# Handbook of Future Technologies (Aircraft Carriers, High-speed trains, Space Missions and Ships)


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# Airbus A350

## Airbus A350

Illustration of Airbus A350 XWB concept in Etihad Airways livery

| | |
|---|---|
| **Role** | Wide-body jet airliner |
| **National origin** | Multi-national |
| **Manufacturer** | Airbus |
| **First flight** | 2012 (scheduled) |
| **Introduction** | 2013 (scheduled) |
| **Status** | Under development, early production |
| **Unit cost** | A350-800: US$236.6 million (2011)<br>A350-900: US$267.6 million (2011)<br>A350-1000: US$299.7 million (2011) |

The **Airbus A350** is long-range, mid-size, wide-body family of jet airliners under development by European aircraft manufacturer Airbus. The A350 will be the first Airbus with both fuselage and wing structures made primarily of carbon fibre-reinforced polymer. It will carry 270 to 350 passengers in three-class seating, depending on variant.

The A350 is being designed to compete with the Boeing 777 and the Boeing 787. Airbus says that it will be more fuel-efficient, with up to 8% lower operating cost than the Boeing 787. The launch customer for the A350 is Qatar Airways, which ordered 80 aircraft of all three variants. Development costs are projected to be US$15 billion. The airliner is scheduled to enter into airline service during the second half of 2013. Qatar Airways, TAM Airlines, and Singapore Airlines are also to be among the first airlines to operate it.

# Development

## Early designs

When Boeing announced its 787 Dreamliner project, it said the lower operating costs of this aircraft would make it a serious threat to the Airbus A330. In public announcements, Airbus initially rejected this claim, stating that the 787 was itself just a reaction to the A330, and that no response was needed to the 787.

The airlines pushed Airbus to provide a competitor, as Boeing had committed the 787 to have 20% lower fuel consumption than the Boeing 767. At first, Airbus proposed a simple derivative of the A330, unofficially dubbed the *A330-200Lite*, with improved aerodynamics and engines similar to those on the 787. The airlines were not satisfied, and Airbus committed €4 billion to a new design to be called the A350. The original version of the A350 superficially resembled the A330 due to its common fuselage cross-section and assembly. A new wing, engines and a horizontal stabiliser were to be coupled with new composite materials and production methods applied to the fuselage to make the A350 an almost all-new aircraft.

On 16 September 2004, then-Airbus president and CEO Noël Forgeard confirmed that a new project was under consideration, but did not give a project name, and would not state whether it would be an entirely new design or a modification of an existing product. Forgeard indicated that Airbus would finalise its concept by the end of 2004, begin consulting with airlines in early 2005, and aim to launch the new development programme at the end of that year. On 10 December 2004, the boards of EADS and BAE Systems, then the shareholders of Airbus, gave Airbus an "authorisation to offer (ATO)", and formally named it the A350.

On 6 October 2005, full industrial launch of the programme was announced with an estimated development cost of around €3.5 billion. This version of the A350 was planned to be a 250– to 300-seat twin-engine wide-body aircraft derived from the design of the existing A330. Under this plan, the A350 would have modified wings and new engines, while sharing the same fuselage cross-section as its predecessor. As a result of a controversial design, the fuselage was to consist primarily of Al-Li, rather than the CFRP fuselage on the 787. It was to see entry into service in 2010 in two versions: the A350-800 capable of flying 8,800 nmi (16,300 km) with typical passenger capacity of 253 in 3-class configuration and the 300-seat (3-class) A350-900 with 7,500 nmi (13,900 km) range. It was designed to be a direct competitor to the 787-9, and 777-200ER.

Almost immediately, Airbus faced criticism on the A350 project by the heads of two of its largest customers, ILFC and GECAS. On 28 March 2006, in the presence of hundreds of top airline executives, Steven F. Udvar-Hazy, of ILFC lambasted Airbus' strategy in bringing to market what they saw as "a Band-aid reaction to the 787," a sentiment that was echoed by GECAS president Henry Hubschman. Udvar-Hazy called on Airbus to bring a clean-sheet design to the table, or risk losing most of the market to Boeing.

Several days later, similar comments were made by Chew Choon Seng, CEO of Singapore Airlines. Chew stated, "having gone to the trouble of designing a new wing, tail, cockpit" and adding advanced new materials, Airbus "should have gone the whole hog and designed a new fuselage." At the time, Singapore was reviewing bids for the 787 and A350.

Airbus responded by stating it was considering improvements for the A350 to satisfy customer demands. At the same time, Airbus then-CEO Gustav Humbert suggested that there would be no quick fixes, stating, "Our strategy isn't driven by the needs of the next one or two campaigns, but rather by a long-term view of the market and our ability to deliver on our promises."

On 13 June 2006 at the Paris Airshow, Qatar Airways announced that it has placed an order for 60 A350 aircraft. In September 2006 Qatar Airways signed an agreement with General Electric to launch the GEnx-1A-72 for the aircraft. Emirates Airline decided against making an order for the initial version of the A350 because of weaknesses in the design, but has since ordered A350 XWBs.

## XWB

Interior mock-up of the Business Class Of the A350 XWB.

As a result of these criticisms, in mid-2006 Airbus undertook a major review of the A350 concept. The proposed new A350 with a wider fuselage cross-section has become more of a competitor to the larger Boeing 777 as well as some models of the Boeing 787. The A350 fuselage can accommodate 10 passengers per row in a high-density configuration.

The A330 and previous iterations of the A350 would only be able to accommodate 8 passengers per row in normal configurations. The 787 can accommodate 8 or 9 passengers per row, while the 777 can accommodate 9 passengers per row, with a few airlines using 10 abreast seating. From a seated passenger's point of view, the A350 cabin is 13 cm (5.1 in) wider at eye level than the competing 787, and 28 cm (11 in) narrower than the Boeing 777, its other competitor. All A350 passenger models will have a range of at least 8,000 nmi (15,000 km).

There was some speculation that the revised aircraft would be called the Airbus A370 or A280, with Airbus going as far as accidentally publishing an advert referring to the aircraft as the "A280" on the *Financial Times* website. However, on 17 July 2006, at the Farnborough Airshow, Airbus announced that the redesigned aircraft would be called *A350 XWB* (Xtra-Wide-Body).

Airbus achieved its first sale of the redesigned A350 four days after its unveiling when Singapore Airlines announced an order for 20 A350 XWBs with options of a further 20. Its CEO, Chew Choon Seng, said in a statement, that "it is heartening that Airbus has listened to customer airlines and has come up with a totally new design for the A350."

Late in 2006, a decision on formal launch was delayed as a result of delays of the Airbus A380 and wrangles about how the development would be funded. EADS CEO Thomas Enders stated that the A350 programme was not a certainty, citing EADS/Airbus' stretched resources.

On 1 December 2006 the Airbus board of directors approved the industrial launch of the A350-800, -900 and -1000. Programme costs are to be bourne mainly from of cash-flow. First delivery for the -900 was scheduled for mid-2013, with the -800 and -1000 following on, respectively, 12 and 24 months later. At a press conference 4 December 2006 a few new technical details of the A350 XWB design were revealed, but no new customers were identified. John Leahy indicated existing A350 contracts were under re-negotiation due to increases in prices compared to the original A350s contracted. On 4 January 2007, Airbus announced that Pegasus Aviation Finance Company had placed the first firm order for the A350 XWB with an order for two aircraft.

The change to the XWB design will impose a couple of years of delay into the original timetable and almost double development costs from $5.3 billion to approximately $10 billion. The total development cost for the A350 was estimated at US$15 billion by *Reuters*. Although the mid-2013 delivery date of the A350 remains unchanged, longer than anticipated development activities for the aircraft have forced Airbus to delay the final assembly and first flight of the aircraft to Q3 2011 and Q2 2012 respectively. As such, flight testing will be compressed from the original 15 months to a 12 month schedule. However, A350 programme chief Didier Evrard stressed that the delays only affect the A350-900 and that the A350-800 and A350-1000 schedules remain unchanged. On November 12, 2010, EADS CFO Peter Ring stated that the delivery date had slipped from mid-2013 to the second half of that year. According to Ring, the major reason for the schedule change is that the "transition phase from design to manufacturing is a bit longer."

# Design

In September 2007, Airbus rolled out new design advances to a gathering of 100 representatives from existing and potential XWB customers. The A350 XWB will be built on the technologies developed for Airbus A380 and will have a similar cockpit and fly-by-wire systems layout. The A350XWB will be made out of 53% composites, 19% Al/Al-Li, 14% titanium, 6% steel and 8% miscellaneous. This compares to the Boeing 787, which consists of 50% composites, 20% aluminium, 15% titanium, 10% steel and 5% the balance. October 2008 was the Airbus internal goal to freeze the design and Airbus expects 10% lower airframe maintenance cost and 14% lower empty seat weight than competing aircraft.

Airbus says that the new design provides a better cabin atmosphere with 20% humidity level during flight and typical cabin altitude at or below 6,000 ft (1,800 m), pressurisation at 6,000 ft (1,800 m) and flow management system that adapts cabin airflow to passenger load with draft-free air circulation. Airbus is aiming to certify the A350 with 350min ETOPS capability upon service entry.

## Fuselage

Standard nine-abreast configuration mock-up of the economy class of the A350.

The new XWB fuselage will have a constant width from door 1 to door 4, unlike previous Airbus aircraft to provide maximum usable volume. The double-lobe (ovoid) fuselage cross-section will have a maximum outer diameter of 5.97 m (19.6 ft), compared to 5.64 m (18.5 ft) for the A330/A340. The cabin's internal diameter will be 5.61 m (18.4 ft) wide at armrest level compared with 5.49 m (18.0 ft) of the 787 and 5.86 m (19.2 ft) of the 777).

In the eight-abreast 2–4–2 arrangement, which is a premium economy layout, the seats will be 49.5 cm (19.5 in) wide between 5 cm (2.0 in) wide arm rests. Airbus says that the seat width will be 1.3 cm (0.5 in) greater than the seat on the 787 in the equivalent configuration. In the nine-abreast, 3–3–3 standard layout, the XWB's seat width will be

45 cm (18 in) which will be 1.3 cm (0.5 in) wider than the proposed equivalent seat layout for the Boeing 787. A ten-abreast high-density is also available.

Although Airbus previously suggested Boeing's use of composite materials for the 787 fuselage was premature, and that the original A350s would be made from aluminium-lithium, the new A350 XWB will feature large carbon fibre panels for the main fuselage skin. After facing criticism for maintenance costs, Airbus confirmed in early September 2007 the adoption of composite fuselage frames for the aircraft structure. The composite frames will feature aluminium strips to ensure the electrical continuity of the fuselage (for dissipating lightning strikes). However, the fuselage crossbeams remain metallic, but Airbus is running trade-off studies to evaluate switching them to composite.

Airbus had signed a firm contract with BMW for development of an interior concept for the original A350.

On February 4, 2010, Airbus signed a contract for delivering in-flight entertainment and communication (IFEC) systems for the Airbus A350 XWB with Panasonic Avionics Corporation.

Airbus will use a full mock up fuselage to develop the wiring, a different approach from the A380, on which the wiring was all done on computers.

## Wings

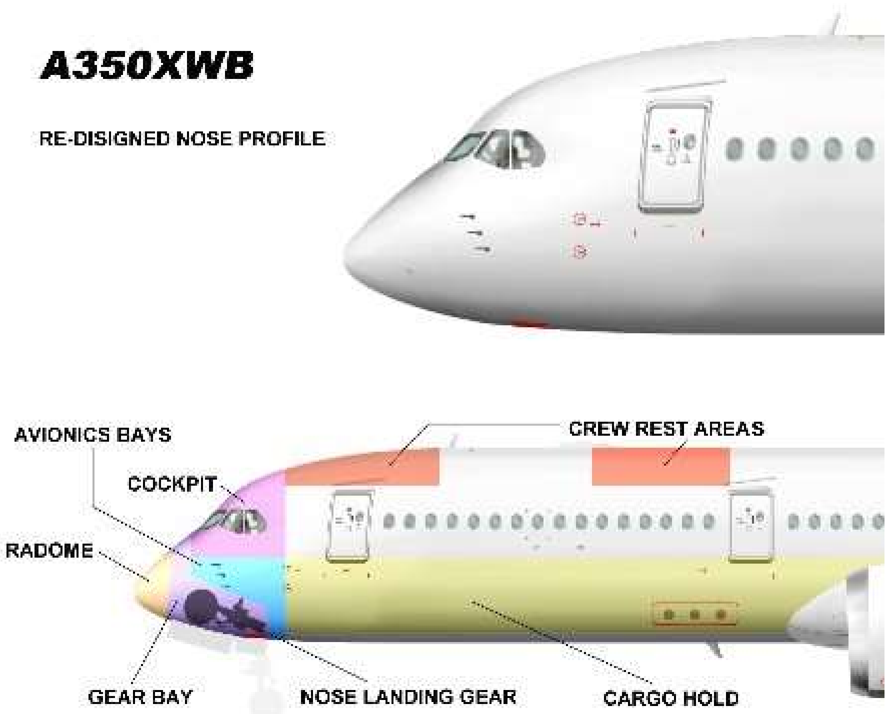
The A350 will feature new all-composite wings that will be common to all three proposed variants. With an area of 443 $m^2$ (4,770 sq ft) it will be the largest wing ever produced for a single-deck widebody aircraft. The geometric wingspan of 64.8 m (213 ft) is 4.5 m (15 ft) greater than that of the A330. This is the same span as the long-range Boeing 777-200LR/777-300ER, which has slightly less area. The new wing will have 31.9-degree sweep (1.9 degrees more than the A330) helping to increase typical cruise speed to Mach 0.85 and maximum operating speed to Mach 0.89.

A new trailing-edge high-lift system has been adopted with an advanced dropped-hinge flap (similar to that of the A380), which permits the gap between the trailing edge and the flap to be closed with the spoiler. The manufacturer has extensively used computational fluid dynamics and also carried out more than 4,000 hours of low- and high-speed windtunnel testing to refine the aerodynamic design, achieving the final configuration of wing and winglet on the "Maturity Gate 5" on 17 December 2008.

Airbus is planning a £570 million (US$760 million) investment to upgrade composite capability at its Broughton site in the United Kingdom, in preparation for its role as final assembly location for the A350 XWB wing. In June 2009, the Welsh Assembly announced provision of a £28million grant to provide a training centre, production jobs and money towards the new production centre.

## Nose

The XWB's nose section will adopt a configuration derived from the A380 with a forward-mounted nosegear bay and a six-panel flightdeck windscreen. This differs substantially from the four-window arrangement in the original design. The new nose will improve aerodynamics and enable overhead crew rest areas to be installed further forward and eliminate any encroachment in the passenger cabin. The new windscreen has been revised to improve vision by reducing the width of the centre post. The upper shell radius of the nose section has been increased. The nose bears a resemblance to the nose of the BAe 146.




A350XWB new nose and general interior arrangement.

The nose is likely to be constructed from aluminium but Airbus is currently running trade-off studies considering a one-piece carbon fibre structure. According to Gordon McConnell, A350 Chief Engineer, a carbon fibre structure would need titanium reinforcements for birdstrike protection, thus the aluminium structure is the best cost-wise.

## Cockpit

The revised design of the cockpit dropped the A380-sized display and adopted 38 cm (15 in) LCD screens. The new six-screen configuration will have two central displays mounted one above the other (the lower one above the thrust levers) and a single (for each pilot) primary flight/navigation display with an on-board information system screen adjacent to it. Airbus says the new cockpit will allow advances in navigation technology to be placed on the displays in the future plus flexibility and capacity to upload new software and to combine data from multiple sources and sensors for flight management and aircraft systems control. The A350 XWB will also feature a head-up display.

The avionics will be a further development of the integrated modular avionics (IMA) concept found on the A380. The A350's IMA will manage up to 40 functions (versus 23 functions for the A380) such as landing gear, fuel, brakes, pneumatics, oxygen system, cabin pressurisation system, and fire detection. Airbus says benefits such as reduced maintenance and less weight because IMA replaces multiple processors and LRUs with around 50% fewer standard computer modules known as line-replaceable modules. The IMA runs on a 100-Mbit/s network based on the avionics full-duplex (AFDX) standard, already employed in the A380 instead of the Arinc 429 system on the A330/A340.

In January 2008, French-based Thales Group won the US$2.9 billion 20-year contract to supply avionics and navigation equipment for the A350 XWB. Thales competed against Honeywell and Rockwell Collins for the flight deck supply contract. However, US-based Rockwell Collins and Moog Inc were chosen to supply the horizontal stabiliser actuator and primary flight control actuation, respectively.

The flight management system will include several new safety features.

## Engines

Airbus has confirmed that it will further develop a full bleed air system on the engines, rather than the bleedless configuration used on the Boeing 787. Rolls-Royce has agreed with Airbus to supply a new variant of the Trent engine for the A350 XWB, currently called the *Trent XWB*. After the low-speed windtunnel test, Airbus has frozen the static thrust at sea level for all three proposed variants in the 330–410 kN (74,000–92,000 lbf) range. Airbus will begin a flight-test programme of the Rolls-Royce Trent XWB using the superjumbo A380 development aircraft in early 2011, ahead of engine certification at the end of 2011. The first engine test on the Trent was made in June 2010 .

GE has stated it will not offer the GP7000 engine on the aircraft, and that previous contracts for the GEnx on the original A350 did not apply to the XWB. Fellow Engine Alliance partner Pratt & Whitney seems to be at odds with GE on this, publicly stating that it is looking at an advanced derivative of the GP7000. In April 2007, Airbus former chief executive Louis Gallois held face-to-face talks with senior General Electric management over developing a new variant of the GEnx engine for the A350 XWB.

In June 2007, Rolls-Royce announced that it had signed its biggest ever contract with Qatar Airways for the Trent XWB to power 80 A350 XWBs on order from Airbus worth $5.6 billion at list prices, and in June 2007, Airbus' Chief Operating Officer John Leahy indicated that the A350 XWB will not feature the GEnx engine, saying that Airbus wants GE to offer a more efficient version for the new Airbus airliner. Since then, largest GE engines operators Emirates Airline, US-based US Airways, Hawaiian Airlines and ILFC have selected the RR Trent XWB for their future fleet of A350.

The Trent XWB family comprises two basic engines to power the three A350 variants. The baseline 370 kN (83,000 $lb_f$) thrust version for the A350-900 will be derated to 330 kN (74,000 $lb_f$) and 350 kN (79,000 $lb_f$) for the -800, while an upgraded 410 kN (92,000 $lb_f$) thrust version will power the A350-1000. The higher rating 410 kN (92,000 $lb_f$) engine will have some modifications to the fan module - it will be the same 118in diameter but will run slightly faster and have a new fan blade design - and some increases in temperatures brought by new materials technologies coming from its research programmes. The basic 248t MTOW -800 will be offered with a 330 kN (74,000 $lb_f$) sea level thrust rating, while the 279t MTOW option will have 350 kN (79,000 $lb_f$) thrust. Airbus also plan to offer a 'hot and high' rating option flat-rated at 350 kN (79,000 $lb_f$) at higher altitudes and temperatures which uses the full capability of the -900's 370 kN (83,000 $lb_f$) thrust engine prompted by the operating requirements for Middle Eastern launching customers Qatar Airways, Emirates, and Etihad.

The Trent XWB will feature a 3-meter fan diameter and the design will be based on the advanced developments of the Trent 900 (Airbus A380) and Trent 1000 (Boeing 787). The Trent XWB may also benefit from the next-generation reduced acoustic mode scattering engine duct system (RAMSES), which is a noise-dampening engine nacelle intake and a carry-on design of the Airbus's "zero splice" intake liner developed for the A380. Engine thrust-reversers and nacelles will be supplied by US-based Goodrich Corporation.

In May 2009, GE said that if it reaches a deal with Airbus to offer the current 787-optimised GEnx for the A350, it will only power the -800 and -900 variants. GE believes it can offer a product that outperforms the Trent 1000 and Trent XWB, but has been reluctant to support an airframe that competes directly with the GE90-115B-powered 777 variants.

## Auxiliary power unit and air management system

The A350 XWB will feature a 1,300 kW (1,700 hp) HGT1700 auxiliary power unit by Honeywell, which has 10% greater power density than the previous generation of Honeywell's 331 APU family. Honeywell will also supply the air management system: the bleed air, environmental control, cabin pressure control and supplemental cooling systems. The ram-air turbine will be supplied by Hamilton Sundstrand and will be located in the lower surface of the fuselage. The generator requirement for the ram air turbine is 100 kVA compared to 150 kVA for the A380.

## Fuel and hydraulic systems

US-based Parker Hannifin has been selected to supply the complete fuel package: inerting system, fuel measurement and management systems, mechanical equipment and fuel pumps. The fuel tank inerting system will feature air-separation modules to generate nitrogen-enriched air that will be used to reduce the flammability of fuel vapour in the tanks.

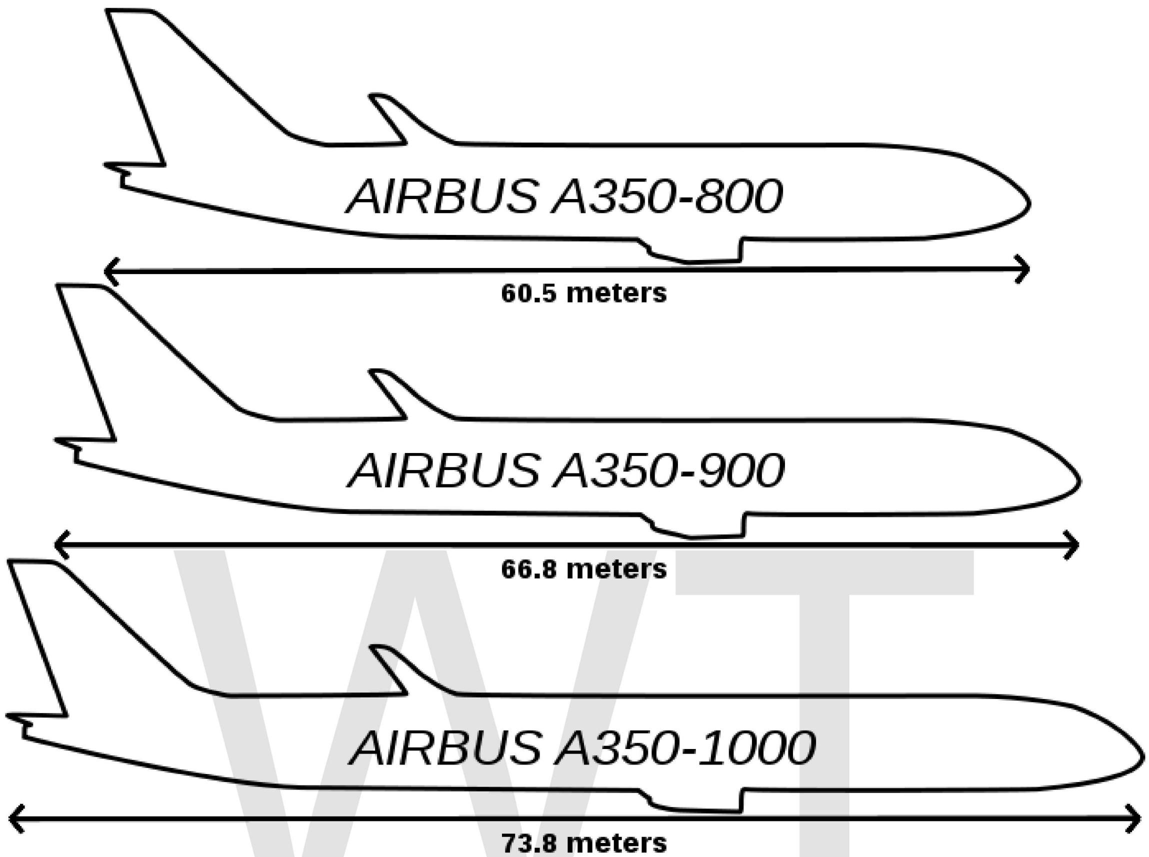
Parker will also provide hydraulic power generation and distribution system: reservoirs, manifolds, accumulators, thermal control, isolation, software and new engine- and electric motor-driven pump designs. Parker estimates the contracts will generate more than US$2 billion in revenues over the life of the programme.

## Landing gear

Airbus adopted a new philosophy for the attachment of the A350's main landing gear as part of the switch to a composite wing structure. Each main landing gear leg is attached to the rear wing spar forward and to a gear beam aft, which itself is attached to the wing and the fuselage. To help reduce the loads further into the wing, a double side-stay configuration has been adopted. This solution resembles the design of the Vickers VC10.

Airbus devised a three-pronged main landing gear design philosophy encompassing both four- and six-wheel bogies to ensure it can keep the pavement loading within limits. The A350-800 and A350-900 will both have four-wheel bogies, although the -800's will be slightly shorter to save weight. Both will fit in the same 4.1 m (13 ft) long bay. The proposed higher weight variant, the A350-1000 (and the A350-900R, which is being proposed to British Airways, with -900 size but with sufficient fuel capacity to allow nonstop London-Sydney flights) will use a six-wheel bogey, with a 4.7 m (15 ft) landing gear bay. French-based Messier-Dowty will provide the main landing gear. The nose gear will be supplied by Liebherr-Aerospace.

## Variants




A350 variants

There are three variants of the A350 and all were launched in 2006. The A350-900 is scheduled to enter service in 2013. The A350-800 is scheduled to enter service in 2014. The A350-1000 is scheduled to enter service at the end of 2015. All variants will also be offered as corporate jets by wholly-owned subsidiary Airbus Executive and Private Aviation. Construction of the first A350-900 centre wingbox is set to start in August 2010. As development continues, Airbus plans to decrease structural weight in the -800, which should be around airframe 20.

### A350-800

The A350-800 will seat 270 passengers in a 3-class cabin 9-abreast layout and will have a range of 15,400 km (8,300 nmi). It is designed to compete with the Boeing 787-9 and to directly replace the Airbus A330-200. In January 2010, Airbus announced that the -800 would be developed as a simple shrink of the -900, incorporating minor changes to the systems and structure and share more hardware with the -900 rather than as an optimised variant as was previously planned. This increased commonality will allow a higher maximum takeoff weight, which will increase the range (or payload) of the A350-800 compared to initial plans. The change will increase fuel burn by "a few per cent", according to the programme's marketing head, Sophie Pendaries. The -800's fuselage is 10 frames shorter (six forward and four aft) compared to the -900 aircraft.

The baseline -800 will be offered with an MTOW of 248 tonne, MLW of 190t, MZFW of 178t, and 330 kN (74,000 $lb_f$) thrust engines. An optional 11 tonne increase in MTOW, to 259t with a corresponding increase of MZFW to 181t, MLW to 193t, and a higher thrust 370 kN (83,000 $lb_f$) engine (common with -900 engine thrust) was announced by Airbus in April 2010 to be made available for customers as an option. While the increased weights compensate for the increased empty weight of the aircraft and associated minor fuel burn penalty due to maintaining commonality with -900, it also resulted in an increase in the aircraft maximum structural payload capability by 3 tonne or 459 km (248 nmi) of additional range.

### A350-900

The A350-900 is the first model scheduled to enter service (EIS) in 2013 and seats 314 passengers in a 3-class cabin 9-abreast layout. It has a standard design range target of 15,000 km (8,100 nmi). Airbus says that the A350-900 will have a decrease of 16% MWE per seat, a 30% decrease in block fuel per seat and 25% better cash operating cost against the Boeing 777-200ER. The -900R and -900F variants also have been proposed but not yet launched. These are to feature the higher engine thrust, strengthened structure and landing gear of the -1000. Range of the "standard" A350-900R was estimated to 17,600 km (9,500 nmi), which would be boosted to about 19,100 km (10,315 nmi) by these design improvements to compete with the Boeing 777-200LR and be capable of Non-stop flight from London-Heathrow to Auckland. The -900 is designed to compete with the Boeing 777-200ER and replace the Airbus A340-300.

### A350-1000

The A350-1000, which has an 11-frame stretch over the -900, is scheduled to enter service at the end of 2015. It is the largest variant of the A350 family and will seat 350 passengers in a 3-class cabin 9-abreast layout. It will have range of 14,800 km (8,000 nmi). It is designed to compete with the Boeing 777-300ER and replace the A340-600.

The A350-1000 will feature a slightly larger wing than the -800/900 models; a trailing-edge extension increasing its area by 4%. This will extend the high-lift devices and the ailerons, making the chord bigger by around 400mm, optimising flap lift performance as well as cruise performance.

## Orders and deliveries

As of December 2010, 35 customers have placed 583 firm orders for the A350XWB.

| A350-800 | A350-900 | A350-1000 | TBD | Total firm orders |
|---|---|---|---|---|
| 158 | 350 | 75 | 0 | 583 |

Source: Airbus orders data Summary to 31st Dec. 2010.

**Orders and deliveries by year**

| | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | Total |
|---|---|---|---|---|---|---|---|
| **Net orders** | 20 | 330 | 133 | 22 | 78 | 0 | **583** |
| **Deliveries** | | | | | | | |

## Specifications

| Model | A350-800 | A350-900 | A350-900R | A350-900F | A350-1000 |
|---|---|---|---|---|---|
| Scheduled service entry | late-2014 | late-2013 | 2016 | 2017 | Late-2015 |
| Cockpit crew | Two | | | | |
| Seating, typical | 3-class: 270<br>2-class: 276-312<br>1-class typical: 375<br>1-class maximum: 440 | 3-class: 314<br>2-class: 315-366<br>1-class typical: 420<br>1-class maximum: 475 | 3-class: 310 | - | 3-class: 350<br>2-class: 369-412<br>1-class typical: 475<br>1-class maximum: 550 |
| Overall length | 60.54 m (198.6 ft) | 66.89 m (219.5 ft) | | | 73.88 m (242.4 ft) |
| Wingspan | 64.8 m (213 ft) | | | | |
| Wing area | 443 $m^2$ (4,770 sq ft) | | | | |
| Wing sweepback | 31.9° | | | | |
| Overall height | 17.05 m (55.9 ft) | | | | |
| Fuselage width | 5.96 m (19.6 ft) | | | | |
| Fuselage height | 6.09 m (20.0 ft) | | | | |
| Cabin width | 5.61 m (18.4 ft) | | | | |
| Maximum takeoff weight | 259 t (571,000 lb) | 268 t (591,000 lb) | 298 t (657,000 lb) | | |
| Maximum landing weight | 193 t (425,000 lb) | 205 t (452,000 lb) | | | 233.5 t (515,000 lb) |
| Maximum zero fuel weight | 181 t (399,000 lb) | 192 t (423,000 lb) | | | 218.5 t (482,000 lb) |
| Manufacturer's empty weight | | 118.2 t (260,586.4 lb) | | | |
| Maximum cargo | 28 LD3 or 9 | 36 LD3 or 11 | | 90 t | 44 LD3 or 14 |

| | | | | | |
|---|---|---|---|---|---|
| capacity | pallets | pallets | | (198,000 lb) | pallets |
| Cruise speed | Mach 0.85 (903 km/h, 561 mph, 487 knots, at 40,000 ft/12.19 km) | | | | |
| Maximum cruise speed | Mach 0.89 (945 km/h, 587 mph, 510 knots, at 40,000 ft/12.19 km) | | | | |
| Maximum range (with passengers and baggage) | 15,730 km (8,490 nmi) | 15,000 km (8,100 nmi) | 19,100 km (10,300 nmi) | 9,250 km (4,990 nmi) Maximum cargo payload | 14,800 km (7,990 nmi) |
| Maximum fuel capacity | 129,000 l (34,100 US gal) | 138,000 l (36,500 US gal) | | | 156,000 l (41,200 US gal) |
| Service ceiling | 43,100 ft (13.1 km) | | | | 43,100 ft (13.1 km) |
| Engines (2×) | RR Trent XWB | | | | |
| Maximum thrust capability | 79,000 lbf (351 kN) | 84,000 lbf (374 kN) | 93,000 lbf (414 kN) | 93,000 lbf (414 kN) | 93,000 lbf (414 kN) |

Sources: Airbus A350-800 specifications, Airbus A350-900 specifications, Airbus A350-1000 specifications.

## Chapter- 2

# E6 Series Shinkansen

| E6 series | |
|---|---|

Set S12 on a test run, July 2010

| | |
|---|---|
| **In service** | March 2013– |
| **Manufacturer** | Hitachi, Kawasaki Heavy Industries |
| **Replaced** | E3 series |
| **Constructed** | 2010– |
| **Number built** | 7 vehicles (1 set) |
| **Number in service** | 0 |
| **Formation** | 7 cars per trainset |
| **Fleet numbers** | S12 |
| **Capacity** | 338 (315 Standard + 23 Green) |
| **Operator** | JR East |

| | |
|---|---|
| **Line(s) served** | Tōhoku Shinkansen, Akita Shinkansen |
| | **Specifications** |
| **Car body construction** | Aluminium alloy |
| **Car length** | 23,075 mm (end cars), 20,500 mm (intermediate cars) |
| **Width** | 2,945 mm |
| **Doors** | One per side |
| **Maximum speed** | 320 km/h (Tōhoku Shinkansen)<br>130 km/h (Akita Shinkansen) |
| **Acceleration** | 1.71 km/h/s (shinkansen), 2.0 km/h/s (conventional) |
| **Electric system(s)** | 25 kV AC, 50 Hz (Tōhoku Shinkansen)<br>20 kV AC, 50 Hz (Akita Shinkansen) |
| **Current collection method** | Overhead catenary |
| **Bogies** | DT210 (motored), TR7009 (trailer) |
| **Safety system(s)** | DS-ATC, RS-ATC, ATS-P |
| **Gauge** | 1,435 mm (4 ft 8 1/2 in) |

The **E6 series** (E6系?) is a Japanese Shinkansen high-speed train type on order by East Japan Railway Company (JR East) for use on *Komachi* 'mini-shinkansen' services on the Tōhoku Shinkansen and Akita Shinkansen from Tokyo to Akita commencing in March 2013. The new 7-car trains will operate in conjunction with newly introduced E5 series trains, initially on just two or three return services daily. They will replace all the existing E3 series trains on *Komachi* services by March 2014.

Technology incorporated in these trains is derived from the experimental Fastech 360Z train previously tested by JR East. The E6 series trains are formed of seven cars, to provide the same seating capacity as six-car E3 series trains, due to the reduced seating capacity in the end cars. All cars feature active suspension with tilting up to 1.5 degrees.

## Formation

| Car No. | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
|---|---|---|---|---|---|---|---|
| Designation | M1sc | Tk | M1 | M1 | M1 | T | M1c |
| Numbering | E611 | E628 | E625 | E625-100 | E627 | E629 | E621 |
| Weight (t) | 45.7 | 44.4 | 42.5 | 43.1 | 42.5 | 44.5 | 43.8 |
| Seating capacity | 23 | 35 | 60 | 60 | 68 | 60 | 32 |

## Exterior

The overall styling was overseen by Japanese industrial designer Ken Okuyama, and is intended to evoke images of the *Namahage* demons and *kantō* festival lanterns for which Akita Prefecture is famous. The main body colour is "Hiun" (飛雲?) white with crimson roof and "arrow silver" bodyside stripe. The end cars are 22,825 mm long with the tapered nose accounting for approximately 13 m (compared with approximately 6 m for the E3 series).

## Interior

The new trains feature similar improvements to passenger accommodation as featured on the E5 series trains, including AC power outlets, and security cameras in vestibule areas. Seating in both Standard class and Green (first class) cars is in the standard 2+2 arrangement for mini-shinkansen trains. Seat pitch is 1,160 mm in Green class and 980 mm in Standard class, the same as for the E3 series trains.

## History

The pre-production set, S12, was delivered to Sendai Depot in June 2010. Test running commenced on the Tōhoku Shinkansen in July 2010.

Revenue service will commence in March 2013, running at a maximum speed of 300 km/h on the Tōhoku Shinkansen. From March 2014, the maximum speed will be raised to 320 km/h on the Tōhoku Shinkansen, with the maximum speed on the Akita Shinkansen tracks remaining at 130 km/h, allowing journey times between Tokyo and Akita to be reduced by between 10 and 15 minutes.

**Chapter- 3**

# BA 330

A photograph of a full-size mock up of the expanded BA 330 module on the ground at Bigelow Aerospace's North Las Vegas plant, to give an impression of its size.

The **BA 330** (previously known as the **Nautilus space complex module**) is the complete, full-scale production model of Bigelow Aerospace's expandable space habitation module program. Ultimately, it is more of a model of space habitation module and not one specific craft as Robert Bigelow, owner and founder of Bigelow Aerospace, intends on building several of the modules for sale at a tentative asking price of US$100 million each. It will have 330 cubic metres (12,000 cu ft) of internal space, hence its numeric designation.

Slated for first launch in 2014 or 2015, the craft will support zero-gravity research including scientific missions and manufacturing processes. Beyond its industrial and scientific purposes, however, it has the potential as a port of call for space tourism.

Other uses for the craft include missions destined for the Moon and Mars and even space yachts.

## Beneficial features

Model of BA-330

A number of features make this form of expandable space station technology particularly well-suited for its purpose.

1. It offers a large habitable space for crews to live and conduct experiments in. The exterior of the predecessor TransHab craft was intended to be 45 feet (14 m) long by 22 feet (6.7 m) in diameter.
2. It can be relatively light for its size, at only 50,000 pounds (23,000 kg) for the predecessor TransHab design, making it easier to place modules in orbit, without having to resort to heavy-lift launch vehicles.
3. Its skin, made of high-strength textiles and Vectran-like materials, is wrapped with several layers of high-tension straps. It is particularly resistant to damage from micrometeoroids and space debris.

The BA 330 provides radiation protection equivalent to, and ballistic protection superior to, the International Space Station.

The module's large size is particularly beneficial for lunar astronauts or the crews of other long-duration space missions, which until now have been restricted to fairly cramped quarters for the several-day flight.

When expanded the outer shell is as hard to the touch as concrete.

The BA 330 design architecture is built on module-independent provision of needed services:

- Electrical power is provided by solar arrays and batteries.
- Module-specific avionics are provided for navigation, re-boost, docking and other on-orbit maneuvering.
- Environmental control and life support system to support up to six persons, including lavatory and hygiene facilities.
- Four large windows coated with a UV protection film will support both terrestrial and celestial viewing.

## Technology

While the details about how Bigelow has evolved the purchased Transhab technology have not been published, NASA states the following about the structure of the module that Bigelow adopted as a starting point:

With almost two dozen layers, TransHab's foot-thick inflatable shell is a marvel of innovative design. The layers are fashioned to break up particles of space debris and tiny meteorites that may hit the shell with a speed seven times as fast as a bullet. The outer layers protect multiple inner bladders, made of a material that holds in the module's air. The shell also provides insulation from temperatures in space that can range from +121°C (+250°F) in sunlight to -128°C (-200°F) in the shade.

The key to the debris protection is successive layers of Nextel, a material commonly used as insulation under the hoods of many cars, spaced between several-inches-thick layers of open cell foam, similar to foam used for chair cushions on Earth. The Nextel and foam layers cause a particle to shatter as it hits, losing more and more of its energy as it penetrates deeper.

Many layers into the shell is a layer of super-strong woven Kevlar that holds the module's shape. The air is held inside by three bladders of Combitherm, material commonly used in the food-packing industry. The innermost layer, forming the inside wall of the module, is Nomex cloth, a fireproof material that also protects the bladder from scuffs and scratches.

—NASA TransHab Concept,

Bigelow has described their technology to news media and have indicated that their proprietary technology inflatable shell, now in validation test in low-earth orbit in two subscale spacecraft, incorporates a layer of Vectran, along with the Kevlar etc. of the NASA technology.

Bigelow has selected Orbitec as the supplier for environmental control and life support systems (ELCSS).

## Further enhancements

Bigelow Aerospace is developing the BA 330 module to mate with other spacecraft. In early illustrations, this was shown as being with the Russian Soyuz spacecraft, but it could theoretically be with any number of other vehicles.

Once assembled, the combined vehicle would offer the benefits of enhanced operating space for the crew, along with the traditional necessities of the 'hard' spacecraft docked to it, such as atmospheric re-entry.

As of 2005, Bigelow Aerospace had plans to develop the *CSS Skywalker*, a space station based upon using BA 330 modules to act as an orbital hotel. Later plans continued to call for construction of a space station, but without the *CSS Skywalker* moniker, with "more usable volume than the existing International Space Station". Current plans include a complex of two smaller Sundancer modules, a combined node and propulsion module and one full-size BA-330. This would give a total volume that is slightly less than that of the ISS, though built from fewer and larger individual modules.

## History

The BA 330 is the brainchild of Robert Bigelow of Budget Suites of America. Its design is based on the cancelled NASA TransHab program. Bigelow gained access to Transhab engineers and workmen, a few of whom now largely advise Bigelow's project.

In July 2010, Bigelow announced that a BA-330 would be the sixth spacecraft component making up the Bigelow Commercial Space Station.

**Chapter- 4**

# Future Chinese Aircraft Carrier

| Class overview | |
|---|---|
| Builders: | Changxingdao Shipyard, Shanghai |
| Operators: | People's Liberation Army Navy |
| In service: | 2015 (projected) |
| Planned: | 2 |
| **General characteristics** | |
| Type: | aircraft carrier |
| Displacement: | est. 50,000–60,000 tons |
| Propulsion: | Conventional |
| Aircraft carried: | Shenyang J-15/Chinese Naval Flanker? |

Since the 1970s, the People's Liberation Army Navy (PLAN) has expressed interest in operating an aircraft carrier as part of its blue water aspirations, and press reports have frequently quoted senior Chinese military officials as expressing an intention to build aircraft carriers.

Since 1985, China has acquired four retired aircraft carriers for study: the Australian HMAS *Melbourne* and the ex-Soviet carriers *Minsk*, *Kiev* and *Varyag*. Reports state that two 50,000-60,000 ton Type 089 aircraft carriers based on the *Varyag* , are due to be finished by 2015. Possibly two 93,000 ton Type 085 nuclear powered are also being built , which may enter service in 2020. Sukhoi Su-33s (navalized Flankers) are the aircraft most likely to be flown from these carriers , but China is also developing its own version of the Sukhoi 33, the J-15 *Flying Shark*.

# Acquisition of retired aircraft carriers

Chinese shipyards have gained some exposure to carrier design with the acquisition of retired hulls such as the Australian HMAS *Melbourne* acquired in 1985. Through various ventures, China has also purchased the ex-Soviet carriers *Minsk* and *Kiev*. These carriers have become floating amusement parks for tourists.

There had been plans to purchase foreign second-hand carriers in the past. After the collapse of the Soviet Union, China had reportedly sought to purchase a *Kiev*-class aviation cruiser, but these deals did not come through. Another possible deal between China and France for the sale of the *Clemenceau* fell through in 1997.

### *Varyag*

*Varyag*

The 67,500 ton ex-Soviet aircraft carrier *Varyag* (*Admiral Kuznetsov* class), which was only 70% completed and floating in Ukraine, was purchased through a private Macau tourist venture in 1998. Since her troublesome tow to Dalian shipyard, the carrier has undergone a long refit. *Varyag* was stripped of any military equipment as well as her propulsion before she was put up for sale. News reports state that she is being refitted to be returned to operational status and is renamed *Shi Lang* . Most likely this (proto)Type 089 carrier will be used for training and acquiring knowledge about carrier operations. According to Vice Admiral David J. Dorsett of the U.S. Navy, sea trials of the *Shi Lang* may start in late 2011.

# Acquisition of designs

In addition to the acquisition of retired aircraft carriers of foreign navies, the PLAN has been actively purchasing foreign aircraft carriers designs as well. One such example was its effort to purchase the blueprints for proposed conventional take off/landing ships from *Empresa Nacional Bazan* of Spain; the 23,000 ton SAC-200 and the 25,000 ton SAC-220 designs. Negotiations started between 1995 - 1996 but it did not result in any purchase.

However, the Spanish firm was paid several million US dollars in consulting fees, indicating the probable transfer of some design concepts.

After the Spanish firm had submitted its findings, Russian aircraft designer Nevskoye Design Bureau completed an aircraft design for China in the late 1990s to meet the Chinese requirement but neither Russia nor China disclosed the price. Neither did the two countries reveal any information on whether China was satisfied with the design or not, but in any case, no aircraft carriers based on the design were built. Limited Chinese industrial capabilities in the late-1990s made it impractical for China to start any construction of aircraft carriers.

A complete set of blueprints of a foreign aircraft carrier design was obtained by China when it purchased the decommissioned Soviet aircraft carrier *Kiev*. Russia insisted on China buying the blueprints as well for higher price, but neither country has revealed the exact dollar value. However, based on the official information released by the Chinese government on aircraft carriers, all of which dictates conventional design, the V/STOL design does not appear to fit the Chinese requirement.

The complete set of blueprints of a foreign aircraft carrier design obtained by China when it purchased the incomplete Soviet aircraft carrier *Varyag* is the most recent purchase. Ukraine urged China to increase the original $18 million bid to include additional purchase of the complete set of blueprints of the design, and after negotiations, China agreed to pay another $2 million to purchase the complete set of blueprints. According to the memoir of Chinese embassy staff members who participated in the process, the blueprints reached China before the ship. This conventional design offers more capability than smaller, V/STOL designs.

In February 2011, Ukraine sentenced a Russian national to six years in prison for stealing secrets to assist China in its carrier program. According to the Ukraine, Aleksandr Yermakov was being paid by Chinese authorities to steal military secrets related to carrier operations from the Land-based Naval Aviation Testing and Training Complex, located in the Crimea near the city of Saki.

## Early plans

The first official plan of PLAN aircraft carrier dated back on March 31, 1987 when the Commission of Science, Technology and Industry for National Defense approved the plan on the aircraft carrier and the next generation nuclear submarine for PLAN submitted by the then commander-in-chief of PLAN, Liu Huaqing. The original plan was to be progressed in stages, with basic research to be completed by the end of the 7th 5-year plan, and development of the platform and aircraft to be completed by the end of the 8th 5-year plan. By the year 2000, construction was to begin when ordered.

To prepare the commanders needed for the future aircraft carriers, the Central Military Commission approved the program of training jet fighter pilots to be future captains in

May, 1987, and the Guangzhou Warship Academy (广州舰艇学院) was selected as the site.

However, Liu Huaqing's plan proved to be too ambitious as the domestic Chinese industry at the time simply could not meet the goal demanded by the plan. As a result, the plan was drastically scaled back to basic research level and the date for an aircraft carrier entering PLAN service was postponed and eventually put on hold. In the meantime, pilot candidates for warship captain training was also altered, with candidates switched to ship-borne helicopter pilots, because it was considered that naval helicopter pilots with much more ship-borne aviation experience would be better prepared than the land-based jet fighter pilots who lack ship-borne aviation experience.

## Current status

In 2006 or 2007 China's Central Military Commision approved both Project 085 (Type 085) and Project 089 (Type 089 *Shi Lang*-class) . In mid-2007, Chinese domestic sources revealed that China had purchased a total of four sets of aircraft carrier landing systems from Russia and this was confirmed by Russian manufacturers. However, experts disagreed on the usage of these systems: while some have claimed that it is a clear evidence of the construction of an aircraft carrier, others claim these systems are used to train pilots for a future ship. It is likely that 3 landing systems will go to the 3 Type 089 *Shi Lang* carriers ( *Varyag* and the two new carriers) and the 4th system will be used for ground training, possibly at *Yanliang*, near *Xi'an* . *Yanliang* already has a ski-jump built to simulate carrier take-offs. In August, 2008, Mr. Huang Qiang (黄强), the speaker of the Commission of Science, Technology and Industry for National Defense announced to the public at news conference that China had mastered all of the technologies for an aircraft carrier, and would build aircraft carriers in the future when time was deemed right. The strongest proof of a Chinese aircraft carrier also appeared in 2008, from an official Chinese governmental source when the training program of jet fighter pilots for warship captains were resumed: PLA Daily (解放军报 ) published the news of Dalian Warship Academy (大连舰艇学院) accepting a total of 50 jet fighter pilots for warship captain training in 2008, and in comparison to the first class that was held more than one and half a decades ago at Guangzhou Warship Academy (广州舰艇学院), the training has been lengthened to four years. Resumption of this plan is viewed by foreign observers and military analysts as another step in preparation for an aircraft carrier entering service.

In late 2008, and through early 2009, there have been foreign reports that China will start building two 50,000-60,000 ton aircraft carriers due to be finished by 2015. Whether the two ships will be similar to the *Varyag* (ski jump) or American carriers (catapult) is not yet known. Since sea trials of the *Shi Lang* (*Varyag*) will probably start in 2011, it seems likely that they are similar.

There are also some reports of a possibility of China building two nuclear powered Type 089 aircraft carriers, though how reliable these are can be questioned. According to the Nippon News Network (NNN), research and development on the planned carriers is being carried out at a military research facility in Wuhan. NNN states that the actual carriers will be constructed at a shipyard in Shanghai. *Kanwa Intelligence Review* reports that the second carrier to be constructed will likely be assigned to Qingdao.

It was also reported in 2009 that the Brazilian Navy will train PLA naval officers in carrier operations in exchange for assistance on nuclear submarine technology and additional funding.

According to a February 2011 report in the *The Daily Telegraph*, the Chinese military has constructed a concrete aircraft carrier flight deck to use for training carrier pilots and carrier operations personnel. The deck was constructued on top of a government building near Wuhan.

Chapter- 5

# USS Gerald R. Ford (CVN-78)

CVN-78 artist's depiction.

| **Career (United States)** |  |
|---|---|
| Name: | USS *Gerald R. Ford* |
| Namesake: | Gerald R. Ford |
| Awarded: | 10 September 2008 |
| Builder: | Northrop Grumman Newport News |
| Cost: | $5.1 billion |
| Laid down: | 13 November 2009 |
| Sponsored by: | Susan Ford |
| Commissioned: | est. 2015 |
| Status: | Under construction |
| **General characteristics** | |
| Class and type: | *Gerald R. Ford*-class aircraft carrier |
| Displacement: | appx. 100,000 tons |

| | |
|---|---|
| Length: | 1,092 ft (333 m) |
| Beam: | 134 ft (41 m) |
| Propulsion: | 2 × A1B reactor |
| Speed: | 30+ knots |
| Range: | Essentially unlimited distance; 20 years |
| Complement: | 4,660 |
| Armament: | Evolved Sea Sparrow Missile<br>Rolling Airframe Missile<br>Close-in weapons system (CIWS) |
| Aircraft carried: | More than 75 |

**USS *Gerald R. Ford* (CVN-78)** is to be the lead ship of her class of United States Navy supercarriers. As announced by the U.S. Navy on 16 January 2007, the ship will be named after the 38th President of the United States, the late Gerald R. Ford, whose World War II naval service included combat duty aboard the light aircraft carrier *Monterey* in the Pacific Theater.

*Gerald R. Ford* was laid down on 13 November 2009. Construction work began on 11 August 2005, when Northrop Grumman held a ceremonial steel cut for a 15-ton plate that will form part of a side shell unit of the carrier. The schedule calls for the ship to join the U.S. Navy's fleet in 2015. *Gerald R. Ford* is slated to replace the current USS *Enterprise*, ending her then 50-plus years of active service with the United States Navy.

## Ship naming

Ford in Navy uniform, 1945

In 2006, while Gerald Ford was still alive, Senator John Warner of Virginia proposed to amend a 2007 defense spending bill to declare that CVN-78 "shall be named the U.S.S. *Gerald Ford*." The final version signed by President George W. Bush on 17 October 2006 declared only that it "is the sense of Congress that ... CVN-78 should be named the U.S.S. *Gerald R. Ford*." Since such "sense of" language is typically non-binding and does not carry the force of law, the Navy was not required to name the ship after Ford.

On 3 January 2007, former Secretary of Defense Donald Rumsfeld announced that the aircraft carrier would be named after Ford during a eulogy for the president at Grace

Episcopal Church in East Grand Rapids, Michigan. Rumsfeld indicated that he had personally told Ford of the honor during a visit to Ford's home in Rancho Mirage a few weeks before Ford's death. This makes the aircraft carrier one of the few U.S. ships named after someone still alive. Later in the day, the Navy confirmed that the aircraft carrier would indeed be named for the former President. On 16 January 2007, Navy Secretary Donald Winter officially named CVN-78 the USS *Gerald R. Ford*. Ford's daughter, Susan Ford Bales, was named the ship's sponsor. The announcements were made at a Pentagon ceremony attended by Vice President Dick Cheney, Senators Warner and Levin, Major General Guy C. Swan III, Bales, Ford's other three children, and others.

USS *America* Carrier Veterans Association (CVA) had pushed to name the ship USS *America*. The CVA is an association of sailors who served aboard USS *America* (CV-66), which was decommissioned in 1996 and scuttled in the Atlantic as part of a classified weapons damage/battle damage test of large deck aircraft carriers in 2005. (*America* will instead be the name of the lead ship of a new class of amphibious assault ships).

# Design and development



The *Nimitz*-class aircraft carrier has been an integral part of United States power projection strategy since *Nimitz* was first commissioned. Displacing approximately 100,000 tons when fully loaded, a *Nimitz*-class carrier is capable of steaming faster than thirty knots, self-sustaining for up to ninety days, and launching aircraft to strike targets hundreds of miles away. The endurance of this class is exemplified by USS *Theodore Roosevelt*, which spent 159 days underway in support of Operation Enduring Freedom without the need to visit a port or be refueled. Over the lifespan of the class many new technologies have been successfully integrated into the design of this vessel. However, with the technical advances made in the past decade the ability of the US Navy to make improvements to this class of ship has become more limited. “The biggest problems facing the *Nimitz*-class are the limited electrical power generation capability and the upgrade-driven increase in ship weight and erosion of the center of gravity margin needed to maintain ship stability.”

With these constraints in mind the Navy developed what was initially known as the "CVN-21" program, which ultimately evolved into CVN-78, *Gerald R. Ford*. Improvements were made through developing technologies and more efficient design. Major design changes include a larger flight deck, improvements in weapons and material handling, a new propulsion plant design that requires fewer personnel to operate and maintain, and a new smaller island that has been pushed aft. Technological advances in the field of electromagnetics have led to the development of an Electromagnetic Aircraft Launching System, (EMALS), and an Advanced Arresting Gear, (AAG). An integrated warfare system has been developed to support flexibility in adapting the infrastructure of the ship to future mission roles. The new Dual Band Radar (DBR) combines S-band and X-band radar in a single system. With new design and technology the Ford will have a 25% increase in sortie generation, threefold increase in electrical generating capacity, increased operational availability, and a number of quality of life improvements. Requirements for a higher sortie rate of around 160 exits a day with surges to a maximum of 220 sorties a day in times of crisis and intense air warfare activity, has led to design changes in the flight deck, which enable greater aircraft launch capabilities.

## Flight deck

Changes to the flight deck are the most visible of the differences between the *Nimitz* and *Gerald R. Ford* classes. Several sections have been altered from the layout of the *Nimitz* class flight deck to improve aircraft handling, storage, and flow. Catapult number four on the *Nimitz* class cannot launch fully loaded aircraft because of a deficiency of wing clearance along the edge of the flight deck. CVN-78 will have no catapult-specific restrictions on launching aircraft, but still retains 4 catapults, 2 bow and 2 waist, and the number of aircraft lifts from hangar deck to flight deck level is also reduced from the earlier ships from 4 to 3. The design changes to the flight deck are instrumental in the maximization of sortie generation.

The route of weapons to the aircraft stops on the flight deck has been replanned to accommodate higher re-arming rates, and in turn higher potential sortie rates.

Another major change: a smaller, redesigned island will be pushed further back relative to the older classes of carriers. Moving the island creates deck space for a centralized re-arming and re-fueling location. This reduces the number of times that an aircraft will have to be moved after landing before it can be launched again. Fewer aircraft movements require, in turn, fewer deck hands to accomplish them, reducing the size of the ship's crew. A similar benefit is realized by altering the path and procedures for weapons movement by redshirts from storage to flight deck, again potentially allowing the new ship to support a higher sortie rate than the Nimitz class ship while using fewer crew members than the Nimitz requires. On *Nimitz*-class carriers the time that it takes to launch a plane after it has landed is defined by the time necessary to re-arm and re-fuel. To minimize this time, ordnance will be moved by robotic devices from storage areas to the centralized re-arming location via re-located weapons elevators. The new path that ordnance follows does not cross any areas of aircraft movement, thereby reducing traffic problems in the hangars and on the flight deck. According to Rear Admiral Dennis M. Dwyer these changes will make it theoretically possible to re-arm the airplanes in "minutes instead of hours."

## Power generation

The propulsion and power plant of the *Nimitz*-class carriers was designed in the 1960s. Technological capabilities of that time did not require the same quantity of electrical power that modern technologies do. "New technologies added to the *Nimitz*-class ships have generated increased demands for electricity; the current base load leaves little margin to meet expanding demands for power." Increasing the capability of the U.S. Navy to improve the technological level of the carrier fleet required a larger capacity power system.

The new A1B reactor plant is a smaller, more efficient design that provides approximately three times the electrical power of the *Nimitz*-class A4W reactor plant. The modernization of the plant led to a higher core energy density, lower demands for pumping power, a simpler construction, and the use of modern electronic controls and displays. These changes resulted in a two thirds reduction of watch standing requirements and a significant decrease of required maintenance.

A larger power output is a major component to the integrated warfare system. Engineers took extra steps to ensure that integrating unforeseen technological advances onto a *Gerald R. Ford*-class aircraft carrier would be possible. The *Gerald R. Ford*-class will be an integral component of the fleet for a total of nearly ninety years. One lesson learned from that is that for a ship design to be successful over the course of a century, a great deal of foresight and flexibility is required. Integrating new technologies with the *Nimitz* class is becoming more difficult to do without any negative consequences. To bring the *Gerald R. Ford* class into dominance during the next century of naval warfare requires that the class be capable of seamlessly upgrading to more advanced systems.

## Launch systems

The *Nimitz*-class aircraft carriers use steam-powered catapults to launch aircraft. Steam catapults were developed in the 1950s and have been exceptionally reliable. For over fifty years at least one of the four catapults has been able to launch an aircraft 99.5% of the time. However, there are a number of drawbacks. “The foremost deficiency is that the catapult operates without feedback control. With no feedback, there often occurs large transients in tow force that can damage or reduce the life of the airframe.” The steam system is massive, inefficient (4–6%), and hard to control.

Control problems with the system results in minimum and maximum weight limits. The minimum weight limit is above the weight of all UAVs. An inability to launch the latest additions to the Naval Air Forces is a restriction on operations that cannot continue into the next generation of aircraft carriers. The Electromagnetic Aircraft Launch System (EMALS) provides solutions to all these problems. An electromagnetic system is more efficient, smaller, lighter, more powerful, and easier to control. Increased control means that EMALS will be able to launch both heavier and lighter aircraft than the steam catapult. Also, the use of a controlled force will reduce the stress on airframes, resulting in less maintenance and a longer lifetime for the airframe. Unfortunately the power limitations for the *Nimitz* class make the installation of the recently developed EMALS impossible.

Electromagnetics will also be used in the new Advanced Arresting Gear (AAG) system. The current system relies on hydraulics to slow and stop a landing aircraft. While effective, as demonstrated by more than fifty years of implementation, the AAG system offers a number of improvements. The current system is unable to capture UAVs without damaging them due to extreme stresses on the airframe. UAVs do not have the necessary mass to drive the large hydraulic piston used to trap heavier manned planes. By using electromagnetics the energy absorption is controlled by a turbo-electric engine. This makes the trap smoother and reduces shock on airframes. Even though the system will look the same from the flight deck as its predecessor, it will be more flexible, safe, reliable, and require less maintenance and manning.

### Communications

Another addition to *Gerald R. Ford* class is an integrated search & tracking radar system. The Dual-band radar is being developed for both the DDG 1000 *Zumwalt* class of guided missile destroyers and the *Gerald R. Ford* class of aircraft carriers. The island can be kept smaller by replacing six to ten radar antennas with a single six-faced radar. The DBR works by combining the X-Band AN/SPY-3 Multi-Function Radar with the S-Band Volume Search Radar. The three faces dedicated to the X-band radar are responsible for low altitude tracking and target illumination, while the other three faces dedicated to the S-band are responsible for target search and tracking regardless of weather. "Operating simultaneously over two electromagnetic frequency ranges, the DBR marks the first time this functionality has been achieved using two frequencies coordinated by a single resource manager." This new system has no moving parts, therefore minimizing maintenance and manning requirements for operation.

### Possible upgrades

Each new technology and design feature integrated into the *Ford*-class aircraft carrier improves sortie generation, manning requirements, and operational capabilities. Preparing for the future is a trademark of *Gerald R. Ford*. New defense systems, such as free electron laser directed-energy weapons, dynamic armor, and tracking systems will require more power. "Only half of the electrical power-generation capability on CVN 78 is needed to run currently planned systems, including EMALS. CVN 78 will thus have the power reserves that the *Nimitz* class lacks to run lasers and dynamic armor." The addition of new technologies, power systems, design layout, and better control systems results in an increased sortie rate of 25% over the *Nimitz* class and a 25% reduction in manpower required to operate.

## Construction

On 10 September 2008 the US Navy signed a $5.1 billion contract with Northrop Grumman Shipbuilding in Newport News, Virginia, to design and construct the carrier. Northrop had begun advance construction of the carrier under a $2.7 billion contract in 2005. The carrier is being constructed at the Northrop Grumman Newport News shipbuilding in Hampton Roads, Virginia, which employs 19,000 workers.

The keel of the new warship was ceremonially laid on November 14, 2009 in Dry Dock 12 (Aprox. at: 36 degrees 59' 32.0" N 76 degrees 26' 41.5" W) by Ford's daughter, Susan Ford Bales. Said Bales in a speech to the assembled shipworkers and DoD officials, "Dad met the staggering challenges of restoring trust in the presidency and healing the nation's wounds after Watergate in the only way he knew how — with complete honesty and integrity. And that is the legacy we remember this morning."

**Chapter- 6**

# Queen Elizabeth Class Aircraft Carrier

| Class overview | |
|---|---|
| Builders: | BAE Systems Surface Ships<br>Thales Group<br>Babcock Marine |
| Operators: | Royal Navy |
| Preceded by: | *Invincible* class |
| Succeeded by: | N/A |
| In service: | Expected to enter service between 2019 and 2023 |
| Building: | 2 |
| Planned: | *Queen Elizabeth*<br>*Prince of Wales* |
| Completed: | 0 |
| **General characteristics** | |
| Displacement: | 65,600 metric tons (72,300 short tons) (full load) |
| Length: | 284 metres (932 ft) |
| Beam: | 39 metres (waterline)<br>73 metres overall |
| Draught: | 11 metres |
| Decks: | 16,000 square metres |

| | |
|---|---|
| Speed: | 25+ knots |
| Range: | 10,000 nautical miles (18,520 km) |
| Capacity: | 1,450 |
| Complement: | 600 |
| Aircraft carried: | Maximum 40 depending on mission could include a mixture of: <br>• 36 F-35 Lightning II<br>• 4 Airborne Early Warning aircraft<br>• 12 Chinook<br>• 12 Merlin<br>• 8 Apache |

The ***Queen Elizabeth* class supercarriers** (formerly the **CV Future** or **CVF** project) are a two-ship class of aircraft carrier being built for the Royal Navy. HMS *Queen Elizabeth* is expected to enter service in 2020 and HMS *Prince of Wales* is expected to initially be kept in a state of "extended readiness" after completion. HMS *Queen Elizabeth* will be built to a CATOBAR configuration. The construction of HMS *Prince of Wales* was assured by the 2010 Strategic Defence and Security Review, although its role in the immediate aftermath of its commission remains uncertain. The vessels will displace about 65,600 tonnes (full load), be 284 metres (932 ft) long and capable of carrying up to 40 aircraft.

The need to replace the ageing *Invincible*-class aircraft carriers was confirmed by the 1998 Strategic Defence Review. From six contractors, the Ministry of Defence (MoD) selected Thales and BAE Systems in late 1999 to compete for the final contract. In September 2002 the MoD announced that the Royal Navy and RAF would operate the STOVL F-35B Lightning II variant, and the carriers would take the form of large, conventional carriers initially configured for STOVL operations. On 30 January 2003 the MoD announced that the Thales design had won the competition but that BAE Systems would operate as prime contractor. The two companies are now part of a "carrier alliance" with the MoD and other companies.

The contract for the vessels was announced on 25 July 2007 by the Secretary of State for Defence Des Browne, ending several years of delay over cost issues and British naval shipbuilding restructuring. The cost is estimated to be £3.9 billion. The contracts were officially signed one year later on 3 July 2008 after the creation of BVT Surface Fleet through the merger of BAE Systems Surface Fleet Solutions and VT Group's VT Shipbuilding which was a requirement of the UK Government.

In the 2010 Strategic Defence and Security Review, it was announced that initially one carrier would be converted to CATOBAR configuration in order to operate the F-35C variant of the F-35 Lightning II, instead of the F-35B STOVL variant.

# History

The CVF carriers will be closer in size to a *Nimitz* class carrier (left) than the *Invincible* class ships they replace (right)

## Requirement

The 22,000 tonne *Invincible* class aircraft carriers, *Invincible*, *Illustrious* and *Ark Royal*, were designed for Cold War anti-submarine warfare in the North Atlantic as part of a combined NATO fleet and have limited space for STOVL fixed-wing aircraft. The 1982 Falklands War demonstrated the need to maintain aircraft carriers to support the United Kingdom's foreign policy.

Since the end of the Cold War the *Invincible* class ships have operated in a more traditional aircraft carrier mission, that of power projection. As a result the Royal Air Force's Harrier GR7s have been routinely deployed on the carriers which have been modified to carry more aircraft and ammunition (notably with the removal of the Sea Dart defensive weapon system). Despite the shortcomings of the Invincible class in this role, formal studies did not begin until 1994 regarding the replacement of the ships.

## Strategic Defence Review

In May 1997, the newly-elected Labour government launched the Strategic Defence Review (SDR) which re-evaluated every weapon system (active or in procurement) with the exception of the Eurofighter Typhoon and the *Vanguard* class ballistic missile submarines. The report, published in July 1998 concluded that aircraft carriers offered the following:

- Ability to operate offensive aircraft abroad when foreign basing may be denied.
- All required space and infrastructure; where foreign bases are available they are not always available early in a conflict and infrastructure is often lacking.
- A coercive and deterrent effect when deployed to a trouble spot.

The report concluded: "the emphasis is now on increased offensive air power, and an ability to operate the largest possible range of aircraft in the widest possible range of roles. When the current carrier force reaches the end of its planned life, we plan to replace it with two larger vessels. Work will now begin to refine our requirements but present thinking suggests that they might be of the order of 30,000–40,000 tonnes and capable of deploying up to 50 aircraft, including helicopters."

It is planned that advanced design and maintenance techniques will eliminate the present requirement for major refits. In addition, HMS *Ocean*, a specialised helicopter landing platform, fills a role previously undertaken by the *Invincible* class carriers.

## Design studies

On 25 January 1999 six companies were invited to tender for the assessment phase of the project; Boeing, British Aerospace, Lockheed Martin, Marconi Electronic Systems, Raytheon and Thomson-CSF. On 23 November 1999 the MoD awarded detailed assessment studies to two consortia, one led by BAe (renamed BAE Systems on 30 November 1999) and one led by Thomson-CSF (renamed Thales Group in 2000). The brief required up to six designs from each consortium with airgroups of 30 to 40 Future Joint Combat Aircraft (FJCA). The contracts were split into phases; The first £5.9 million phase was for design assessment which would form part of the aircraft selection, the second £23.5 million phase involved "risk reduction on the preferred carrier design option."

In the course of the design period, several different configurations were considered and submissions included large and small air groups based around three types of vessel.

STOVL

A carrier operating Short Take Off and Vertical Landing aircraft could dispense with the costly steam catapults and arrestor gear of a conventional (CATOBAR) carrier. This would also take advantage of the UK experience in STOVL technology. This is at the expense of aircraft range and payload capability (for an equal size CATOBAR carrier). The aircraft would be similar to the F-35B

Lightning II. The F-35B is significantly more capable than the Harrier in every respect, but has lower range and payload than even previous generation CATOBAR aircraft such as Super Hornet.

STOBAR

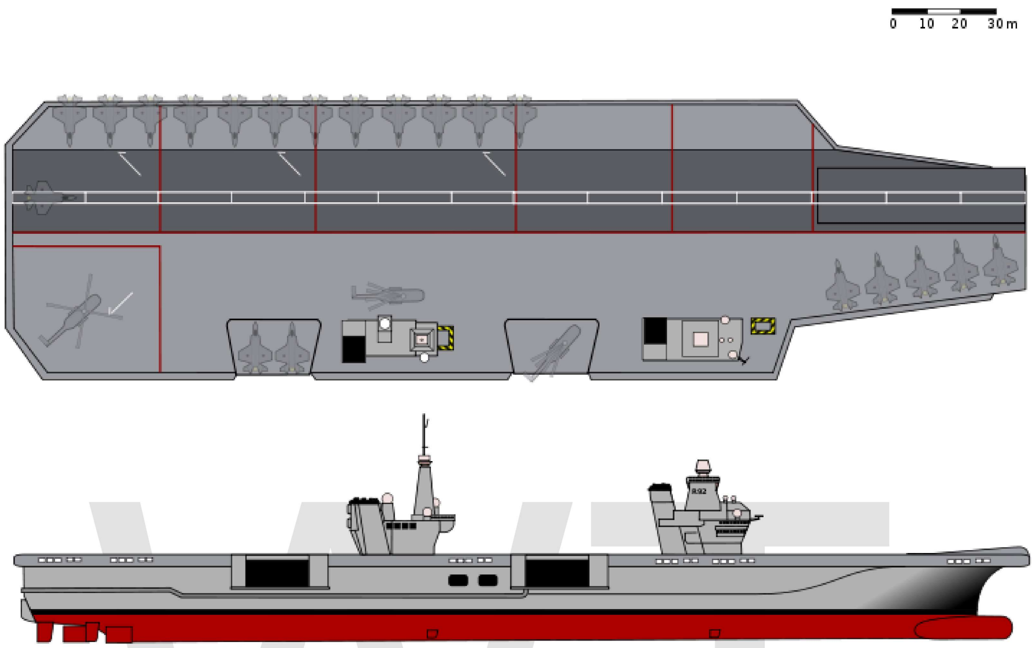
Short Take-Off But Arrested Recovery (STOBAR) again removes the requirement for the expense of catapults but uses arrestor gear. In this way conventional aircraft (albeit modified) can be used. Any STOBAR design would most likely have used a navalised version of the Eurofighter Typhoon on order for the RAF. The modifications would require strengthened landing gear, modified flight control system and inclusion of an stronger arrestor hook suitable for carrier use. The advantages of this would be increased range, manoeuvrability, greater weapons stand-off and payload compared to a STOVL design and higher operating efficiency than a CATOBAR design.

CATOBAR

A Catapult Assisted Take-Off But Arrested Recovery (CATOBAR) CVF would use catapults and arrestor cables and an angled flight deck with existing naval aircraft, most likely the F/A-18 or Rafale-M. This had the advantage of reducing technical risk for development of both the aircraft and carriers and offering maximum payload and range capabilities. There are disadvantages however, including higher operating costs and the minimal British involvement in development of the aircraft due to the "off-the-shelf" purchase.

In addition BAE made a submission of hybrid configuration, featuring a STOVL ski-jump and an angled flight deck, catapults and arrestor cables. Advantages of this design include the ability to operate STOVL offensive aircraft and also conventional aircraft. This would allow the operation of established, and therefore cheaper, designs of AEW aircraft e.g. the E-2 Hawkeye rather than new development.

## Aircraft and carrier format selection




The original STOVL version of CVF

On 17 January 2001 the UK signed a Memorandum of Understanding (MoU) with the U.S. Department of Defense (DoD) for full participation in the Joint Strike Fighter programme, confirming the JSF as the FJCA. This gave the UK input into aircraft design and the choice between the Lockheed X-35 and Boeing X-32. On 26 October 2001 the DoD announced that Lockheed Martin had won the JSF contract.

On 30 September 2002 the MoD announced that the Royal Navy and RAF will operate the STOVL F-35B variant. At the same time it was announced that the carriers would take the form of large, conventional carriers, initially adapted for STOVL operations. The carriers, expected to remain in service for 50 years, are designed for but not with catapults and arrestor wires. The carrier is thus said to be "future proof", allowing it to operate a generation of CATOBAR aircraft beyond the F-35.

On 30 January 2003 the Defence Secretary Geoff Hoon announced that the Thales Group design had won the competition but that BAE Systems would operate as prime contractor. In the course of this some equipment specified for the BAE design replaced that of the Thales group.

As of August 2009, speculation mounted that the UK may drop the F-35B for the F-35C model, which would mean the carriers being built to operate conventional take off and landing aircraft using the US-designed Electromagnetic Aircraft Launch System catapults.

Meanwhile, Converteam UK is working on a different electro-magnetic catapult (EMCAT) system for the carrier.

### Strategic Defence and Security Review 2010

On 19 October 2010, the government announced the results of its Strategic Defence and Security Review. Only one carrier is certain to be commissioned; the fate of the other is undecided. The second ship of the class may be placed in "extended readiness" to provide a continuous single carrier strike capability when the other is in refit or to provide the option to regenerate more quickly a two carrier strike ability. Alternatively the second ship may be sold with "cooperation with a close ally to provide continuous carrier-strike capability".

It was also announced that the operational carrier will have catapult and arrestor gear (CATOBAR) installed in order to accommodate the F-35C variant of the Joint Strike Fighter rather than the STOVL F-35B. On 23 November 2010 the Chief of the Defence staff General Sir David Richards confirmed that HMS *Queen Elizabeth* would be fitted as a conventional carrier. "The short delay to the first carrier, to allow it to be fitted with 'cats and traps', means that when it comes into service in 2019 it will be equipped with the hugely capable carrier variant of Joint Strike Fighter."

## Design

The vessels will displace approximately 65,600 tonnes each, over three times the displacement of the current *Invincible* class. They will be the largest warships ever built in the UK and the most capable aircraft carriers outside of the U.S. Navy. Nothing of the scale has been proposed for the Royal Navy since the cancelled 1960s CVA-01 programme. Giving evidence to the House of Commons Defence Committee, the First Sea Lord Admiral Sir Alan West explained that interoperability with the United States Navy was a factor in deciding of the size of the carriers as the firepower of the carrier's airwing:

[for a] deep strike package, we have done ...quite detailed calculations and we have come out with the figure of 36 joint strike fighters ...that is the thing that has made us arrive at that size of deck and that size of ship, to enable that to happen. I have talked with the CNO (Chief of Naval Operations) in America. He is very keen for us to get these because he sees us slotting in with his carrier groups. He really wants us to have these, but he wants us to have the same sort of clout as one of their carriers.

The design features two small island structures, one devoted to ship navigation, and the other to air operations. This allows optimal placement of bridges for both tasks: navigation calls for a bridge placed forward (as on the *Charles De Gaulle*), while air operations are made easier with a bridge placed abaft (as seen on the US Gerald R. Ford class aircraft carrier). Two deck lifts will be used, both on the starboard side.

## Carrier Air Group

The vessels are expected to be capable of carrying 40 aircraft; which could be up to 36 F-35 Lightning II as well as helicopters or V-22 Osprey aircraft. In context, one carrier's air wing is almost three times the size of the Tornado GR.1 force deployed in Operation *Desert Fox* and the same number as the Tornado GR.4/Harrier GR.7 offensive fleet which participated in Operation *Telic*. Both of these land based deployments required the agreement of a local friendly nation. It was anticipated that the carriers would operate the Harrier GR9s until around 2018, as the RN will not have a complete F-35 group until then.

The Airborne Surveillance and Control (ASaC) component began as "Future Organic Airborne Early Warning" (FOAEW), with contracts being placed with BAE/Northrop Grumman and Thales in April 2001. In April 2002 BAE and Northrop Grumman received a follow-on study contract for Phase II of the project by then renamed Maritime Airborne Surveillance & Control (MASC).

The ships were originally intended to carry STOVL F-35B aircraft, but on 19 October 2010, Prime Minister David Cameron announced that the UK intends to purchase the CATOBAR-capable F-35C variant instead. The F-35C is cheaper and has a greater range and payload than the F-35B. The CATOBAR configuration will also enable the UK's defence partners such as the United States and France to operate aircraft from the carriers in joint mission situations.

## Powerplant

The MoD decided not to use nuclear propulsion due to its high costs. The carrier's propulsion system will be Integrated Full Electric Propulsion (IFEP). Electric power is generated at 11,000 volts by two Rolls-Royce Marine Trent MT30 36 MW gas turbine generator units and four Wärtsilä Diesel Generator sets (two 9 MW and two 11MW sets). This power is used for both the electric propulsion system and the ship's domestic system. The electric power is used to drive four, Converteam, Advanced Induction Motors, two per shaft and situated in three separate compartments to improve survivability in the event of action damage or flooding. Each 20 MW motor is driven by a Converteam VDM 25000 pulse width modulated converter which produces a variable frequency output allowing the shaft speed to be controlled across the full operating range. The propulsion power management system is integrated fully with the ship's platform management system provided by L-3 Communications. This unique propulsion system eliminates the need for large gearboxes, is compact and by minimizing the number of running generating sets for a given speed is very fuel efficient.

The design places one gas turbine generator unit under each island in the starboard sponson. This relatively high placement removes the requirement for air downtakes/exhausts deep into the ship. Conversely, the Diesel Generator sets are mounted low down in the ship, the weight of these units contributing to the stability of the ship. The unrefuelled range of the carrier will be 10,000 nautical miles (18 520 km).

The power and propulsion system system is being designed and built in a Sub Alliance arrangement which brings together leading companies in their specific fields to provide the most cost effective mechanism for delivery of the integrated system for the QEC programme. This innovative arrangement is led by Thales UK as members of the Aircraft Carrier Alliance and partnered by Converteam UK, Rolls-Royce and L-3 Communications.

### Systems

Many of the systems remain unspecified, but most of the designs that have been released so far show a BAE Systems Insyte/Thales S1850M long range radar on the forward island structure. However, it was announced on 4 August 2008 that they would also be fitted with BAE Systems Insyte Artisan 3D Radars as a medium range radar fitted to the aft island.



## Construction

During a speech on 21 July 2004 Geoff Hoon announced a one year delay to allow contractual and cost issues to be resolved. The building of the carriers was confirmed in December 2005. The building is to be across seven shipyards (BAE Systems Surface Ships - Govan, Scotstoun and Portsmouth, Babcock Marine - Rosyth and Appledore, A&P Group - Hebburn and Cammell Laird - Birkenhead) with final block integration and assembly at Rosyth. In preparation for the construction phase of the project, long-lead items were ordered in Autumn 2007, including key parts of the main and emergency propulsion systems for the new aircraft carriers from Wärtsilä.

On 4 March 2008 contracts for the supply of 80,000 tonnes of steel were awarded to Corus Group, with an estimated value of £65 million. Other contracts included £3 million for fibre optic cable, over £1 million for reverse osmosis equipment to provide over 500 tonnes of fresh water daily, and £4 million for aviation fuel systems. On 3 April 2008 a contract for the manufacture of aircraft lifts (worth £13m) was awarded to MacTaggart Scott of Loanhead, Scotland.

In mid May 2008, the Treasury announced that it would be making available further funds on top of the regular defence budget, reportedly allowing the construction of the carriers to begin. This was followed, on 20 May 2008, by the government giving the "green light" for construction of *Queen Elizabeth* class, stating that it was ready to sign the contracts for full production once the creation of the planned shipbuilding joint venture between BAE Systems and the VT Group had taken place. This joint venture, BVT Surface Fleet, became operational on On 1 July 2008. VT Group later sold its share to BAE Systems which renamed the unit BAE Systems Surface Ships. It will undertake approximately 40% of the project workload.

On 1 September 2008, the MOD announced a £51 million package of important equipment contracts; £34 million for the Highly Mechanised Weapons Handling System for the two ships, £8 million for supply of uptake and downtake systems for both ships, £5 million for Air Traffic Control software, £3 million for supply of pumps and associated systems engineering, and £1 million for emergency diesel generators. On 6 October 2008, it was announced that contracts had been placed for "the carriers' Rolls-Royce gas turbines, generators, motors, power distribution equipment, platform management systems, propellers, shafts, steering gear, rudders and stabilisers". On 11 February 2009, Thales indicated that the S1850M radar will be used on the carriers.

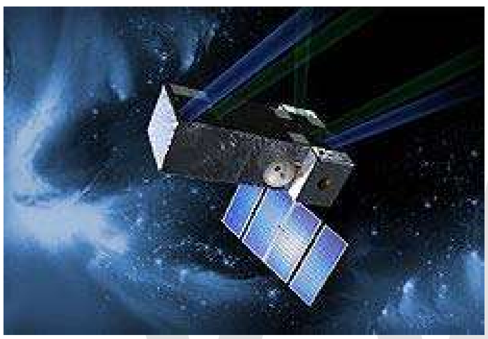
Construction of Lower blocks 3 and 4 began at BAE Systems Clyde in July 2009 (the first steel cut for the project) and January 2010 respectively, while construction of the bow Lower Block 1 was carried out at Appledore, North Devon and were completed in March 2010. When the four lower blocks are completed they will be transported to Rosyth to be assembled.

It was announced on 25 January 2010 that the Cammell Laird shipyard of Birkenhead has secured a £44 million contract to build the flight decks of the carriers. On the same date 25 February 2010 construction began in Portsmouth of the Lower Block 2, one of the large structures, that forms part of the hull of HMS Queen Elizabeth. The structure will house machinery spaces, stores, switchboards and some of the ship's accommodation. The block will weigh around 6,000 tonnes and will stand over 18 metres (59 ft) tall, 70 metres (230 ft) long and 40 metres (130 ft) wide.

## Chapter- 7

# Space Interferometry Mission

**SIM Lite**



Artist's concept of the SIM Lite Astrometric Observatory

**General information**

| | |
|---|---|
| **Organization** | NASA / JPL |
| **Major contractors** | Northrop Grumman |
| **Launch date** | 2016-2017 at earliest |
| **Launch vehicle** | Intermediate class launch vehicle (EELV) similar to an Atlas V 521 |
| **Mission length** | 5½ to 10 years |
| **Type of orbit** | Earth-trailing heliocentric orbit |
| **Telescope style** | Optical Michelson Interferometer |
| **Wavelength** | 0.4 to 0.9 μm |
| **Diameter** | 0.5 m × 2 |

**Instruments**

| | |
|---|---|
| **Science Interferometer** | 6 m baseline; 0.5 m×2 mirrors |
| **Guide Interferometer**<br>**Guide-2 Telescope** | 4.2 m baseline, 0.3 m×2 mirrors |
| **Website** | NASA SIM Lite |

The **Space Interferometry Mission**, also known as **SIM Lite** (formerly known as **SIM PlanetQuest**), was a planned space telescope developed by the U.S. National Aeronautics and Space Administration (NASA), in conjunction with contractor Northrop Grumman. One of the main goals of the mission was the hunt for Earth-sized planets orbiting in the habitable zones of nearby stars other than the Sun. SIM was postponed several times and finally cancelled in 2010.

In addition to hunting for extrasolar planets, SIM would have helped astronomers construct a map of the Milky Way galaxy. Other important tasks would have included collecting data to help pinpoint stellar masses for specific types of stars, assisting in the determination of the spatial distribution of dark matter in the Milky Way and in the Local Group of galaxies and using the gravitational microlensing effect to measure the mass of stars.

The spacecraft would have used optical interferometry to accomplish these and other scientific goals. This technique collects light with multiple mirrors (in SIM's case, two) which is combined to make an interference pattern which can be very precisely measured.

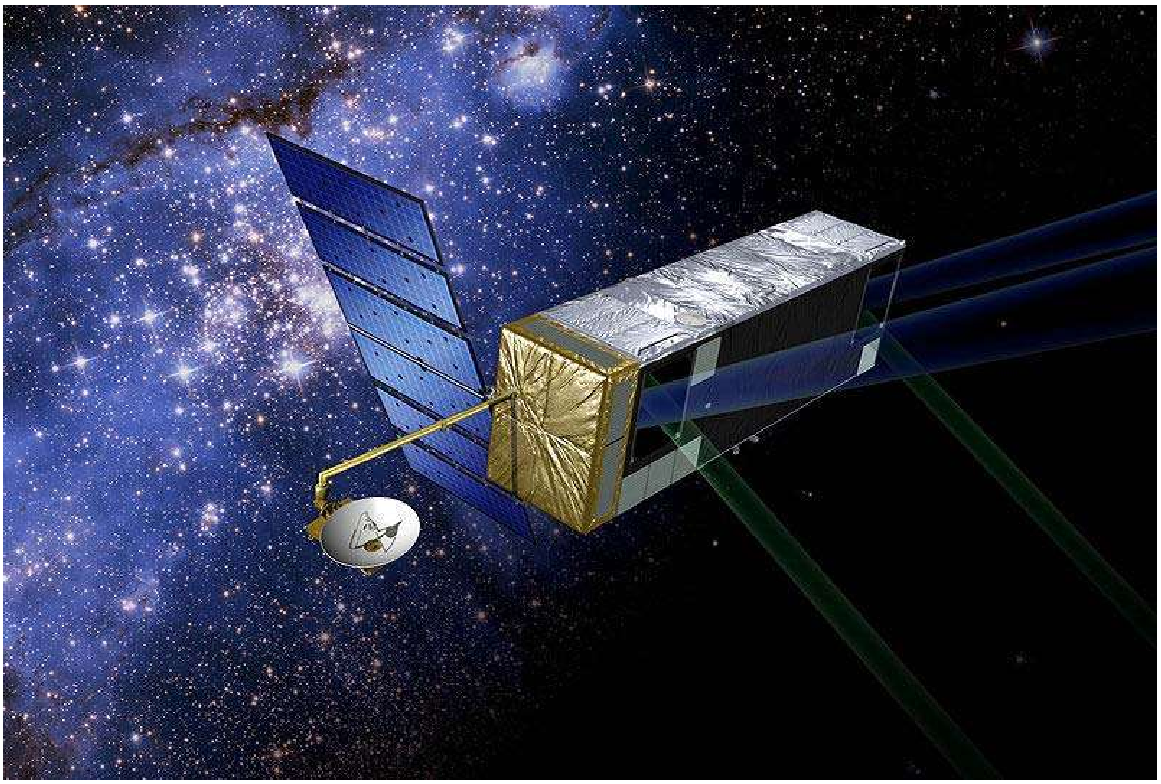
The initial contracts for SIM Lite were awarded in 1998, totaling US$200 million. Work on the SIM project required scientists and engineers to move through eight specific new technology milestones, and by November 2006, all eight had been completed.

SIM Lite was originally scheduled for a 2005 launch, aboard an Evolved Expendable Launch Vehicle (EELV). As a result of continued budget cuts, the launch date has been pushed back at least five times. NASA has set a preliminary launch date for 2015 and U.S. federal budget documents confirm that a launch date is expected "no earlier" than 2015. The budget cuts to SIM Lite are expected to continue through FY 2010. As of February 2007, many of the engineers working on the SIM program had moved on to other areas and projects, and NASA directed the project to allocate its resources toward engineering risk reduction. However, the preliminary budget for NASA for 2008 included zero dollars for SIM.

In December 2007 the Congress restored funding for fiscal year 2008 as part of an omnibus appropriations bill which the President later signed. At the same time the Congress directed NASA to move the mission forward to the development phase. As of the end of 2009, the project continues its risk reduction work while NASA's decision on the project's future awaits the findings and recommendations of the Astronomy and Astrophysics Decadal Survey, Astro2010, performed by the National Academy of Sciences, due in the second half of 2010.

On August 13, 2010, the Astro2010 Decadal Report was released and did not recommend that NASA continue the development of the SIM Lite Astrometric Observatory. This prompted NASA Astronomy and Physics Director, Jon Morse, to issue a letter on September 24, 2010 to the SIM Lite project manager, informing him that NASA was discontinuing its sponsorship of the SIM Lite mission and directing the project to discontinue Phase B activities immediately or as soon as practical. Accordingly, all SIM Lite activities were closed down by the end of calendar year 2010.

## Mission

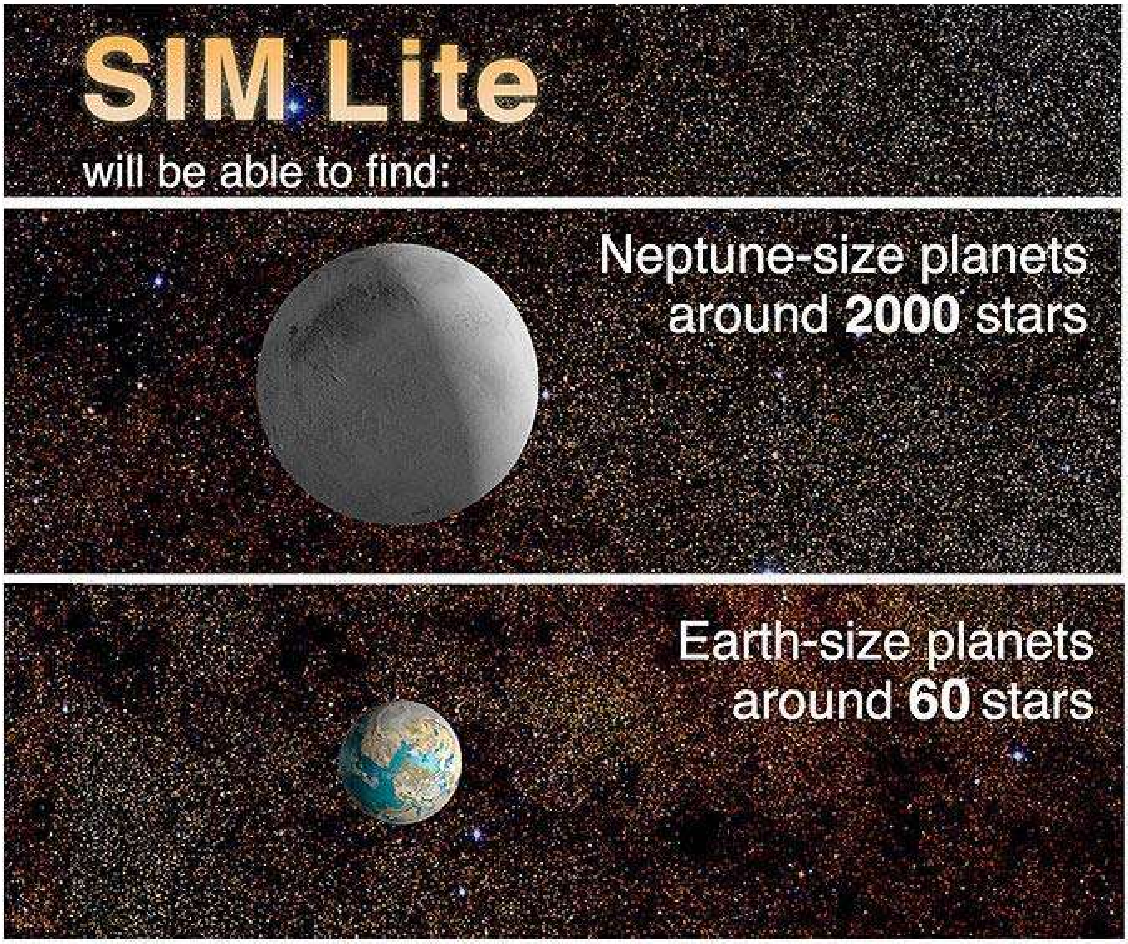


A 2006 artist's impression of the SIM Lite predecessor, SIM PlanetQuest, design

SIM Lite would have operated in an Earth-trailing heliocentric orbit. The SIM would have drifted away from Earth at the rate of 0.1 AU per year. At the end of the planned mission, it would have reached a distance of 82 million km from Earth. This would have taken approximately 5½ years. The Sun would have continuously shone on the spacecraft, allowing it to avoid the occultations of target stars and eclipses of the sun that would occur in an Earth orbit.

Had it been launched, SIM would have performed scientific research for five years.

**Planet hunting**



*Number of terrestrial planets assumes 40% of mission time.*

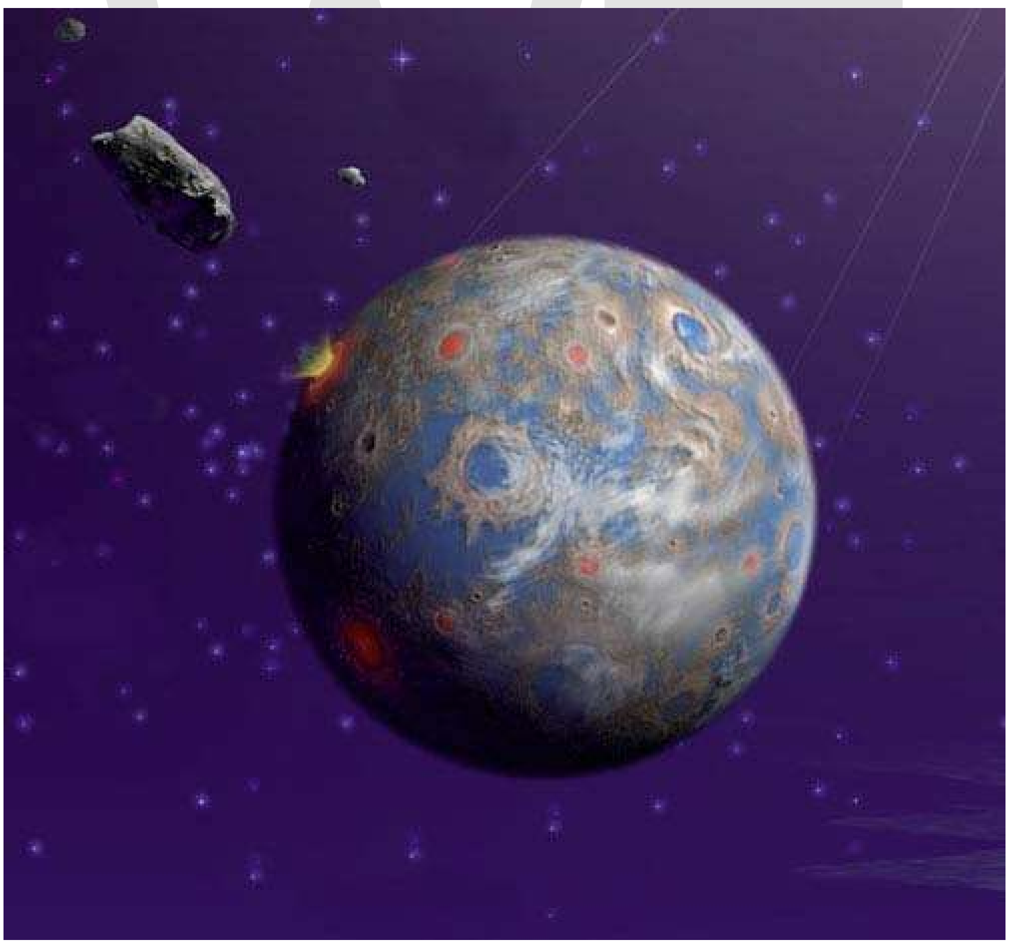
This chart depicts the potential number of habitable planets and other planets that SIM Lite might detect. The number of one-Earth mass planets assumes 40% of mission time is assigned to the search.

SIM Lite, when completed, will be the most powerful extrasolar planet hunting space telescope ever built. Through the technique of interferometry the spacecraft would be able to detect Earth-sized planets. SIM Lite will perform its search for nearby, Earth-like planets by looking for the "wobble" in the parent star's apparent motion as the planet orbits. The spacecraft will accomplish this task to an accuracy of one millionth of an arcsecond, or the thickness of a nickel viewed at the distance from Earth to the Moon. Titled the Deep Search, the planet hunting program is intended to search approximately 60 nearby stars for terrestrial planets (like Earth and Venus) in the habitable zone (where liquid water can exist throughout a full revolution (one “year”) of the planet around its star). The Deep Search is the most demanding in terms of astrometric accuracy, hence the name, Deep Search. This program will use the full capability of the SIM Lite spacecraft to make its measurements.

A flexible search strategy tunes SIM Lite's mass sensitivity at each star to a desired level in the habitable planet search. The value of $\eta_{Earth}$ (Eta_Earth), the fraction of stars carrying Earth-analog planets, will be estimated by the Kepler Mission some time before SIM Lite launches. One strategy for a habitable planet search is to do a 'deeper' search (i.e. to lower mass sensitivity in the habitable zone) of a smaller number of targets if Earth analogs are common. A 'shallower' search of a larger number of targets could be done if Earth analogs are rarer. For example, assuming that 40% of mission time is allocated for the planet search, SIM Lite could survey:

- 65 stars for planets down to one Earth mass, in scaled 1 AU orbits, OR
- 149 stars for planets down to two Earth masses, in scaled 1 AU orbits, OR
- 239 stars for planets down to three Earth masses, in scaled 1 AU orbits.

Aside from searching for Earth-sized planets SIM Lite was scheduled to perform what has been dubbed the "Broad Survey". The Broad Survey would have looked at approximately 1,500 stars to help determine the abundance of Neptune-mass and larger planets around all star-types in Earth's sector of the Milky Way.

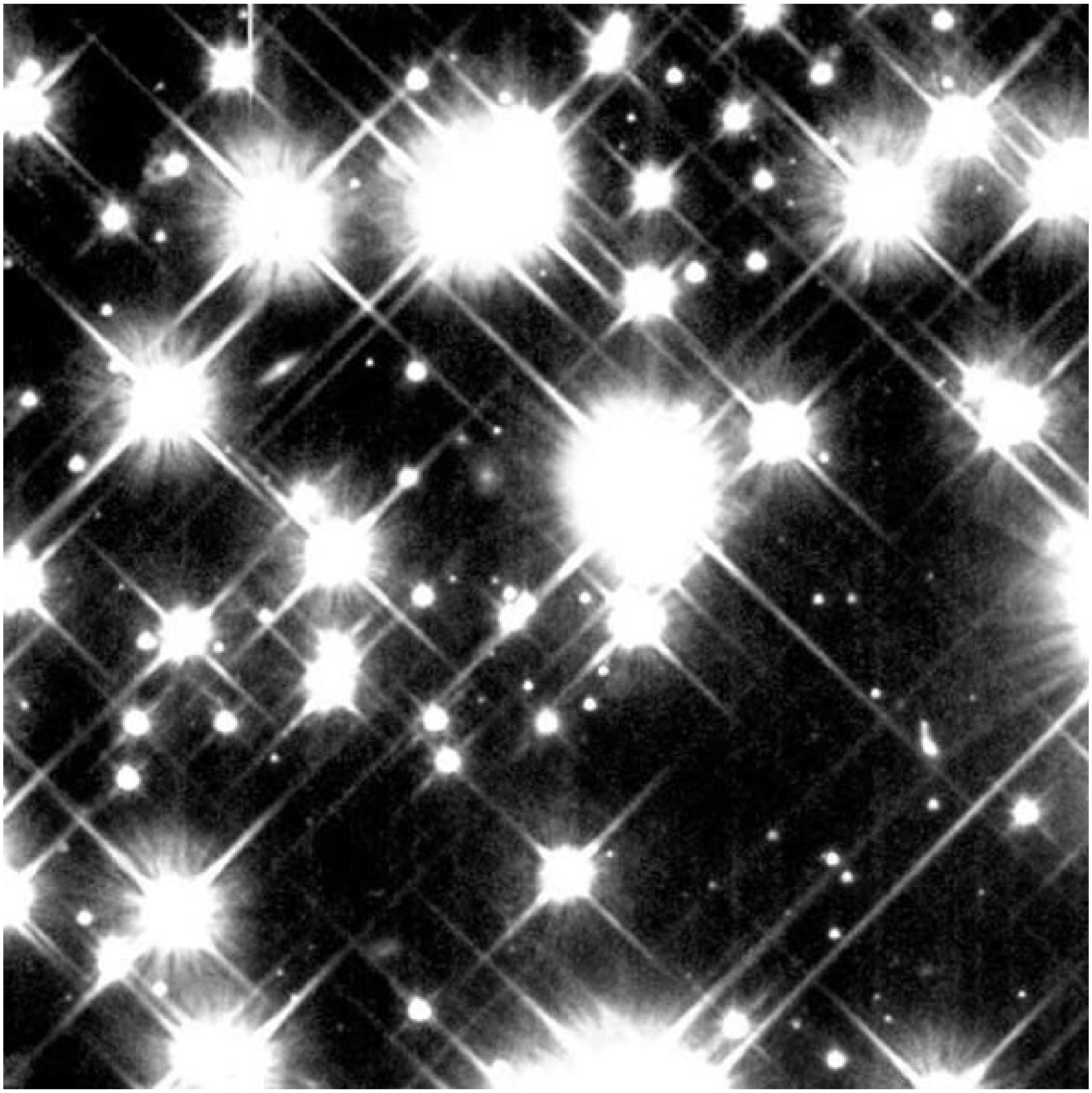


SIM Lite would have been able to detect Earth-sized planets, such as in this artist's rendering.

A third part of the planet finding mission was the search for Jupiter-mass planets around young stars. The survey would have helped scientists understand more about solar system formation, including the occurrence of hot Jupiters. This portion of the planet hunt is designed to study systems with one or more Jupiter mass planets before the system has reached long term equilibrium. Planet hunting techniques using a star's radial velocity cannot measure the regular, tiny to-and-fro wobble motions induced by planets against the strong atmospheric activity of a youthful star. It is through the techniques pioneered by Albert Michelson that the SIM will be able to execute its three primary planet-finding missions.

The mission's planet finding component was set up to serve as an important complement to the future missions designed to image and measure terrestrial and other exoplanets. SIM Lite will perform an important task that these missions will not be capable of: determining planet masses. Another task that the SIM was envisioned to perform for the future missions will include providing the orbital characteristics of the planets. With this knowledge other missions can estimate the optimal times and projected star-planet separation angles for them to observe the terrestrial (and other) planets SIM has detected.

## Stellar mass

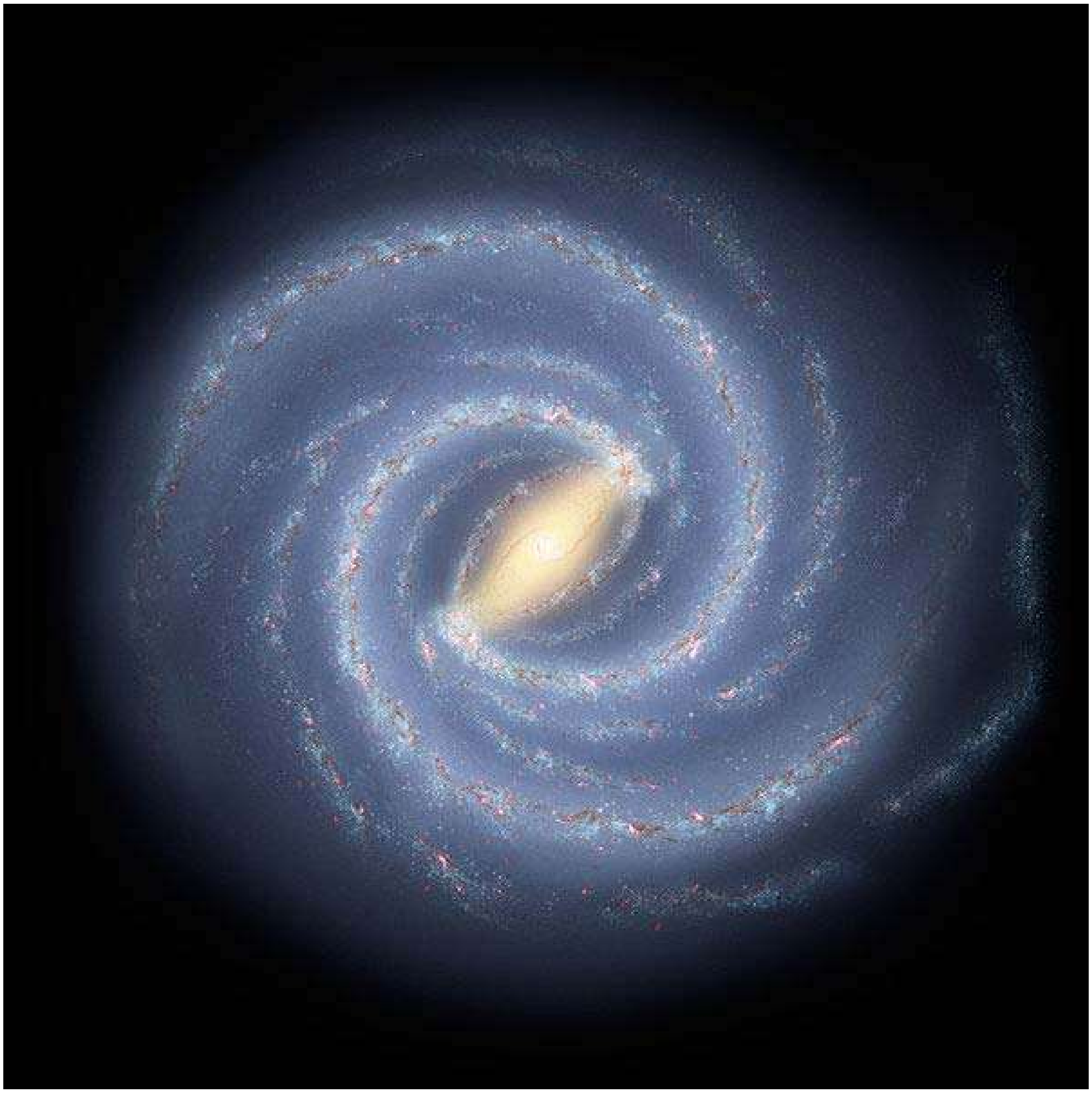


White dwarfs, imaged by NASA's Hubble Space Telescope

Another key aspect of SIM Lite's future mission was determining the upper and lower limits of star's masses. Today, scientists understand that there are limits to the how small or large a star can be. Objects that are too small lack the internal pressure to initiate thermonuclear fusion, which is what causes a star to shine. These objects are known as brown dwarfs and represent the lower end of the stellar mass scale. Stars that are too large become unstable and explode in a supernova.

Part of the SIM's mission is to provide pinpoint measurements for the two extremes in stellar mass and evolution. The telescope will not be able to measure the mass of every star in the Galaxy, since there are over 200 billion, but instead, it will take a "population census." Through this technique, SIM will be able to output accurate masses for representative examples for nearly every star type, including brown dwarfs, hot white dwarfs, red giant stars, and elusive black holes. Current space telescopes, including NASA's Hubble Space Telescope, can accurately measure mass for some types of stars, but not all. Estimates put the range for stellar mass somewhere between 8% the mass of the Sun and in excess of 60 times the mass of the Sun. The entire study will be focused on binary star systems, stars coupled through a mutual gravitational attraction.

## Galactic mapping



How scientists think the Milky Way is shaped

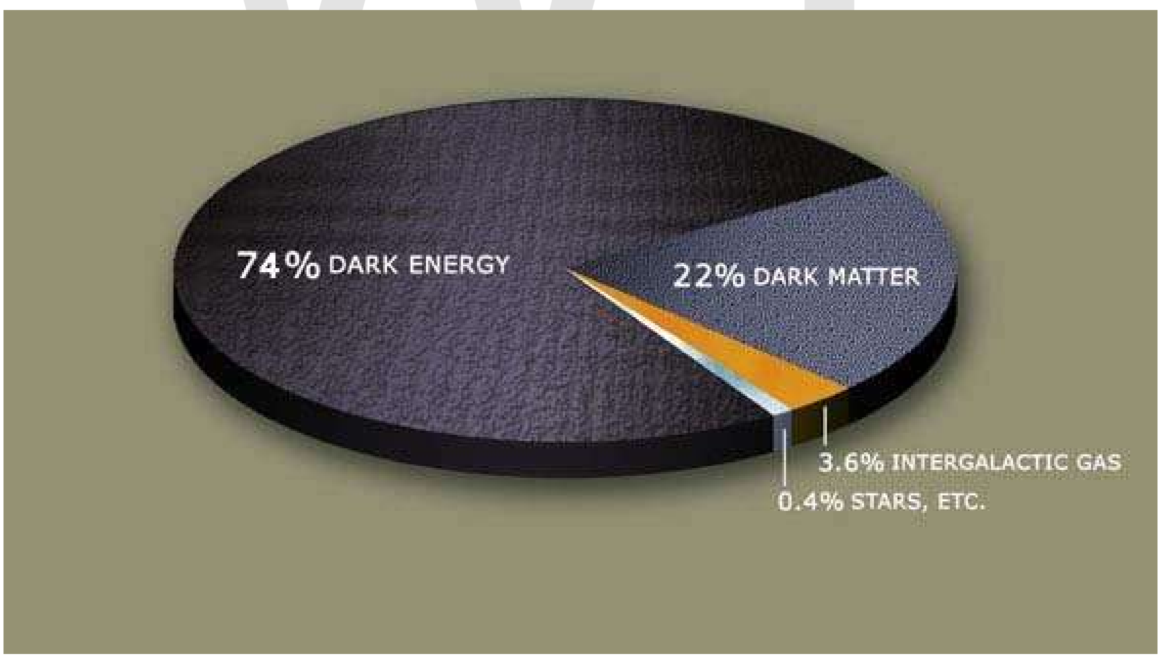
Interferometric measurements of stellar positions over the course of the mission will permit SIM to precisely measure the distances between stars throughout the Milky Way. This will allow astronomers to create a "roadmap" of the Galaxy which will answer many questions about its shape and size.

Currently, astronomers know little about the shape and size of our galaxy relative to what they know about other galaxies; it is difficult to observe the entire Milky Way from the inside. A good analogy is trying to observe a marching band as a member of the band. Observing other galaxies is much easier because humans are outside of those galaxies. Steven Majewski and his team plan to use SIM Lite to help determine not only the shape and size of the Galaxy but also the distribution of its mass and the motion of its stars.

SIM Lite measurements of Milky Way stars will yield data to understand four topics: fundamental Galactic parameters, the Oort Limit, disk mass potential, and mass of the Galaxy to large radii. The first, fundamental Galactic parameters, is aimed at answering key questions about the size, shape and the rotation rate of the Milky Way. The team hopes to more accurately determine the distance from the Sun to the Galactic center. The second topic, the Oort Limit, will attempt to determine the mass of the Galactic disk.

The third project topic is disk mass potential. This topic is designed to make measurements of the distances to disk stars as well as their proper motions. The results of the third topic of study will be combined with the results of the fundamental Galactic parameters portion of the study to determine the Solar System's position and velocity in the Galaxy. The final topic deals with dark matter distribution in the Milky Way. SIM data will be used to create a three-dimensional model of mass distribution in the Galaxy, out to a radius of 270 kiloparsecs (kps). They will then use two different tests to determine the Galactic potential at large radii.

## Dark matter




The gray portion of this pie graph shows the estimated distribution of dark matter in the universe.

Dark matter is the matter in the universe that cannot be seen. Because of the gravitational effect it exerts on stars and galaxies, scientists know that approximately 80% of the matter in the universe is dark matter. The spatial distribution of dark matter in the universe is largely unknown; SIM Lite will help scientists determine an answer to this question through another integral part of its mission.

The strongest evidence for dark matter comes from galactic motion. Galaxies rotate much faster than the amount of visible matter suggests they should; the gravity from the ordinary matter is not enough to hold the galaxy together. Scientists theorize that the galaxy is held together by huge quantities of dark matter. Similarly, clusters of galaxies do not appear to have enough visible matter to gravitationally balance the high speed motions of their component galaxies.

Besides measuring stellar motions within the Milky Way, SIM Lite will measure the internal and average galactic motion of some of the neighboring galaxies near the Milky Way. Many of these measurements will be the first of their kind. The telescope's measurements will be used in conjunction with other, currently available, data to provide astronomers with the first total mass measurements of individual galaxies. These numbers will enable scientists to estimate the spatial distribution of dark matter in the Local Group of galaxies, and by extension throughout the universe.

# Development

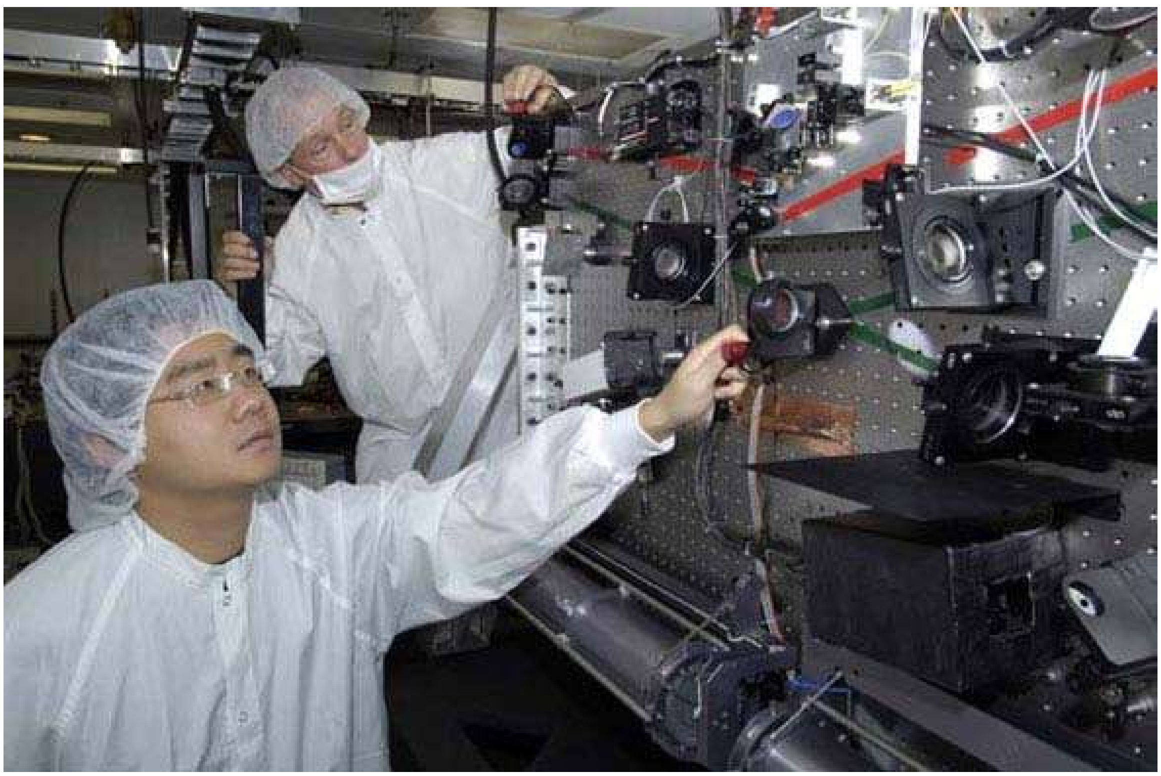
## Beginnings

The Space Interferometry Mission began as a four-month preliminary architecture study in March 1997. NASA selected TRW's Space & Electronics Group, Eastman Kodak and Hughes Danbury Optical Systems to conduct the study. In 1998, TRW Inc. was selected as the contractor for the SIM Lite project; Northrup Grumman acquired part of TRW in 2002 and took over the contract. Also selected was Lockheed Martin Missiles and Space located in Sunnyvale, California. The two contracts, which included the mission formulation and implementation phases, were announced in September 1998 and worth a total of over US$200 million. The formulation phase of the mission included initial mission design and planning for the full scale implementation of the mission. At the time of the NASA announcement, launch was scheduled for 2005 and the mission was part of the Origins Program, a series of missions designed to answer questions such as how and why humans are on Earth.

In August 2000, NASA asked project managers to consider looking at the Space Shuttle, instead of the previously proposed EELV, as a launch vehicle. In late November 2000, NASA announced that the project's scientific team was selected. The group included notable names from the world of extrasolar planet research including Geoffrey Marcy. The entire group consisted of 10 principal investigators and five mission specialists. At the time of this NASA announcement launch was scheduled for 2009 and the mission was still part of the Origins Program.

## New technologies

SIM's new technology is meant to lead to the development of telescopes powerful enough to take images of Earth-like extrasolar planets orbiting distant stars and to determine whether those planets are able to sustain life. NASA has already started developing future missions that will build on SIM's technological legacy. The technological development phase of the mission was completed in November 2006 with the announcement that the eight, mission-technology-milestones set by NASA were reached. The milestones were necessary steps in the technological development before flight control instruments could begin to be designed. The completion of each milestone meant that new systems had to be developed for nanometer control as well as picometer knowledge technology; these systems enable the telescope to make its accurate measurements with such extreme accuracy.



Engineers at JPL examine components on an optical bench that simulates the precision performance of NASA's future SIM Lite mission.

One of the new technologies developed for the mission were high-tech "rulers", capable of making measurements in increments a fraction of the width of a hydrogen atom In addition, the rulers were developed to work as a network. The mission team also created "shock absorbers" to alleviate the effects of tiny vibrations in the spacecraft which would impede accurate measurements. Another one of the milestones involved combining the new "rulers" and "shock absorbers" to prove that the Space Interferometry Mission craft could detect the tiny wobbles in stars caused by Earth-sized planets. The fifth of the technology milestones required the demonstration of the Microarcsecond Metrology Testbed at a performance of 3,200 picometers over its wide angle field of regard. The wide angle measurements will be used to determine the fixed positions of stars each time they are measured. This level of performance demonstrated SIM Lite's ability to calculate the astrometric grid. Another key development was the ability to apply the measurement capability worked out in the wide angle milestone and take it a step further, into narrow-angle measurements. The narrow angle field will be used by SIM to detect terrestrial planets; the team applied the same criteria to both the narrow and wide angle measurements. The final requirement before beginning work on flight controls was to make sure that all of the systems developed for the mission worked cohesively; this final NASA technology goal was completed last as it was dependent upon the others.

## Status after 2006

Between the end of April and June 2006 the project completed three engineering milestones and from November 2–November 8, 2006 SIM completed a "Spacecraft Internal Design Review." As of June 2008, all of the eight engineering milestones have been successfully completed.

The project has been in Phase B since June 2003, (and that is still the case as of July 2010). Jet Propulsion Laboratory's "Phase B" is called the "Preliminary Design" phase. Phase B further develops the mission concept developed during Phase A to prepare the project for entry into the Implementation Phase of the project. Requirements are defined, schedules are determined, and specifications are prepared to initiate system design and development." In addition, as part of Phase B, the SIM Lite project will go through a number of reviews by NASA including System Requirements Review, System Design Review, and Non-Advocate Review. During this phase, experiments will be proposed, peer reviewed, and eventually selected by NASA's Office of Space Science. Experiment selections are based on scientific value, cost, management, engineering, and safety. The project has been in Phase B since June 2003.

## Planned launch

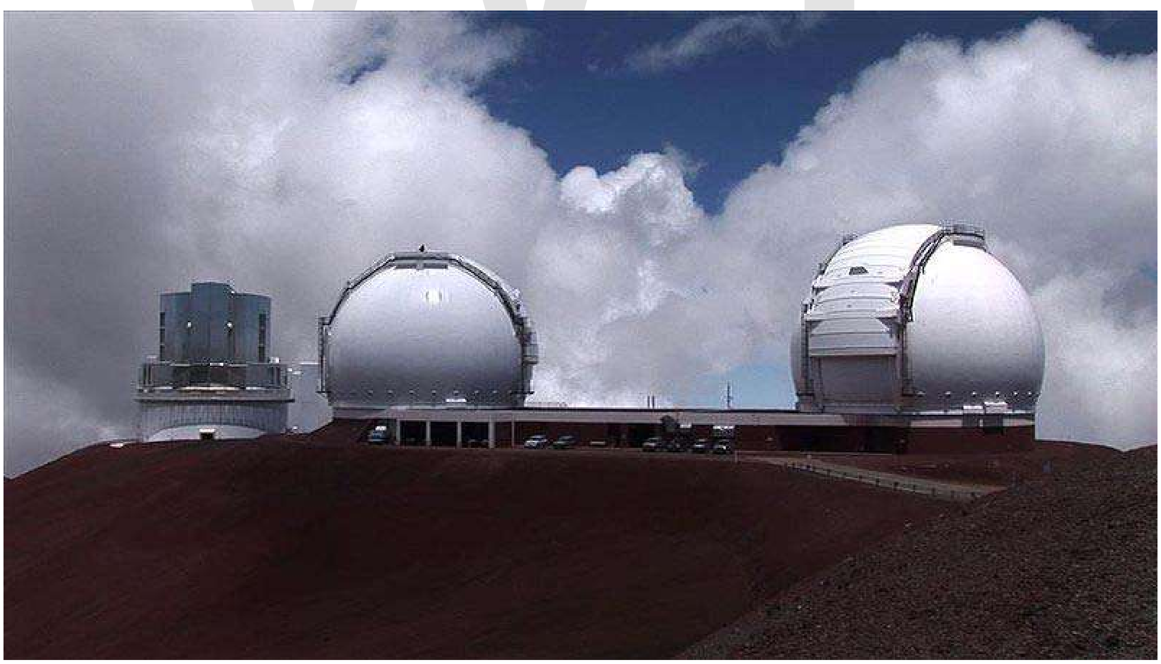
An Atlas V 551, such as this one launching the New Horizons probe, is one of the possible launch vehicles for SIM.

The launch date for the SIM Lite mission has been pushed back at least five times. At the program's outset, in 1998, the launch was scheduled for 2005. By 2000, the launch date had been delayed until 2009, a date that held through 2003; though some project scientists cited 2008 in late 2000. Between 2004 and 2006, contractor Northrop Grumman, the company designing and developing SIM, listed a launch date of 2011 on their website. With the release of the FY 2007 NASA budget, predictions changed again, this time to a date no earlier than 2015 or 2016. The delay of the launch date is primarily related to budget cuts made to the SIM Lite program. The 2007 change represented a difference of about three years from the 2006 launch date, outlined in NASA's FY 2006 budget as being two years behind 2005 budget predictions. Other groups predict dates matching officially predicted launch dates; the NASA Exoplanet Science Institute (formerly the Michelson Science Center) at the California Institute of Technology also sets the date at 2015. As of June 2008, NASA has postponed the launch date "indefinitely".

The launch date of the SIM mission cannot be predicted with any certainty. A May 2005 NASA operating plan put the mission into a replanning phase through the spring of 2006. No definitive mission schedule has been published on the SIM Lite website, maintained by the Jet Propulsion Laboratory (JPL), as of April 2007, aside from the estimated launch date of 2015. When the launch does occur it is planned to be via an Evolved Expendable Launch Vehicle (EELV), likely an Atlas V 521 or equivalent.

## Budget

SIM Lite is considered the flagship mission of NASA's Exoplanet Exploration Program (formerly known as the Navigator Program). According to the 2007 Presidential Budget for NASA, the program is, "a coherent series of increasingly challenging projects, each complementary to the others and each mission building on the results and capabilities of those that preceded it as NASA searches for habitable planets outside of the solar system." The program, in addition to the Space Interferometry Mission, includes the Keck Interferometer and the Large Binocular Telescope Interferometer. When originally approved in 1996, the mission was given a $700 million cap (in 1996 dollars) which included launch costs and five years of operation. The first contracts, for the preliminary architecture study, were worth $200,000 each.



The telescopes at the Keck Observatory are used as the Keck Interferometer, another of NASA's Exoplanet Exploration programs to suffer budget cuts in 2007.

NASA's budget outlined plans for the three projects for fiscal year (FY) 2007. Of the three missions, SIM Lite was delayed further and the Keck Interferometer saw budget cuts. The 2007 NASA budget stipulated, "SIM Phase B activity will continue while new cost and schedule plans are developed, consistent with recent funding decisions." The funding decisions included a US$118.5 million cut over the FY 2006 NASA budget request for the Exoplanet Exploration Program. The budget also laid out projections for the program through the year 2010. Each year will have successive funding cuts, if compared to the 2006 request numbers. Starting with FY 2008, the Exoplanet Exploration Program will receive around $223.9 million less compared to 2006. The following years will have cuts of $155.2 million in 2009 and $172.5 million in 2010, compared to the 2006 request.

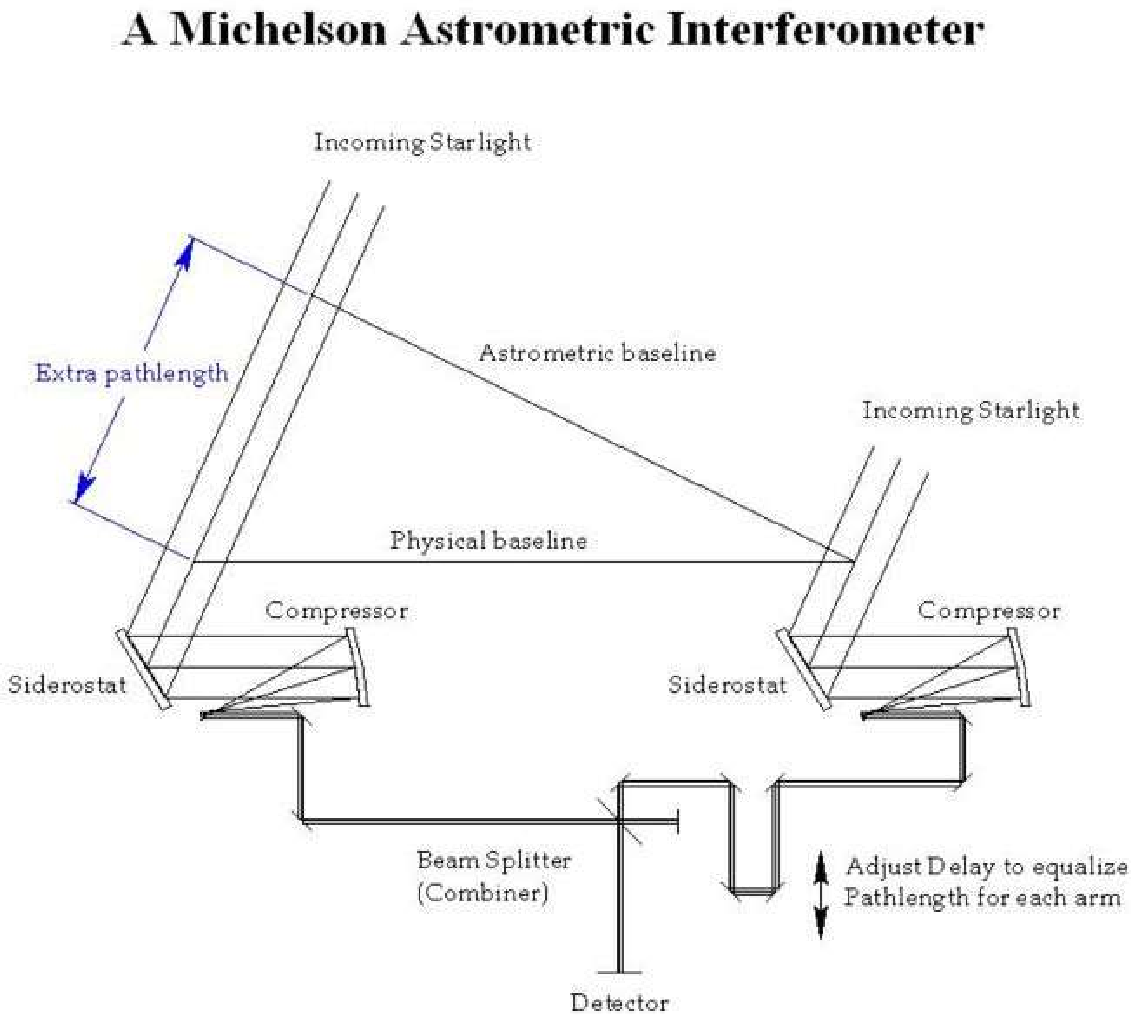
When SIM Lite entered what JPL terms "Phase B" in 2003 *Fringes: Space Interferometry Mission Newsletter*, called it a most important milestone on the way to a 2009 launch. The delays are budgetary in nature. In 2006, the mission received $117 million, an increase of $8.1 million over the previous year, but 2007 cuts amounted to $47.9 million less for the SIM program. In 2008, $128.7 million of the $223.9 million estimated to be cut from the Exoplanet Program budget will come from the SIM Lite mission. After an additional $51.9 million decrease in FY 2009, the program was reduced to $6 million in FY 2010 supplemented by substantial carryover from the previous year while awaiting the results of the Astronomy and Astrophysics Decadal Survey, Astro2010.

By February 2007 many of the budget cuts outlined in the FY 2007 budget were already being felt within the project. Engineers who worked on SIM were forced to find other areas to work in. A February 2007 editorial in the *Space Interferometry Mission Newsletter* described the situation as, "entirely due to budget pressures and priorities within the Science Mission Directorate at NASA (with) scientific motivation for the mission...as strong as ever." NASA, per the budget cuts, directed the SIM project to refocus its efforts toward engineering risk reduction. As of the February 2007 newsletter the plans for the refocus were in the process of being completed.

SIM Lite project status as of April 2009 and August 2009 can be found on the JPL SIM public web site in the form of two submissions to the National Research Council (NRC) Astronomy and Astrophysics Decadal Survey (Astro2010) Request for Information, Part 1 and Part 2. While these documents use a 2015 launch date for reference in communicating schedule and budget, NASA has not yet set a launch date for SIM Lite and will not do so until after the Astro2010 Decadal report is released in mid- to late 2010.

# Instruments

## Optical interferometry




How the Astrometric Interferometer works

Interferometry is a technique pioneered by Albert Michelson in the 19th century. Optical interferometry, which has matured within the last two decades, combines the light of multiple telescopes so that exquisitely precise measurements can be made, akin to what might be accomplished with a single, much larger telescope. It is the interaction of light waves, called interference, that makes this possible. Interference can be used to cancel out the glare of bright stars or to measure distances and angles accurately. The construction of the word partially illustrates this: interfere + measure = interfer-o-metry. At radio wavelengths of the electromagnetic spectrum, interferometry has been used for more than 50 years to measure the structure of distant galaxies.

The SIM Lite telescope functions through optical interferometry. SIM is composed of one science interferometer (50 cm collectors, 6 m separation [baseline]), a guide interferometer (30 cm collectors, 4.2 m baseline), and a guide telescope (30 cm aperture). The sophisticated guide telescope stabilizes instrument pointing in the third dimension. The spacecraft's operational limiting magnitude goes down to 20 at 20 millionths of an arcsecond (μas) and its planet-finding, astrometric accuracy of 1.12 μas is for single measurements. The accuracy of its global, all-sky astrometric grid is 4 μas.

SIM's design since 2000 consists of two light collectors (strictly speaking, they are Mersenne telescopes) mounted on opposite ends of a six-meter structure. The observatory will be able to measure the small wobbles in stars and detect the planets causing them down to one Earth mass at distances up to 33 light years (10 parsecs) from the Sun.

## Chapter- 8

# Vikrant Class Aircraft Carrier

Vikrant class carrier

| Class overview | |
|---|---|
| Name: | Project 71 (Vikrant class aircraft carrier) |
| Builders: | Cochin Shipyard Limited |
| Operators: | Indian Navy |
| Built: | 2008- |
| In commission: | CV-01 in 2014/2015 and CV-02 in 2017/2018 |
| Building: | 2 |
| Planned: | 3 |
| **General characteristics** | |
| Class and type: | *Vikrant Class* |
| Type: | Aircraft Carrier |
| Displacement: | • CV-01 40,000 tonnes<br>• CV-02 65,000 tonnes<br>• CV-03 ?? tonnes |
| Length: | 262 metres (860ft) |
| Beam: | 60 metres (197ft) |
| Draught: | 8.4 metres (28ft) |

| | |
|---|---|
| Propulsion: | 4 General Electric LM2500+ gas turbines, driving four shafts. |
| Speed: | 28 knots |
| Range: | 7,500 nautical miles |
| Complement: | 1,400 (incl air crew) |
| Armament: | 4x Otobreda 76 mm and various point defence SAM and CIWS |
| Aircraft carried: | 29 Mikoyan MiG-29K + HAL Tejas<br>+ 10 Ka-31 'Helix' or HAL Dhruv |

The ***Vikrant* class aircraft carriers** (formerly, the Project 71 "Air Defence Ship" (ADS)) are the first aircraft carriers of the Indian Navy to be designed and built in India. They are being built by Cochin Shipyard Limited (CSL).

The *Vikrant class* carriers will be the largest warships built by CSL. Work on the lead vessel of the class started in 2008, and the keel was laid in February 2009. In 2007, eighty percent of work on the carrier was expected to be completed before a launch in 2010, but by October 2010 only two of the 21 blocks had been completed. The first carrier of the class was expected to enter service by 2012, but was delayed by a year reportedly due to the inability of Russia to supply the AB/A grade steel. As a result, Steel Authority of India Limited (SAIL) created facilities to manufacture the steel in India. In August 2009, the military purchasing publication *Defence Industry Daily* reported that the service date had slipped to at least 2015. CSL expects the Navy to place the order for the second carrier of the class 2010, and work is planned to begin in 2010.

# History

India announced in 1989, a plan to replace the aging British-built carriers with two new 28,000 ton aircraft carriers. The first vessel was to replace the Vikrant, which was set to decommission in early 1997. Construction was to start at the Cochin Shipyard (CSL) in 1993 after the Indian Naval Design Organisation had translated this design study into a production model. In 2001, CSL released a graphic showing the 32,000-ton STOBAR (Short Take-Off But Arrested Recovery) design with a pronounced ski jump. Though the proposal to build a 20,000 ton Air Defence Ship (ADS) had been in the pipeline since the early 1990s, it received formal government approval only in January 2003. By that time, the vessel had doubled in displacement, to a 37,500 ton warship that would carry jet fighters like the MiG-29K and not the Sea Harriers as first planned. In August 2006 the Chief of Naval Staff Admiral Arun Prakash stated that the designation for the vessel had been changed from Air Defence Ship (ADS) to Indigenous Aircraft Carrier (IAC). The misnomer ADS was adopted by the navy to ward off objections to the Navy going in for an aircraft carrier, especially by the IAF when the SU-30s were being acquired.

The design and construction of a carrier is a technical complexity which far outstrips any such challenge faced hitherto by the Indian Navy. The earlier planned displacement of

37,000 tons was increased to 40,000 tons due to design changes. The length of the ship also increased from 252 metres (827 ft) to 260 metres (853 ft).

## Design

The first carrier will feature a ski-jump in STOBAR (Short Take-Off But Arrested Recovery) configuration. The deck is designed to enable aircraft such as the MiG-29 and smaller to operate from the carrier.

The *Vikrant class* is designed to deploy up to 40 aircraft, primarily the Mikoyan MiG-29K and the HAL Tejas Mark 2, including 10 Kamov Ka-31 or HAL Dhruv helicopters.

The naval version of HAL Tejas is hoped to be ready by the time *INS Vikrant* is commissioned.

## Status

Mikoyan MiG-29K

The keel for the lead vessel of the class, *INS Vikrant*, was laid by the defence minister A.K Antony at the Cochin Shipyard on 28 February 2009. The ship will use modular construction. A total of 874 blocks will be joined together to speed up the building process. By the time the keel was laid, 423 blocks weighing over 8,000 tons, were completed.

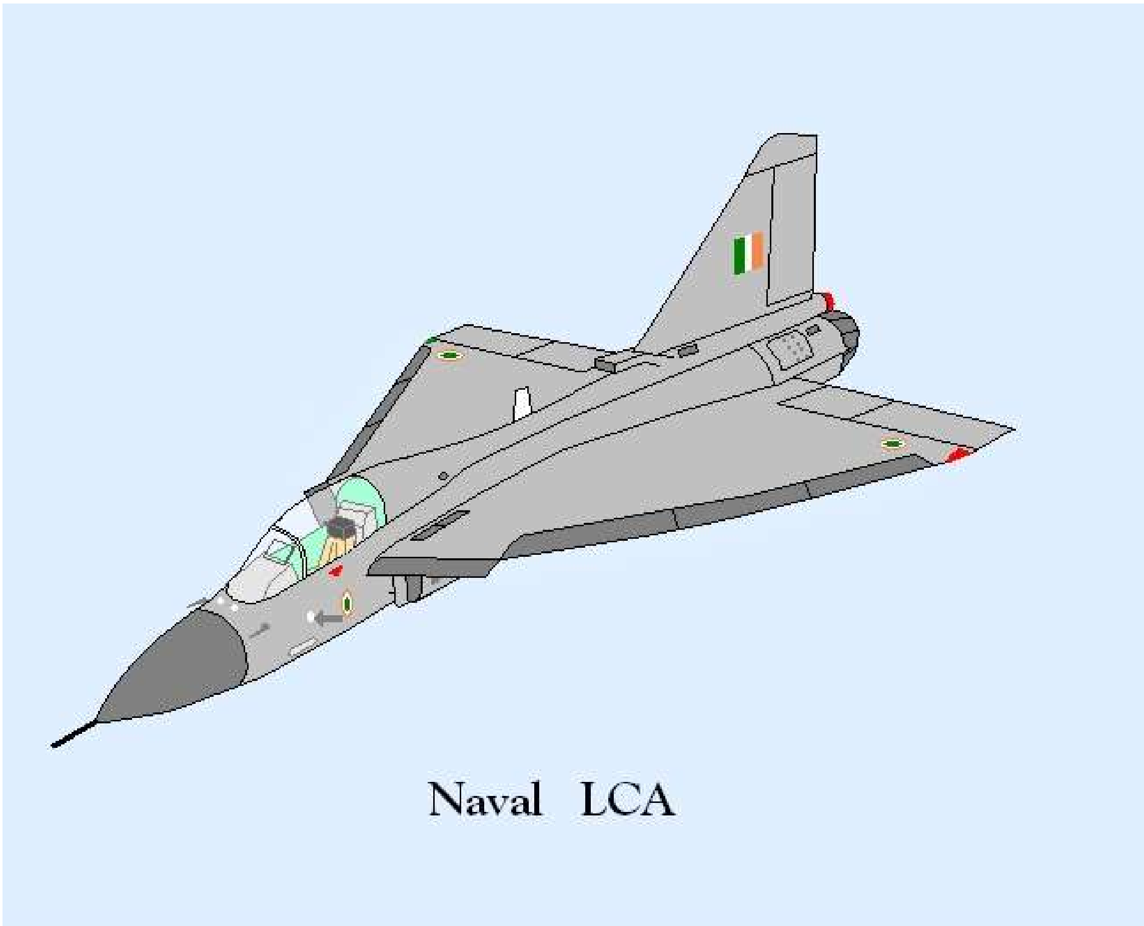
The vessel will be launched in 2010 when it would have completed some 20,000 tonnes, including the hull, as it cannot be launched at a higher displacement from the building bay. After about a year's development in the refit dock, it will be launched again when all major components and everything underwater would be in place. Only outfitting would then remain. As per the CCS (Cabinet Committee on Security) plan, sea trials were initially planned to commence in 2013, with the ship to be commissioned in 2014.

The order for the second aircraft carrier in the series is expected to be placed by 2010. The second carrier is planned to be inducted into the Indian Navy by 2017. The second aircraft carrier is said to be of higher tonnage of 65,000 tons and will utilise steam catapults. A 65,000-tonne IAC-II is on the drawing board. ''It will be much bigger and capable of operating fighters, AEW (airborne early-warning) aircraft, tankers etc,'' Admiral Verma said.There are plans of constructing at least 3 Vikrant class carriers

## Ships in class

| Name | Pennant | Tonnage | Laid down | Launched | Sea trials | Commissioning | Details |
|---|---|---|---|---|---|---|---|
| INS Vikrant | | 40,000 | Feb 2009 | | *2013* | *2014* | Conventional-powered STOBAR carrier |
| INS *Vishal* | | 65,000 | *Mid 2011* | | *2015* | *2017* | Conventional-powered CATOBAR carrier |

## Aircraft




Computer graphics of Tejas naval variant

It has not been confirmed what aircraft IAC1 will carry. On 18 January 2010, it was reported that India and Russia were close to signing a deal for 29 Mig 29k fighters to operate from IAC1. In addition,the navy signed a deal for six naval HAL Tejas.

IAC2 could have a CATOBAR layout, because IN showed interest in the new US Electromagnetic Aircraft Launch System . Among the five aircraft for which the Indian Navy has sent Requests for Information (RFI) are the F-35C, the carrier-based variant of the F-35 Lightning II , the F/A-18E/F Superhornet (made by Boeing for the US Navy), Eurofighter Typhoon (EADS supported by a European consortium), Sukhoi for Sukhoi Su-33, SAAB for Sea Gripen (version of Gripen adapted for carrier operations) and France’s Dassault Aviation for the Rafale.

India’s biggest military hardware supplier, Russia, which was asked for information on the Sukhoi Su-33, has opted out of the race saying it is phasing out the plane, a navy source told The Telegraph.

The Indian Navy had originally not sent an RFI to Sweden's SAAB but the company expressed interest and has sent a request for the naval variant of the Gripen JAS 39.

Chapter- 9

# Other Applications of Future Technologies



# Aditya (spacecraft)

| Aditya | |
|---|---|
| **Operator** | Indian Space Research Organisation |
| **Mission type** | Solar study |
| **Satellite of** | Earth |
| **Launch date** | 2012 from Sriharikota, India |
| **Launch vehicle** | GSLV |
| **Mass** | 100 kg |

**Aditya**, (Sanskrit: आदित्य, lit: Sun ) is a space craft whose mission is to study the Sun. It was conceptualised by the *Advisory Committee for Space Research* in January 2008. It has been designed and will be built and launched by the Indian Space Research Organisation (ISRO). ISRO Chairman G. Madhavan Nair announced the approval of this mission on 10 November 2008.

## Spacecraft

Aditya is proposed to be sent to space by 2012 to study the solar corona. This part of the Sun has temperatures of over one million degrees, with raging solar winds that reach a velocity of up to 1000 km a second. The satellite will carry as its payload an advanced solar coronagraph.

It will be a small 100 kilograms (220 lb) satellite projected to cost about ₹50 crore (US$10 million), and likely to be placed into a near earth orbit of 600 km. The spacecraft's mission will be to study the fundamental problems of coronal heating, and other phenomena that take place in the Earth's magnetosphere.

## Objectives

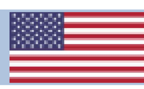
- to study the Coronal Mass Ejection (CME)
- to study the crucial physical parameters for space weather such as the coronal magnetic field structures, evolution of the coronal magnetic field etc.

## Progress

This is one of the first scheduled projects in a road map formulated by the Advisory Committee for Space Research. .A working group of individuals from the ISRO Satellite Centre, Udaipur Solar Observatory, Indian Institute of Astrophysics, Radio Astronomy Centre, National Centre for Radio Astrophysics, and several universities. was constituted to work out the optimum configuration for the coronagraph, among other parameters. The design of solar coronograph has been completed by Indian Institute of Astrophysics.

ISRO is working on development of sensors and thermal structures of the satellite after which a prototype of the satellite is expected to be built by 2011.

# USS *America* (LHA-6)

| **Career (United States)** |  |
|---|---|
| Name: | USS *America* |
| Namesake: | America |
| Awarded: | 1 June 2007 |
| Builder: | Northrop Grumman Ship Systems |
| Laid down: | 17 July 2009 (Ceremony) |
| Sponsored by: | Lynne Pace |
| Commissioned: | 2013 (estimated) |
| **General characteristics** | |
| Class and type: | *America*-class amphibious |

| | |
|---|---|
| | assault ship |
| Displacement: | 45,000 tons |
| Aircraft carried: | up to 36 fighters and helicopters |

The **USS *America* (LHA-6)** will be the first of the *America*-class amphibious assault ships for the U.S. Navy, and she will be the fourth American warship to bear this name. The *America*-class will replace the last of the *Tarawa*-class amphibious assault ships. Based upon the USS *Makin Island* (LHD-8) design, the USS *America* will be a gas-turbine powered warship capable of carrying a Marine Expeditionary Brigade with the capacity for carrying many Marine helicopters, V-22 Osprey tilt-rotor aircraft, and F-35B V/STOL Joint Strike Fighters. This warship is due to be delivered to the Navy in 2012. At a displacement of 45,000 tons, and carrying a complement of F-35 Joint Strike Fighters, it will be able to serve in the role of a small aircraft carrier, as demonstrated by Landing Helicopter Dock operations in Operation Iraqi Freedom.

The U.S. Navy awarded Northrop Grumman Corporation's Ingalls Shipyard Division a $2.4 billion fixed-price incentive contract for the detailed design and construction of the new amphibious assault ship, USS *America* (LHA-6). Work will be performed primarily at the company's shipyard in Pascagoula, Mississippi, and her delivery to the Navy is scheduled for 2012.

The USS *America* will replace one of the aging *Tarawa*-class warships of amphibious assault ships. Like current LHAs and LHDs, an *America*-class ship will be able to operate as a flagship for an expeditionary strike group or amphibious ready group. Many warships of this type may also play a key role in the Maritime Pre-Positioning Force (Future).

The USS *America's* design modifications (as compared with the USS *Wasp-class*) optimize aviation operations and support activities. Removal of the well deck for landing craft provides for an extended hangar deck with two significantly-wider high bay areas, each fitted with an overhead crane for aircraft maintenance. Other enhancements include a reconfigurable command and control complex, an on-board hospital, additional aviation fuel capacity, and numerous aviation support spaces. These changes were required in order to operate the F-35B and MV-22 which are considerably larger than the aircraft they replace.

Current Under Secretary of the Navy Robert O. Work had previously questioned the utility of the well deck-less *America*, given the failure of the Landing Platform Helicopter concept when tested off Lebanon in the late 1970s, however *America* will have over twice the mass of the old USS Iwo Jima (LPH-2).

Christopher P. Cavas writes that with the cancellation of the EFV and the delay and possible cancellation of the F-35B the Navy may have to reconsider building any more ships in this class.

# E657 series

| E657 series | |
|---|---|
|  | |
| Artist's rendering of E657 series train | |
| **In service** | Spring 2012 (scheduled) |
| **Replaced** | 651 series, E653 series |
| **Number under construction** | 160 vehicles on order (16 sets) |
| **Formation** | 10 cars per trainset |
| **Capacity** | 600 (Green: 30, Standard: 570) |
| **Operator** | JR East |
| **Specifications** | |
| **Car body construction** | Aluminium alloy |
| **Maximum speed** | 130 km/h (80 mph) |
| **Electric system(s)** | 1,500 V DC / 20 kV AC |
| **Current collection method** | Overhead catenary |

| | |
|---|---|
| **Gauge** | 1,067 mm (3 ft 6 in) |

The **E657 series** (E657系?) is an AC/DC dual-voltage electric multiple unit on order by East Japan Railway Company (JR East) in Japan for use on limited express services between Ueno in Tokyo and Iwaki on the Jōban Line from spring 2012.

A total of 160 vehicles are on order, formed as sixteen 10-car sets. These will replace the 651 series and E653 series EMUs currently used on *Super Hitachi* and *Fresh Hitachi* limited express services on the Jōban Line. The first trains are scheduled to be introduced from spring 2012, with the entire fleet in operation by autumn 2012.

## Design

The front end design is derived from the earlier *Super Hitachi* 651 series trains, and the pale pink body colour with red lining is intended to evoke an image of the *ume* plums for which the area served by the trains is famous.

The end cars and Green cars will feature full active suspension for improved ride quality, and yaw dampers will be fitted between cars.

## Formation

Each unit will consist of ten cars, with six cars motored.

## Interior

Internally, Green car (first class) accommodation will be in 2+2 abreast configuration with a seat pitch of 1,160 mm. Standard class will be arranged 2+2 with a seat pitch of 960 mm, compared to 970 mm for *Super Hitachi* 651 series trains and 910 mm for *Fresh Hitachi* E653 series trains.

AC power outlets will be provided at each seat, and WiMAX wireless broadband internet access will be available. The trains will include wheelchair-accessible toilets and security cameras.

# Intelsat 20

| Intelsat 20 | |
|---|---|
| **Operator** | Intelsat |
| **Major contractors** | Space Systems Loral |

| | |
|---|---|
| **Bus** | LS-1300 |
| **Mission type** | Communications |
| **Launch date** | 2012 |
| **Mission duration** | 15 years |
| **Orbital elements** | |
| **Regime** | Geostationary |
| **Orbital period** | 24 hours |
| **Longitude** | 68.5º East |
| **Transponders** | |
| **Transponders** | 28 IEEE C-band<br>46 IEEE Ku-band |
| **Coverage area** | Asia-Pacific<br>Asia<br>Africa<br>Middle East |

**Intelsat 20** is a geostationary communications satellite which is to be operated by Intelsat. It is currently being constructed by Space Systems Loral, and is based on the LS-1300 satellite bus. It will be launched in 2012, and will replace the Intelsat 7 and Intelsat 10 spacecraft at 68.5º East longitude.

Intelsat 20 will carry 28 IEEE C-band (NATO G/H-band), and IEEE Ku-band (NATO J-band) transponders. The C-band payload will cover the Asia-Pacific region, whilst the Ku-band transponders will be used for Direct to Home broadcasting to Asia, Africa, and the Middle East.

# Intelsat 21

| **Intelsat 21** | |
|---|---|
| **Operator** | Intelsat |
| **Major contractors** | Boeing Satellite Systems |
| **Bus** | BSS-702B |
| **Mission type** | Communications |

| | |
|---|---|
| **Launch date** | 2012 |
| **Mission duration** | 15 years |
| **Orbital elements** | |
| **Regime** | Geostationary |
| **Orbital period** | 24 hours |
| **Longitude** | 58º West |
| **Transponders** | |
| **Transponders** | 40 IEEE C-band<br>40 IEEE Ku-band |
| **Coverage area** | Canada<br>United States<br>Latin America<br>Caribbean<br>Europe |

**Intelsat 21** is a new satellite under construction by Boeing Space Systems for the Intelsat Corp. It is scheduled for launch in 2012, and will replace the Intelsat 9 satellite at 58º West Longitude.

# Intelsat 22

**Intelsat 22** is a new satellite under construction by Boeing Space Systems for the Intelsat Corp. The satellite is planned to be located at 72 degrees East Longitude over the Indian Ocean.

The Australian Defense Force (ADF) has signed a $167 Million contract with Intelsat for the UHF payload on the Intelsat 22 satellite. The contract is for 15 years of service.

## Communications Payloads

Intelsat 22 will have a three distinct communications payloads. A 48 channel C-band payload with 36 MHz channels, a 24 channel Ku-band payload with 36 MHz channels, and a 18 channel UHF payload with 25 kHz channels.

### C-band payload

The Intelsat 22 C-band payload consists of 48 operational 36 MHz channels. Two antennas will provide service to the Africa and Asia regions. There is some cross connect capability between the two regions.

### Is-22 Ku-band payload

The Intelsat 22 Ku-band payload consists of 24 operational 36 MHz channels with coverage for the Middle East, Africa, and Europe.

### Intelsat 22 UHF payload

The UHF payload consists of 18 operational 25 kHz channels which is being added to the Intelsat 22 satellite as a result of the contract with ADF.

## Launch

The launch of Intelsat 22 is currently planned for the first quarter of 2012.



# Ivar Huitfeldt class frigate

| Class overview | |
|---|---|
| Builders: | Odense Staalskibsværft |
| Operators: | Royal Danish Navy |
| Preceded by: | *Niels Juel*-class corvette |
| Built: | 2008-2011 |
| In commission: | 2012 onwards |
| Building: | 3 |
| Planned: | 3 |
| **General characteristics** | |
| Type: | Air defence frigate |
| Displacement: | 6,645 tonnes (full load) |
| Length: | 138.7 metres (455 ft) |
| Beam: | 19.75 metres (64.8 ft) |
| Draft: | 5.3 metres (17 ft) |
| Propulsion: | Four MTU 8000 20V M70 |

| | |
|---|---|
| | diesel engines, 8 MW each. |
| Speed: | 28 knots (52 km/h; 32 mph) |
| Range: | 9,000 nautical miles (17,000 km) at 15 knots (28 km/h; 17 mph) |
| Complement: | 165 |
| Crew: | 101 |
| Sensors and processing systems: | 1 Thales Nederland SMART-L long-range air and surface surveillance radar<br><br>1 Thales Nederland APAR air and surface search, tracking and guidance radar (I band)<br>Atlas ASO 94 sonar<br>4 Saab CEROS 200 fire control radars<br>ES-3701 Tactical Radar Electronic Support Measures (ESM) |
| Electronic warfare and decoys: | 4 × 12-barrelled Terma DL-12T 130 mm decoy launchers<br>2 × 6-barrelled Terma DL-6T 130 mm decoy launchers<br>Seagnat Mark 36 SRBOC |
| Armament: | 4 x VLS with up to 32 SM-2 IIIA surface-to-air missiles (Mk 41 VLS)<br>3 × VLS with up to 36 RIM-162 ESSM/RIM-7 Sea Sparrow (Mk 56/Mk 48 VLS)<br>8-16 × Harpoon Block II SSM<br>1 × Oerlikon Millennium 35 mm Naval Revolver Gun System CIWS 2 x Otobreda 76 mm<br>MU90 Impact ASW torpedoes<br>4 × Stinger Point-defence SAM |
| Aircraft carried: | 1 × EH-101 |
| Aviation facilities: | Aft helicopter deck and hangar |

The ***Iver Huitfeldt* class** will be a three-ship class of frigates entering service with the Royal Danish Navy in 2012 and 2013.

## Background

The class is built on the experience gained from the *Absalon*-class command and support ships, and by reusing the basic hull design of the *Absalon* class the Royal Danish Navy have been able to construct the *Iver Huitfeldt* class considerably cheaper than comparable ships. The frigates are compatible with the Danish Navy's StanFlex modular mission payload system used in the *Absalons*, and are designed with slots for six modules.

While the *Absalon* class ships are primarily designed for command and support roles, with a large ro-ro deck, the planned three new *Iver Huitfeldt* frigates will be equipped for a fighting role, and the potential to use Tomahawk cruise missiles, a first for the Danish Navy.

## Anti-air warfare

These ships share their Anti-Air Warfare suite with the Royal Dutch Navy's De Zeven Provinciën class frigates and the German Navy's Sachsen class frigates. The sensors of this suite include the long range surveillance radar SMART-L and the multi-function radar APAR. The SMART-L and APAR are highly complimentary, in the sense that SMART-L is a L band radar providing very long range surveillance while APAR is an I band radar providing precise target tracking, a highly capable horizon search capability, and missile guidance using the Interrupted Continuous Wave Illumination (ICWI) technique, thus allowing guidance of 32 semi-active radar homing missiles in flight simultaneously, including 16 in the terminal guidance phase. The primary anti-air weapons are the point defence Evolved Sea Sparrow Missile and the area defence SM-2 IIIA. The Mk 41 Vertical Launch System is used to house and launch these missiles. Up to 36 Evolved Sea Sparrow Missile and 32 SM-2 IIIA may be carried.

## Ship list

The three ships will be named HDMS *Iver Huitfeldt* (F361), *Peter Willemoes* (F362) and *Niels Juel* (F363).

# Kuafu

**Kuafu** project (simplified Chinese: 夸父计划; traditional Chinese: 夸父計劃; pinyin: *Kuāfù Jìhuà*), is a Chinese space project to establish a space weather forecast system composed of three satellites to be completed by 2012.

One of these satellites will be placed at the Sun-Earth Lagrangian Point L1 and the other two in polar orbits.

# LEO (spacecraft)

### LEO - Lunar Exploration Orbiter

| | |
|---|---|
| **Operator** | German Aerospace Center |
| **Mission type** | Orbiter |
| **Satellite of** | **Moon** |
| **Launch date** | 2012 |
| **Mission duration** | 4 years |
| **Mass** | ca. 650 kg (Main- and sub-satellite) |
| | **Orbital elements** |
| **Periapsis** | 50 km |

**LEO** (**L**unarer **E**rkundungs**o**rbiter - engl.: Lunar Exploration Orbiter) is the name of a proposed, but currently indefinitely postponed, German mission to the Moon, announced by the German Aerospace Center (*Deutsches Zentrum für Luft- und Raumfahrt e.V.*) Director Walter Doellinger on March 2, 2007.

Precise characteristics of the mission were announced in early 2008, and estimated costs are €350 million (~$514 million) over five years, however the mission will involve a lunar orbiter that DLR intends to build and launch in 2012 to map the lunar surface.

It would be the first German mission to the Moon and the first European mission to the Moon since SMART-1.

Because the needed money for the year 2009 will not be available on time, the start of the project was delayed indefinitely.

Numerous leading German planetologists, among them Gerhard Neukum, Ralf Jaumann and Tilman Spohn, have condemned the indefinite postponement and argue for resuming the LEO-project.

## Design

The main satellite will weigh about 500 kilograms and is accompanied by a small sub-satellite, which weighs about 150 kilograms. The intended orbital altitude is about 50 km.

Experiments will measure lunar gravitational and magnetic fields.

The main satellite will carry a microwave radar to probe beneath the lunar surface up to a depth of a few hundred meters. At maximum depth the radar will be able to resolve structures up to two meters.

## Science objectives

The duration of the mission around the Moon will be four years, during which the entire surface will be charted for the first time. The survey is to be three-dimensional and in colour.

"The probe will examine the moon's surface and provide indications of significant geological formations that could later be of interest for drilling," Doellinger said.

The probe will also investigate the moon's magnetic and gravity fields, look for water and analyse the minerals on its surface. It will use the best camera currently available, the best radar sensors and unique spectrum sensors for measuring the mineral composition.



# SELENE-2

**SELENE-2**

| | |
|---|---|
| **Operator** | JAXA |
| **Mission type** | Orbiter \ lander \ rover |
| **Satellite of** | The Moon |
| **Launch date** | ~2015 |
| **Launch vehicle** | H-2A |
| **COSPAR ID** | SELENE2 |

**Mass** 30-kilogram rover

**SELENE-2**, or the **Sel**enological and **En**gineering **E**xplorer **2**, is a proposed Japanese moon lander to be launched sometime before the middle of the decade as a successor to the 2007 Kaguya (SELENE) moon orbiter.

## Penetrators

One option JAXA was investigating in 2006, was to integrate a small data relay satellite and penetrators into the mission.

# Sentinel 2

**Sentinel 2** is a future space mission from ESA, the second in GMES program. It will provided multispectral earth observation data. It is design for data continuity of Landsat and SPOT-type missions. It is foreseen a launch date around 2012.

## Mission characteristics

- **Role**: Earth Observation
- **Launch date**: 2012
- **Launch mass**: ~1100 kg
- **Launcher**: Vega or Soyuz/Kourou
- **Launch location**: French Guiana
- **Orbit**: Sun-synchronous
- **Altitude**: 786 km
- **Orbit cycle**: ~100 minutes
- **Nominal duration**: 7.25 years

## Instruments

Sentinel 2 spacecrafts are designed to carry a single multi-spectral instrument.

# Sentinel 3

**Sentinel 3** is a future space mission from ESA, the third in the GMES program. It will provided medium resolution optical and radar altimetry Earth observation data. It is design for data continuity of ERS and Envisat missions, with coverage and instrument performance improvements. A launch date around 2013 is foreseen.

## Mission characteristics

- **Role**: Earth Observation
- **Launch date**: 2013
- **Launch mass**: ~1250 kg
- **Launcher**: Vega or Soyuz/Kourou
- **Launch location**: French Guiana
- **Orbit**: Sun-synchronous
- **Altitude**: 800 km
- **Orbit cycle**: ~100 minutes
- **Nominal duration**: 7.25 years

## Instruments

- Ocean and Land Colour Instrument
- Sea and Land Surface Temperature Instrument
- Radar Altimeter
- Microwave Radiometer
- GNSS receiver
- Laser retroflector

## Applications

- Sea and land colour data
- Sea and land surface temperature
- Sea surface topography data

# Solo (car)

**Solo** is a Hungarian hybrid car prototype presented in summer 2008 and planned to enter mass production by 2012. It can reach 140 kilometres per hour, and consumes between 1.5 and two litres per 100 kilometres, has solar panels and foot pedals as auxiliary power sources, and can run on bio fuels. It is expected to not cost more than an average city car.

According to manufacturing company Antro Group's website carbon dioxide emissions of the prototypes Solo (3 seats) and Duo (six seats) will be 4,5-6.3 kg per 100 km (while the most modern car existing has CO2 emissions of 9-14 kg on 100 km, according to the same website), owing to minimum mass and air resistance. The smaller of the first two planned models SOLO weights 350 kg, family size DUO approximately 700 kg. (Part of the idea is to make the SOLO modular so that it can be linked to another vehicle to form a six-seater, thus creating a DUO out of two SOLOs.) Antro's prototype has been built using a light magnesium alloy/carbon fiber frame and body construction. The ultra-light vehicle is powered by a combination gasoline engine and lithium ion batteries. "When burning vegetable oil, alcohol, or synthetic, renewable fuels, the amount of carbon dioxide released is equal to the amount the plant already absorbed during its growth as part of the agrienergetic cycle." Photovoltaic cells incorporated in the roof provide the power for the electric hub motors at each wheel and although the current model doesn't have one yet, the designers are aiming to install a fuel engine to give a longer range than the roughly 20 kilometres that the electric motors currently provide.

# Tokyo Metro 1000 series

| Tokyo Metro 1000 series | |
|---|---|
|  Artist's impression of 1000 series | |
| **In service** | Spring 2012– (scheduled) |
| **Replaced** | Tokyo Metro 01 series |
| **Number under construction** | 38 sets (on order) |
| **Operator** | Tokyo Metro |
| **Line(s) served** | Tokyo Metro Ginza Line |
| **Specifications** | |
| **Electric system(s)** | 600 V DC |
| **Current collection method** | 3rd rail |
| **Gauge** | 1,435 mm (4 ft 8 ½ in) |

The **Tokyo Metro 1000 series** (東京地下鉄1000系 *Tōkyō Chikatetsu 1000-kei*?) is an electric multiple unit train type on order by Tokyo Metro in Japan for use on the Tokyo Metro Ginza Line from spring 2012. The first set is scheduled to be introduced in spring 2012 with full-production sets entering service from 2013. The fleet of 38 Tokyo Metro 01 series sets is scheduled to be replaced by fiscal 2015.

## Design

The 1000 series will use newly developed bogies with steerable axles to reduce flange noise on sharp curves.

PMSM (permanent magnet synchronous motors) will be used, offering 20% energy savings compared to the VVVF inverter controlled motors used in earlier 01 series trains.

## Exterior

The trains will be painted lemon yellow, recreating the appearance of the original 1000 series trains introduced on the line in 1927.

Original 1000 series car preserved at Tokyo Subway Museum

## Interior

Internally, the new trains will feature pairs of 17-inch LCD passenger information displays above each door. Seat width will be increased from 430 mm to 460 mm. Luggage racks and strap handles will be lowered by 100 mm compared to the 01 series trains.

# HMS *Queen Elizabeth* (R08)

| Career (United Kingdom) |  |
|---|---|
| Ordered: | 20 May 2008 |
| Builder: | BAE Systems Surface Ships<br>Thales Group<br>Babcock Marine |

| | |
|---|---|
| Laid down: | 7 July 2009 |
| Homeport: | HMNB Portsmouth |
| Identification: | IMO number: 4907892 |
| Motto: | *Semper Eadem* ("Always the Same") |
| Status: | Expected to enter service in 2020 |
| **General characteristics** | |
| Class and type: | *Queen Elizabeth*-class aircraft carrier |
| Displacement: | 65,600 metric tons (72,300 short tons) (full load) |
| Length: | 284 metres (932 ft) |
| Beam: | 39 metres (waterline) 73 metres overall |
| Draught: | 11 metres |
| Decks: | 16,000 square metres |
| Speed: | 25+ knots |
| Range: | 10,000 nautical miles (18,520 km) |
| Capacity: | 1,450 |
| Complement: | 600 |
| Aircraft carried: | 40 aircraft, including up to 36 F-35 Lightning II |



**HMS *Queen Elizabeth*** will be the first of the Royal Navy's two new *Queen Elizabeth* class aircraft carriers and is scheduled to enter service in 2020. She will be the second ship to be called HMS *Queen Elizabeth*, after Queen Elizabeth I.

*Queen Elizabeth* and her sister ship (*Prince of Wales*) will be the first super-carriers and the largest warships ever built for the Royal Navy. They are multi purpose carriers that can adapt to complete multiple roles. Capable of carrying forty aircraft such as the F-35 Lightning II, Chinook or Merlin helicopters, they will provide a major capability upgrade from the current *Invincible* class carriers. Both ships of the class will be based at HMNB Portsmouth.

# Design and construction

On 25 July 2007 the then Defence Secretary Des Browne, announced the £3.8bn order for the two new carriers. On December 11, 2008, Defence Secretary John Hutton announced that the two ships would enter service one or two years later than the originally planned dates of 2014 and 2016. The in-service date was further extended to 2020 in The Strategic Defence and Security Review 2010.

Construction of *Queen Elizabeth* is, as of 2010, well under-way. The *Queen Elizabeth* class ships will be assembled in the Firth of Forth at Rosyth Royal Dockyard from nine blocks built in six UK shipyards; BAE Systems Surface Ships in Glasgow, Babcock at Appledore, Babcock at Rosyth, A&P in Newcastle, BAE at Portsmouth and Cammell Laird (flight decks) at Birkenhead.

Number One dry dock at Rosyth has been modified to accommodate one of the *Queen Elizabeth* class vessels at one time.

## Carrier Air Wing

The aircraft initially selected to be used on these carriers was the Short Take Off Vertical Landing (STOVL) variant of the F-35 Lightning II, known as the F-35B. However, on 19 October 2010, David Cameron announced that the UK would change their order to the carrier variant (F-35C) and that the carrier design would be modified to use a catapult launch and arrestor recovery (CATOBAR) system to allow for the launch and recovery of these aircraft.