



## USS *Independence's* Aircraft

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Published online: 26 July 2018

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### Abstract

Submerged aircraft are a newly emerging area of study in underwater archaeology. In August 2016, a multidisciplinary team conducted the first archaeological survey of the deep water (829 m) wreck of the ex-USS *Independence* (CVL22), a WWII era light carrier scuttled off San Francisco after its use as an atomic bomb test target and subsequently as a floating radiological laboratory and training facility. Using the remotely operated vehicles *Argus* and *Hercules*, the expedition documented and studied *Independence* including assessment of a sonar target thought to be an aircraft resting inside the sunken carrier's forward elevator pit. The survey confirmed the presence of a plane, but previous assumptions as to the type and identity of this aircraft, based on archival records, proved erroneous. As well, the remains of a second, and possibly a third, aircraft were also encountered during the 2016 survey. These artifacts, through their context, both as naval warplanes on an aircraft carrier, and as test articles for seaborne nuclear weapons development, more precisely fit within the parameters of maritime archaeology. They join other archaeological evidence at the *Independence* site that helps define its significance within the context of World War II and the Cold War.

**Keywords** World War II · Aircraft · Operation Crossroads · Cold War · Aircraft carrier

### Introduction

An ROV mission in August 2016 to the wreck of USS *Independence* (CVL22) discovered one partially intact aircraft and the additional fragmentary remains of at least one other plane inside the sunken carrier, which lies at 829 m off San Francisco. The

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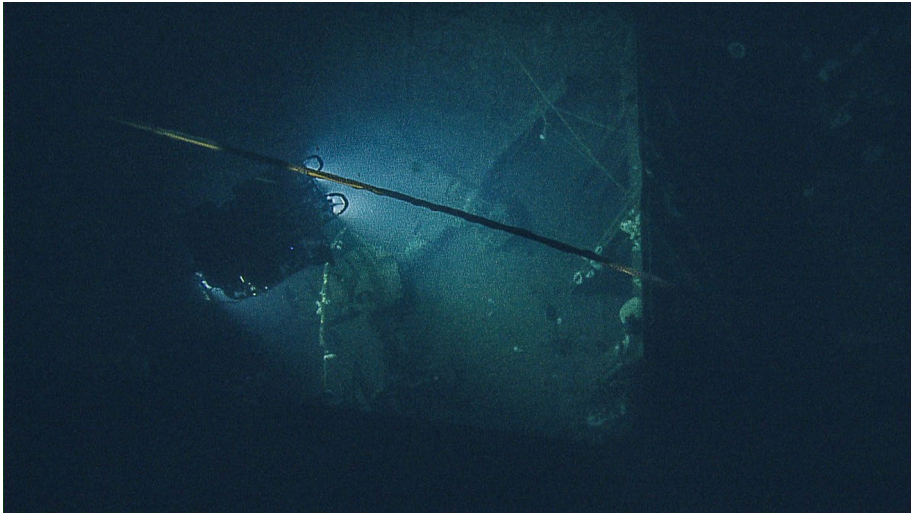
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discoveries were in some ways not surprising, as a suggestion of at least one aircraft was observed in data from a 2015 sonar survey and the archival record is silent on the fate of one warplane known to have been transported to the United States with *Independence* after its use as an atomic target vessel (Fig. 1) (Delgado 2016; Delgado et al. 2016a, b). The identification of these artifacts, as will be seen, shows at least one of them is an aircraft that was no longer supposed to be on the ship as part of a post-Crossroads site, but instead was reported to be part of the primary Crossroads archaeological site, on the seabed of Bikini Lagoon.

The discovery of this aircraft inside the shipwreck with ROVs *Hercules* and *Argus* (Fig. 2) not only documents an additional element of the *Independence* site, it also brings up questions about the completeness and accuracy of the historical record. More importantly, however, it also raises the issue of the nature and scope of the material culture that comprises the maritime archaeological assemblages of Operation Crossroads. The aircraft onboard *Independence*, we maintain, are maritime elements not only because of their underwater deposition on a shipwreck, but because they were distinctly naval in terms of their original development and deployment in World War II, and were then used in naval tests of the atomic bomb. These aviation artifacts are a reminder of other Crossroads aircraft that are part of the archaeological record. They point to a significant element of the submerged maritime archaeological site that is the simulated atomic battlefield at Bikini Atoll.



**Fig. 1** Oil painting of USS *Independence* with Hellcats flying overhead by Danijel Frka, Russell Matthews Collection



**Fig. 2** ROV image from *Argus* of ROV *Hercules* exploring the Grumman F6F-5N Hellcat wreckage inside the elevator pit. Image courtesy of Ocean Exploration Trust

## Operation Crossroads and Aircraft

Operation Crossroads utilized 156 planes, 73 of which were deployed on 22 vessels in “combat ready” condition as targets (Berkhouse et al. 1946:17, 63, 65 and 67; Bureau of Aeronautics 1946:7–8). Many other aircraft were deployed operationally by Army Air Forces and Navy units for command, observation, photographic, bomb and test instrument drops, as well as radiological reconnaissance, with the Navy Air Group primarily flying from the carriers USS *Saidor* (CVE117) and USS *Shangri La* (CV38) (Berkhouse et al. 1946:38; Shurcliff 1947:98). A significant aspect was the use of a variety of unpiloted airplanes as “drones” for observation and for radiological sampling by remotely steering them into the atomic blast clouds (Berkhouse et al. 1946:17, 63, 65 and 67). The “drones” were another technological test and demonstration within the context of Operation Crossroads. This was excitedly shared with the public in the official, non-classified report on Crossroads published in 1947:

To be sure, a few war weary B-17’s had been flown without crews during the latter part of the recent war, but their cargoes of explosives were deliberately crash-landed. Also, a few B-17’s had been landed by remote control; but pilots were aboard, ready to take over control in case of trouble. Operation Crossroads was the first operation in which take-off, flight and landing were accomplished with no one aboard. The feat was an impressive one; many experts had thought it could never be accomplished with planes of this size (Shurcliff 1947:98).

The classified report noted that the drone program required “extensive logistics and material support as well as new development programs” (Bureau of Aeronautics 1946:16). In all, thirty F6F-3K drones were produced along with thirty F6F-5 control aircraft. “Additional equipment required consisted of radio control equipment, design and installation of radioactivity filters, installation of Geiger counters and indicators, and installation of VGTA recorders in a number of the drone aircraft. Some

photographic equipment with radio controlled circuits was provided” (Bureau of Aeronautics 1946:18).

Then-classified general observations on the drones reported, in simple language, dramatic aspects of their “experiences” in the Able test:

One Navy drone was swept upward, in passing through the cloud, from 20,000 to 26,000 feet. This was the greatest change in altitude recorded of any drone sent through or above the cloud, and it may have been caused partially by a tilt of the aircraft when released by the mother. The drone was recovered with some difficulty but was safely landed. There was considerable variation in the recorded intensity of radioactivity of the drone aircraft. The drones which were at high altitude and which passed through the edge of the cloud were but slightly affected. Those which passed through the center of the cloud remained lethal for several days (Bureau of Aeronautics 1946:45).

Naval planes only were deployed “to simulate the normal disposition of shipborne aircraft on combat vessels (Bureau of Aeronautics 1946:7). This included “observation type seaplanes” on board the battleships *Nevada* (BB36) *Arkansas* (BB33) *Pennsylvania*, (BB38) and *New York* (BB34), the cruisers *Pensacola* (CA24) and *Salt Lake City* (CA25), and “carrier types” on the flattops *Saratoga* (CV3) and *Independence* (CVL22). Two carrier aircraft each were placed on the 14 attack transport targets, and two Consolidated PB2Y Coronado seaplanes were moored in the target array (Bureau of Aeronautics 1946:7).

The “combat ready” status for the subject aircraft was defined as:

Gasoline was omitted from all aircraft except two each fueled to capacity on the stern of the carrier flight decks. Ammunition was reduced to ten rounds per gun and pyrotechnics omitted. Those bombs, mines, rockets and torpedoes exposed on aircraft were inert, loaded and fused. Additional aviation materials were exposed throughout the target array by BuOrd, BuShips and the Army Air Forces (Bureau of Aeronautics 1946:7).

The omission or separate (outside of the aircraft) testing of highly flammable and/or explosive material was done because of the concern that “ignition of which might cause the destruction of aircraft as a secondary effect (Bureau of Aeronautics 1946:21).

After each atomic detonation, scientists and technicians conducted visual inspections “supplemented as practicable by functional tests,” and some instruments and parts were shipped back to the United States for laboratory analysis (Bureau of Aeronautics 1946:7). All but 19 of 73 aircraft exposed as targets during the first blast, the Able Test, were damaged. Fourteen planes were recorded as missing because they had either sunk with their target ship or had been blown overboard, and 23 suffered major damage (Bureau of Aeronautics 1946:8). In all, 40 aircraft remained that could be used for the next blast, Baker. Following the second and final test, eleven of those were reported missing and sixteen suffered major damage (Bureau of Aeronautics 1946:9).

Of the fourteen target aircraft “missing” after the Able Test, half had come from USS *Independence* (Figs. 3, 4) (see Table 1). The other seven included an OS2U-3 Kingfisher spotter plane from USS *Arkansas*, an OS2U-3 each from the cruisers USS *Salt Lake City* and USS *Pensacola*, plus two F6F-5 Hellcats and two FM-2 Wildcat aircraft lost when the attack transports USS *Gilliam* and USS *Carlisle* sank with them aboard (Bureau of Aeronautics 1946:155, 162, 163, 165, 189). A further eleven badly-damaged planes had to be jettisoned from the battleships USS *Nevada* and USS *Pennsylvania*, as well as the



**Fig. 3** Historic aerial photo USS *Independence* equipped for Operation Crossroads with aircraft positioned on deck. National Archives



**Fig. 4** Historic photo of aircraft on the deck of USS *Independence* before the Baker test. National Archives

attack transports USS *Banner* (APA60) USS *Barrow* (APA61), USS *Butte* (APA68), USS *Crittenden* (APA77), USS *Dawson* (APA79) and USS *Fillmore* (APA83) (Bureau of Aeronautics 1946:159, 160, 167, 168, 169, 173, 177, 178, 179, 184). In addition to the target aircraft, one of the drones, an F6F-3K Hellcat flown off of USS *Shangri La*, was lost when it went out of control and crashed (Shurcliff 1947:99).

Eleven more aircraft were reported missing after the Baker test. Ten were placed on board the fleet carrier USS *Saratoga* and lost when she sank following the blast (Bureau of Aeronautics 1946:198–207), plus an FG-1D Corsair fighter aircraft disappeared from the deck of the attack transport USS *Fallon* (Bureau of Aeronautics 1946:233). Baker-related

**Table 1** Aircraft deployed on *Independence*, test Able

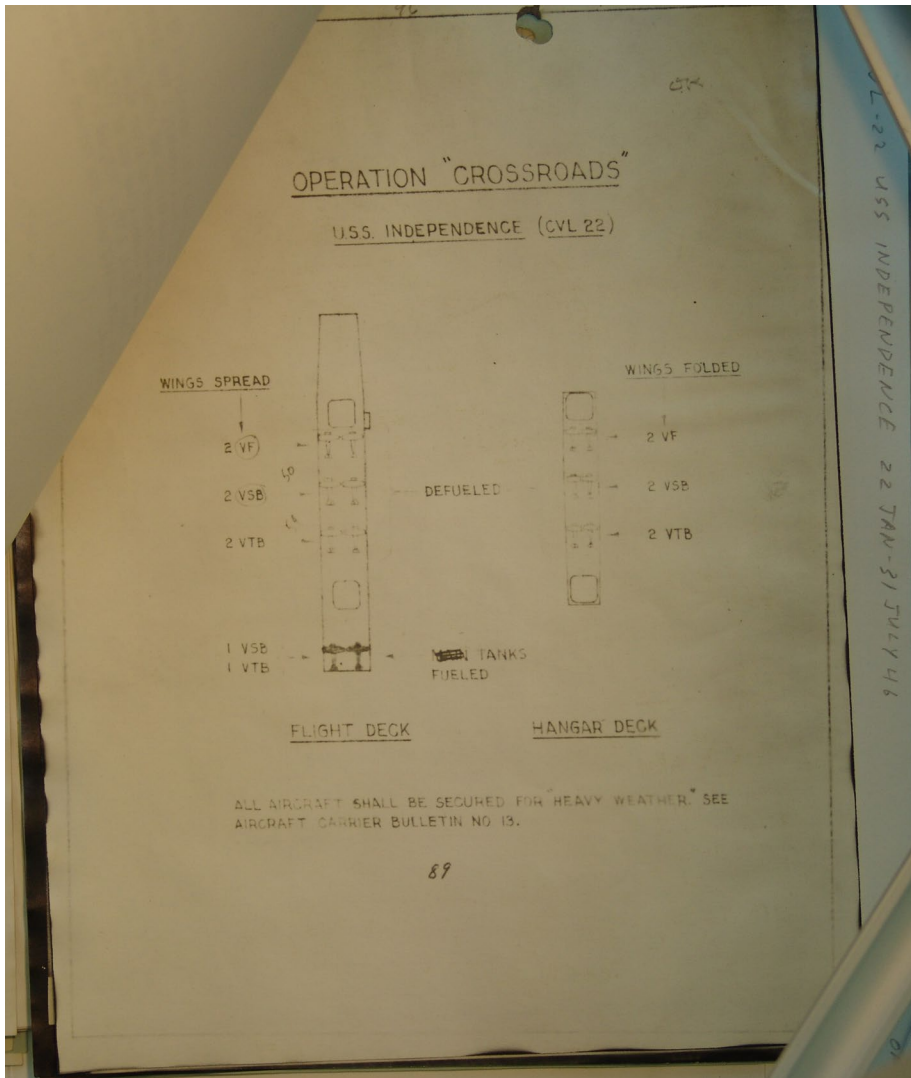
Type	Serial number	Deck position	Test	Disposition
TBM-3E	BuNo. 69116	Hangar Starboard	Able	Jettisoned
TBM-3E	BuNo. 69275	Hangar Port	Able	Jettisoned
TBM-3E	BuNo. 69063	Flight Port	Able	Missing
TBM-3E	BuNo. 69239	Flight Starboard	Able	Missing
TBM-3E	BuNo. 69124	Flight Starboard	Able	Missing
F6F-5N	BuNo. 77569	Hangar Port	Able	Jettisoned
F6F-5N	BuNo. 77349	Hangar Starboard	Able	Jettisoned
F6F-5N	BuNo. 77492	Flight Starboard	Able	Missing
F6F-5N	BuNo. 77433	Flight Port	Able	Missing
SBF-4E	BuNo. 31843	Hangar Starboard	Able	Jettisoned
SBF-4E	BuNo. 31849	Hangar Midships	Able	Jettisoned
SBF-4E	BuNo. 31856	Flight Starboard	Able	Jettisoned
SBF-4E	BuNo. 31857	Flight Port	Able	Missing
SBF-4E	BuNo. 31852	Flight Port	Able	Missing
TBM-3E	BuNo. 69169		Baker	Aboard to SF
SBF-4E	BuNo. 31899		Baker	Aboard to SF

aircraft damage reports, unlike those from Able, are silent on post-test jettisoning. The ultimate fate of the 38 target planes not specifically listed as either “missing” or “jettisoned” ( $n=35$ ) was most probably disposal at sea, either at Bikini or post-Crossroads at the various locations where target ships were towed for further evaluation. We have not pulled the Bureau of Aeronautics cards for each and every Crossroads target aircraft, but suspect they may not be accurate. The same may be true with reports filed after the tests, as the case of *Independence*’s planes demonstrates.

## Target Aircraft on USS *Independence*

The final report from the Bureau of Aeronautics Group at Crossroads noted that out of the 73 aircraft deployed on target vessels, 14 had been placed on *Independence* for Able, and two more for Baker (Fig. 5). These were made up of five Grumman TBM-3E Avengers, five Grumman F6F-5N Hellcats (Figs. 6, 7), and four Fairchild-Canada SBF-4E Helldivers (Figs. 8, 9) for Able, as well as an SBF-4E and TBM-3E for Baker. The Able planes were either noted as “missing” ( $n=8$ ) because they had been blown off the flight deck or were found to be badly damaged and subsequently jettisoned ( $n=7$ ) (Table 1). The pair of aircraft staged just prior to Baker survived that blast and remained on *Independence* post-Crossroads (Fig. 10). Indications on the sonar survey of a possible plane inside the forward elevator pit led us to surmise that it may have been one of these two particular aircraft.

Archival records noted that the two planes, a TBM-3E Avenger (BuNo. 69169), and an SBF-4E Helldiver (BuNo. 31899), came to San Francisco on board the carrier. The Avenger was removed from *Independence* in October 1947, shipped to Philadelphia, dismantled for detailed analysis of bomb damage, and then disposed of at sea (Heilman 1950:5–7). The historical record is silent on the fate of the SBF-4E. However, it is clearly visible on the flight deck near the forward elevator pit in a photograph taken of *Independence* at Hunter’s Point Naval Shipyard on April 19, 1948 (Fig. 11). Prior to the 2016



**Fig. 5** Operation Crossroad report of the positioning of aircraft on USS *Independence* for the tests. National Archives

mission, our hypothesis was that if an aircraft was indeed resting in the elevator, it might well be this dive bomber (Fig. 12) (Delgado et al. 2016a, b:21). However, our subsequent survey of the damaged but substantially intact plane inside *Independence* showed it to be a Hellcat rather than the anticipated Helldiver.

Within moments of first glimpsing the aircraft, its single seat cockpit arrangement and streamlined high backed fuselage clued us to the fact we were looking at a Grumman fighter instead of a Curtiss dive bomber (Fig. 13). The conclusion quickly followed that the wreck we found must undoubtedly be one of the two F6F-5N Hellcats known to have been placed on the flight deck of *Independence* for Able, either BuNo. 77492 or BuNo.



**Fig. 6** Historic photo of a Grumman F6F-5N Hellcat on deck. National Archives

77433, both of which were positioned near the forward elevator, at frames 60 and 65. It is apparent that the resulting blast wave knocked one of these planes down into the hangar, where it remained during the ensuing Baker test and subsequent decontamination work in San Francisco. If it was the 40-degree roll to starboard caused by the underwater atomic detonation that displaced the aircraft into the elevator pit, then the most likely candidate is BuNo. 77433, sited on the flight deck at frame 60 on the port side (Bureau of Aeronautics 1946:153). Unfortunately, the wreck was shorn of its tail section, forestalling any attempt to inspect the vertical stabilizer for traces of a USN Bureau of Aeronautics number stenciled there and precluding definitive identification.

Developed in 1941–1942, the Hellcat went through three variations, the F6F-3, F6F-4, and culminating with the F6F-5, which went into production in April 1944 (Kinzey 1996:6). The version found on *Independence* is particularly appropriate for this setting, as it is presumed to be a night fighter F6F-5N variant, and it was *Independence* that pioneered night fighting carrier operations for the U.S. Navy (Lambert 2015). Accumulated silt and debris combined with restricted maneuvering space inside the ruined hangar deck conspired to prevent the team from spotting either the pilot's cockpit scope or the outer starboard wing mounted radome of the APS-6 radar system that gave night fighter Hellcat its advantage and would firmly establish this wreck as an N model F6F-5. The distinctive radomes are however, visible in aerial photographs of target aircraft spotted on the deck of *Independence* shortly before test Able (Fig. 3), leaving little doubt as to the nature of the plane we found at the bottom of the elevator shaft. It's also worth mentioning that the





**Fig. 7** Historic photo of Grumman F6F-5N Hellcats flying in formation. National Archives

first combat between the brand-new Hellcat fighter and enemy Japanese aircraft occurred on September 1, 1943, when freshly deployed F6Fs from USS *Independence* shot down a Kawanishi H8K Emily flying boat (Dean 1997:559).

The Bureau of Aeronautics' final report from Crossroads, as noted, stated that all target planes from both tests were either missing or "destroyed" and that any aircraft debris was jettisoned after Able. However, close examination of photographs taken of *Independence* following the first blast reveals a damaged aircraft in the forward elevator pit (Fig. 14) (Bureau of Ships Group 1946a, 3:253). And it seems this aircraft was also referenced by commanding officer, Capt. F.X. Forest, USN, in his conclusion to the Bureau of Ships post-Able final technical inspection report on *Independence*. Forest noted that after the initial detonation, *Independence* took a deep roll of about 40 degrees to starboard which slid an Army tank off the flight deck and "put the P-47 in the forward elevator pit" (Director of Ship Material 1947:257). The U.S. Army Air Forces Republic P-47 Thunderbolt fighter was powered by the same Pratt and Whitney R-2800 Double Wasp engine as the Grumman F6F and early model Thunderbolts featured a raised or "razorback" rear fuselage structure highly suggestive of the Hellcat fighters aboard *Independence*, making it probable that Capt. Forest was mistaken in referencing the plane's identity.

As we now know, this aircraft remained on board *Independence*. Its current arrangement is different from that shown in the post-Able photograph (Fig. 15), either due to repositioning for ocean transit or as a result of the carrier rolling during sinking. As previously described, the empennage was not observed by our team, nor the outer edge of the



**Fig. 8** Historic photo of a Fairchild-Canada SBF-4E Helldiver on deck. National Archives

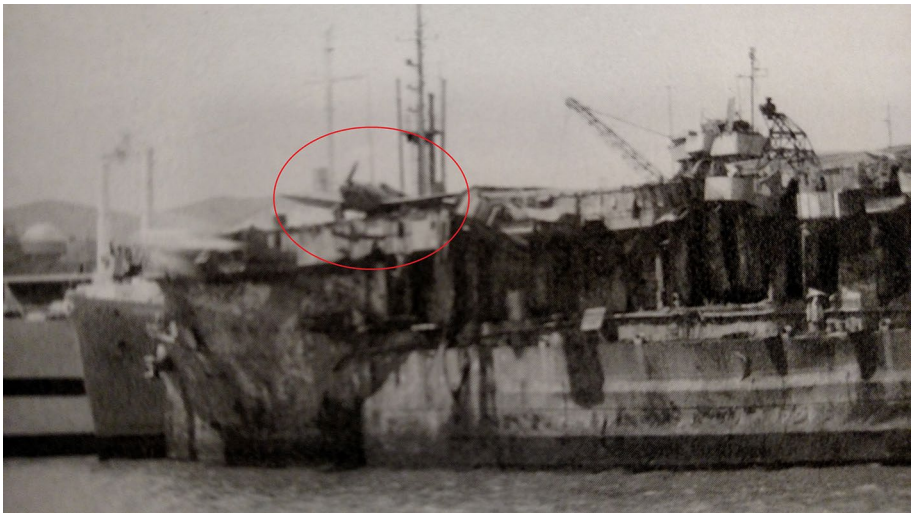
starboard wing. However, the rear fuselage, cockpit area (Fig. 16) and power plant were documented, along with the broken port wing resting upright against the forward bulkhead of the elevator pit. All six AN/M2 Browning .50 caliber air cooled machine guns, comprising the Hellcat's potent primary armament, were still present, arranged in offset rows of three in each wing. The canopy glass was missing along with the armored windscreen, the frame of which appeared crushed back and downwards, as might be expected to result from a fall into the open elevator shaft. Many of the nose panels were likewise gone, exposing the engine mounts, oil tank and other accessories, while the powerplant itself sagged forward. No sign of the 3-bladed Hamilton Standard propeller was readily apparent.

The cockpit is partially filled with sediment (Fig. 17), but close visual inspection by the ROV revealed some instruments in the (unobscured left-hand portion of the) panel and the top edge of the throttle with its super charger control knob (indicated by the appropriate initials "SC") was plainly visible. We were unable to view the port side of the fuselage with our cameras, but there are remnants of Navy blue paint and stenciled lettering on the starboard side (Fig. 18). The white "star and bars" of the US national insignia still stand out proudly on the top skin of the port wing (Fig. 19).

Remains of the second plane consist of little more than a wing section with an associated pile of unidentifiable aluminum debris (Fig. 20). This wing was ultimately recognized to be from the port side of a Helldiver aircraft. The general determination was made possible by noting the presence of perforated flaps, known as "dive brakes." Characteristic only of dive bombing planes, these specially ventilated split flaps would be deployed in combat,



**Fig. 9** Historic photo of Fairchild-Canada SBF-4E Helldivers flying in formation. National Archives



**Fig. 10** Historic photo of USS *Independence* after the Able test showing an aircraft remaining on deck. National Archives

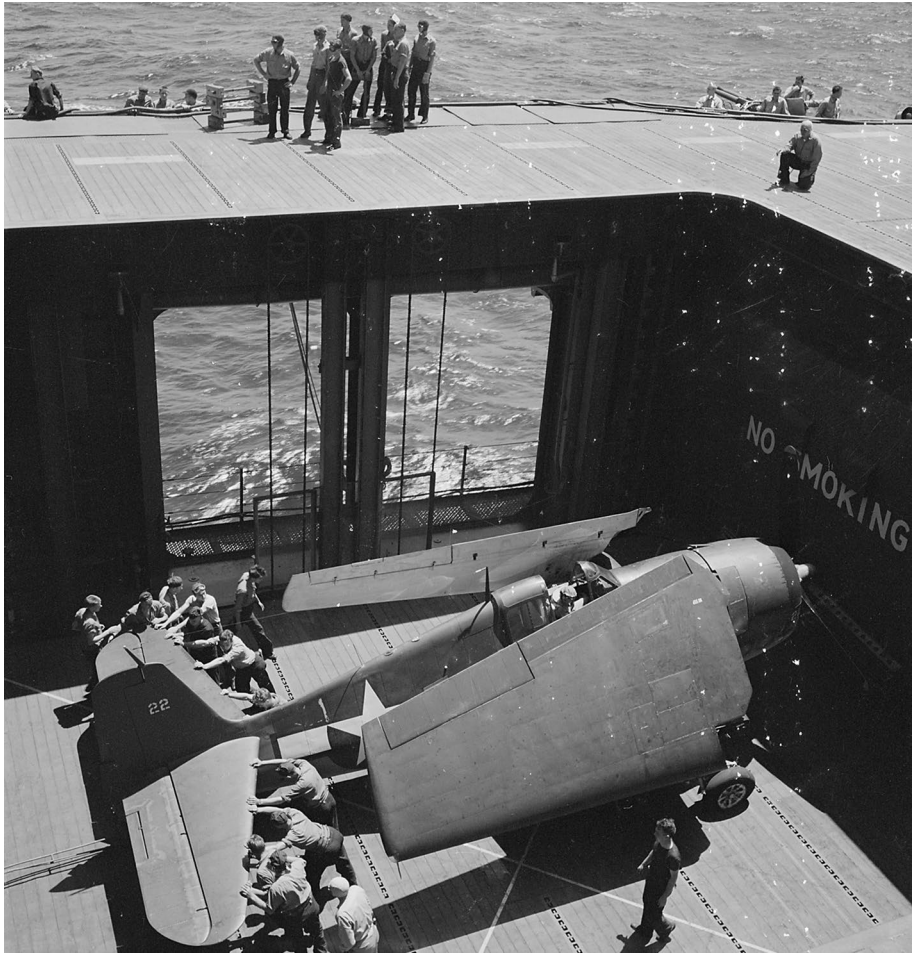


**Fig. 11** Aerial photograph of Hunter's Point Naval Shipyard in San Francisco from 1948 showing USS *Independence* (CVL22) at the pier. National Archives

slowing the craft during its near vertical attack plunge from high altitude, reducing stress on the airframe while allowing the pilot time to aim more accurately in lining up an enemy ship or target. Identification as a Helldiver type in particular was permitted thanks to the arrangement of crenellations along the trailing edge of the upper dive brake. Intended by the Curtiss engineers to address instability issues by disrupting airflow, these small regular protrusions are a feature entirely unique to the later Helldiver design. In addition, the overall shape of the wing and the configuration/placement of the pitot tube at its outboard tip further confirm this analysis.

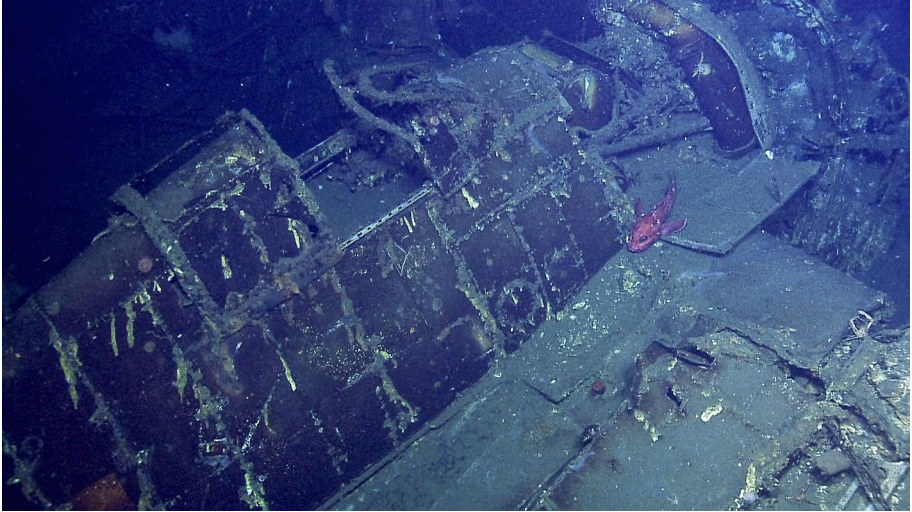
Both aircraft retained traces of paint, including some stenciling. The intact wing of the Hellcat, as well as the partial wing of the Helldiver also retained the white-painted elements of the “star” national insignia they had been painted with when in service. No trace of the blue or red paint was observed. This find is in line with post-Able observations that darker paint had blistered or burnt away, as did dark fabric and rope on target ships, aircraft and test equipment (Shirley 1946: 4–6 and Bureau of Ships 1946a:114). The same phenomenon had been noted at Hiroshima with light-colored clothing remaining intact while darker clothing and patterns on light clothing burned away and left burns on skin in the same pattern (Glasstone 1950:203–204). This is because atomic blast induced thermal radiation, heat will be absorbed depending on the reflectivity of the surface (Glasstone and Dolan 1977:282). The white paint, being the most reflective, survives on the aircraft wings because it reflected the thermal energy of the Able blast while the red and blue paint absorbed it and was either burned or charred off, or in the case of reds, faded within a few days.

The SBF-4E Helldivers aboard *Independence* for Able were Canadian Fairchild-built versions of the Curtiss SB2C Helldiver (Fig. 8), which was developed in 1939–1940 but



**Fig. 12** Historic photo showing an aircraft in the elevator pit on USS *Independence*. National Archives

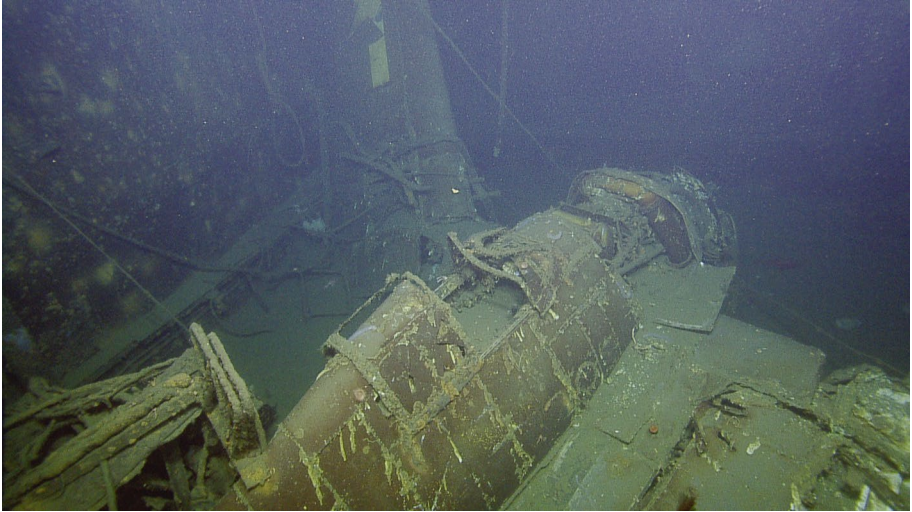
due to numerous and persistent deficiencies did not enter combat service until November 1943 (Kinzey 1997). For Crossroads, the Bureau of Aeronautics Group placed three SBF-4E aircraft on *Independence*'s flight deck and two on the hangar deck prior to Able. Given the position of the wing artifact, on the edge of the hangar, it could be from either one of those planes, BuNo. 31843 or BuNo. 31849, which were placed on the lower deck at frame 75 (starboard) and frames 72–80 (amidships). Both aircraft were badly damaged and disarticulated by the blast, and the final report notes that pieces of the two planes were jettisoned (Bureau of Aeronautics 1946:144–145). Another possibility is that it is the SBF-4E BuNo. 31899, which was still on *Independence* in April 1948. We surmise that it was stowed in the hangar, along with other material left on deck, prior to the 1951 scuttling. The damage to the aircraft could have come not from Able, but from the powerful hydrodynamic forces unleashed inside the sinking carrier during her death throes as it rolled to port and then plunged to the bottom.



**Fig. 13** ROV image of Hellicat wreckage in the elevator pit on the USS *Independence* wreck. Image courtesy of Ocean Exploration Trust



**Fig. 14** Historic photo of a damaged aircraft in the forward elevator pit following the Able test. National Archives



**Fig. 15** ROV image of Hellcat wreckage in elevator showing port wing resting against the forward bulkhead. Image courtesy of Ocean Exploration Trust

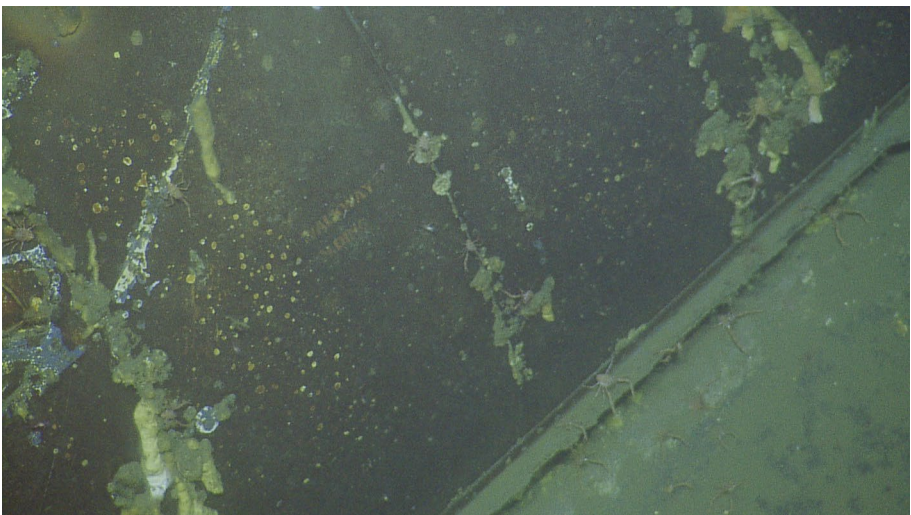


**Fig. 16** ROV image of the cockpit of the Hellcat in the elevator pit. Image courtesy of Ocean Exploration Trust

Perhaps the wing, and possibly the crumpled mass we observed at a distance in the hangar, might also suggest, like the aircraft in the elevator pit, that not all pieces of aircraft reportedly “jettisoned” after Crossroads were disposed of. Radiation monitors and readings following each test detonation at Bikini showed a very hot ship. It took four days before personnel could even board *Independence* after Able to assess damage, recover instruments, and prepare the carrier for Baker. Given that working environment, it is not surprising to see a discrepancy between the written and the archaeological record.



**Fig. 17** ROV image showing the sediment filling the interior of the Hellcat's cockpit. Image courtesy of Ocean Exploration Trust

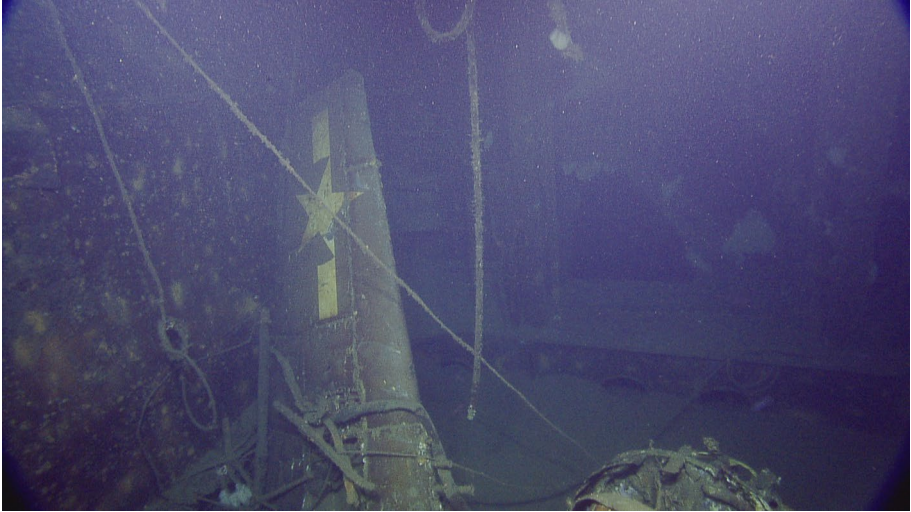


**Fig. 18** ROV image of the starboard side of the Hellcat showing the remnants of Navy blue paint and stenciled lettering. Image courtesy of Ocean Exploration Trust

### **Target Aircraft as Elements of the Larger Crossroads Archaeological Landscape**

As previously noted, 35 aircraft deployed as targets for Crossroads tests Able and Baker are known to have been deposited on the seabed at Bikini Atoll in July 1946. These include planes blown off or sunk with target ships, as well as those jettisoned after Able. Thirty-eight other aircraft may have also been discarded at sea, either at Bikini, Kwajalein,





**Fig. 19** ROV image of the port Hellcat wing against the forward bulkhead showing the white “star and bars” of the US national insignia. Image courtesy of Ocean Exploration Trust



**Fig. 20** ROV image of the wreckage of the Helldiver, consisting of the remains of a wing section with an associated pile of unidentifiable aluminum debris. Image courtesy of Ocean Exploration Trust

Hawai'i, California or Washington between 1946 and 1951, but the record is silent on that subject. We know of only one Crossroads airframe that survives outside of a submerged archaeological context an F6F-3K Hellcat (BuNo. 41834) used during the operation as a drone and now on display at the National Air and Space Museum's Udvar Hazy facility outside Washington, D.C.

Archaeological study of Bikini Lagoon was undertaken by the National Park Service, working in conjunction with the U.S. Navy, in 1989–1990, with the lead author of this

paper acting as a participant and principal author of the final report (Delgado et al. 1991). In addition to assessing the target ship wrecks of USS *Saratoga* (CV3) USS *Arkansas* (BB33), USS *Gilliam* (APA57), USS *Carlisle* (APA69), USS *Pilotfish* (SS386), USS *Apo-gon* (SS308), the Japanese battleship HIJMS *Nagato*, the floating concrete drydock ARDC-13, and the oiler YO-160, the team also documented the remains of four target aircraft, all on *Saratoga*. These planes were comprised of three SBF-4E Canadian Fairchild built Hell-divers (BuNo. 31894, BuNo. 31850, BuNo. 31840) and a single TBM-3E Avenger torpedo bomber (BuNo. 69095), all of which were reported as “missing–Sank with *Saratoga*” after the Baker test (Bureau of Aeronautics 1946:198–207).

The aircraft were found resting in their original Baker test positions within the sunken carrier’s hangar. BuNo. 31894 was just aft of the elevator pit, with BuNo. 31840 and BuNo. 31850 further back at frames 100 and 110, starboard (Bureau of Aeronautics 1946:205–207). TBM-3E Avenger BuNo. 69095 was discovered partially crushed and buried by collapsed flight deck debris in its assigned location on the hangar deck at frame 120 starboard (Bureau of Aeronautics 1946:201). The 1989–1990 survey did not see any traces of the five planes noted as lost at the *Gilliam*, *Carlisle* or *Arkansas* sites. However, these dives were not as comprehensive as those on *Saratoga*. Likewise, there was no opportunity for the team to explore sites where target vessels had been moored but were no longer present (i.e. had not sunk at the mooring). Because the reconnaissance of *Saratoga* rarely went below the flight deck (except to enter the hangar), only a few chance discoveries were made of material lying on the seabed around the carrier, including a mooring clump and the remains of a trailer. This suggested to the National Park Service divers that additional material swept or blown off the decks of target ships, including lost aircraft, could still lie on the lagoon bottom.

The archaeological documentation of warplanes inside USS *Saratoga* that was undertaken in 1989–1990 essentially compared the physical record with the archival record, which gave individual accounts of each aircraft listed within the final report of the Bureau of Aeronautics Group, as well as documenting the placement of 5-gallon “Jerry Cans” in the cockpits of the those planes to approximate pressure effects on pilots. In assessing the wrecks at Bikini, and with regard to *Saratoga* in particular, aircraft were considered as naval archaeological elements of the site, even when not specifically mentioned other than characterizing them as part of the ship’s armament.

Following the 1989–1990 survey, numerous highly experienced wreck divers made extensive dives in the lagoon after Bikini was opened in June 1996 as a carefully regulated charter diving location. All of the major target vessels lost there during Crossroads that had not been located during the initial NPS explorations were later found by the charter operation’s managers and clients. These were the destroyers USS *Lamson* (DD367) and USS *Anderson* (DD411), plus the Japanese light cruiser HIJMS *Sakawa*. In addition, two more aircraft were discovered on the seabed next to USS *Saratoga*. They are SBF-4E Helldivers that lie, partially intact, and upside down, off *Sara*’s starboard side ahead of the island and forward 5-inch gun mount. The principal author was able to dive and investigate one of these planes in 1999 on a subsequent return to Bikini. According to the archival record, three such types were placed on the carrier’s flight deck for the Baker test, BuNo. 31853, BuNo. 31839, and BuNo. 31859. The last, BuNo. 31859 was known to be positioned at the starboard fantail and so the two Helldivers discovered after 1996 must be BuNo. 31853 and BuNo. 31839, which had been spotted at frames 90 and 120 (Bureau of Aeronautics 1946:202, 203, 204).

The example of USS *Saratoga*’s site, as one discrete assemblage within the larger maritime cultural landscape that is the simulated nuclear battlefield of Bikini Atoll, strongly

suggests that many of the Crossroads target ship mooring locations should and will include scattered material that was either blown off or jettisoned at the Able and Baker positions for those ships which were damaged and not sunk, as well as at the sites of vessels that did founder on the spot, like *Saratoga*. Somewhere near the carrier, unless it landed on top of one of them when it sank, it should be possible to find the rest of the target aircraft missing from *Saratoga's* flight deck, the previously mentioned SBF-4E Helldiver (BuNo. 31859), and three TBM-3E Avengers (BuNo. 69099, 69094 and 69080).

The same might be true for the “missing” planes at the *Arkansas*, *Gilliam* and *Carlisle* sites. These are an OS2U-3 Kingfisher spotting aircraft from USS *Arkansas* (BuNo. 09632), while somewhere in or around *Gilliam* and *Carlisle* should be two F6F-5 Hellcats (BuNo. 71358 and BuNo. 71544) and two FM-2 Wildcats (BuNo. 73535 and BuNo. 47336) that vanished along with the attack transports which sank after the Able burst. Drawing on the final report of the Bureau of Aeronautics Group, we can assert the same for the sites where target ships lost aircraft in the blasts, or had them jettisoned after the Able and Baker tests. The largest of these assemblages would have to be at the mooring for USS *Independence*, which as previously mentioned, should include as many as twelve airplanes in various stages of “intactness.” Here it is important to reiterate a simple point made earlier, that based solely on the archival record, we would previously have asserted up to fourteen planes potentially lay near the *Independence* target mooring location at Bikini until the archaeological record of its 1951 scuttling site noted aircraft and their major components still aboard the sunken carrier. Table 2 enumerates potential Crossroads aircraft sites associated with the moorings for non-sunk Bikini target ships other than *Saratoga* and *Independence*.

As previously noted, the fates of other damaged planes noted on board target ships after Baker is not recorded in the final report of the Bureau of Aeronautics Group. Some of those aircraft, or parts of them, may have been jettisoned at Bikini, while under tow from Bikini to Kwajalein, at Kwajalein, or while under tow from Kwajalein to Pearl Harbor and other US mainland ports. Some may also have remained on board the ex-target ships, as we know to be the case with USS *Independence*. What is not known is whether the other

**Table 2** Potential aircraft archaeological sites at Bikini target ship moorings (excluding USS *Saratoga* and USS *Independence*)

Type	Serial number	Target ship	Archival disposition
OS2U-3	BuNo. 09574	USS <i>Salt Lake City</i>	Missing (Able)
OS2U-3	BuNo. 09632	USS <i>Arkansas</i>	Missing (Able)
OS2U-3	BuNo. 5956	USS <i>Pensacola</i>	Missing (Able)
OS2U-3	BuNo. 5765	USS <i>Nevada</i>	Jettisoned (Able)
OS2U-3	BuNo. 5742	USS <i>Nevada</i>	Jettisoned (Able)
OS2U-3	BuNo. 5342	USS <i>Pennsylvania</i>	Jettisoned (Able)
OS2U-3	BuNo. 5584	USS <i>Pennsylvania</i>	Jettisoned (Able)
FG-1D	BuNo. 88033	USS <i>Fallon</i>	Missing (Baker)
FM-2	BuNo. 55299	USS <i>Banner</i>	Jettisoned (Able)
FM-2	BuNo. 65901	USS <i>Butte</i>	Jettisoned (Able)
FM-2	BuNo. 56736	USS <i>Barrow</i>	Jettisoned (Able)
FM-2	BuNo. 56945	USS <i>Crittenden</i>	Jettisoned (Able)
FM-2	BuNo. 55266	USS <i>Crittenden</i>	Jettisoned (Able)
F6F-5	BuNo. 71553	USS <i>Dawson</i>	Jettisoned (Able)
FM-2	BuNo. 55449	USS <i>Fillmore</i>	Jettisoned (Able)

such planes were then subsequently removed prior to scuttling of any former test vessels or if they may still survive aboard the as-yet unfound wreck sites off California and Hawai'i today.

Additionally, while the location of the crashed F6F-3K Hellcat drone from USS *Shangri La* is not currently known, it would also comprise an important part of the aviation assemblage at Bikini, especially as it would be the sole remaining drone available for study within an archaeological context and that retains its unaltered Crossroads configuration. Only one other F6F-3K Hellcat drone is known to exist; stripped of its Crossroads equipment and restored to stock condition, BuNo. 41834 is on display at Dulles Airport in the Smithsonian National Air and Space Museum's Stephen F. Udvar Hazy Annex outside Washington, D.C. (Fig. 21).

## Conclusions

The *Independence* airplanes join other archaeological evidence at the shipwreck that defines that site's significance within the context of both World War II and the Cold War. Submerged relics of aviation history are an emerging area of study in underwater archaeology. Not unlike shipwrecks, sunken aircraft were initially the exclusive focus of salvage and recovery efforts, with no thought spared for academic discipline or methodology. Paralleling the development of shipwreck archaeology into nautical archaeology, and from there to maritime archaeology, archaeological interest in site characterization, methodologies for recovery compatible with archaeology, and placing aircraft within theoretical perspectives led to a growing body of work known as "aviation archaeology" or "aeronautical archaeology" (Fix 2011). Within that construct, the field encompasses not only individual aircraft but also collections of aircraft, especially those associated with battles, as well as related aviation infrastructure. As early as 1983, anthropologist Richard Gould argued for assessing the Battle of Britain (1940) through the study of its aircraft wrecks. He further posited that the archaeological signatures of each battle were



**Fig. 21** Restored F6F-3K Hellcat drone from Operations Crossroads, BuNo. 41834, on display at Dulles Airport in the Smithsonian National Air and Space Museum's Stephen F. Udvar Hazy Annex outside Washington, D.C. Photo by Hill Godspeed

in many ways a parallel (Gould 1983). Without delving into the specifics of his argument, what we stress here is that Gould was the first to look at aircraft wrecks as more than individual crash sites, and his paradigm is applicable to naval/maritime sites.

This concept guided the expansion of the National Park Service's study of USS *Arizona* into a larger examination of the entire Pearl Harbor battlefield (Lenihan et al. 1989:9). As part of that study's final phase, in 1988, the NPS team worked to identify underwater sites where Japanese aircraft had been lost during the attack, assessing twenty locations and recommending further work on thirteen of them (Lenihan et al. 1989:62–65). Efforts by Hans Van Tilburg to identify the archaeological signatures of Hawai'i's role as a base for naval and military activities from the late nineteenth century through the present time is particularly pertinent. Van Tilburg expands the assessment of the battle beyond Pearl Harbor to multiple sites on the islands of O'ahu and Ni'i'hau as well as the surrounding waters (as cited in Delgado et al. 2016a, b:4–5).

This work includes the detailed archaeological assessment of a Consolidated PBY Catalina flying boat wreck in Kaneohe Bay, one of the loci of the December 7, 1941 battle (Rodgers et al. 1998). Van Tilburg has calculated the number and nature of aircraft sites in an underwater context around Hawai'i as part of a comprehensive study of U.S. Navy wrecks and a soon-to-be published inventory of potential submerged cultural resources surrounding the Hawaiian Islands (Van Tilburg 2002:259; Van Tilburg 2003). The same approach has been applied in Australia by McCarthy (1997) and Jung (2001) with a concentration of scuttled as well as combat-lost PBY Catalinas at Darwin, Western Australia.

It is within this framework that we submit the aircraft wrecks of Crossroads, whether within a sunken vessel (such as USS *Saratoga* and USS *Independence*) or at the Bikini site where they were blown or jettisoned from an atomic-bombed target ship, constitute discrete yet intertwined elements of a maritime archaeological assemblage that represents the entire unprecedented operation. Further, these artifacts, through their context, both as naval warplanes on an aircraft carrier, and as instruments for naval nuclear tests, are more than aeronautical archaeological sites. They also fall well within the parameters of maritime archaeology as significant elements of America's initial attempt to come to grips with how contemporary military and especially naval power would fare in the dawning Atomic Age.

As naval aircraft, developed to fight a war at sea and project martial might from mobile floating platforms, the Crossroads airplanes are inherently "maritime" instruments, dedicated to dominating the waves by battling for control of the skies above. In the context of both what has been observed at Bikini, and now with USS *Independence*, we can assert that the archaeological signature of Operation Crossroads is much larger than ever previously conceptualized. The aircraft, whether in the scattered shipwrecks, or still on the lagoon floor at Bikini with other test material such as tanks, small craft, and military equipment deposited as a result of the Able and Baker blasts, speak to the potential for understanding more about the world's first, albeit simulated, atomic battle site. They also suggest opportunities for further advances into the theoretical frontier of aeronautical archaeology to include using new technology for the study of entire naval aviation battlefields that could now be assessed in strategic and tactical terms down to each individual commitment, expenditure and loss as has been demonstrated on land battle sites (e.g. Scott et al. 1989). As we see with *Independence*, the impact of the simulated battle that was Operation Crossroads, and the costs of that battle, extend far beyond Bikini Atoll. In that, the archaeological signature also serves as an apt metaphor for the legacy of Crossroads and the possibilities and consequences of global nuclear conflict.

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