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Flight Deck Design of the Next Generation Aircraft Carrier

ABSTRACT The U.S. Navy's next generation aircraft carrier (CVNX) program has developed various new concept designs to improve upon the current Nimitz (CVN 68) class carrier. Significant changes in Flight Deck arrangement, operations processes, and advanced technology systems will provide an increase in aircraft sortie generation rate while decreasing manpower and cost.

Introduction

Since World War II, the U.S. Navy has relied on the aircraft carrier as the primary tool for projecting power throughout the world. The U.S. Navy next generation aircraft carrier program, known as CVNX, is developing new carrier designs to meet the Navy's evolving requirements to remain in the forefront of maritime aviation. New carrier development is accomplished by CVNX Engineering Process Teams that analyze all aspects of carrier design. Inputs to the program for all aspects of aviation are provided by the Aviation Process Team. A major contributor to the Aviation Process Team is the Naval Air Warfare Center Aircraft Division (NAWCAD) at Lakehurst, New Jersey, which is responsible for aircraft integration, aircraft launch and recovery equipment, aircraft support equipment, and development of Flight Deck and Hangar Deck designs for the CVNX program.

The CVNX Program has developed a number of new carrier concept designs which include several modified *Nimitz* class ships as well as completely new designs. The new concept designs incorporate advanced technology systems as well as significant changes in arrangement and processes that reduce operational costs. A goal of the program is to significantly reduce the manpower required to operate the carrier while maintaining or improving on the combat capability of the *Nimitz* class aircraft carrier design. This paper focuses on the unconstrained new designs, which are based on a completely new carrier configuration.

Background

The advent of improved aircraft performance and reliability has made the Flight Deck design a limiting factor in the operational efficiency of the shipboard airwing. The CVNX program's aggressive manning reduction goals mandate a process-centered approach to Flight and Hangar Deck designs. The major carrier deck processes were modeled to determine efficiency improvements and workload savings possible through the incorporation of new processes, technologies, or improved design. The resulting ship concept requires less manning than today's designs, and the process-centered approach has resulted in efficiencies that also improve the combat capability of the carrier.

General Arrangement

AIRWING PARKING

The numerous operational modes of a carrier airwing and their associated parking arrangements are the primary design drivers of Flight Deck size and arrangement. The air plan describes the launch and recovery schedule of aircraft, mission profiles, ordnance load plans, fuel loads, etc., for the day's flight operations. There is a strong relationship between the Flight Deck operations of the airwing as described by the airplan and the parking arrangements that are developed for the carrier.

The available space and arrangements of the Flight and Hangar Decks determine the number of aircraft deployed to U.S. Navy carriers. Historically, the most common limiting factor for deployable aircraft on U.S. carriers is the final recovery parking arrangement or final recovery "spot". A carrier must have sufficient Flight Deck and Hangar Deck to spot the entire complement of aircraft and equipment, while leaving the recovery area clear to arrest the last airborne fixed wing aircraft.

Parking arrangements used prior to a launch, known as "pre-launch" parking, are an increasingly significant Flight Deck design driver. This is due primarily to the advent of more reliable aircraft and to increases in exhaust temperatures of high performance aircraft. As aircraft become more reliable, the proportion of mission capable aircraft on the carrier increases. Since the natural tendency of the carrier operator is to maximize the use of mission capable assets, demand increases for either pre-launch parking on the Flight Deck or for elevator use as a way to make up for limited Flight Deck parking.

Increases in aircraft exhaust temperature have increased the amount of space required for pre-launch parking. Navy carriers have experienced problems when high performance aircraft such as the F/A-18 and F-14 start and warm up their engines with the exhaust pointed at other aircraft or ship structures. Operators have been forced to park aircraft at the deck edge with the exhaust blowing overboard due to heat damage occurrences at distances of several hundred feet from the exhaust nozzles. The trend toward increasing exhaust temperatures and mass flows is expected to continue with the next generation of fighter and strike aircraft such as the F/A-18E/F and the Joint Strike Fighter. The carrier design solution is to provide additional deck edge parking space by lengthening or widening the Flight Deck and by arranging the components of the Flight Deck for efficient deck edge parking. Parking aircraft in the middle of the Flight Deck with the exhaust blowing across an open area such as a catapult or recovery area is also becoming more restricted. Hot exhaust ingestion degrades aircraft performance during launch and recovery, so directing the exhaust of idling aircraft across these areas is often prohibited. As exhaust temperatures increase, this parking practice may be prohibited altogether, placing further demand on deck edge parking.

All Flight Deck parking arrangements need to accommodate a number of spare and alert aircraft. Spare aircraft are reserves that can be substituted for aircraft that are scheduled for a launch but are unable to make it. Alert aircraft are typically fighter or tanker aircraft held in a ready state on the Flight Deck to be launched on short notice. Alert and spare aircraft need to be parked out of the way of the aircraft that are scheduled to operate since they remain in one location for extended periods. They also need to be parked at the deck edge with their exhausts oriented overboard. Parking for pre-launch aircraft plus the required alert and spare aircraft tends to dictate the amount of deck edge space required. As more and more aircraft must be placed at the deck edge, pre-launch parking can become the dominant parking arrangement for sizing and configuring the Flight Deck. Aircraft parked during final recovery can be located more freely near the center of the deck since their engines are shut down rapidly, and heat exposure times are limited. This reverses the historical trend of final recovery parking dictating the required Flight Deck size.

Aircraft parking during cyclic operations is essential in determining the effectiveness of the carrier airwing. Cyclic operations are typically conducted with two groups of aircraft. The first group is launched, then some time later the second group is launched. Soon after the second group is launched, the first group recovers. There is a delay while the aircraft on the Flight Deck are respotted, and then turnaround servicing commences. After servicing, the first group is launched, and then the second group promptly recovers. This cycle continues until the completion of the operating day. Cyclic operations create open deck space for aircraft servicing by ensuring that a significant number of aircraft are always airborne. The amount and configuration of deck space available during cyclic operations strongly effects the time and efficiency of turnaround servicing.

Historically, the density of aircraft parking on carriers has been relatively high. This high density tends to force aircraft to be repositioned, or "respotted", at the end of each cyclic recovery event. There is insufficient deck space outside the recovery area to park the recovered aircraft, spare aircraft, and alert aircraft on the deck without obstructing several catapults. Respotting interrupts servicing activities on aircraft, requires a significant amount of time to complete, and requires significant numbers of tractors and personnel. After respot, aircraft are often parked in the recovery area which forces an additional respot and time delay if an unplanned or emergency recovery is required.

Several CVNX concept designs include a larger Flight Deck that is arranged specifically to accommodate aircraft parking and servicing during cyclic operations. The deck is configured to allow all the aircraft in a recovery event to taxi away from the recovery area, taxi into a parking spot, shut down engines, and begin servicing. There is sufficient space outside of the recovery area to create parking spots for all the aircraft in the recovery event with only one catapult (out of four) obstructed by parked aircraft. This arrangement allows turnaround servicing to be completed without extensive aircraft respotting. This type of operational concept has been named "pit stop". Operations analysis has shown a potential sortie generation increase simply through this reduction in aircraft respotting. After turnaround servicing is complete, each aircraft can start its engines, warm up, and taxi to a catapult regardless of the aircraft parked next to it. This is accomplished by providing adequate space between the aircraft parking locations. Providing a space buffer between aircraft also benefits aircraft turnaround servicing by providing additional space for personnel and equipment working on the aircraft and by reducing the need to move the aircraft to conduct maintenance.

A Flight Deck configured for pit stop has more Flight Deck area per aircraft outside of the recovery area. This added area reduces the impact of final recovery parking on carrier design. The added Flight Deck area required for pit stop style operations leaves a slight excess of area for final recovery. In many cases, a final recovery can be conducted without respotting aircraft on deck. This allows an emergency or unplanned recovery to be conducted at any time with little notice. Figure 1 shows cyclic operations parking arrangements for aircraft turnaround servicing on the CVNX Expanded Capability Baseline (ECBL) design and a typical *Nimitz* class carrier. Both carriers have identical airwings operating with 29 aircraft on the Flight Deck, 26 on the Hangar, and 20 aircraft airborne. The *Nimitz* class ship must respot several aircraft after each recovery is complete, while the aircraft on the ECBL ship taxi directly from the recovery area to the "pit stop" areas along the bow and down the starboard side.

ISLAND ARRANGEMENT

Island location is critical to the ship's ability to generate sorties and to take advantage of the airwing capabilities to the fullest extent. *Nimitz* class carriers have islands on the starboard side, slightly aft of midships. This arrangement creates a narrow "choke point" on the Flight Deck between the island and the recovery area, effectively blocking transit of aircraft fore and aft during recovery operations. This choke point forces all the recovered aircraft to be initially spotted on the forward half of the Flight Deck. During recovery, there is insufficient area forward of the island to arrange the aircraft in a manner so they can be serviced and started without obstructing both bow catapults. The lack of space forces several of the recovered aircraft to be respotted after the recovery is complete. Navy studies have indicated that eliminating choke points on the Flight Deck is an essen-

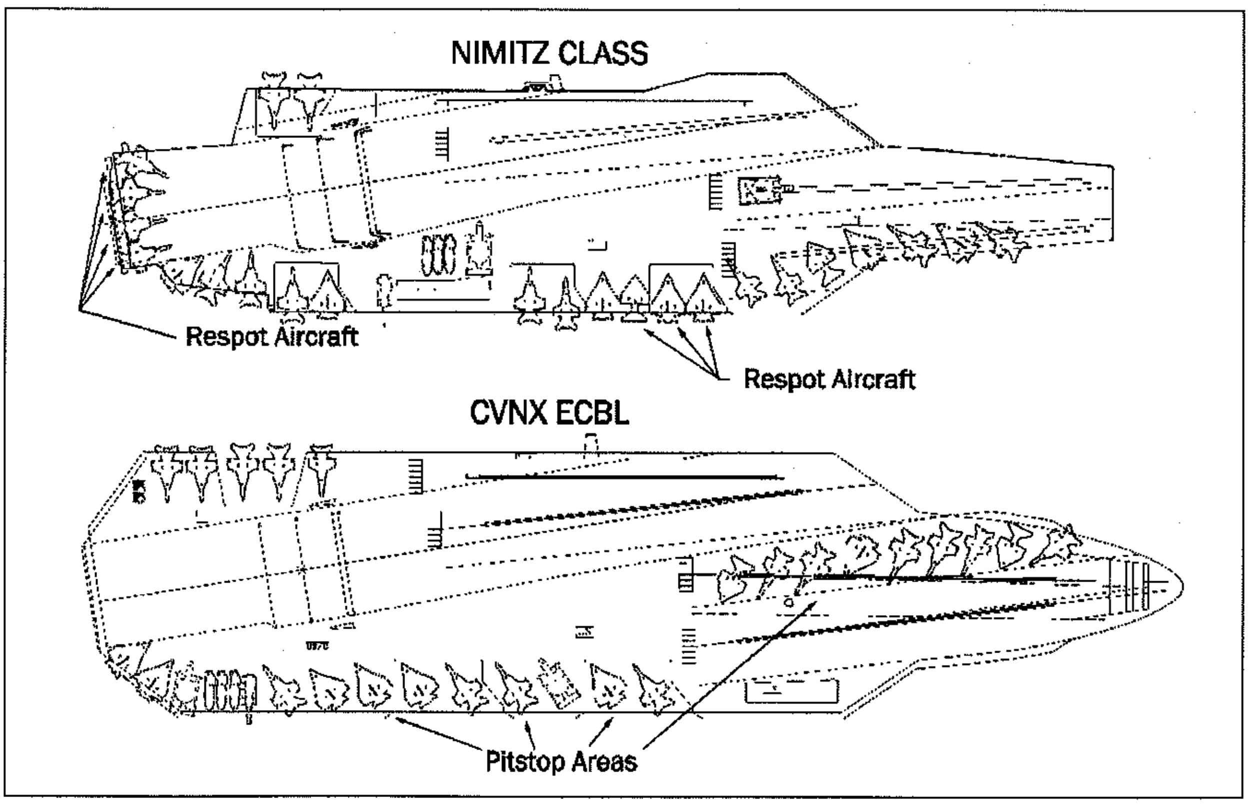

FIGURE 1. *Nimitz* Class and CVNX ECBL Compared

tial element in increasing sortie generation for a given airwing.

There are several key drivers in the CVNX island placement: field of view, turbulence effects, aircraft movement considerations, weight and stability, electrical emissions, and environmental (thermal and acoustic impact) concerns. An adequate line of sight must be maintained from the bridge for command purposes, from primary flight control for aviation operations, and from the various radar and communications sensors for proper functioning. Turbulence from the island becomes a factor when the combined airwake from the island and the exposed hullform join to form a "burble" that approaching aircraft must pass through. The island must be placed far enough away from the launch and recovery areas to not interfere with aircraft movement during recovery and turnaround of aircraft. Finally, the island must be located and designed to protect its occupants from the acoustic and thermal effects of aircraft exhaust.

In the CVNX program, four general island configurations were considered: a fully aft island, multiple island locations, a forward island, and a traditional midship island. From an aircraft handling point of view, an aft island placement is the ideal. An aft island's greatest advantage is that it allows the unencumbered flow of aircraft around the Flight Deck. The disadvantages include the significant burble that recovering aircraft must fly through and the poor field of view this location gives the command element and sensors. The multiple island configuration with one forward and one aft eliminates the field of view concerns and provides improvements in survivability, but is much less desirable from the perspective of aircraft spotting and maneuvering.

The CVNX ECBL design places a single island in a relatively forward location. Advantages of this include reduced effects of island induced turbulence, excellent field of view, and acceptable line of sight for sensors. The disadvantages of this placement are a slight impact on aircraft movement and parking and the weight of the additional acoustical treatments and insulation needed to protect an island located close to the catapults.

AIRCRAFT ELEVATORS

Two types of elevators were considered on the CVNX Program: through deck elevators and deck edge elevators. The advantages of through deck elevators are primarily in their usability in heavy seas, and a reduced contribution to radar profile. Their shortcomings are their impact on Flight Deck arrangements, structural limitations of positioning the elevator, obstruction of aircraft movement routes on the Flight Deck, space consumed within the ship and on the hangar bay, and sizing constraints for aircraft.

Because of these shortcomings, current carriers exclusively use deck edge elevators. These elevators are designed for relatively infrequent operations and for positioning of aircraft on the platform using a tractor or manual pushback. An important design consideration for deck edge elevators is the ability of an aircraft to perform a turnaround maneuver on the elevator platform without impacting elevator cables. This maneuver allows aircraft to be reoriented at the hangar bay level, improving aircraft parking efficiency within the hangar.

Aircraft elevator platforms must be positioned to provide reasonably sized Flight Deck areas around and between them. This allows access to the platforms, ensures adequate movement paths around the elevators, and creates usable parking areas on the adjacent Flight Deck that can accommodate a variety of aircraft. The elevators should be positioned outside of the recovery area to prevent a non-functioning elevator from rendering a ship unable to conduct flight operations. There must also be at least one elevator available to service each of the hangar bays below. Both port and starboard sides of the ship should have at least one elevator to provide better access in beam seas and to preclude an incapacitating hit on one side of the ship.

Pit stop style operations mandate an elevator sized to accommodate aircraft taxiing onto the platform and parking without assistance from a tractor. The key design driver for ECBL is the need to park two aircraft entirely on the platform so it can be raised or lowered without repositioning the aircraft. This causes the ECBL platform to be larger than current carrier designs. The ECBL design, however, employs only three elevators as opposed to four on the *Nimitz* class. Another driver is the need to position as many aircraft as possible at the deck edge for the pre-launch spot at the start of operations, again with the aircraft entirely on the platform. A balanced design has been developed that accommodates three aircraft oriented athwartships which are positioned by a tractor, or two aircraft, angled aft, that can maneuver into position under their own power (see Figure 1). The elevators designed for pit stop operations also have a greater lifting capacity since they can accommodate an additional aircraft.

ORDNANCE FLOW

Among the primary issues addressed in the CVNX program is weapons flow from the magazine to the aircraft. Currently, weapons are transported to the Hangar Bay or the Second Deck by lower stage weapons elevators. From there they are moved across the Hangar or Second Deck onto either an aircraft elevator or a weapons elevator to be raised to Flight Deck level. Once there, they are moved either directly to an aircraft, or to a munitions staging area known as the "bomb farm", where they remain until needed.

Several new carrier concepts include the addition of ready service weapons handling and staging areas in the sponsons between the Hangar and the Flight Deck. These provide a protected and dedicated area for weapons build-up and storage near the aircraft. The sponson staging areas are supplied by weapons elevators running directly from the main magazines and have additional elevators running directly to the Flight Deck. This allows for unhindered access to weapons regardless of sea state or flight condition. The combination of these changes results in vastly improved weapons flow, greater survivability, a decrease in manpower, improved ability to use concepts such as "just-in-time" ordnance delivery, and will free up valuable flight and Hangar Deck real estate.

Survivability considerations and side protection systems can dictate a minimum separation between weapons elevator trunks and the sides of the ship. This can have the effect of limiting design flexibility by forcing the lower stage weapons elevators toward the center of the hangar where they must open into aircraft parking areas. A significant design change expected with the CVNX is the use of inclined elevator shafts to allow a more direct elevator run from the main magazines to the outboard sponson staging areas. This approach is facilitated by the use of electrically driven weapons elevators that can move upwards at angles, and will provide better performance and reliability compared to current hydraulically driven elevators. This concept will reduce weapons transit time and workload, and will increase weapons throughput to the Flight Deck.

CVNX ECBL FLIGHT DECK FEATURES

The CVNX ECBL concept ship is shown compared to the existing *Nimitz* class in Figure 1. ECBL is a monohull design with a port angled recovery area, two bow catapults, two waist catapults, and a single island. The Flight Deck is about 1164 feet long and 285 feet wide. The catapults are electromagnetic and the minimum distance from the catapult to the jet blast deflector (JBD) has been increased compared to the *Nimitz* class carriers. There are two deck edge aircraft elevators starboard and one to port. The starboard elevators are longer and wider than those of the *Nimitz* class to facilitate parking of aircraft during pit stop style operations described above. The island is located relatively forward in order to eliminate choke points, facilitate pit stop operations, and provide space for taxiing aircraft fore and aft during launch and recovery operations. The port midships catapults have been rearranged to allow for simultaneous spreading of the wings of short span aircraft such as F/A-18E/F or Joint Strike fighter. These catapults have also been moved farther from the deck edge to allow better access to the outboard catapult and to eliminate obstructions to launching at the deck edge.

The bow catapults are moved aft to create a space reservation for a possible future variable exit angle ski jump. The ski jump would allow Short Takeoff Vertical Landing (STOVL) aircraft to launch with significant payloads from just forward of the bow catapult JBDs. This would permit mixed STOVL and catapult launch operations with minimal disruption to Flight Deck operations. The ski jump would be retracted when launching with the catapults.

There are three weapons elevators with one located inside the aft end of the island, and the remaining two located so they do not obstruct the typical operational aircraft parking locations. A sponson weapons handling area supplies each Flight Deck weapons elevator. The weapons handling areas total approximately 15,000 square feet. The two forward staging areas are supplied directly from the ship's main magazines by lower stage weapons elevators.

Processes

Process improvements can provide benefits in terms of performance and cost without large investments in technology and with minimal carrier design impact. The aircraft turnaround process, from approach and recovery to launch, has been modeled to uncover possible improvements. An example of a promising process improvement for reducing turnaround time is simultaneous weapons loading and fueling. Because of safety considerations, the practice of loading forward firing weapons concurrently with fueling operations is prohibited. The advent of improved ordnance and aircraft systems has fostered interest in the modification of this restriction. Analysis and testing is planned to assess the risks involved with changing this policy while ensuring safety is maintained. Performing these tasks concurrently could potentially reduce turnaround time and enable CVNX to increase sortie generation.

Another potential improvement being studied is the removal of the liquid oxygen and nitrogen (O_2/N_2) generation plant based on the diminishing requirements for aircraft liquid oxygen use. Removing the O_2/N_2 plant and replacing it with a stand alone nitrogen generation unit could reduce weight by 91 tons, free over 1000 cubic feet of space, and significantly reduce operating and acquisition costs.

Technologies

Various emerging technologies will provide personnel reductions in addition to increased capabilities. any of these technologies can also be backfit into existing Navy platforms.

Steam catapults are slated to be replaced by a fully electromagnetic system on the first CVNX carrier, the CVN 78. The Electromagnetic Aircraft Launch System (EMALS) and the Electromagnetic Aircraft Recovery System (EARS), currently in the developmental stage, are the next step in the evolution of the aircraft launch and recovery systems. Both replace technologies that have been in place since the 1940s. The basic technologies are being developed through the Advanced Linear Motor ATD project. Both EMALS and EARS are expected to significantly reduce the cost of launching and recovering aircraft and reduce manpower needed to operate the system. Other advantages are increased reliability, below-deck space and weight savings, and reduced peak acceleration loads on aircraft during launch and recovery.

The Embarked Aircraft Tracking System (EATS) is designed to automatically track aircraft locations and orientations on Flight and Hangar Decks using cameras and machine vision. This system is envisioned to streamline Flight Deck operations by supplying Flight Deck operators with accurate, up-to-the-minute information on aircraft position and status. The EATS system will also provide connectivity to other key decision makers in the ship's air department, provide more surveillance capability, and provide the aircraft handlers with a powerful planning and training tool. A contract has been issued for a system that can determine the position and orientation of every aircraft on the carrier within an accuracy of 1.5 feet and update the computer generated scene at a rate of sixty frames per second. A demonstration system has been shown to work in daytime, nighttime and poor visibility.

An Aviation Weapons Information Management System (AWIMS) is envisioned to deliver a fully integrated weapons inventory management and information management system that can be used to plan magazine arrangements and track weapons movement, with links to mission planning. Benefits include improved coordination of just-in-time weapons delivery and improved ordnance strike up efficiency through the reduction in likelihood of human error and miscommunication.

Human Amplification Technology (HAT) will significantly improve weapons loading processes. Because of the time it takes to hook up the existing weapons loading hoist, the Navy routinely loads weapons by hand, using five to eight people for a typical weapon. A U.S. Air Force funded research program produced a prototype system that enabled one person to load a 3,000lb bomb onto an aircraft in roughly half the time it takes to do it manually. Force feedback schemes sensed the forces exerted by the operator's hand and multiplied those forces through a robotic arm to create very good sensitivity and response. Algorithms were also developed that help guide the pins on the weapon into the holes in the pylon. The challenge is to identify reliable ship-based equipment that will reduce the time and manning necessary to load weapons. HAT systems could potentially produce a 30% decrease in ordnance manpower.

An In-Line Fuel Sampling system is being developed to reduce the cost and workload associated with the 400 to 600 fuel samples taken per day on a carrier. The objective is to develop a sensor that can automatically and continuously measure the type and concentration of contaminants in an enclosed fuel line. Preliminary results show that laser scattering technology can detect sediment and water at the low concentrations required.

Operational Impact

There are two significant changes that will enhance the Flight Deck efficiency and operational capabilities of the CVNX concept designs: rearrangement of the deck for pit stop style operations and introduction of technologies for rapid aircraft servicing. The rearrangement of the Flight Deck for pit stop operations should significantly reduce the number of aircraft respots required during normal operations. Flight Deck operations modeling indicates that the effect of the pit stop design alone is an increase in sortie generation capability up to 12% compared to a *Nimitz* class ship with the same airwing and mission parameters. This is due to the reduction in cycle time allowed through reduction of aircraft respotting. When pit stop operations and technologies to decrease turnaround servicing times are combined in the CVNX Flight Deck, the sortie generation capability increases up to 50%. It is interesting to note that when those same technologies are incorporated in a traditional Flight Deck that does not incorporate pit stop style operations, the increase in sortie generation is only up to 12%. This is due to the need to respot several aircraft after each recovery, which significantly increases the total time required to complete turnaround servicing for all the aircraft in a recovery group. Increases in sortie generation are accomplished primarily through a reduction in cycle times. The projected cycle times vary from approximately 90 minutes for an unmodified *Nimitz* class ship to 60 minutes for the CVNX ECBL with turnaround servicing technology enhancements.

Conclusion

The CVNX ECBL aviation support system provides significant reductions in workload while improving the overall combat capability of the carrier and its airwing. ECBL design features and technologies combine to allow up to 50% more aircraft sorties with fewer personnel on the Flight Deck. The pit stop concept is the foundation of these operational improvements that derive from improved arrangements and increased Flight Deck area. The CVNX design approach will allow the Fleet to take full advantage of emerging aircraft capabilities while reducing costs.

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