Carrier Arresting Gear: It all Began With Sandbags

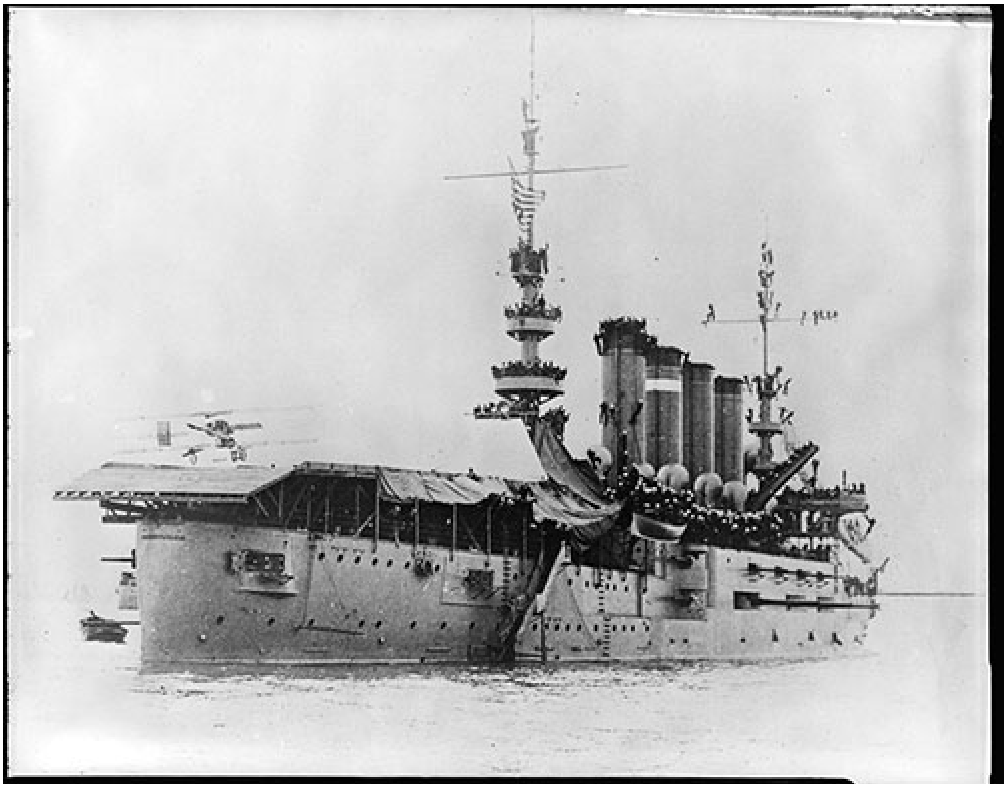
Naval Aviation

AN Eric Eisenbarth, stands by to check an arresting gear wire before an F/A-18F from the VFA-41 Black Aces lands on the flight deck aboard USS John C. Stennis (CVN 74) on 5 March. (Photo by MCSA Ignacio D. Perez)

"What goes up, must come down" is an old adage that has helped keep the skills and mindsets of Navy and Marine Corps pilots sharp for nearly a century. The carrier catapult has often been regarded as the symbol of carrier aviation, complete with the steam-enveloped carrier deck, and the roar of jet engines rocketing into the sky. Represented by a few cables positioned across the expanse of the flight deck, arresting gear systems are the slightly less-sexy unsung hero of carrier aviators.

While arresting gear has changed throughout the years to meet the ever-growing demands of heavier, jet-propelled aircraft and higher sortie rates, the basic concept and design remains the same. A single tailhook, (or in early tests, "hooks") from the aircraft is designed to catch one of three or four arresting wires that cross the carrier deck. These wires are attached on both ends of the runway to hydraulic cylinders that are stored below the carrier deck and absorb the kinetic energy created by the force of the aircraft. This slows the aircraft until it reaches a complete stop. The tailhook is then removed from the wire and the system is prepared for its next arrestment. If an aircraft breaks loose from the wire or cannot be stopped through the conventional tailhook arresting gear, a barricade netting (closely resembling a tennis net) functions as an emergency backup. A "bolter" occurs if an aircraft misses the wires during an attempted arrested landing. Bolter aircraft accelerate from the flight deck at full throttle and try to land again on a subsequent pass.

The Navy's newest carrier, Gerald R. Ford (CVN 78), expected to join the fleet in 2016, will be fitted with the Advanced Arresting Gear (AAG), replacing the MK-7 hydraulic arresting gear system that has served the Navy for more than 60 years.



Eugene Ely lands his Curtiss Pusher biplane aboard USS Pennsylvania (ACR 4) on 18 January 1911 off the coast of San Francisco, Calif.

Early History

The first shipboard landing of an aircraft via arresting gear occurred aboard the Pacific Fleet's armored cruiser USS Pennsylvania (ACR 4) off the coast of San Francisco, Calif. on 18 January 1911, by Eugene B. Ely aboard his Curtiss Pusher biplane. Capt. Washington I. Chambers, the Navy's aviation officer, capitalized on Ely's earlier historic success following "successful" launches from the scout cruiser USS Birmingham (CL 2) and Pennsylvania, and proposed to Ely that he double-down in the history books by becoming the first pilot to both launch and land an aircraft on a ship. (Ely actually damaged his aircraft during the launch from Birmingham, as the plane buzzed the water, damaging his propeller, and forcing him to land on nearby Willoughby Spit after nearly five minutes of flight.)

A showman to the end, Ely saw an opportunity to generate interest and fanfare for his aerial exhibitions, as he was also a test pilot for aircraft manufacturer Curtiss Pusher. Ely excitedly accepted Chamber's offer and plans were made to turn Pennsylvania from the first ship altered to launch an aircraft, to the first ship altered to land one.

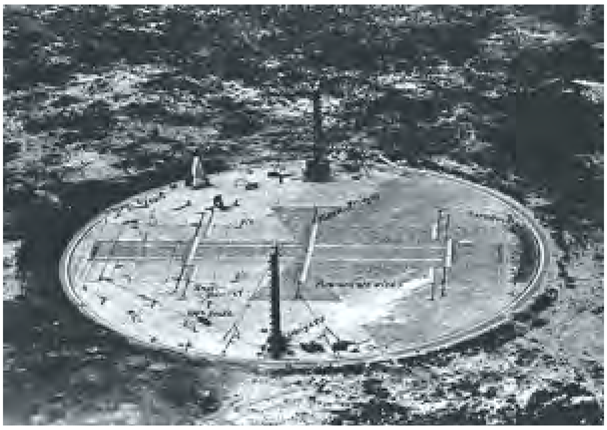
First, a landing deck aboard Pennsylvania had to be designed and built. The design wasn't complex: ropes, anchored at their ends by 22 pairs of sandbags, each weighing approximately 50 lbs., were stretched across the ship's 120-by-30 ft. deck. The aircraft's landing gear was equipped with hooks to catch the ropes stretched across the deck, where the weight of the sandbags would slow the plane down until it eventually stopped. In case of an overrun, or a swerve off the ship's edge, canvas awnings were rigged in front and to the sides to catch the plane and pilot.

So it was on mid-morning of 18 January 1911, that Ely took off from the Tanforan Racetrack in nearby San Bruno, Calif., for the historic landing of his bi-plane on the "deck" of Pennsylvania, anchored just off the coast of San Francisco. Thousands of spectators gathered around the city's waterfront and watched as Ely initially flew around the ship for a true bird's-eye view of the arresting gear set-up, then angled his aircraft downward onto the deck, catching the set-up, and coming to a complete stop before reaching the emergency barriers.

"Momentum and the tail wind carried the plane over the first arresting wires," wrote Norman Polmar in Aircraft Carriers: A Graphic History of Carrier Aviation and its Influence on World Events. "Then the hooks took hold and with a deck run of 30 feet the biplane came to a halt at 11:01 a.m."

Although the Ely landing was successful, it would take the Navy more than a decade to begin significant testing and demonstration of a shipboard arresting gear system.

On 11 August 1921, the practical development of carrier arresting gear began at NAS Hampton Roads, Va., when Lt. Alfred M. Pride taxied an Aeromarine onto a dummy deck aboard the station and engaged its arresting wires



An early aerial photograph of the NAS Hampton Roads, Va. arresting gear test site.

An Aeromarine sits on a dummy carrier deck at NAS Hampton Roads, Va., with fore and aft wires in front of the aircraft to keep it on a straight path during its landing. These wires and their associated equipment were subsequently removed beginning in 1929.

Eight months later, on 1 April 1922, the call went out for the design of an arresting gear to be used upon USS Lexington (CV 2) and USS Saratoga (CV 3). The Navy specifications stated the "arresting gear will consist of two or more transverse wires stretched across the fore and aft wires… [and which] lead around sheaves placed outboard to hydraulic brakes. The plane after engaging the traverse wire is guided down the deck by the fore and aft wires and is brought to rest by the action of the traverse wire working with the hydraulic brakes." During its conversion from a partially-built battlecruiser into a full-time aircraft carrier, Lexington was initially fitted with an electrically-operated arresting gear design which used both fore-and-aft and transverse wires. This electric-based system was replaced by the MK-2 hydraulic arresting gear on 11 August 1931.

In the meantime, it was the collier-turned aircraft carrier USS Langley (CV 1), which handled the first true test and evaluation of the early aircraft carriers and their namesake capabilities. On 26 October 1922, Lt. Cmdr. Godfrey DeCourcelles Chevalier became the first Navy pilot to land an aircraft on a ship, when he landed his Aeromarine aboard Langley off Cape Henry, Va.

"At the time, the Langley's arresting gear consisted of wires running fore and aft suspended about 10 inches above the deck," wrote Polmar. "While not entirely successful, this system of fore-and-aft wires was used on U.S. carriers until 1929."

The initial arresting systems were weight-based, operating under similar principals as the early "sandbag" version which caught Ely. However, in early 1930, the Navy began developing a hydraulic arresting gear capable of great refinement to absorb the energy of heavy aircraft landing at high speeds. On 2 May 1932, the Bureau of Aeronautics directed that hydraulic cylinder-type arresting gear be installed on Langley to replace weight-based gear used previously. Langley was once again modified in 1937, this time as both a tender for seaplane aircraft transport and a service center.

USS Ranger (CV 4) was the first U.S naval vessel built with the intent of functioning as a true aircraft carrier.

Unlike the ships that came before it, USS Ranger (CV 4) was the first U.S. naval vessel to be built from the keel up with the intent of operating as a true aircraft carrier. Commissioned on 4 June 1934, Ranger wasted no time in performing the most primary duties of an aircraft carrier, as it began launching and arresting aircraft on 21 June. The first landing was made using an SBU-1 bi-plane fighter piloted by Lt. Cmdr. A.C. Davis. Ranger primarily operated in the Atlantic, as its turbines could not power the vessel above 29 knots, thus was deemed "too slow" for use in the Pacific Fleet.

Post World War II

As aircraft grew heavier and sortie rates increased, the Navy was forced to adapt to the demanding requirements of successful and safe aircraft recovery. Much like the Navy's adoption of the British-developed steam catapult, a system was needed to handle increased weight and speed of returning aircraft, while still meeting the space requirements of the arresting gear systems below deck. In fact, so great was the advance of jet aircraft technology after World War II that the Navy looked to dynamically upgrade and alter their entire carrier fleet.

On 4 June 1947, the Chief of Naval Operations (CNO) announced that new aircraft carrier characteristics would be incorporated in a modernization effort dubbed Project 27A.

"The principal changes involved in the 27A project were directed toward the capability of operating aircraft of up to 40,000 pounds gross weight," wrote Scot MacDonald in the May 1962 Naval Aviation News.

These changes allowed for jet aircraft launch and landing testing using aircraft such as the FD-1 Phantom and FJ-1 Fury, as well as launches of the P2V Neptune aboard USS Coral Sea (CV 43). According to MacDonald, Project 27A was originally intended for more than nine aircraft carriers, but the testing and subsequent introduction of the steam catapult and acceptance of newer and heavier jet aircraft made it apparent that the project needed to be modified to meet the inevitable future needs of the fleet.

Sailors aboard USS Yorktown (CV 10) disengage the arresting hook from an F6F Hellcat.

On 1 February 1952, the CNO approved a modification of the Project 27A carrier conversion program which provided an increase in the capacity of deck operating equipment, including installation of more powerful arresting gear. In mid-June of that year, the Bureau of Aeronautics proposed that USS Antietam (CV 36) receive a new canted flight-deck to allow aircraft landings to be angled 10 degrees off the carrier's centerline, thus allowing pilots to avoid barricades, parked planes, and other obstacles present on the traditional flat-top design.

The test design was a success, with the December 1953 BuShips Journal noting "the clear deck ahead on every carrier pass relieved the pressure of the pilot. Primarily for this reason, pilots who have flown from the canted deck are unanimous in their favorable enthusiasm." The canted deck also allowed for fewer cross-deck pendants and arresting gear engines. The landing area for aircraft was recommended to be kept as far aft as practical, yet forward enough to decrease the rate of descent.

The tests aboard Antietam resulted in Project 27C, which focused on implementing the technology and design associated with the canted deck. According to MacDonald, Project 27C also allowed for the improvement for the then-current MK-7 hydraulic arresting gear, cutting the number of cross-deck pendants in half and reducing the ratio of arresting gear sheaves from two to one.

"[USS] Lexington (CV 16), [USS] Shangri La (CV 38), and [USS] BonHomme Richard (CV 31) all received these improvements of this project," wrote MacDonald, "and they were so successful that [USS] Hancock (CV 19), [USS] Intrepid (CV 11), and [USS] Ticonderoga (CV-14) returned to the yard for this new conversion."

Through the years, carriers and their capabilities continued to evolve. Relying on technological advantages and designs to maximize capabilities from aircraft that continued growing in size and weight, the MK-7 arresting system has largely remained the same since its introduction. All carriers are currently equipped with either the MK-7 Mod 3 or Mod 4 version, which have the ability to arrest airplanes of up to 50,000 pounds gross weight at engaging speeds of 175 mph. The MK-7 Mod 3 arresting engine is composed of the engine structure, a cylinder and ram assembly, a crosshead and fixed sheaves, a control valve system, an accumulator system, air flasks, and a sheave and cable arrangement.

In 2007, the job of arresting gear operators became a bit easier when the Navy introduced the Advanced Recovery Control (ARC) system aboard USS Ronald Reagan (CVN 76), during a scheduled maintenance period. ARC is a digital arresting gear control system modification for the MK-7, and is now operational on all active carriers. ARC replaced the MK-7's older, analog mechanical system with a digitally controlled system to allow easier maintenance and use, while requiring fewer Sailors to operate. Another benefit of the ARC is its ability to electronically collect the data from the aircraft arrestment log, which gathers and stores information from the aircraft's carrier landing systems.

Although the ARC will not be used in conjunction with the AAG, it will continue to operate with the MK-7 systems installed aboard Nimitz-class carriers, according to Andrew Sussman, the recovery integrated product team lead for the Navy's Aircraft Launch and Recovery Equipment (ALRE) program.

"The ARC system is a digital control system that was developed to extend the MK-7 arresting engine life and provide better operator situational awareness, and health and system diagnostics," he said. "The AAG architecture, including a digital control system and the Health Monitoring Assessment and Prognostics system, provides its own integrated control system designed for the operation of the system and does not require ARC.

A sailor performs routine maintenance on flight deck barriers aboard an escort carrier.

The Future

In baseball terms, AAG will be battery mate to the Electromagnetic Aircraft Launch System (EMALS), tasked with catching the metaphoric Super Hornet fastball hurled into the sky by the catapult. As EMALS will allow for a larger and more varied class of aircraft to launch from carrier decks, there needs to be a reliable arresting gear that will bring pilot and aircraft back home safely.

According to Capt. Jim Donnelly, ALRE program manager, in 2001 the Navy recognized the need for an advanced recovery system for future aircraft carriers that would improve reliability and maintainability, and would allow for the recovery of current and future carrier-based aircraft. That system would be the AAG.

“AAG is a completely new system and a leap in technology for future aircraft carriers, employing advanced technologies to provide higher reliability and safety margins,” said Donnelly. “[The system] is designed to recover current and projected future carrier-based aircraft, from the lightest unmanned aerial vehicles to the heaviest manned fighters.”

The AAG is a modular, integrated system consisting of energy absorbers, power-conditioning equipment, and digital controls. The AAG will be installed during construction of the Ford-class carriers, beginning with initial installation aboard Gerald R. Ford.

Another of the AAG’s benefits over its MK-7 predecessor are built-in test and diagnostic capabilities, resulting in less maintenance and manpower to operate than the MK-7, while providing greater reliability and safety margins.

“The legacy [MK-7] system requires 86 Sailors to operate, while AAG is projected to reduce manning to 46,” said Donnelly. “AAG also allows for increased sortie rates and a decreased gross ship weight.”

Delivery of specific AAG system subcomponents to Gerald R. Ford began in March 2012, although the system is still undergoing developmental testing at its jet car track site at Joint Base McGuire-Dix-Lakehurst in Lakehurst, N.J. Donnelly notes that initial dead-load recovery testing of the system has been successful.

“The Navy has conducted more than 380 dead-load recoveries as part of the [System Development and Demonstration] phase at the Jet Car Track Site (JCTS) in Lakehurst, N.J.,” he said. “Runway Arrested Landing Site components will soon be delivered and installed at Joint Base McGuire-Dix-Lakehurst, N.J. to support manned aircraft arrestments, which is the follow-on to dead-load testing at the JCTS.”