriers in the way of one strike was not likely to increase the toll in USN carriers. Separation might have resulted in the IJN focusing additional strikes on an already crippled carrier, but that potential benefit was unlikely to outweigh the real value of combining CAP assets.

While the IJN never wavered from concentrating its fleet carriers, it did devise a variation on the theme of concentration that proved fairly effective at Santa Cruz. This was the use of non-carrier task forces that operated in advance of the carriers with the intention of drawing off enemy strike forces. Combined with out-ranging (in this case, fighting the battle at longer ranges), putting the advance forces in harm's way effectively tempted the USN strikers to hit the vanguard force rather than burn dwindling gas looking for the carriers.

The advanced forces served a second purpose as well. Unlike the USN, the IJN relied on floatplanes as primary search aircraft. This allowed the aircraft on the IJN carriers to focus more on striking and less on search. For the advanced forces, it also put the

cruisers and floatplane tenders operating the floatplanes out ahead of the carriers and in a good position to make searches.

The numbers bear out the effectiveness of this tactic. At Santa Cruz, only 15 of 51 USN strike aircraft found the IJN carriers. All the strike aircraft found the advance IJN forces first, but all except the 15 SBDs of the Hornet's first strike settled for bombing the advance force ships. At Eastern Solomons, only seven strike aircraft were sent to strike the IJN fleet carriers. In bad visibility, they also settled for attacks on the IJN advance force ships.

In summary, the USN considered separation pre-war but rapidly abandoned it. It was able to pool its carrier CAP resources reasonably well, but it failed during 1942 to concentrate the offensive power of its carriers. The IJN was wedded to concentration from the start, and had a well-developed doctrine of multi-carrier strikes, but struggled to deal with the vulnerability of its carriers given the relative ineffectiveness of their active defenses. Its response was a modified form of separation, in which advanced scouting forces were used to attract some of the USN strikers.

Conclusions

This study shows that in 1942 there was no absolute defense against carrier air strikes. Despite combat air patrols and anti-aircraft fire, the bomber would in fact get through. Despite maneuver, the bomber would almost always score. But having taken hits, aircraft carriers turned out to be something less than floating bombs. They were lost in numbers, but they engaged in numbers. Among them, both *Enterprise* and *Shokaku* survived multiple bomb hits on two separate occasions. *Yorktown* survived one bomb hit at Coral Sea and would probably have survived another three at Midway had she not been torpedoed. Armor protection and damage control played an important role in these battles, making up for the inability of CAP and AA to stop all attacks.

No IJN strike had enough B5Ns to cripple – on average – more than one USN fleet carrier. IJN dive bombers proved unable to inflict more than moderate damage on USN carriers. USN torpedo planes proved to be completely ineffective against IJN fleet

carriers, but USN dive bombers proved that they could disable carriers and even cause their demise in the right circumstances. The USN required more attacking dive bombers to achieve these results, but the low losses among the SBDs meant that a carrier could put enough of them into a strike to knock an IJN carrier out of the battle. The SBDs never sank a fleet carrier outright, but then neither did the B5Ns. All of the fleet carriers lost in 1942 were scuttled. It is undeniable, however, that aerial torpedo hits caused more damage than most bomb hits. Dive bombers came to the fore only when they caught their targets with large numbers of planes armed and gassed in their hangers, as in the attacks against *Akagi*, *Kaga*, and *Soryu*. Of the three USN carriers torpedoed by B5Ns, *Lexington* was a constructive total loss before being scuttled, *Yorktown* was exposed to submarine torpedo attack after the torpedo bombers knocked out her powerplant, and *Hornet* was abandoned after she could not be towed clear of advancing IJN forces.

While neither side proved capable of completely stopping the other's strikes, the USN inflicted the heavier aircraft and aircrew losses throughout the period. The six IJN fleet carriers that attacked Pearl Harbor carried 135 D3As and 144 B5Ns into that attack.[157] In the four great carrier battles of 1942, the USN knocked down 64 D3As and 42 B5Ns. Counting the IJN carriers' losses in other operations against the Americans, the IJN's total losses from her fleet carrier air groups were at least 80 D3As and 54 B5Ns.[158] This is more than two-thirds of the IJN fleet carrier dive bombers at the start of the war, and more than one-third of all torpedo bombers. Most of crews of these aircraft were killed, starting the IJN on a downward spiral of crew quality from which it would never recover.

By contrast, the USN lost 22 SBDs and 46 torpedo planes to IJN carrier defenses, from a total of about 210 SBDs and 100 TBDs embarked on USN fleet carriers at the start of

[157] Based on the composition of the IJN Pearl Harbor attacks, I allocate these aircraft as follows: *Kaga* – 27 D3A and 27 B5N, *Akagi* – 18 D3A and 27 B5N, *Hiryu* and *Soryu* – 18 D3A and 18 B5N each, *Shokaku* and *Zuikaku* – 27 D3A and 27 B5N each. By Coral Sea, *Shokaku* and *Zuikaku* had only 18 B5Ns and 18 D3As each. By Midway, the B5N complement on *Akagi* had shrunk to 18, while *Kaga* had only 18 D3As.

[158] This includes losses in the four carrier battles, the Pearl Harbor attack, the attacks on Wake, the strike against oiler *Neosho* and the attack on Midway. It does not include losses incurred elsewhere (such as in the Indian Ocean) or operational losses.

the war. Not only were overall USN losses much lower, but more of the aircrews were rescued. And the losses were backed by a massive program of aircrew training and aircraft production.

The USN resolved the dilemma of concentration versus separation by opting for concentration, while the IJN chose both. The USN ultimately put gave each carrier a separate anti-aircraft screen, but kept them close enough to provide mutual combat air patrol support. USN AA effectiveness increased throughout the period; CAP continued to struggle with the challenges of making good interceptions but still managed to pool carrier resources fairly effectively. The same could not be said for USN air strikes. Perhaps the greatest failing of the USN in this time period was its general inability to assemble coordinated multi-carrier strikes.

The IJN managed to answer "Both" to the question of separation or concentrating by concentrating its carriers but separating them from its search and screening ships. The advanced screen could provide valuable reconnaissance information while drawing off USN strikes. The concentrated carriers could mount powerful well-coordinated strikes from all of the assembled carriers.

All of this provides more than a glimpse of the way forward for both navies. USN combat air patrol equipment and procedures would improve until interceptions 50 miles out from task forces were routine. The widespread installation of 40 mm guns and the adoption of the radar proximity fuse greatly increase the deadliness of USN anti-aircraft fire. Both developments combined to make aerial sorties against USN carrier task forces near-suicide missions. From there, it was a short step to the widespread adoption of suicide tactics by the IJN.

While suicide tactics made explicit the implicit risks of attacking USN carrier groups, they also reflected the decrease in the quality of IJN aircrews. The IJN attempted to rebuild its carrier air groups on more than one occasion, only to see the new groups demolished by Allied air power. Suicide attacks gave unskilled pilots a greater chance of scoring hits. USN air power also pushed the IJN to further the use of advance and decoy groups to deflect that air power from the main IJN forces. At the Battle of the

Philippine Sea, the advance group included some light carriers as bait. At the Battle of Leyte Gulf, the surviving IJN carriers were themselves the bait, and the IJN battleships the ships to be protected. That action ended carrier versus carrier warfare in a way that clearly demonstrated the USN's ultimate dominance.