

SET AND DRIFT

DOCTRINE MATTERS WHY THE JAPANESE LOST AT MIDWAY

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Dallas Isom's article "The Battle of Midway: Why the Japanese Lost" [*Naval War College Review*, Summer 2000, pp. 60–100] is laudable for its use of Japanese sources and for the interesting points it raises. In particular, we applaud Isom's interviews with Japanese survivors, which contribute new and useful information regarding Japanese aircraft rearmament procedures. This new data is crucial to building an accurate account of the events that transpired aboard the Japanese carriers on the morning of 4 June 1942. However, in our opinion, Professor Isom's arguments appear to rely too much on a rather rigid (and highly debatable) interpretation of Japanese communications: namely, exactly when did Vice Admiral Chuichi Nagumo receive transmissions from scout plane 4, launched by the cruiser *Tone*. In addition, while Isom's rearmament information

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(which he puts forward as central to Nagumo's inability to launch his anticarrier strike before being fatally attacked) is clearly important to understanding the Japanese side of the battle, we feel that he did not carry his operational analysis far enough. As a result, we cannot accept his conclusions.

At the time of Isom's writing, we were engaged in a reappraisal and rewriting of the Japanese account of Midway as a result of our own work in identifying wreckage from the carrier *Kaga*.¹ A key part of our approach was to build an accurate model of the operations of the Japanese carrier striking force. As we will show, the disaster that befell the Japanese carrier force hinged neither on whether Nagumo received

Tone 4's message at 0740 or at 0800, nor on how quickly the armorers in the Japanese hangars could do their work. Rather, the fate of the Japanese Mobile Striking Force (*Kido Butai*) revolved around what was happening on its flight decks. Armed with a knowledge of Japanese carrier doctrine, as well as the operational information from the battle, one can reach an accurate assessment of the state of readiness of Nagumo's force at the time of the climactic American attack without resorting to Isom's indirect method.

A major error in the Isom article is that it repeatedly misstates what aircraft actually were on the Japanese flight decks. In several places, Isom presumes that the Japanese antiship strike force was on the flight decks when it is demonstrable that those aircraft were still in their hangars. This presumption carries forward

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the (mistaken) conventional view that the Japanese had spotted their antiship strike force on the flight decks shortly after the initial Midway attack force had taken off and

had only briefly moved these antiship strike aircraft below for the purposes of rearming them or recovering the first-strike wave. As will be shown, this is the root of the fundamental misunderstanding of circumstances at the time the carriers were struck.

In fact, both Japanese doctrine and the operations of the Japanese combat air patrol (CAP) fighters would have kept the reserve strike planes securely below in their hangars until they were definitely needed. Not only that, but because of Japanese hangar design, the window of time necessary to lift, spot, and launch the aircraft was substantially longer than has been previously understood. As a result, given the frenetic nature of Japanese CAP operations after about 0800 (particularly aboard *Akagi* and *Kaga*), it is unlikely that many of these second-wave aircraft were ever spotted on the flight decks before the fatal American dive-bomber attack commenced at 1020.

This point cannot be overemphasized, because from the conventional belief of what was on the flight decks flow nearly all Western interpretations of the battle. To put the matter succinctly, at the time *Akagi*, *Kaga*, and *Soryu* were struck, *their flight decks were more empty than occupied. This is almost the reverse of the standard view, which has the Japanese flight decks packed with strike aircraft awaiting takeoff. There were aircraft on deck, but most were CAP fighters, not attack aircraft. There were also fewer aircraft on deck than is generally supposed. Though potentially startling, this is less a "revision" than a correction and careful restating of the existing historical record. We will show that official Japanese sources on the battle have been aware of this for some thirty years.*

These errors in both the conventional Western interpretation and Isom's article cannot be addressed without first developing a sense of how the Japanese conducted carrier operations. Unfortunately, standard English-language histories

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of the battle of Midway have not well understood Japanese carrier operations. From the common misperception that Japanese naval aviation was derivative of Western

(primarily British) practice, Western writers typically believe that the Japanese carriers of World War II behaved much like their Western counterparts. In fact, they did not. Japanese carrier operations contained elements of both U.S. Navy and Royal Navy practices. However, as a result of differences in physical design and operational doctrine, by the late 1930s Japanese carriers fought in a fashion all their own. Without understanding these points of divergence, understanding Nagumo's actions is likewise impossible.

Before the days of modern angled flight decks, a carrier flight deck could be doing only one of three things: spotting aircraft, launching aircraft, or recovering aircraft. To this list most American writers would be quick to add "parking aircraft" and "servicing aircraft." However, it is important to understand that the Japanese avoided performing these activities on the flight deck. Japanese carriers did not use permanent deck parks in the fashion of the U.S. Navy. While temporary deck parks were established forward of crash barriers during recovery operations, they acted only as transitional "overflow" mechanisms until returning aircraft could be moved below decks.² Furthermore, while the Japanese could service aircraft on the flight deck (Japanese carriers were equipped with refueling points around the deck edge, for instance), most fueling occurred in the hangars. Likewise, except for arming dive-bomber aircraft, the Japanese serviced planes in the hangar as well.³

Japanese carrier design is also notable for its use of enclosed hangar decks. In contrast to U.S. carriers, whose hangars could be opened to the elements by rolling up metal screens along their sides, Japanese hangars were fully enclosed by storerooms, workshops, and crew spaces, with no natural ventilation. This meant that aircraft engines were never warmed up below.⁴ This is in direct contrast to American practice, where aircraft commonly were warmed up in the hangars, brought to deck, and immediately launched. These factors had important ramifications during the battle of Midway and imposed severe restrictions on Japanese operational tempos.

In order to spot a strike force on the flight deck and launch it against the Americans (assuming it was already armed), Nagumo's ships had to perform a

complex series of operations. Some tasks could be done in parallel, some only sequentially, and each entailed fixed or variable time costs. These included:

- Bringing the aircraft up to the flight deck (sequential: approximately one minute per plane).⁵
- Spotting the aircraft, unfolding its wings, and chocking wheels (conducted mostly in parallel with elevator movements, but five sequential minutes are added to account for these movements).⁶
- Warming up engines (sequential: fifteen minutes minimum for the entire force).⁷
- In the case of dive-bombers, arming the aircraft (largely concurrent with engine warmup, but could take as long as twenty minutes).⁸
- Delivering final briefings to the pilots (again, mostly in parallel with elevator movements, five sequential minutes minimum for the entire force).⁹
- Moving crew to planes and performing final preflight checks (five minutes).¹⁰
- Launching the strike (sequential: fifteen to thirty seconds per plane).¹¹

Taken together, it is apparent that spotting a twenty-one-plane strike for launch would take around forty minutes total, and another five to ten minutes would be required for the launch.¹² If the deck spot contained dive-bombers, the spotting time would be perhaps five to ten minutes longer, because these planes had to be armed during engine warm up. This timing is directly confirmed in official Japanese sources.¹³ The need to warm up engines on the flight deck, dictated by Japanese hangar design, reveals itself as a major hindrance to Japanese operational tempos. Unfortunately, warm-up could not be shortened—aircraft casualties were the inevitable outcome of slighting this activity, and needless losses had to be avoided at all costs.¹⁴ Thus, if Nagumo was to attack the American strike force, he needed to find an unbroken forty-five-minute window of opportunity on all four flight decks during which to spot and then launch his strike.¹⁵

The final piece of the puzzle is found in the activities of the Japanese combat air patrol that morning. An examination of *Akagi's* flight operations reveals the basic point:

0430—launch Midway attack force

0445—launch initial combat air patrol (three fighters)

0543—launch CAP (three fighters)

0655—launch CAP (three fighters)
 0659—recover CAP (three fighters)
 0710—launch CAP (five fighters)
 0720—recover CAP (one fighter)
 0726—recover CAP (one fighter)
 0736—recover CAP (three fighters)
 0750—recover CAP (two fighters)
 0808—launch CAP (three fighters)
 0832—launch CAP (four fighters)
 0837–0900—recover Midway attack force plus three CAP fighters
 0910—recover CAP (one fighter)
 0932—launch CAP (five fighters)
 0945—launch CAP (three fighters)
 0951—recover CAP (two fighters)
 1010—recover CAP (three fighters).¹⁶

The other carriers were involved in similar activities, albeit at different times.¹⁷ The important point is that recovery operations absolutely required a clear flight deck aft. Aircraft could not be spotted aft while aircraft were landing, nor would they usually be spotted aft during *fighter* takeoff operations.¹⁸

This information enables us to appreciate several things. First, it is clear that *Akagi* was very busy on the morning of the fourth. The constant American air attacks from 0700 onward necessitated a continuous cycling of the Japanese CAP fighters above Nagumo's formation. It was very difficult to find a spot to squeeze in forty minutes of uninterrupted deck time to spot a strike, let alone launch it.¹⁹ This is a crucial realization in determining what was possible aboard the Japanese carriers and in analyzing Nagumo's decision-making process.

Second, upon closer examination it is apparent that *Akagi's* 1010 CAP recovery dictates that there cannot have been many strike planes on its deck when it was fatally bombed at 1025. Fifteen minutes would not have been sufficient time to bring its twenty-plane strike to the flight deck, let alone spot them, brief the pilots, and warm up engines.²⁰ Thus, the common belief that the American dive-bomber attack found the Japanese flight decks practically chock-a-block with strike planes revved up and waiting to take off is clearly untrue. The aircraft on deck were primarily CAP fighters.

As it turns out, this latter observation, while perhaps shocking to an American audience steeped in the popular lore of this battle, is directly supported by official Japanese sources. In Japan, a clearer picture of Japanese Midway operations began emerging in the 1970s, with the publication of the official

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Japanese war histories (known as *Senshi Soshō*) and other substantive works. Unfortunately, it is only very recently that some of these works have been translated into English. *Senshi Soshō* explic-

itly states that at the time of the attack, every Japanese carrier had its attack aircraft in the hangars; the only aircraft on deck were either CAP fighters or, in the case of *Soryū*, strike force escort fighters that were being launched to augment the CAP.²¹

Third, this operational information casts doubt on whether Nagumo's reserve strike force was ever on deck in the first place. The conventional wisdom has always been that when Lieutenant Joichi Tomonaga's Midway attack force was launched, the reserve antiship strike force was immediately brought up to the flight decks and spotted. In fact, this would be contrary to typical Japanese operational patterns, which would have preferred to keep the strike in the hangars until needed. It is absolutely certain that this force was *not* on deck during the 0800–0820 time frame, when Nagumo was making some of his most crucial decisions. Attacking B-17s photographed the Japanese formation during this period, and their pictures of *Soryū*, *Hiryū*, and *Akagi* show no strike planes on deck, only a handful of fighters. This is corroborated by Japanese records that show the force launching additional CAP fighters during this time.

With this information in hand, we now turn to several of the assertions in Isom's article. For instance, regarding Nagumo's supposedly tardy receipt of *Tone 4*'s message and its dire implications for subsequent Japanese preparations, Isom states (p. 75), "It should thus be apparent that if the rearming operation was reversed at this point—at 0745—it would not have taken much time to restore the torpedoes on half the planes from which they had been removed and respot all the planes on the flight decks of the two carriers, perhaps only about thirty minutes." In light of the need for forty minutes just to respot the strike, not to mention the time needed to rearm, this gives a grossly optimistic impression of Nagumo's chances of launching a strike before Tomonaga's returning force would begin to occupy the flight decks at 0837.

Isom later states (p. 77), "Thus, at about 0920 operations to respot the second-wave strike force on the flight decks could have begun, had the torpedo planes been rearmed with torpedoes. Had the countermand order been given at

0745, as the standard scenario holds, the torpedoes almost certainly would have been restored by 0920.” The ability of the Japanese carriers to begin a respot at 0920, had they been rearmed or not, is highly questionable given the high tempo

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of CAP operations and their monopolization of the flight decks. At this point in the battle, Japanese records clearly show, the Japanese were alert to a constant stream of incoming American strikes. Until the coast was rea-

sonably clear and his CAP well stocked with fresh fighters to last through the spotting process, Nagumo cannot have been expected to spot his strike. *Akagi's* air officer (*hikocho*) in charge of flight operations, Commander Shogo Masuda, as well as the other experienced air officers around Nagumo (such as Mitsuo Fuchida and Minoru Genda) could not have helped impressing this point upon the admiral.

Even more questionable is Isom's subsequent statement (p. 78) regarding the state of Carrier Division 1 at 1000. When the attack was over at 1000, “about ten minutes of work still remained to rearm the last division of *Akagi's* torpedo planes, and even more time was needed for *Kaga's*. The torpedo planes that had been rearmed were brought up to the flight decks, beginning around 0920, but at least a third remained in the hangar decks at 1000. By 1015, the rearming had probably been completed on *Akagi*, and the last torpedo planes were being brought up and spotted on its flight deck. Had the whole strike force been ready to go at 1000, it, along with Zero escorts, could have been launched during this fifteen-minute window between attacks on the Mobile Force.”

This is wrong on several counts. First, we know that *Akagi* landed a CAP fighter at 0910 and two more at 0951, meaning that even if there had been strike aircraft on deck at 0920 (which we think highly unlikely in any case), they had to have been moved back down into the hangar by 0951. Also, Isom clearly does not factor in the immutable time costs associated with spotting and engine warm-up—a “fifteen-minute window between attacks” simply does not suffice. In fact, in this case Isom also ignores Nagumo's own estimate that the strike force would be ready at 1100, although a 1030 takeoff was hoped for, if things went well. Launching at 1000, though, for all the reasons cited above, was never even remotely in the cards, and Nagumo knew it.

Furthermore, the assertion that two-thirds of *Akagi's* torpedo planes were on deck at 1000 is clearly wrong. *Akagi* had landed CAP nine minutes earlier, at 0951, and would do so again at 1010. Isom's assertion is also directly contradicted by *Senshi Soshō*, which states that at the time of the 1025 attack all of *Akagi's*

strike aircraft were in the hangar. This is further corroborated by Richard Best, lead dive-bomber pilot against *Akagi*, who states that when he dove for his attack, the only aircraft on deck were Zeros.²²

Isom makes a different error regarding rearmament activities aboard Carrier Division 2 (*Hiryu* and *Soryu*). He writes (p. 79), “[the strike aircraft] could be re-armed on the flight deck as well as in the hangar deck. (It appears that only half of each squadron was lowered to the hangar deck after the 0715 rearming order, thus saving elevator time.)” Furthermore, he states (p. 80), “Most, if not all, of those [strike aircraft] had probably been changed back to armor-piercing bombs by very soon after 0830; at least half of each squadron on *Hiryu* and *Soryu* was already on the flight decks at 0830.”

Again, his statement is at odds with the photographic evidence obtained between 0800 and 0815, which shows no strike planes whatsoever on either carrier’s flight deck. In addition, it is known that *Soryu* launched CAP at 0710, and recovered CAP at 0730. *Hiryu* recovered CAP at 0700 and 0740, launched CAP at 0825, and was recovering CAP again at 0840. Thus even if strike planes had begun to be promptly brought up on *Hiryu* after the American B-17s departed at 0815, they would have had to be stowed below again by 0840—the window of opportunity was not long enough to have performed warm-up and launch.

Isom repeats this error later when he states (p. 81), “At 0830, when Nagumo had to make a decision whether to launch an attack on the American force or postpone it, we have seen that he had ready no torpedo planes and no Zeros for escort. But he did have dive-bombers on *Hiryu* and *Soryu* available. They could have been launched fairly quickly.” Again, this is incorrect, as the B-17 photographs and other evidence incontrovertibly demonstrate. The Japanese dive-bombers were all in their hangars at the time and would have taken another forty minutes to put into action, even if they had been rearmed.

Isom’s concluding point, and his central thesis (p. 89), “considering how close [Nagumo] came to launching his attack before being bombed at 1025, every minute saved could have made a significant difference in the outcome of the battle,” is shown to be incorrect by the cumulative weight of the evidence at hand. It was not the inefficiency of Japanese communications (which is debatable) that doomed Japanese hopes in the battle but *the inefficiency of Japanese flight operations*. Nagumo was nowhere near ready to launch by 1025; in fact, he had probably barely begun preparations to do so. Even assuming *Akagi* had begun lifting its strike aircraft to the flight deck immediately after its CAP was recovered at 1010, *Akagi* would not have been ready to launch its strike for forty minutes more (1050) and could not have gotten it completely airborne before 1100. *Kaga* was in a slightly better state, having last launched six CAP fighters

at 1000, but it was hampered because of its larger torpedo bomber wing (twenty-seven aircraft) to lift and spot.

It is no coincidence that after the devastating American attack on the other three Japanese carriers, *Hiryu's* actual operational tempo corresponds very closely with the hypothetical earlier timetable for Carrier Division 1 we have just



U.S. Air Force Photo Battle of Midway, 4–6 June 1942
Japanese aircraft carrier *Hiryu* under attack by USAAF B-17s on 4 June 1942

put forth. The flagship of the aggressive Rear Admiral Tamon Yamaguchi can be presumed to have launched its own strike as quickly as possible after the 1022–1027 debacle. Yet in the event it only managed to get that strike aloft by 1057, directly supporting the idea that its own deck-spotting activities had barely begun when the other three carriers were being attacked. Indeed, if the conventional view were true, planes should have been quite literally zooming off *Hiryu's* flight deck at 1025 even as its compatriots were struck. Clearly, they were not, and this point is often overlooked.

The picture that emerges from this analysis is of a rather conservative admiral operating within the constraints of 1942 Japanese carrier doctrine. In contrast to the standard American accounts that have the Japanese observing the feeble American attacks (poorly executed and

delivered piecemeal) with a measure of contempt, the operational tempo of Nagumo's CAP reveals something rather different. Regardless of whether they accorded the American attackers much respect in terms of technique, the Japanese command was certainly concerned about the aerial assault, both for its disruption of the force's timetable and for the overt danger posed by the attacks themselves. Upon close reading of the Nagumo report and other Japanese sources, there is no question that Nagumo and his staff knew the peril they were in. One good hit on any of the carriers could have disastrous consequences, and each of the carriers had survived near-misses during the morning.

Considering this, Nagumo probably thought he was playing it safe—keeping the strike aircraft in the hangars until the worst of the danger was past, keeping the flight decks clear to support constant CAP operations, and repelling American attacks with the best weapon available, his fighters. When the attacks abated, he expected to spot a coordinated combined-arms strike force on the decks of his two carrier divisions and then deliver a crushing blow to his opponent. Unfortunately for the Japanese, their desire to launch an integrated

attack force from all four flight decks deprived them of flexibility in the face of the enemy.

Because of the remarkably small cannon-magazine capacities of the Zero fighter, defensive CAP operations necessitated frequent landing, rearming, and launching of engaged fighters. Nagumo clearly appreciated the danger in which he would place his ships during deck spotting of strike force aircraft, in that it created a window of time during which no additional CAP could be cycled. As a consequence, his options were more constrained than has been previously understood—spotting an offensive strike meant hanging his CAP out to dry for nearly an hour at a time when American attacks were constant. As it was, Nagumo's defensive approach very nearly paid off, as only the final American attack delivered telling damage. Indeed, it can be argued that had Nagumo played it a little safer, by putting additional CAP aloft, he might have saved *Akagi*, *Kaga*, or *Soryu* from the American dive-bomber attack.²³

Japanese carrier doctrine of the time did not specify what to do when suddenly faced with an enemy force within the enemy's striking range while one's own armed and fueled aircraft were still in their hangars.²⁴ This was a doctrinal failing—although in fairness, both the Japanese and Americans were grappling with this issue. Later in the war, it would have been considered imperative upon detection of an enemy force to immediately launch as many aircraft as possible (whatever their armament) against it. If nothing else, this would get the aircraft out of the hangars, where they presented a dire threat to the carrier itself. Indeed, by 1944 the Japanese Combined Fleet developed just such a command for the signal books in the event of a sudden enemy detection.²⁵

In conclusion, we applaud Professor Isom for his efforts in bringing Japanese sources to the fore of the Midway discussion, as well as his presentation of valuable information regarding Japanese rearming procedures. It is also important to bear in mind that he was laboring under the conventional belief that the second-wave strike was spotted and ready to launch on the flight decks, rather than below in the hangars. However, his interpretation of Japanese operations focuses almost exclusively on what it took to arm an airplane and fails to account for the fundamentals of how the Japanese got that plane spotted on the flight deck and then into the air. The article also overlooks the relationship between defensive CAP activities and the inability to mount offense strikes. Its view of carrier operations is therefore both limited and at odds with a great deal of what we know to be true about how Japanese carriers actually fought. Without an adequate appreciation of these factors, a proper assessment of Nagumo's command options and performance cannot be constructed.

Editor's note: Professor Isom responds on pp. 158–63 of this issue.

NOTES

1. The authors assisted Nauticos Corporation in identifying a large section of wreckage from the *Kaga*, discovered at a depth of seventeen thousand feet in September 1999. As a result of this project, the authors are currently working on a forthcoming book that will examine in detail the operations of the four Japanese carriers at Midway, bringing new Japanese sources to light in the process.
2. The Japanese referred to this process as “continuous stowage” (*renzoku shuyo*) and practiced it from the 1930s onward. From an unpublished manuscript by Mark Peattie, tentatively entitled “Sunburst: The Rise of Japanese Naval Air Power, 1909–1941,” used by permission of the author; Air Technical Intelligence Group [hereafter ATIG], Report 2, Bureau of Aeronautics, 1946, p. 2.
3. It should be noted that our comments pertain to early-war Japanese carrier design and doctrine. As such, some of our remarks may, at first glance, appear to be at variance with such sources as *U.S. Naval Technical Mission to Japan* [hereafter *NavTech*] *Report A-11* (Washington, D.C.: Govt. Print. Off., 1946), which discusses Japanese naval aviation equipment and carrier design. However, it must be remembered that the goal of the *NavTech* reports was to gather information after the war to improve the U.S. Navy’s own practices. As such, its primary area of interest was documenting late-war Japanese doctrine and equipment, rather than chronicling the development of that doctrine per se. For instance, carriers such as the late-war *Unryu*-class (which was a derivative of the original *Hiryu* design) did indeed have the ability to perform more operations on the flight deck than their predecessors, and by 1944 Japanese doctrine had evolved to view the flight deck in a different light. However, it must be remembered that these doctrinal changes were the direct result of battle experience (much of it negative) gained early in the war at places such as Midway. As a result, the way Japanese carriers operated in 1942 was different in certain respects from the way they operated in 1944.
4. *ATIG Report 2*, p. 3, and *ATIG Report 5*, p. 3. This was due to the inability of the forced-air ventilation systems used in the hangars to cope with the exhaust from multiple aircraft. *NavTech Report A-11*, p. 9.
5. Aircraft were usually brought to the flight deck via a single elevator for several reasons. Japanese aircraft were segregated by type and stowed in specific portions of both the upper and lower hangars. Fighters were typically stowed forward, dive-bombers amidship, and torpedo bombers aft. Fighter aircraft, requiring shorter runoffs, were sensibly stored forward, where they were also more immediately accessible. Spotting *Akagi*’s antiship strike therefore would have required lifting the torpedo aircraft using the aft elevator, and the Zeros from the fore. Elevator cycles varied depending on raw elevator speed and whether the aircraft was being delivered from the upper or lower hangar. *Akagi* and *Kaga*’s elevators were older, slower models requiring cycles longer than one minute to the lower hangar, and they therefore took longer to perform their evolutions than the newer ships of Carrier Division 2. This was particularly unfortunate in light of *Kaga*’s large torpedo plane squadron.
6. Spotting sometimes required relatively long lateral deck pushes, though the spotting of one aircraft could occur as another was being brought to deck. Nevertheless, a certain amount of “jockeying” was required during such operations.
7. Initial engine start-up was accomplished by a crewman, while air crew were receiving briefings. Detailed information on Japanese take-off procedures was provided by Mr. Nisohachi Hyodo, an expert on Japanese aircraft ordnance, in a letter to Jon Parshall dated 7 February 2001.
8. Hyodo states that Japanese aircraft carriers were equipped with enough bomb carts to rearm one-third of the carrier’s complement of dive-bombers at a time. Rearmament occurred on the flight deck, immediately prior to engine warm-up. Both the Japanese 242 kg high-explosive bomb and the 250 kg semi-armor-piercing bomb used the same mounting hardware, speeding the process of switching between these weapons considerably. Even so, five to six minutes per plane would be required and would have to be repeated three times to arm the entire force, for

- a total of about twenty minutes. To this must be added the time required to load and move the ordnance across the flight deck. Hyodo to Parshall, 7 February and 10 February 2001.
9. This was conducted on the flight deck near blackboards attached to the side of the island.
 10. This included an assistant air officer (*sho-hikocho*) visiting each aircraft in the strike force to ensure that it was running properly. Hyodo to Parshall, 7 February 2001.
 11. The fastest Japanese combat launching on record to this point in the war had been for Pearl Harbor, when the carriers launched aircraft at the rate of one every twenty-eight seconds. Gordon Prange, *At Dawn We Slept* (New York: Viking Press, 1991), p. 490. *ATIG Reports 2*, p. 2, and 5, p. 3, cite optimal takeoff intervals as being ten seconds.
 12. As corroboration of this estimate, one need only look at the operational tempo of the Pearl Harbor Striking Force six months earlier. During that attack, the Japanese were able to spot the second wave attack force of 171 aircraft for launch in fifty-five minutes from when the first attack wave and the formation's CAP fighters were finished launching at 0620. In this attack, the six Japanese carriers were spotting an average of twenty-eight aircraft per ship, as opposed to the average twenty-one planes Nagumo's Midway force would have spotted. Using the model we have developed, and adding an additional seven to ten minutes for extra elevator cycles, as well as a longer warm-up time in the early morning air, the figure of fifty-five minutes agrees well with our estimate. Prange, pp. 490-2.
 13. Japan's official war history series, *Boeicho Boeikenshujo Senshibu* (originally *Boeicho Boeikenshujo Senshishitsu*, and often referred to in its abbreviated form *Senshi sosho* [war history]), was published by Asagumo Shimbunsha. The Midway volume, *Midowei kaisen* [Battle of Midway], published in 1971, states on page 289, "Provided that the strike forces were fully equipped, it would have taken no less than 40 minutes to get them out of the hangar to the deck and then finish preparation for launch." We are grateful to Nisohachi Hyodo and Takashi Koganemura for their assistance in these matters.
 14. Takeoff from a carrier required using full military power. Radial aircraft engines were (and still are) built with very thin cylinder walls to extremely tight tolerances, and they required uniform distribution of heat and lubricant to maintain efficient operation. If not properly warmed up, a radial engine was likely to blow up outright under full power. We are grateful to Eric Bergerud and Clint Bauer for their insights on this crucial issue.
 15. It must be remembered that the Japanese operated the aircraft of their carrier groups in a much more integrated fashion than Western navies could at this point in the war. Japanese carrier divisions were trained to combine like-type squadrons into divisional strike teams. Thus, during the initial strike against Midway, the Type 99 dive bombers from *Akagi* and *Kaga* formed a single attack unit, likewise the Type 97 attack bombers from *Soryu* and *Hiryu*. Consequently, the time requirements of rearming procedures, and certainly deck-spotting activities, were likely to be similar among the carriers of a division, meaning that information concerning a particular carrier can give us clues as to the state of its divisional counterpart as well.
 16. Reconstructed from "Mobile Force's Detailed Battle Report 6," translated and published in 1947 by the Office of Naval Intelligence as "The Japanese Story of the Battle of Midway, OPNAV P32-100" (often referred to simply as the "Nagumo Report"), pp. 13-20, as well as "Battle Report of Battle of Midway" (extract translation from document 160985B—MC 397.901, U.S. Naval Historical Center, Operational Archives Branch, Washington, D.C.). All times are given in local (Midway) time. We are grateful to both John Lundstrom and Mark Horan for their expertise and assistance in developing a highly detailed and accurate picture of Japanese CAP activities.
 17. *Ibid.* *Kaga*, as the other big flight deck in Nagumo's force, carried an equally large CAP burden.
 18. Any strike force spotted aft would likely have contained a fighter escort of some sort, requiring Zeros to be brought up from the forward section of the hangars via the forward elevators, thereby obstructing the flight deck for takeoffs in any case.
 19. The Japanese Type 0 fighter was not constrained by range or fuel capacity but rather by its cannon ammunition. Each Zero carried

only sixty rounds for each of its two 20 mm cannons, which constituted the main offensive armament necessary to bring down the large American attack aircraft. As a result, Japanese fighters had a tendency to “shoot their bolt” quickly during combat. The importance of cannon ammunition cannot be overestimated—Mark Horan, contributor to *A Glorious Page in Our History* (Missoula, Mont.: Pictorial Histories, 1990), has pointed out to us that casualties among the attacking American squadrons are strongly correlated with whether the Japanese fighters they encountered carried fresh loads of cannon ammunition. Japanese doctrine normally called for two-hour fighter patrols (*ATIG Report 2*, p. 2). During the morning’s air battles, at least seventeen CAP fighters ended their missions after an hour or less, some after as little as twenty-six minutes in the air. This evidence indicates that the Japanese were cycling their fighters frequently in order to keep them fully munitioned.

20. *Akagi’s* strike force was to consist of eighteen Type 97 (Kate) torpedo bombers and three Zero fighters. *Kaga’s* contribution was to be twenty-six Kates and three Zeros, *Soryu’s* eighteen Type 99 (Val) dive-bombers plus three Zeros, and *Hiryu’s* eighteen Vals plus three Zeros.
21. *Senshi sosho, Midowei kaisen*, pp. 372–8.
22. Best, in an interview with John Lundstrom, April 2000. Best stated that during the time of his attack, six to seven aircraft were on the flight deck, and they were clearly Zeros. Furthermore, Best commented that the Zeros were using most of the flight deck for run-off room. As he was attacking, a Zero was in the process of taking off.
23. Commander Aircraft Battle Force, “Current Tactical Orders and Doctrine, U.S. Fleet Aircraft, vol. 1, Carrier Aircraft,” ser. USF-74, rev., 20 April 1941.
24. Given the enclosed nature of Japanese hangars (which amplified explosive effects upon the ship’s structure of internal bomb hits), Japanese carriers with planes in the hangar were in an even more dangerous position than if they had planes on the flight deck. Having no planes aboard when struck was, of course, optimal.
25. Japanese “Mobile Fleet Doctrine,” promulgated 28 March 1944, under “Air Combat,” paragraph 9, states: “When enemy aircraft carriers are discovered at close range the command ‘Send up ‘Q’ ’ will be given. At this time every ship will quickly send up the airplanes standing ready on deck. The *hikokitai* [carrier air group] will assemble in the air and will fly off to the attack organized in the fixed *hikokitai* [i.e., standing Table of Organization].” Translations of these doctrinal works, recovered from the sunken cruiser *Nachi* in Manila Bay in 1944, are in the personal collection of David Dickson.