DBR & AN/SPY-6(V) AMDR & EASR Radar & C4I

Status: New Development
System Type: Naval Radar & C4I

Program Briefing

The new ***Dual Band Radar (DBR)*** includes the ***AN/SPY-3 MFR (Multi-Function Radar)*** which was developed as the next-generation X-band multi-function air defense radar for the *Zumwalt* DDG-1000 class (was DD(X) land attack destroyer), as well as aircraft carriers and potentially other non-Aegis ships. It was to provide search, detect, track, and weapon control functions, with reduced manning and life-cycle costs compared to the multiple legacy radars that provide these functions today. The DBR was designed as a smaller, simpler, less capable radar than Lockheed Martin's AN/SPY-1 Aegis radar system, which includes ballistic missile defense (BMD) capabilities.

MFR concept development contracts were awarded to three teams in June 1997, and an EMD contract worth almost $300 million was won by Raytheon in 1999. But cancellation of the DD(X) predecessor DD-21 put the MFR behind schedule and over cost. It was not ready for its first planned platform, CVN-77, and is now planned primarily for the three DDG-1000 class destroyers and just one aircraft carrier (CVN-78).

In the DBR, the MFR was to operate in conjunction with the S-band ***AN/SPY-4 VSR (Volume Search Radar)***, the next generation over-the-horizon long range S-band (was L-band) 3D volume search radar. It was to be mounted in conjunction with the Navy's SPY-3 MFR as part of the DBR system, serving the same functions as the legacy AN/SPS-48 and SPS-49. In April 2004, Raytheon won a $78 million contract modification to switch the VSR program from L-band to S-band. Lockheed Martin is developing the S-band array.

But in June 2010, the Navy decided to remove the SPY-4 VSR from the DDG-1000 DBR in order to reduce costs as part of the Nunn-McCurdy certification process. The full DBR (MFR and VSR) will only be mounted on a single aircraft carrier, CVN-78, and plans in 2016 involved relatively near-term replacement of this full, lame-duck, DBR system. Following VSR removal from the DDG-1000 class, the SPY-3 MFR added software modifications to better perform volume search, but while optimized for volume search, horizon search capabilities will be limited, further decreasing DDG-1000 radar capability compared to the AN/SPY-1 Aegis system.

In January 2019, the US Navy commissioned the second *Zumwalt* class Destroyer, the USS *Michael Monsoor* (DDG-1001). The third and last, the USS *Lyndon B. Johnson*, was launched in December 2018 and will be commissioned in 2022.

The ***TSCE (Total Ship Computing Environment)*** data center comprises two ruggedized Electronic Modular Enclosures that house and protect the open architecture computing environment for DDG-1000's combat and ship control systems, and provide more data processing and storage capacity than existing US Navy destroyers. TSCE will manage the ship's advanced systems, including sensors.

The ***AN/SPY-6(V)1 Air and Missile Defense Radar (AMDR)*** is a next-generation radar system designed to provide ballistic missile defense (BMD), air defense, and surface warfare capabilities. AMDR was initially being developed to support theater air and missile defense requirements as part of the next generation cruiser (CG(X)) radar suite, with a special emphasis on BMD. But following CG(X) cancellation, by early 2013 the AMDR was planned to "initially support" the *Arleigh Burke* follow-on DDG-51 Flight III destroyer, beginning with ships to be funded in 2016, with future expectations of AMDR "providing the foundation for a scalable radar architecture" to supplant the AN/SPY-1 Aegis for "multiple ship classes."

The very high-power AMDR will provide multi-mission capabilities, supporting long range, exo-atmospheric detection, tracking and discrimination of ballistic missiles, as well as area and self-defense against air and surface threats. The AMDR had originally been planned as a direct follow-on to the AN/SPY-1 Aegis radar, with greater capabilities, but in October 2009 the Navy announced a competition for a dual-band AMDR suite, similar to the DDG-1000's DBR, to consist of an ***S-band AMDR-S*** (volume search, tracking, BMD discrimination, and missile communications), an ***X-band AMDR-X*** (horizon search, precision tracking, missile communication, and terminal illumination), and a ***Radar Suite Controller (RSC)***.

In October 2013, Raytheon was awarded a $385.7 million contract for EMD through LRIP of the AMDR-S and RSC for the Flight III *Arleigh Burke* (DDG-51) class destroyers, beginning with DDG-118/119, with the ship itself to be funded in 2016. For now, Raytheon will integrate AMDR-S and RSC with the legacy AN/SPQ-9B X-band radar. The contract includes options which, if exercised, would bring the cumulative value to $1.6 billion.

In May 2018, the first Flight III *Arleigh Burke* guided-missile destroyer, the USS *Jack H. Lucas*, began construction at Huntington Ingalls Shipbuilding in Pascagoula, MS. The *Louis H. Wilson Jr.* is also under contract. In September 2018, ten new Flight III ships were approved for construction by the Navy – the *Ted Stevens*, *Jeremiah Denton*, and eight other unnamed ships.

In early 2019, the US Navy expected the SPY-6 to achieve initial operational capability (IOC) in 2023.

The Flight III *Arleigh Burke* guided-missile destroyers will have the Baseline 10 system. In March 2019, the US Navy awarded Raytheon a $402.6 million contract modification for three low-rate initial production (LRIP) SPY-6 AMDR systems to be deployed on DDG-51 Flight III destroyers.

The ***AN/SPY-6(V)2*** and ***SPY-6(V)3 Enterprise Air Surveillance Radar (EASR)*** will modify an existing radar technology (the AMDR…) to meet the air surveillance requirements for multiple ship classes, including forward-fit for the CVN-79+, LHA(R), and LX(R) classes, and potential back-fit to CVN, LHA, and LPD classes. EASR will be one sensor in a suite that is designed to meet the performance needs for ship self-defense, situational awareness, and air traffic control. EASR will replace the Volume Search Radar (VSR) in the CVN-78 class Dual Band Radar (DBR) system and the AN/SPS-48/49 radar systems in numerous ship classes.

The US Navy also plans to procure a separate X-band radar to compliment the EASR for both future carriers and large deck amphibious warfare ships.

In August 2016, the US Navy awarded Raytheon a $92 million contract to develop EASR, planned as the volume air search radar initially for the new *Gerald R. Ford* class aircraft carriers (CVN-78) beginning with the *John F. Kennedy* (CVN-79), and future big deck amphibious warships beginning with the planned LHA-8.

Following the EMD phase, there are up to $723 million in contract options to support 16 ship sets of the radar – 6 fixed-face for the *Ford* carriers and 10 for amphibious ships. If all the options are exercised the program is set to run through 2026.

In March 2019, Raytheon announced the SPY-6(V)2 EASR had completed subsystem testing. In June 2019, EASR systems-level testing began at Wallops Island, Virginia.

In June 2019, the US Navy released the final request for proposals (RfP) for the next-generation guided-missile frigate (FFG(X)) – which now is a very different (and even larger) beast than planned in 2016. In addition to the COMBATSS-21 system, the FFG(X) will primarily mount government-furnished equipment (GFE) for all its major sensors and systems. A fixed-face Raytheon Enterprise Air Surveillance Radar (EASR) will be required as the primary air search radar for all FFG(X)s (see *Littoral Combat Ship (LCS) & Frigate (FFG(X)) Radar & C4I* report for LCS/FFG(X) program details and FFG(X) EASR forecasts).

Enterprise X-Band Illuminator (EXI) funding will develop an X-band illuminator compatible with the EASR radar and Combat System suite. Funding will also integrate a missile illuminator for future CVN applications as well as other ship classes.

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(Raytheon was DD(X) Systems Integrator, responsible for radar integration and MFR development) (Lockheed Martin was developing the S-band VSR array [worth about 67% of VSR funding])

(By August 2016, Raytheon was prime for all three radar programs – DBR, AMDR, EASR – which now have much in common)

Functional Description

Configuration (Raytheon Website [2019])

According to information on Raytheon's website in July 2019, both EASR and AMDR are built with the same individual 'building blocks' called Radar Modular Assemblies (RMA). Each RMA is a self-contained radar in a 2'x 2'x 2' box. These individual radar RMAs can stack together to form various size arrays to fit the mission requirements of any ship.

The ***AN/SPY-6 Air and Missile Defense Radar (AMDR)*** is comprised of 37 RMAs – which is equivalent to the AN/SPY-1D(V) +15 dB in terms of sensitivity. To give this perspective, it means that SPY-6 can see a target of half the size at twice the distance of today's radars.

The SPY-6 radar will reportedly be "up to 30 times more sensitive than the older SPY-1D radars," but requires much more power. The Flight III destroyer will have a new power plant that converts 4,160-volt AC power into 1,000-volt DC power.

The ***Enterprise Air Surveillance Radar (EASR)*** is a 9 RMA configuration – which is equivalent to the sensitivity of the current SPY-1D(V) radar on today's destroyers, and at only 20% of the size of the legacy AN/SPS-48. These are considerable enhancements over the radars in service on current (and future) EASR-designated ship classes.

Two variants of EASR will be provided (each face an identical 9-RMA array):

- AN/SPY-6(V)2 (Designated radar for LHA-8 and LX(R); Planned for *Nimitz* class carriers) – Single face, rotating radar: Upgraded capability replacing SPS-48 and AN/SPS-49 air search radars; Primary sensor for ship self-defense and situational awareness
- AN/SPY-6(V)3 (Designated radar for CVN-78 *Ford* class carriers, starting with CVN-79; Planned for FFG(X) guided missile frigates) – Three face, fixed array radar: Upgraded capability replacing AN/SPY-4 Volume Search Radar (VSR); Primary sensor for ship self-defense, situational awareness, and air traffic control

EASR's commonality – in both hardware and software – with the SPY-6 AMDR offers a host of advantages, including performance, availability, and reliability, and maintenance, training, logistics, and lifecycle support. Its open architecture design enables maximum use of commercial-off-the-shelf components and the seamless and rapid insertion of future technology.

According to Raytheon, the EASR's performance and reliability are a direct result of more than 10 years of investment in core technologies, leveraging development, testing and production of high-powered Gallium Nitride (GaN) semiconductors, distributed receiver exciters, and adaptive digital beamforming. GaN components cost 34% less than Gallium Arsenide alternatives, deliver higher power density and efficiency, and have demonstrated a mean time between failures of an impressive 100 million hours.

Both variants of the radar have an extremely high predicted operational availability due to the reliable GaN transmit/receive modules, the low mean-time-to-repair, and a very low number of Line Replaceable Units. Designed for maintainability, standard LRU replacement in the RMA can be accomplished in under six minutes – requiring only two tools.

Configuration

The DDG-1000 was to mount the ***AN/SPY-3 Dual Band Radar (DBR)***, which will combine the functions formerly provided by five separate radar systems, reducing equipment and manpower costs. To provide as small a signature as possible to other ships, phased array radar antennas will be incorporated into the DDG-1000's composite superstructure (composite material cannot currently be identified by radar). The DBR will replace 6 to 10 legacy radar antennas and interfaces with one 6-faced radar (3 faces at X-band, 3 faces at S-band), controlled by one interface to the ship's command and control system.

The DBR consists of Raytheon's X-band AN/SPY-3 ***Multi-Function Radar (MFR)*** and the S-band ***Volume Search Radar (VSR)***, being developed primarily by Lockheed Martin under subcontract from Raytheon. Many search and track functions can be allocated to either frequency. Horizon search (to detect anti-ship cruise missiles) and precision track (to provide high update rate, fire control quality data) are examples. Since environmental phenomena affect different frequencies in different ways, the ability to bring both frequencies to bear increases performance during multipath and anomalous propagation. In addition, in situations where one band becomes taxed (such as when supporting multiple missiles in flight), the other band can effectively share the workload.

Phased array radar systems have done much to improve reliability, due to their absence of moving parts in the antenna. The DBR active electronically steered arrays have also been engineered to offer graceful antenna degradation, minimizing the possibility of system-wide or single-point antenna failures. However, nail that composite superstructure at the right spot and all ship radar is gone…. Built-in redundancy ensures system operability if radar component failures occur. The DBR is designed to operate 24/7 over a very long mission time at an operational availability better than 95%.

The DBR contains a robust fault detection/fault isolation system, which notifies the ship system of any required maintenance. Replacement of components for the DBR arrays, subsystems, computers and other ancillary equipment typically involves swapping out circuit cards, solid state transmit/receive integrated multichannel modules (TRIMMS), or other modular components, all of which keep potential down time to a minimum. Access to all antenna components is from the rear, which will permit servicing from within the ship. The DBR is being designed to require fewer than 100 hours of corrective and preventive maintenance per mission-year and has a mean time to repair (MTTR) of less than 30 minutes.

The DBR requires no dedicated operator and has no manned display consoles. The system automatically senses the complex man-made and natural environment and adjusts its processing accordingly. Specific tactical radar behavior is governed by doctrine, entered by a tactical action officer or sensor supervisor within the ship's Total Ship Computing Environment (TSCE) or host command and control system. Being fully automated, the DBR takes the reaction time associated with manual operator action out of the loop.

The only human interaction involves maintenance and repair activities, performed by technicians using a maintenance local area network (LAN) that allows them to take control of the radar and to run offline tests.

The DBR is the first radar for which complex signal and data processing is done entirely in a COTS computer. Computing products from IBM, Hewlett-Packard and Sun Microsystems all offer competitive solutions. All DBR software has been designed using object-oriented techniques and is written in the widely used C++ and Java languages. DBR software is fully interoperable with the ***TSCE (Total Ship Computing Environment)*** data center, an open architecture solution that integrates all of the ship's computer functions into a single enterprise network. The TSCE also serves as a basis for the Navy standard combat system, designed for fleet-wide use. The TSCE comprises two ruggedized Electronic Modular Enclosures.

For the BMD capability, increased ***Air and Missile Defense Radar (AMDR)*** sensitivity and bandwidth over the current AN/SPY-1 system is needed to detect, track and support engagements of advanced ballistic missile threats at the required ranges. For the area air defense and self-defense capability, increased sensitivity and clutter rejection capability is needed to detect, react to, and engage very low observable /very low flying (VLO/VLF) threats in the presence of heavy land, sea, and rain clutter. This effort provides for the development of an active phased array radar with the required capabilities to pace the evolving threat. Modularity of hardware and software, a designed-in growth path for technology insertion, and open architecture (OA) compliance are required for performance and technology enhancements throughout service life. The AMDR is planned to be very high power – 30-31 MW, versus 5 MW for the AN/SPY-1 Aegis radar.

The AMDR had originally been planned as a follow-on to the AN/SPY-1 Aegis radar, with greater capabilities, but in October 2009 the Navy announced further details of a competition for a dual-band AMDR suite, similar to the DDG-1000's DBR, to consist of an ***S-band AMDR-S*** (volume search, tracking, BMD discrimination, and missile communications), an ***X-band AMDR-X*** (horizon search, precision tracking, missile communication, and terminal illumination), and a ***Radar Suite Controller (RSC)***.

As of early 2013, The Navy and shipbuilders had determined that a 14-foot active radar is the largest that can be accommodated by the existing DDG-51, though AMDR is also being developed as a scalable design.

The ***Enterprise Air Surveillance Radar (EASR)*** will modify an existing radar technology (the AMDR…) to meet the air surveillance requirements for multiple ship classes, including forward-fit for the CVN-79+, LHA(R), and LX(R) classes, and potential back-fit to CVN, LHA, and LPD classes. EASR will be one sensor in a suite that is designed to meet the performance needs for ship self-defense, situational awareness, and air traffic control. EASR will replace the Volume Search Radar (VSR) in the CVN-78 class Dual Band Radar system and the AN/SPS-48/49 radar systems in numerous ship classes.

The SPS-48 Radars are long-range, three-dimensional (3D) radars used to search, detect, and provide space-stabilized, three-coordinate (range, bearing, height) data for air intercept control and designation to a weapon system. The AN/SPS-49A(V)1 radar system is a long range, two-dimensional (2D), L-Band air surveillance radar installed on USN major combatants. The AN/SPY-4 Volume Search Radar (VSR) is an S-Band active phased array radar deployed on CVN-78, providing volume surveillance and air traffic control.

EASR funding will develop a modern 3D air search radar that addresses the latest requirements for Aviation and Amphibious Warfare Ships and closely conforms to existing combat system interfaces, as well as aligns with existing shipboard space, weight, and power limits. The architecture and acquisition strategy for EASR is intended to drive a lower recurring cost by utilizing the same core technology for both fixed-face and rotating array variants. EASR will provide for engineering of component and system level technology improvements for equipment used by in service air search radars.

Following the EMD contract to Raytheon in August 2016, the Active Electronically Scanned Array (AESA) radar will be based on Raytheon's AN/SPY-6 S-band Air and Missile Defense Radar (AMDR) planned for the Navy's newest Flight III *Arleigh Burke*-class (DDG-51) guided missile destroyers. According to Raytheon, "It's using identical hardware, identical signal processing software, data processing software. It's as near identical as possible. The goal of the program to drive affordability and commonality…. Therefore EASR gets significant affordability off of AMDR SPY-6's larger [industrial] base."

The initial engineering development model (EDM) contract will develop two variants of EASR – a rotating variant for the amphibs and a fixed-face array for the CVNs. The testing program is planned to run to 2020.

Enterprise X-Band Illuminator (EXI) funding will develop an X-band illuminator compatible with the EASR radar and Combat System suite. Funding will also integrate a missile illuminator for future CVN applications as well as other ship classes.

Platforms

The ***DBR (MFR and VSR)*** was planned for the DD-21 (Surface Combatant for the 21st Century) class (now DDG-1000) and CVN-77. Due to development delays, DBR was only ready for the CVN-78. Due to cost overruns in the DDG-1000 program, the VSR was removed from the DDG-1000 class radar suite, which now only mounts the MFR.

The *Gerald R. Ford* (CVN-78) class carriers, along with the DDG-1000 *Zumwalt* class guided missile destroyer, were originally set to field the Raytheon-built Dual Band Radar. The DBR will be installed on the first-in-class *Gerald R. Ford* but the Navy has cancelled plans to install the DBR on the rest of the fleet after the *Zumwalt* class was truncated to three ships from a planned class of almost 30. Instead, future carriers will receive the EASR (see below).

Note that according to the Navy in February 2016, the VSR procured for DDG-1002 is being transferred to CVN-79, now to operate alongside the EASR radar (DDG-78 will keep its MFR, along with VSR, for the near-term). The first EASR was originally planned to be first installed on CVN-80 but was moved left after the delivery schedule for CVN-79 was shifted to a two-phase delivery. In 2015, then Program Executive Officer Carriers Rear Adm. Tom Moore said, "That gave me a little extra time. If I had to deliver CVN-79 in 2022 when it was originally designed, it wouldn't have had the radar on it…. The two-phased strategy gives me the lowest possible cost for the ship, and the radar is a big piece of that."

Following CG(X) cancellation, by early 2013 the ***Air and Missile Defense Radar (AMDR)*** was planned to "initially support" the *Arleigh Burke* follow-on DDG-51 Flight III destroyer, beginning with ships to be funded in 2016, with future expectations of AMDR "providing the foundation for a scalable radar architecture" to supplant the AN/SPY-1 Aegis for "multiple ship classes."

The ***Enterprise Air Surveillance Radar (EASR)*** is planned for forward-fit for the CVN-79+, LHA(R), and LX(R) classes, and potential back-fit to CVN, LHA, and LPD classes. EASR will replace the Volume Search Radar (VSR) in the CVN-78 class Dual Band Radar system and the AN/SPS-48/49 radar systems in numerous ship classes.

The first EASR was originally planned to be first installed on the future USS *Enterprise* (CVN-80) but was moved left after the delivery schedule for the *John F. Kennedy* (CVN-79) was shifted to a two-phase delivery. In 2015, then Program Executive Officer Carriers Rear Adm. Tom Moore said, "That gave me a little extra time. If I had to deliver CVN-79 in 2022 when it was originally designed, it wouldn't have had the radar on it…. The two-phased strategy gives me the lowest possible cost for the ship, and the radar is a big piece of that."

Variants/Related Systems

AN/SPS-48E—The Navy's current three dimension air search radar, to be produced for the LPD-17 class and CVN-76. It will be superseded by the MFR.

AN/SPY-2—The MFR has been referred to as the AN/SPY-2 by Lockheed Martin.

Specifications

	MFR (DBR)	*VSR (DBR)*
Frequency:	X-band	S-band
Antenna height:	107 in.	160 in.
Antenna width:	82 in.	152 in.
Antenna depth:	25 in.	30 in.
Antenna weight:	5,500 lbs.	22,500 lbs.
Total weight below-decks:	45,025 lbs.	62,909 lbs.

Contract Briefs

The following is a listing of contract announcements that have been made by the Pentagon involving the award of, or modification to, unclassified prime contracts with a base value of $5 million or more since the beginning of FY06 (10/1/05).

Date	Contract Number	Agency	Obligation	Details
General Dynamics, Bath Iron Works				
2/14/2008	N00024-06-C-2303	NAVSEA	$1,395,382,679	Modification to a previously awarded contract for DDG 1000 Zumwalt Class Destroyer construction and DDG-1000 Class Services.
Northrop Grumman, Ship Systems				
2/14/2008	N00024-06-C-2304	NAVSEA	$1,402,539,861	Modification to a previously awarded contract for DDG-1000 Zumwalt Class Destroyer construction and Class Services.
Raytheon, Integrated Defense Systems				
9/21/2007	N00024-05-C-5346	NAVSEA	$994,300,000	Cost-type modification to previously awarded contract for DDG-1000 and DDG-1001 mission system equipment (MSE) production and engineering support services.

Funding History

RDT&E ($ Millions)	FY12	FY13	FY14	FY15	FY16*	FY17**	FY18	FY19*	FY20**	FY21**
PE# 0204202N DDG-1000										
Proj. #2464 DD(X) System Design, Development and Integration	215.0	96.1	187.9*	197.0	103.2	45.6	134.7	140.3	111.4	107.9
PE# 0603271N Electromagnetic Systems Advanced Technology	102.5	102.5*	n/a	62.9	34.9	26.4	9.2	8.8	9.5	8.0
PE# 0604501N Advanced Above Water Sensors										
Proj. #3186 Air and Missile Defense Radar (AMDR)	148.6	193.9	125.1*	—	—	—	—	—	—	—
Proj. #3187 Periscope Detection	21.7	4.6	—*	—	—	—	—	—	—	—
Proj. #3188 Dual Band Radar	21.0	11.6	15.9*	8.6	6.4	4.8	7.2	—	—	—
Proj. #3236 Advanced Radar Technology EASR	—	—	—	0.6	23.3	68.0	64.7	23.6	1.9	—
PE# 0604522N Advanced Missile Defense Radar (AMDR) System										
Proj. #3186 Air and Missile Defense Radar	—	—	—	126.5	232.7	144.4	49.6	27.0	55.3	78.1

Procurement ($ Millions)	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19*	FY20**	FY21**
Navy Other Procurement (OPN) BA 2: Communications and Electronics Equipment										
Other Shore Electronic Equipment (BSA 10)										
DBR	n/a	n/a	n/a	n/a	n/a	n/a	16.4	35.8	21.9	n/a

Procurement ($ Millions)	FY07	FY08	FY09	FY10*	FY11**	FY12**	FY13	FY14	FY15	FY16*
Navy Procurement										
DDG-1000	n/a	n/a	1,504.3	1,378.5	186.3	139.4	n/a	n/a	460.8	433.4
DBR	539.5(2)	—	230.5(1)	—	—	—	n/a	n/a	n/a	n/a
Common Array Cooling System (CACS)	16.0(2)	—	6.9(1)	—	—	—	—	—	—	—
Common Array Power System (CAPS)	85.9(2)	—	37.4(1)	—	—	—	—	—	—	—
EXCOMMS (SHIPSET)	272.3(2)	—	115.7(1)	—	—	—	—	—	—	—
Ship Control System (SCS)	100.6(2)	—	44.8(1)	—	—	—	—	—	—	—
Total Ship Computing Environment (TSCE)	214.1(2)	—	86.0(1)	—	—	—	—	—	—	—
Mission System Engineering Integration & Test (MSEIT)	443.7(2)	—	183.0(1)	—	—	—	—	—	—	—
DDG-51	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2,933(2)	4,267(2)
SPY-6 (AMDR)	—	—	—	—	—	—	—	—	—	262(1)

*Appropriation
**Request

Costs

DBR was expected to cost less than the AN/SPY-1 Aegis radar (as it is considerably less capable), but DDG-1000 funding breakouts first available in February 2010 allocated a stunning $250 million for each DBR suite. Teal Group had forecast a ***DBR*** suite unit cost in the $120 million range. DDG-1000 funding truly seems of questionable wisdom….

MFR cost was planned as $33 million in 2003-2004. Development cost was estimated at about $300 million. In mid-2001 the Navy was estimating the cost of developing an enhanced MFR at $600 million (with a $132 million production unit cost).

VSR development cost was initially projected at $100-150 million, with a unit cost of $10 million hoped for. Teal Group expects development to cost at least $150 million, with a unit cost of about $33 million expected in 2003-2004.

In the February 2016 Navy budget, unit cost of the Raytheon MFR was $157/157/190 million for three systems for the DDG-1000 class. Technical support services and NRE *added another 40-70%*.

In the February 2016 Navy budget, unit cost of the Raytheon TSCE was $98/98/134 million for three systems for the DDG-1000 class. Technical support services and NRE *added another 90-100%*.

The ***AMDR*** will eventually cost at least as much as the SPY-1 Aegis radar, as it will improve on Aegis capabilities, for BMD as well as air defense. Today's SPY-1 still benefits to some degree from high production rates from the rationally-costed Cold War-era CG-47 and DDG-51 programs. Today's SPY-1 suite probably costs about $180 million. Teal Group suspects the AMDR will be costed at sky's-the-limit JSF-era rates. We did not feel it absurd to estimate an actual $400 million cost for a full AMDR suite for DDG-51 Flight III, including C4I, possibly more for initial production.

In the February 2016 Navy budget, unit cost of the SPY-6 AMDR system was $262 million for one system in FY16, and $176 million for each of two systems in FY17, for the new Flight III version of the DDG-51. Whether or not this includes related C4I costs was not mentioned; Teal Group suspects it does not, and still forecasts a unit cost of $320-420 million when including related C4I.

In August 2016, the ***EASR*** EMD contract to Raytheon also provided up to $723 million in contract options to support 16 ship sets of the radar through 2026 – 6 fixed-face for the *Ford* carriers and 10 for amphibious ships. Teal Group estimates actual cost of an EASR radar suite – remember, these radars are to be of lower capability than either Aegis or AMDR – could be between $120-200 million, when including related C4I.

Program Overview

History

MFR Concept

The MFR (Multi-Function Air Defense Radar) began as a "black" (classified) program to develop the next generation multi-function air defense radar for the DD-21 class. The DD-21 is the first Surface Combatant for the 21st Century (SC-21), and will be a land attack destroyer partially derived from the Arsenal Ship concept, slated to replace the *Spruance* class destroyers and *Perry* class frigates.

MFR Concept Development Contracts

On June 16 1997, the Navy's program executive office for theater air defense issued concept development design contracts to three teams: Lockheed Martin (prime), Northrop Grumman, and Texas Instruments; H&R Co. (a Hughes Aircraft/Raytheon joint venture); and ITT Gilfillan (prime) and Boeing.

Volume Search Radar

The Navy is also looking to develop a 3-D L-band volume search radar (VSR) for the DD-21, which would combine with the MFR to replace the AN/SPS-48 and SPS-49. The VSR might have a 3.6 m diameter circular active phased-array, with a range of 220-250 nm, and interface with CEC. Development cost is projected at $100-150 million, with a unit cost of $10 million hoped for. A largely, or entirely, COTS radar is sought. The VSR is not yet a funded program.

MFR/VSR for CVX? LPD-17?

A flat panel phased-array radar is reportedly being considered for the CVX future carrier. Several options are possible, including the MFR/VSR and a version of Lockheed Martin's AN/SPY-1 Aegis radar. Derivatives of commercial air traffic control radars may even be considered. In May 1998, the House Authorization Committee (HAC) ordered a study considering the SPY-1 for the 12-ship LPD-17 class. The study is due for completion by March 30, 1999. Refurbished/upgraded AN/SPS-48E and AN/SPQ-9B radars are currently planned for the LPD-17. The MFR/VSR will likely be considered for later ships in the class, and for backfit to earlier vessels.

MFR Program Plan

In late 1998, in response to complaints from the companies involved, the Navy switched MFR development from a fixed-price contract to a cost-plus contract. A classified RFP is expected in early 1999. The Navy originally planned to downselect to two developers, but now expects to choose only one, in 1999. This will speed EMD, which would not begin until 2001 if there were two downselects. The Navy needs the radar sooner than that, for the CVN-77. A four-year EMD contract is expected in 1999. An EMD model or prototype is sought to be ready for testing no later than FY04, with another radar bought that year for the lead ship in the DD-21 class. The radar for the CVN-77 would also be needed about this time.

VSR Program Plan

The VSR has not yet been funded, but development schedules will probably follow the MFR fairly closely. It is hoped that development will be quicker, cheaper, and easier than the more sophisticated MFR. A four-year MFR EMD contract is planned for 1999, with an EDM model or prototype sought to be ready for testing no later than FY04, with another radar bought that year for the lead ship in the DD-21 class. The radar for the CVN-77 would also be needed about this time.

Raytheon Wins MFR EMD

Raytheon won the development contract in June 1999, but first unit production likely won't occur until at least 2006. Lockheed Martin is not taking its loss lying down, and in January 2000 announced it was teaming with Alenia Marconi Systems SpA to consider development of a multifunction radar for small ships.

MFR Behind Schedule, Over Cost

In early 2001, MFR development was 14-16 months behind schedule and over budget by $40 million. Raytheon submitted a revised cost estimate to the Navy, but claimed increases were due to delays in the DD-21 program, not technical problems.

DD-21 Dies, DD(X) Born

In the most recent evolution of the next-generation surface combatant saga (remember the Arsenal Ship?), in November 2001 the Navy canceled the DD-21 program and began a new DD(X) development program, with these comments: "Formerly known as DD-21, the program will now be called "DD(X)" to more accurately reflect the program purpose, which is to produce a family of advanced technology surface combatants, not a single ship class."

MFR/VSR Not Ready for CVN-77

The Navy decided in early 2002 to not procure the MFR and VSR for CVN-77, in order to avoid new prior-year shipbuilding costs, since the radars would not be developed in time. Rather than develop a variant of the AN/SPY-1 Aegis system, the Navy instead chose to go with the legacy suite of the AN/SPS-48E, AN/SPS-49, and Ship Self-Defense System (SSDS). However, the House then voted in June 2002 to restore the originally planned radars, and included $250 million extra in the FY03 budget to speed development. But the Navy said that would not be enough; it still could not be done.

DD(X) Goes to Northrop Grumman

In April 2002, NAVSEA awarded the Ingalls Shipbuilding Group of Northrop Grumman Ship Systems (NGSS) in Pascagoula, MS a $2.9 billion cost-plus-award-fee (CPAF) contract to finance DD(X) Design Activities, including the design, building and testing of engineering development models (EDM) of major subsystems and components for the DD(X) destroyer. NGSS was the leader of a team of contractors called the "Gold Team" that included Raytheon Systems Co. as the combat systems integrator, and a number of other companies. Gold Team's proposal also incorporated "Blue Team" member Bath Iron Works (BIW) as a subcontractor to perform DD(X) design and test activities, which will ensure BIW will have the ability to produce a detailed DD(X) design and build these ships in the future. Work is to be completed by September 2005.

The DD(X) is to be multi-mission surface combatant tailored for maritime dominance. It is to provide independent forward presence and deterrence, and operate as an integral part of joint and combined expeditionary forces. The award signals the start of a revolution for the Navy's surface combatant fleet, with the development of transformational technologies that will create new capabilities while reducing crew size and yielding significant combat advantage. DD(X) is the foundation of a family of surface combatants, including a future cruiser, CG(X), and littoral combat ship (LCS), providing the nation with a balanced set of warfighting capabilities to meet the national security requirements in the 21st Century.

The DD(X) program will provide a baseline for spiral development of the DD(X) and the future cruiser or CG(X) with emphasis on common hullform and technology development. Advanced combat system technology and networking capabilities from DD(X) and CG(X) will be leveraged in the spiral development of the littoral combat ship to produce a survivable, capable near-land platform for the 21st century. The intent is to innovatively combine the transformational technologies developed in the DD(X) program with the many ongoing R&D efforts involving mission focused surface ships to produce a state-of-the art surface combatant to defeat adversary attempts to deny access for U.S. forces.

"DD(X) and its associated transformational technologies will be at the core of U.S. Navy capabilities and missions for the 21st Century," said Chief of Naval Operations Adm. Vern Clark. "These great ships and other members of the family of surface combatants will transform the Navy fleet, multiply our combat effectiveness, and play a crucial role in dominating the future battle space."

MFR/VSR Joined to Become "Dual-Band Radar"

Originally the DD(X) program called for 11 EDMs (MFR in FY02, VSR in FY03), but now Raytheon will provide a single Dual-Band Radar EDM.

VSR Changed from L- to S-band

In April 2004, NAVSEA issued Northrop Grumman Ship Systems a $78 million CPAF modification to effect change from L-Band to S-Band VSR, and to establish a land-based testing facility in support of the DD(X) program. Most funding will go to Raytheon and Lockheed Martin (which is producing the S-band arrays). The work is to be performed in Tewksbury, MA (66%); Moorestown, NJ (24%); and in Pascagoula, MS (10%), and is to be completed by June 2006. Contract funding is expected to come initially from the Navy Shipboard Component System Development element (PE# 0603513N) (N00024-02-C-2302).

DD(X) Plans

The 14,500 ton DD(X) destroyer will provide land attack support for ground forces as well as performing anti-air, anti-surface and anti-submarine warfare missions. It will eventually replace the *Oliver Hazard Perry* class frigates and *Spruance* class destroyers.

In September 2005, DD(X) passed its Critical Design Review, and in November 2005, Pentagon acquisition executive Kenneth Krieg approved DD(X) milestone B, authorizing the beginning of systems development and demonstration (SDD) and low-rate production of 8 ships (although only 7 are planned).

DD(X) cost estimates have been all over the place. In December 2005, the House and Senate placed a $2.3 billion cost cap (up from $1.7 billion, earlier in 2005) on the fifth and subsequent DD(X)s, but at the same time the Congressional Budget Office estimated a $3.7 billion average cost for all ships. The Navy estimates $3.3 billion for each of the two lead ships, though analysts have projected real costs at $4.5 billion or more. RDT&E total development cost is estimated at $7 billion. Cost caps have several times been raised to allow continued development.

In 2005, the Navy suggested competing the DD(X) build between Northrop Grumman Ship Systems (Pascagoula, Mississippi) and General Dynamics Bath Iron Works (Bath, Maine), who are now simultaneously building identical ships (with a 50-50 work split, but sometimes working on different parts). But in December 2005, Congress announced that both shipyards will continue to build DD(X) – even if there are only 7 ships over the next decade – prohibiting a winner-take-all competition (which especially concerns General Dynamics, as Northop Grumman led the initial design effort). These and other issues, which have dragged on and on since 1994, are just some of the things that have been contributed to the "unreality" of the entire SC-21/DD-21//DD(X) program.

Now, with SDD approved, the next big decision will probably come in 2009 when the first two ships are built, and the Navy has to prove that it can continue production at a reasonable price. No definite DD(X) plans exist for after FY09.

DBR Status

Development of the DBR is lagging behind other DD(X) component development, in part due to the Navy's decision in 2004 to change the VSR radar frequency from L-band to S-band. All DD(X) Engineering Development Models have been completed, except for the DBR.

Land-based testing has been completed successfully at Wallops Island, VA, and the DBR is scheduled to begin at sea testing in the spring of 2006. The next year will be spent primarily with software development.

DD(X) C4I

In May 2005, the Navy awarded Raytheon Integrated Defense Systems (IDS) a $3 billion contract for DD(X) ship system integration and detail design, associated with specific DD(X) ship systems. Work will be performed by Raytheon IDS in Tewksbury, MA, Lockheed Martin MS 2 (Moorestown, NJ), United Defense LP (Minneapolis, MN), Northrop Grumman Missile Systems (King George, VA), and Ball Aerospace & Technology Corp. (Westminster, CO). The work is expected to be completed in December 2009. Contract funding will come from the Navy DD(X) Total Ship System Engineering program element (PE# 0604300N).

CG(X) Radar?

The CG(X) cruiser is planned to eventually replace the Ticonderoga class Aegis cruisers. The CG(X) will provide an "umbrella" of air and missile defense with longer-range missiles, protecting carrier strike groups and other vessels. It will also be able to track and engage ballistic missiles hundreds of miles inland. Today's plans call for CG(X) to utilize the same or a similar DD(X) hull.

In July 2005, Navy acquisition executive John Young discussed eventual plans for a competition for the future CG(X) radar, without setting dates. Lockheed Martin (SPY-1 Aegis, DD(X) S-band radar [VSR]), Raytheon (DD(X) X-band radar [SPY-3 MFR], Cobra Judy Replacement [CJR] radar prime), and Northrop Grumman (S-band CJR radar) are all expected to compete.

New AMDR Acquisition Plans

In February 2007, plans for the AMDR were to leverage research and development investments, integrate sufficiently matured fundamental advanced technologies from technology risk reduction efforts and allies, and incorporate open architecture approaches to develop a scalable radar design with major improvements in power, sensitivity, and resistance to natural and man-made environments over current radar systems for multi-mission TAMD (BMD and Area AAW). System design will be accomplished using proven advanced technologies and commercial standards to lower schedule risk and develop a product with the lowest life-cycle cost.

DDG-1000 Lame Duck Land Attack Mission: The Navy's DeLorean?

In early 2008, sources reported the US Marine Corps had dropped its requirement for heavy shore gunfire support, the original rationale for the DDG-1000. It is not often mentioned today that the DDG-1000 mission is actually a *land attack ship*, with its two 155 mm guns and a new generation of long-range (80 km), precision rocket assisted rounds. It may be hard to believe two six-inch guns will provide massive firepower, but this is what the Navy has been saying for a decade. However, its Advanced Gun System (AGS) gets very little press today, and many assume the DDG-1000 is intended as an *Arleigh Burke* replacement. Not so; in fact, its radar will be inferior to the Aegis system, including an inability to perform the Ballistic Missile Defense (BMD) mission.

With the greatly increased availability of armed UAVs, unquestioned US air superiority, and ubiquitous precision guided munitions, the decades-in-planning DDG-1000 seems to increasingly be a ship without a purpose, except as a very expensive technology demonstrator of potentially unneeded technologies. Unless, of course, its unique stealthy tumblehome hull sinks, in which case it will provide useful data on what not to do with modern hull design. If it is ever built, I anticipate DDG-1000 will be a regular entry in future "Bizarre War Machines" coffee table books, right next to the tome on that spiffy-looking DeLorean.

DDG-1000 Down to Two?

The Navy might be crazy, but apparently the legislators are not. In February 2008, the Navy awarded production contracts for DDG-1000 and DDG-1001, with plans to eventually build seven ships. But in March 2008, many in Congress were discussing ending the procurement at just two ships and transferring future funds to other platforms. Congress is concerned about unrealistic Navy estimates of future production costs, and the difficulty of reaching a 313 ship fleet with current plans. DDG-1000 is now forecast to cost more than $5 billion, more than twice the cost of the more effective *Arleigh Burke*, and more than twice what the Navy claims it will cost – see "LCS" for other stunning Navy cost underestimations. In March 2008, the Congressional Budget Office (CBO) reported that the Navy will actually need 1.5 to 2 times as much money annually as it is currently budgeting to reach the 313 ship fleet.

Teal Group suspects the DDG-1000 might never sail at all, but ending the procurement at two ships is probably the most likely outcome. Possibly a couple more might be funded, but a full seven-ship build is unlikely. As the program has delayed for more than a decade, the looming Ticonderoga class cruiser retirement has become more and more urgent. We suspect the Navy will find a way to shift focus to the CG(X) over the next few years, and probably even claim they planned it that way.

CG(X) Schedule

In early 2008, Navy funding plans included a buy of the first CG(X) in FY11 with a second in FY13, and a total of 19 ships planned (to replace 22 *Ticonderoga*s, projected for retirement from 2021-2029).

CG(X): Unnecessary Stealth, Necessary Ship

In early 2008, some legislators pointed out that, unlike the land attack DDG-1000, the CG(X) is not intended to operate near-shore, where a stealthy hull might be useful. Even without US air dominance, "The radars are going to be so powerful that there's no way on earth you can make that ship stealthy," according to Rep. Gene Taylor, D-Miss. So, why share the expensive and unproven tumblehome hull design from the DG-1000? Especially as the negative buoyancy properties of this versus a flared hull (as all other ships) severely limit weight aloft, reducing both the size and mounting height of the new radar.

These problems could be just the tip of the iceberg of another go-nowhere failed Navy design – at least so far as ties to the DDG-1000 go. But unlike for the newer *Arleigh Burk*es, a CG-47 Ticonderoga class replacement will be desperately needed in a decade or two. We don't expect the Navy's planned schedule to stick, but we have forecast the first in class CG(X) reaching production somewhere around the middle of the next decade. Just be forewarned before investing the farm in any particular configuration, especially anything connected to the DDG-1000.

CG(X) Radar Power Requirements

In late 2007, the CG(X) radar was planned to be very high power – 30-31 MW peak power, versus 5 MW for the AN/SPY-1 Aegis radar. The requirement for power generation will be a major factor in designing the CG(X) hull (and could tip the balance toward nuclear power).

The *Arleigh Burke* class displaces 9,200 tons, the Ticonderoga 9,500 tons, the DDG-1000 14,500 tons. In 2007, the Navy reported to Congress that a 21,000 to 26,000 ton CG(X) would cost $600-700 million extra for nuclear versus conventional power, but that the life cycle cost break-even point would be oil costing $70-225 a barrel, a level which has now been reached.

Nuclear *Arleigh Burke* for CG(X)?

In early 2008, legislators proposed a non-DDG-1000 idea for a Ticonderoga-replacement next-generation cruiser. The Navy doesn't like the idea, but an upscaled *Arleigh Burke* hull could conceivably be powered by one nuclear reactor of the type developed for the CVN-78 class *Gerald Ford* (which uses a twin reactor) As the superb DDG-51 hull would have to be enlarged, cost savings could well be lost, however (though the upscaled Super Hornet has worked out well), but this idea is indicative of the current uncertainty in CG(X) plans.

CVN-78 On Schedule

In early 2008, the CVN-78 carrier was funded for FY12, as per earlier plans, with a likely DBR radar build about 2014.

DDG-1000 Problems

In mid-2008, the Navy "officially" reduced the DDG-1000 program from seven to three ships, but this would mean tooling up and building ships at both General Dynamics' Bath Iron Works in Maine, as well as Northrop Grumman Ship Systems' yard in Virginia, which would be incredibly inefficient, even for the Navy. The Navy is now trying to convince Northrop Grumman to give up its DDG-1000 in exchange for restarted production of DDG-51 class *Arleigh Burke* destroyers at its Pascagoula, Mississippi plant. In early 2009, SecDef Gates threatened to end DDG-1000 production at just one ship if an agreement could not be reached to shift all production (all two or three, that is) to Maine. The Navy's FY10 budget has funding for the third ship, but obviously that can be changed.

Teal Group suspects the DDG-1000 might never sail at all, but funding and contracts have been awarded, so ending the procurement at two or possibly three ships is probably the most likely outcome. Our forecast assumes the Navy manages to simply cut the Northrop Grumman ship and build two in Maine, probably using already-awarded third ship funding to cover further cost overruns on the first two….

DBR Schedule

In May 2009, land-based MFR/VSR EDM testing was to be completed by mid-2009. Full-up DBR EDM testing is to be complete by mid-2010.

In May 2009, the first DBR production unit was to delivered to the shipyard in mid-2010.

Fabrication of the first ship, DDG-1000, began in early 2009. DDG-2001 fabrication was planned to begin in mid-2009.

CG(X) Delayed

In May 2009, the FY10 budget reduced CG(X) funding, and the Navy now plans to delay both development and production, with SDD now to occur several years after the earlier-planned FY11, and with procurement postponed beyond FY17 and thus conveniently beyond out forecast period.

DBR Production Contract

In June 2009, the Navy awarded Raytheon a $217 million contract for production of two VSR arrays, for DDG-1000 and CVN-78.

AMDR Concept Study Contracts Awarded

In June 2009, Northrop Grumman, Lockheed Martin, and Raytheon were awarded $9.9 million concept study contracts, which run through December 2009.

In October 2009, the Navy also announced it would award up to three AMDR technology development contracts, initially covering the AMDR-S and RSC.

DDG-1000 Currently on Schedule?

In August 2009, the US Navy feverishly explained how current DDG-1000 development schedules honestly haven't slipped for awhile. The MFR completed at-sea testing in spring 2008, and both the MFR and VSR have been operating together since January 2009 at the Wallops Island Engineering Center, tracking actual ships and aircraft off the Virginia coast. DDG-1000 software development was "much greater than 50% done" in August 2009; radar costs were reportedly on track without significant growth.

Raytheon Proposes BMD Upgrade for DDG-1000

In September 2009, Raytheon submitted an unsolicited proposal to the Navy to "fully populate" the AN/SPY-4 VSR with transmit/receive modules, upgrade computers and software based on Raytheon's THAAD and/or SBX radars, and upgrade launchers to handle the SM-3 (BMD) versus current SM-2 (Standard) missiles, to provide a BMD capability for the DDG-1000. The AN/SPY-3 X-band MFR radar will need few enhancements. Raytheon offered this development to the Navy for a fixed price of $580 million (development only, and not including all components needed). As of November 2009, the Navy had not responded. At all. Not even a thank you note, according to Navy sources.

As a couple more *Arleigh Burke*s would almost certainly be a better way to get more BMD capability ("Hey Cletus, do we need a new ship for BMD? Don't we already have a few parked out back?"), the Navy has understandably remained mute regarding Raytheon's offer. With the construction of DDG-1000 only about 16% complete at Bath Iron Works in November 2009, DDG-1001 not scheduled to begin construction until 2010, and DDG-1002 not certain to begin at all, accepting a BMD mission shift now would be asking for trouble (the Navy still hopes to fund three ships).

Future Surface Combatant/CG(X) Hull/Radar Study

In October 2009, the Navy was awaiting the results of a CNO OPNAV Hull/Radar Study begun in the spring of 2009, intended to determine the maximum BMD capability that could be put into a destroyer hull. The idea of a large, nuclear-powered cruiser (CGNX) as the Future Surface Combatant (the new name taking over from CG(X) in the imaginary ship name game) has apparently lost favor, due to expense. Unlike the Cold War Ticonderogas and *Arleigh Burke*s, any future ships are destined to be incredibly expensive (witness the massive cost increases for both DDG-1000 and LCS). For once, perhaps the Navy is wising up and starting small. A future nuclear cruiser is forecast to cost $7 billion or more – almost the price of a carrier. Unfortunately, the only hulls available are the DDG-51 (thought to be too small for the power and cooling requirements of a future BMD cruiser) and the larger but untested "will it sink?" DDG-1000 wave-piercing hull. In any case, AMDR development will continue.

Bath Awarded 2nd & 3rd DDG Construction

In July 2010, the Navy awarded Bath Iron Works, a subsidiary of General Dynamics, a $105.4 million modification to a previously awarded contract for procurement of long-lead-time material and engineering, production and support services associated with the construction of DDG-1001, and for long-lead-time material procurement associated with DDG-1002. The original contract was awarded in February 2008. Work encompassed by this modification is expected to be completed by February 2011.

Jeff Geiger, president of Bath Iron Works, said, "We see this award as yet another expression of the Navy's confidence in our ability to efficiently construct and deliver all three ships of the *Zumwalt* class. We're making good progress building the lead ship, DDG-1000, building momentum as we ramp up our construction efforts. This award will allow us to maintain progress on our DDG-1001 start-up and initiate timely procurement of key long-lead material items to support the DDG-1002 construction schedule."

Northrop Grumman will retain its DDG-1000 class deckhouse and other work, and in exchange for "losing" its own class lead-ship DDG-1001 build will be favored with additional DDG-51 *Arleigh Burke* class destroyer builds.

DDG-1000 Design Work Winding Down

In January 2011, General Dynamics Bath Iron Works (BIW), Bath, ME was planning to lay off around 130 workers. BIW President Jeff Geiger said that the layoffs at the are due to an anticipated reduction in design work for the DDG-1000, and reflect BIW's need to adjust staffing levels in response to the budget environment of its sole customer, the US Navy. "Our customer is buying fewer ships and is under severe budget pressure. Competition for those ships is intense and the need for us to be affordable has never been greater," the Bangor Daily News reports Mr. Geiger as saying. "As difficult as today's action is, I must act now to adjust resource levels to the available work and ensure we remain affordable and poised to compete and win future contracts." After the layoffs, BIW will employ about 5,700 workers.

Nav System Tested

In January 2011, the Navy successfully tested the Next Generation Navigation System (NAVDDX) produced by Raytheon, Tewksbury, MA, prime contractor for DDG-1000. NAVDDX is a modern open architecture solution for distributing navigation and high-precision time data to ship mission systems. System development was a joint effort between Raytheon Integrated Defense Systems (IDS) and the Navy's Space and Naval Warfare Systems Center Pacific, San Diego, CA.

First TSCE and Sonar Delivered

In April 2011, Raytheon, Tewksbury, MA, delivered critical mission systems ahead of schedule for DDG -000, including the ship's first Total Ship Computing Environment (TSCE) data center (2 months early) and the AN/SQS-60 mid-frequency sonar array (8 months early).

The TSCE data center comprises two ruggedized Electronic Modular Enclosures that house and protect the open architecture computing environment for DDG-1000's combat and ship control systems, and provide more data processing and storage capacity than existing US Navy destroyers. TSCE will manage the ship's advanced systems, including sensors.

Under the Navy's DDG-1000 Detail Design and Integration contract awarded in 2005, Raytheon IDS serves as the prime mission systems equipment integrator for all electronic and combat systems for the DDG-1000 program, employing more than 800 Raytheon employees as well as by approximately 1,800 subcontractors and supplier partners in 43 states across the country.

$16 Billion for AMDR? Oh, No, Probably Not….

In June 2011, the GAO estimated the AMDR would cost $15.7 billion – about the same as the Navy's annual shipbuilding budget. According to the radar developers, however, that cost estimate is high (well, what do you expect them to say?). According to Brad Hicks, Lockheed Martin's VP of naval radar programs, "Lockheed Martin's development costs for the AMDR – based on what we understand from the data – is significantly less than the development costs cited by the GAO." Really very different from JSF, one hopes….

Nonetheless, the Navy is reportedly content with the GAO's estimate, given the accepted continuing costs of Aegis, the need, and the increased importance of naval BMD for maintaining Navy relevance.

Build Status

In January 2012, the Navy estimated DDG-1000, which began fabrication in February 2009, was 63% complete. DDG-1001, which began fabrication in March 2010, was 22% complete.

DDG-1000 Delivery Plan

In 2011, the *Zumwalt* (DDG-1000) was expected to "enter into service" – likely for many years of testing – in April 2013.

By early 2013, lead ship "delivery" had slipped to July 2014.

Ship Program Status

In March 2013, the GAO reported the DDG-1000 design was stable and all three ships were in fabrication. The Navy had awarded contracts for all elements for the first two ships. Contracts for the third ship deckhouse, hangar, aft peripheral vertical launching system, and mission systems equipment were not yet finalized.

However, most critical technologies (8 of 11) will not be fully mature and demonstrated in a realistic environment until ship installation. Releases 1 to 5 of the Total Ship Computing Environment (TSCE) software were complete and certified; release 6 had begun integration and testing; and the development of the follow-on spiral which activates the mission systems was under contract.

As of December 2012, the first two ships were 80% and 48% complete respectively, and the third ship began fabrication in April 2012. The Navy is using a joint inspection process with prime contractors to manage the transfer of class products.

DBR/VSR Delays Slow DDG-1000

In March 2013, the GAO reported that delays developing and producing the ***Dual Band Radar (DBR)*** (and also the advanced arresting gear [AAG]) for the DDG-1000 have driven inefficient, out of sequence construction work and caused the Navy to defer some key tests until after installation.

The Navy's decision to remove the DBR's ***AN/SPY-4 Volume Search Radar (VSR)*** component from the DDG-1000 shifted responsibility for maturing the DBR to the CVN-78, and the resulting restart of testing was slow. Further, because a fully configured, production unit VSR was unavailable, the Navy is using a less robust, lower powered prototype to complete testing. The first test of a fully configured, integrated DBR will be aboard CVN-78 after ship delivery—a strategy that introduces risks.

The DDG-1000 class will now only carry the ***AN/SPY-3 MFR (Multi-Function Radar)***.

DDG-1000 Delay Forecast Comparison/Perspective

Though it is perhaps an apples-to-oranges comparison, it is instructive to compare the DDG-1000 and its current JSF-like development optimism – for a totally new surface combatant class that is 40% larger than the *Arleigh Burke* – to the much more follow-on *Gerald R. Ford* nuclear carrier (CVN-78).

The Navy awarded a construction contract for the CVN-78 in September 2008, when 8 of the ship's 13 current critical technologies were not mature and the ship's three-dimensional (3D) product model was incomplete. By January 2013, lead ship procurement costs had grown by over 17%, with ship construction approximately 51% complete. Only 6 of the currently planned technologies were mature, with the rest approaching maturity, and the ship's 3D product model was complete. Lead-ship delivery was planned for September 2015, with IOC in March 2017.

In March 2013, the GAO reported 8 of the DDG-1000's 11 critical technologies would not be fully mature and demonstrated in a realistic environment until ship installation. Releases 1 to 5 of the Total Ship Computing Environment (TSCE) software were complete and certified; release 6 had begun integration and testing; and the development of the follow-on spiral which activates the mission systems was under contract.

As of December 2012, the first two ships were 80% and 48% complete respectively, and the third ship began fabrication in April 2012. The Navy is using a joint inspection process with prime contractors to manage the transfer of class products.

The Navy has awarded contracts for all elements for the first two ships. Contracts for the third ship deckhouse, hangar, aft peripheral vertical launching system, and mission systems equipment were not yet finalized.

Admittedly, CVN-78 is a larger, more complex ship than DDG-1000. But CVN-78 also is essentially a follow-on to generations of nuclear carriers. The DDG-1000 will be the Navy's largest surface combatant since WW II, with a totally untried tumble-home hull form and many of its own new technologies.

Given delays already – from an originally planned 123-month acquisition cycle (planned in January 1998) to a 222-month cycle as of August 2012 – Teal Group is fairly certain DDG-1000 IOC will continue to slip further to the right.

Contract for 9-10 New DDG-51s

In June 2013, the Navy awarded construction contracts worth more than $6 billion to General Dynamics Bath Iron Works (BIW) and Huntington Ingalls Industries (HII) to build nine new DDG 51 *Arleigh Burke*-class destroyers (flights IIA and III), with an option for a tenth ship (DDG-117 through DDG-125/126).

The first new ships will be Flight IIA versions, as have been all ships since DDG-79. The second ship in 2016 is planned to be a Flight III, with the new AMDR instead of the AN/SPY-1D, to initially operate with the Aegis combat system. The switch to the Flight III will be contractually handled as an "engineering change proposal," according to the Navy in mid-2013.

However, the Flight III is essentially an all-new ship, and Teal Group finds it highly unlikely an all-new ship with the all-new AMDR radar will be built in a timely fashion.

DBR Upgrade Contract for CVN-78

In September 2013, Raytheon was awarded a not-to-exceed $7.2 million contract modification to produce hardware upgrades for the DBR and

Common Array Power Systems, required to implement DBR power system interface modifications aboard the new nuclear aircraft carrier USS *Gerald R. Ford* (CVN-78). Work is expected to be completed by March 2015.

Massive DDG-51 AMDR Contract to Raytheon; Pending Protest

In October 2013, Raytheon was awarded a $385.7 million cost-plus-incentive-fee contract for the engineering and modeling development phase design, development, integration, test and delivery of the Air and Missile Defense S-Band Radar (AMDR-S) and Radar Suite Controller (RSC), intended for the Flight III *Arleigh Burke* (DDG-51) class destroyers. This contract was awarded following a full and open competition, with three offers received.

Under the contract, Raytheon will build, integrate and test the AMDR-S and RSC Engineering Development Models (EDMs), and integrate these with the existing AN/SPQ-9B X-band radar. The contract includes options which, if exercised, would bring the cumulative value to $1.6 billion.

In January 2014, Raytheon received a resume work order from the US Navy to commence development of the AMDR. The order followed the official Government Accountability Office update of its database to reflect the status of the AMDR contract award protest as withdrawn. "The Raytheon team and plans are in place, ready to move forward on the program," said Raytheon's Kevin Peppe, vice president of Integrated Defense Systems' Seapower Capability Systems business area. "Our focus is now dedicated to delivering this critical AMDR capability to the Navy."

But in early February 2015, the Navy was reportedly still re-evaluating bids from Raytheon, Lockheed and Northrop after Lockheed and Northrop lodged AMDR contract protests.

AMDR Acquisition Strategy

In March 2014, Navy plans for the AMDR were to leverage research and development investments, integrate sufficiently matured advanced technologies from technology risk reduction efforts, and incorporate Open Architecture approaches to develop a scalable radar design with major improvements in power, sensitivity, resistance to natural and man-made environments over current radar systems for simultaneous multi-mission BMD, Area and Self Defense Anti-Air Warfare (AAW). System design will be accomplished by employing proven technologies and commercial standards to lower schedule risk and develop a product with the lowest life-cycle cost.

Planned program scope consisted of the following phases: a Concept Studies phase; a Technology Development phase, which included competitive prototyping; an E&MD phase, which includes completion of a full Engineering Development Model (EDM) for land-based testing; and transition to production. The detailed scope of this acquisition is defined in the approved Milestone B AMDR Acquisition Strategy (AS).

In March 2014, AMDR LRIP was still optimistically scheduled to begin in 4QFY17, for the Flight III DDG-51 class.

DDG-1000 Build Status

The USS *Zumwalt* (DDG-1000), named for former Chief of Naval Operations Admiral Elmo R. "Bud" Zumwalt, launched October 28, 2013 and was Christened April 12, 2014. The future *Michael Monsoor* (DDG-1001), named for Medal of Honor recipient Petty Officer Michael Monsoor, had its keel laid May 23, 2013, and the future *Lyndon B. Johnson* (DDG-1002), named for the former U.S. president, started fabrication April 4, 2012.

In October 2014, the DDG-1000 was 92 percent complete and in the test and activation phase of construction. The ship was successfully activating its fuel systems, advanced induction motors (AIM) and generators, with fuel onload and AIM light-off completed in July, and generator light-off achieved in September 2014.

In addition, Huntington Ingalls Industries (HII) delivered the DDG-1001 composite deckhouse to the Navy. The 900-plus ton deckhouse was transported from Gulfport, MS via barge to the BIW shipyard in Bath, ME. It arrived in September 2014 for subsequent lift and integration on the DDG-1001 hull at the shipbuilder's land level test facility.

DDG-1000 TSCE Computer Activation

Concurrent with light-off activities, activation of DDG-1000's computer system, the Total Ship Computing Environment (TSCE) was completed in October 2014. Consisting of hardware, middleware and software operating systems, the TSCE is responsible for the operation and integration of the combat systems, engineering control systems, bridge and navigation systems, and damage control systems utilizing layered open architecture which allows for network flexibility and growth for future capabilities. With over six million lines of code, the TSCE, has been designed to maximize automation and watchstander efficiency in order to optimize crew size. The DDG 1000 TSCE is the most advanced and complex shipboard computer operating system the Navy has produced, representing the cutting edge in future surface combatant capability.

Why the Navy advertises the TSCE's complexity is something of a mystery to Teal Group, as past extremely complex one-off computing systems – such as for the *Seawolf* class submarine, have often been expensive failures. Maintaining and upgrading such a system for just three ships seems something the Navy would *not* want to talk about much….

Recent History: Dual Band Radar (DBR)

DBR Upgrade RDT&E Plans

In February 2016, Navy PE# 0604501N provided funding for Dual Band Radar (DBR) system upgrades to implement cost savings initiatives for Volume Search Radar (VSR) modifications, supportability analysis, and associated logistics product updates; future upgrades/technology insertion efforts for Multi-Function Radar (MFR)/VSR as a part of the DBR suite on CVN-78 class ships and the MFR on DDG-1000 class ships. Funding is also provided to resolve the hardware and software issues discovered during the various test events to include: DTB2-411, SDTS testing, Land Based Testing, and pertinent At-Sea test events.

The upgrades will include all aspects of the radar system/subsystems, including hardware and software. Specific subsystem areas include the Array, Transmit/Receive (T/R) module, Receiver/Exciter, Signal Data Processor, Radome, and power/cooling systems. Upgrades and technology insertions are required to maintain the level of force protection needed for ship defense against all threats envisioned in the littoral environment. The supportability analysis and logistic products associated with these upgrades will also be developed and updated.

Funding is also provided for development of the DBR Battle Force Tactical Trainer (BFTT)/Cooperative Engagement Capability (CEC)/Surface Electronic Warfare Improvement Program (SEWIP) Interface. The FY15 requirement supports the design and development of the software interface between DBR and AN/USQ-46 BFTT, CEC, and SEWIP to enhance CVN-78 combat readiness.

Funding is also provided for DBR CVN-78 Testing and Certification. The FY15-FY18 requirement supports DBR At-Sea Test and Evaluation (T&E), Environmental Testing, and DBR Systems Certification for CVN-78.

DDG-1000: RCS of a 40- to 50-foot Fishing Boat…

In April 2016 in Bath, Lawrence Pye, a Maine lobsterman, told the Associated Press that on his radar screen the 610-foot long DDG-1000 looked like a 40- to 50-foot fishing boat. But it is actually 100 feet longer, displaces much more (15,000 vs. 8-9,000 tons), and towers over the DDG-51 class destroyers. The DDG-1000 is essentially a "pocket battleship" in size.

DDG-1002 Nearly Cancelled… Mission Still Uncertain

In September 2015, reports indicated the Department of Defense was considering terminating funding for the *Lyndon B. Johnson* (DDG-1002) during construction. However, other reports claimed the program shutdown costs and contract termination penalties would be so high that cancellation could cost as much as completion – yet another less than useful program continued due to contracts written in favor of industry (see JSF…), despite decades of developer delays that only received more and more money from the Navy. Why are the delays not grounds for contract termination?

By December 2015, the Pentagon had apparently decided in favor of keeping the ship, despite the fact that the ship class's mission is currently very uncertain. There have suggestions of use for special operations because of the ship's stealth. But why not unload those SOF forces from an actual 40- to 50-foot boat, rather than a massively expensive battleship with two popguns – now without the follow-on munition types originally planned for a 30-ship fleet, and long since replaced in its land attack purpose by much less vulnerable UAVs?

Additionally, despite its surface radar stealth, there has been suspiciously little written about the DDG-1000's resistance to mines and diesel submarines, or its EO/IR signature and detectability by the current generation of longer-range naval and UAV EO/IR systems, and fighter-bomber long-range IRSTs. You can't hide a battleship in the fog today. Teal Group suspects a pocket battleship that generates 80 MW of power is about as hot above and about as loud underneath the surface as, well, a pocket battleship.

With an untried tumblehome hull, Teal Group fears the DDG-1000 will never come near the littorals in a real combat situation. It is just too big and expensive to lose for political reasons, and it could turn turtle and sink from a single well-targeted torpedo, especially considering its reduced manning for damage control (143 crew vs. 323 aboard the much smaller *Arleigh Burke*s…). While experts today generally agree thorough Navy testing of the unique hull has shown an ability to survive weather and high seas, very little is known about its resistance to sinking and capsize when damaged (especially in high seas). At least there would be fewer lives lost, but many more than aboard UAVs.

Recent History: AN/SPY-6 AMDR

AMDR RDT&E Plans

In February 2016, Navy PE# 0604522N provided funding for the Air and Missile Defense Radar (AMDR). FY14 and prior year funding was in PE# 0604501N. RDT&E funding will increase abruptly in FY19, continuing through FY21, to support long lead hardware procurement for unmanned self-defense test ship at-sea testing in support of DDG-51 Flight III and AEGIS ACB20 requirements.

AMDR Acquisition Plans

In February 2016, the Navy's plan for AMDR acquisition was leverage research and development investments, integrate sufficiently matured advanced technologies from technology risk reduction efforts, and incorporate Open Architecture approaches to develop a scalable radar design with major improvements in power, sensitivity, resistance to natural and man-made environments over current radar systems for simultaneous multi-mission BMD, Area and Self Defense Anti-Air Warfare (AAW).

System design will be accomplished by employing proven technologies and commercial standards to lower schedule risk and develop a product with the lowest life-cycle cost.

AMDR program scope consists of the following phases: a Concept Studies phase; a Technology Development phase, which included competitive prototyping; an E&MD phase, which includes completion of a full Engineering Development Model (EDM) for land-based testing; and transition to production.

First DDG-51 Flight III/SPY-6 Radars to be Installed Later

In February 2016, the Navy planned procurement funding for the first DDG-51 class Flight III/SPY-6 configuration in FY16 for one ship, and in FY17 for both ships. However, the actual radar systems will be executed via Engineering Change Proposals (ECP) as they will not ready in time for scheduled ship construction. FY15 Advance Procurement was the first to support Flight III Introduction.

AMDR Static Face Testing to Begin

In July 2016, Raytheon's AMDR program director, Tad Dickenson, announced testing of the SPY-6 would soon begin at the Navy's Pacific Missile Range Facility (PMRF) in Hawaii, with a production representative face from the S-band volume search radar on a specialized testing tower at the PMRF. "Last week we did initial light off at low power of the array and are just now working to graduate up to full power and head toward satellite tracking by the end of summer," according to Dickenson. "Throughout the next 12 months – ending in the summer of 2017 – we will be doing live fire, anti-air warfare and ballistic missile defense testing." The year-long testing program in Hawaii will be followed by combat system validation at the Navy's Surface Combat Systems Center (SCSC) on Wallops Island, Virginia.

The radar face on the tower is paired with a Northrop Grumman X-band AN/SPQ-9B for the testing – the same pairing that will be used on the Flight III *Arleigh Burke* class guided missile destroyers.

According to Dickenson, "We should begin long lead material before the end of the year for the first FY 2016 ship and we'll be seeing an award option for the entire array system for the first ship – following Milestone C which will be the end of Fiscal Year 2017…. Currently the program is nearing 80 percent complete and the majority of all the design is completed. We still have a couple of software builds to complete which give the final capabilities."

Reportedly, the radar could provide a 30-times boost in sensitivity over the current Lockheed Martin AN/SPY-1D radars found on current *Arleigh Burke*s.

Recent History: EASR & EXI

EASR & EXI Development Plans

In February 2016, the US Navy planned that the Enterprise Air Surveillance Radar (EASR) will modify an existing radar technology to meet the air surveillance requirements for multiple ship classes, including forward-fit for the CVN-79+, LHA(R), and LX(R) classes, and potential back-fit to CVN, LHA, and LPD classes. EASR will be one sensor in a suite that is designed to meet the performance needs for ship self-defense, situational awareness, and air traffic control. EASR will replace the Volume Search Radar (VSR) in the CVN-78 class Dual Band Radar system and the AN/SPS-48/49 radar systems in numerous ship classes.

The SPS-48 Radars are long-range, three-dimensional (3D) radars used to search, detect, and provide space-stabilized, three-coordinate (range, bearing, height) data for air intercept control and designation to a weapon system. The AN/SPS-49A(V)1 radar system is a long range, two-dimensional (2D), L-Band air surveillance radar installed on USN major combatants. The AN/SPY-4 Volume Search Radar (VSR) is an S-Band active phased array radar deployed on CVN-78, providing volume surveillance and air traffic control.

EASR funding will develop a modern 3D air search radar that addresses the latest requirements for Aviation and Amphibious Warfare Ships and closely conforms to existing combat system interfaces, as well as aligns with existing shipboard space, weight, and power limits. The architecture and acquisition strategy for EASR is intended to drive a lower recurring cost by utilizing the same core technology for both fixed-face and rotating array variants. EASR will provide for engineering of component and system level technology improvements for equipment used by in service air search radars.

Enterprise X-Band Illuminator (EXI) funding will develop an X-band illuminator compatible with the EASR radar and Combat System suite. Funding will also integrate a missile illuminator for future CVN applications as well as other ship classes.

EASR & EXI Acquisition Plans

In February 2016, the EASR acquisition was to be a planned competitive procurement based on a radar specification that incorporates the latest requirements for aviation and amphibious warfare ships, closely conforms to existing combat system interfaces, and includes physical Space Weight and Power (SWAP) Not-to-Exceed (NTE) interface requirements for forward-fit to the CVN-79+, LHA(R), and LX(R) classes, and for back-fit to CVN, LHA, LPD classes.

The EXI acquisition is a planned procurement based on an illuminator specification that incorporates the latest requirements for aviation and amphibious warfare ships, closely conforms to existing combat system interfaces, and includes physical SWAP NTE interface requirements applicable to CVN-79+, LHA(R), and LX(R) classes.

EASR Development Contract to Raytheon

In August 2016, the US Navy awarded Raytheon a $92 million contract to develop EASR, planned as the volume air search radar initially for the new *Gerald R. Ford* class aircraft carriers (CVN-78) beginning with the *John F. Kennedy* (CVN-79), and future big deck amphibious warships beginning with the planned LHA-8.

The Active Electronically Scanned Array (AESA) radar will be based on Raytheon's AN/SPY-6 S-band Air and Missile Defense Radar (AMDR) planned for the Navy's newest Flight III *Arleigh Burke*-class (DDG-51) guided missile destroyers.

According to Tad Dickenson, "It's using identical hardware, identical signal processing software, data processing software. It's as near identical as possible. The goal of the program to drive affordability and commonality…. Therefore EASR gets significant affordability off of AMDR SPY-6's larger [industrial] base."

The initial engineering development model (EDM) contract will develop two variants of EASR – a rotating variant for the amphibs and a fixed-face array for the CVNs. The testing program is planned to run to 2020.

The US Navy also plans to procure a separate X-band radar to compliment the EASR for both the future carriers and the amphibs.

Following the EMD phase, there are up to $723 million in contract options to support 16 ship sets of the radar – 6 fixed-face for the *Ford* carriers and 10 for amphibious ships. If all the options are exercised the program is set to run through 2026.

EASR will have an additional capability over the AMDR SPY-6 to function as an air traffic control radar. It will also have access to common software building blocks of AMDR. Raytheon officials would not say explicitly, but the implication is the inclusion of the radar on the amphibs and the CVNs would allow it a higher degree of compatibility with the Navy's ongoing-networked warfare push – like the carrier strike group centric Naval Integrated FirControl-Counterer Air (NIFC-CA) construct.

The *Ford* class carriers, along with the DDG-1000 *Zumwalt* class guided missile destroyer, were originally set to field the Raytheon-built Dual Band Radar. The DBR will be installed on the first-in-class *Gerald R. Ford* but the Navy has cancelled plans to install the DBR on the rest of the fleet after the *Zumwalt* class was truncated to three ships from a planned class of almost 30. Note that in February 2016, the Navy still planned to install the

The first EASR was originally planned to be first installed on the future USS *Enterprise* (CVN-80) but was moved left after the delivery schedule for the *John F. Kennedy* (CVN-79) was shifted to a two-phase delivery. In 2015, then Program Executive Officer Carriers Rear Adm. Tom Moore said, "That gave me a little extra time. If I had to deliver CVN-79 in 2022 when it was originally designed, it wouldn't have had the radar on it…. The two-phased strategy gives me the lowest possible cost for the ship, and the radar is a big piece of that."

LHA-8 Contract Awarded

In June 2016, the Navy awarded a contract to General Dynamics National Steel and Shipbuilding Co. (NASSCO) for the planning, advanced engineering, and procurement of long lead time material in support of the LHA-8 amphibious assault ship, a new version of the big deck LHA-6 class with a well deck inserted back into the design.

The USS *America* (LHA-6) and Tripoli (LHA-7) are aviation-enhanced ships that sacrifice the ability to launch surface craft in favor of having more space to maintain the F-35B Joint Strike Fighter. With Marine Corps ground vehicles getting larger and heavier, in some cases precluding air lift from ship to shore, the Navy decided to add the well deck back in for LHA-8 and beyond.

The LHA-8 radar suite was until recently expected to remain the same as for the LHA-6 and the recently laid down (June 2014) LHA-7. But following the August 2016 EASR EMD contract to Raytheon, the LHA-8 is now planned as one of the first ships to receive the EASR.

LPD-28 Long Lead Contracts Awarded

In March 2016, the Navy awarded a $117 million contract modification to Ingalls Shipbuilding to continue procurement of long lead time material and advance construction activities on the last LPD-17 class amphibious transport dock, the future Fort Lauderdale (LPD-28). This announcement followed a December 2015 award of $200 million to begin early shipbuilding activities, including main engines, diesel generators, deck equipment, shafting, propellers, valves and other long-lead systems.

In January 2016 – after the initial materials contract – the Navy released a request for proposals for the ship's design and construction. In March 2016, Ingalls Shipbuilding submitted its proposal for construction of the

LPD-28. An award is expected by the end of the fiscal year, in September 2016, with the ship set for completion in September 2021.

The LPD-28 is planned to serve as a "bridge" between the LPD-17 class and the upcoming LX(R) dock landing ship replacement program. In January 2016, Director of Expeditionary Warfare Maj. Gen. Chris Owens said the LPD-28, "Is going to be slightly different from the rest of the LPD-17 class, and it's going to be a bridge to what will become the replacement to the *Whidbey Island*-class LSDs." One major difference – which could affect the radar suite – is that the Fort Lauderdale will have a traditional stick mast as planned for the future LX(R) ships, rather than a composite mast like the rest of the LPD-17 class. Huntington Ingalls Industries' Gulfport Composite Center of Excellence, which built the composite masts, has since shut down.

LX(R) Dock Landing Ship Replacement

In late 2015, the Navy and Marine Corps were claiming the future LX(R) dock landing ship replacement – to replace the LSD-41/49 class – would provide greater capability for less money by basing it on the LPD-17 San Antonio class design, "stripping away unneeded features and adding back in desired ones."

In October 2015, the Navy approved the LX(R) capability design document – which includes key performance parameters and key system attributes – and forwarded it to the Joint Staff for approval, according to Marianne Lyons, deputy program manager for LPD and LX(R). She said the program was in the preliminary design phase, and would move to contract design in early 2016 and then detail design and construction in FY20. "We are working on sort of the rough arrangement of equipment," said Lyons. The Navy is working with both LPD-17 contractor Ingalls Industries as well as General Dynamics NASSCO during the design process.

According to Lyons, "We're redesigning the topside – as I mentioned, we're going from [a composite-materials, radar cross section-reducing Advanced Enclosed Mast/Sensors] mast to a conventional stick mast. We are also incorporating all the affordability initiatives that we are receiving from industry. So when we transition out of preliminary design, which we're looking to do sometime in the spring [of 2016], [we will] transition into contract design [where] we focus on development of ship specifications…."

The change from the enclosed composite mast to a traditional stick mast is due to the fact that Huntington Ingalls Industries' Gulfport Composite Center of Excellence in Mississippi – which produced composite materials for shipbuilding – closed in 2013. Ingalls had planned major series production of enclosed composite masts for the DDG-1000 destroyer program, which has been reduced in the past decades to only three ships.

LPD-28 and LX(R) Radars

The LPD-28 is becoming a rather risky program in Teal Group's eyes, as are most programs intended to be "bridges" to long-running future-generation programs. We do not see much point in one-off ships, which complicates and increases the expense of everything from design to production to future maintenance and repairs, involving design, production, and 40 years of replacements of many custom parts and systems.

However, not only does the one-off LPD-28 seem to be going ahead, but both it and the LX(R) may be accelerated. Reportedly, industry is arguing to bring forward the start date of the next-generation LX(R) ships. The Navy's official program of record calls for buying the first LX(R) in FY20, and then buying one a year starting in FY22. Industry has instead suggested FY18 as the best year to begin LX(R), with LPD-28 being a FY16 ship, and some (presumably Ingalls) have asked lawmakers to consider including advance procurement funding in the FY17 spending bill to support a 2018 start for LX(R) development.

Teal Group would find it more rational to skip the LPD-28 entirely and move directly to the LPD-17-derived LX(R), or to extend LPD-28 class production. It is unfortunate that suppliers can no longer provide for another regular LPD-17 ship. It remains to be seen what will happen – the LPD-17 class itself was long-delayed and trouble-plagued – but either way, a common radar suite would make sense for the stick masts of both the LPD-28 and LX(R). This is what we are forecasting, with delays and possibly all-new radars for the new stick masts – EASR, if development continues on schedule. We see series production beginning only near the end of our forecast period.

Current Developments: Dual Band Radar (DBR)

Oops… *Zumwalt*s Aren't Even Warships Anymore…

In August 2018, the 2019 defense authorization bill clarified what counts as a "battle force ship" in the US Navy. Apparently (egads!), a warship now needs to have a functioning combat system – which the *Zumwalt*s still (in mid-2019) do not have. So, DDG-1000 and DDG-1001 were removed from the battle force ship count, and will not be added back on until they complete a combat system activation in San Diego.

According to the committee, "…all three ships in the *Zumwalt* class will employ a dual delivery approach with hull, mechanical, and electrical (HM&E) systems delivery at the shipbuilder in Maine and combat systems activation in California. In the case of USS *Zumwalt* (DDG-1000), HM&E delivery is scheduled for 2016 and combat systems activation is scheduled for 2018 [which has since been considerably delayed – ed]."

DDG-1001 Commissioned, But Needed New Engine…

In January 2019, the US Navy commissioned the second *Zumwalt* class Destroyer, the USS *Michael Monsoor* (DDG-1001). The third and last, the USS *Lyndon B. Johnson*, was launched in December 2018 and will be commissioned in 2022.

In August 2018, the *Monsoor* was still at the Bath Iron Works yard in Maine, after it was determined that the main turbine engine needed to be replaced after engine blades were damaged during ship's acceptance trials.

DDG-1000 Sounds Lonely to Us: "Mission" Changes Again

In March 2019, the US Navy's FY20 budget discussed the DDG-1000, and managed to sound pretty unimpressed. PE# 0204202N DDG-1000 introduced the ship with the hope that it would achieve at least a "credible" presence, but to us DDG-1000 and its ungainly brothers sound like the kids no one wants to hang out with, and also like the kids that will never be trusted with a truly important task: "The mission of the DDG-1000 class is to provide credible independent forward presence/deterrence and operate as an integral part of Naval, Joint or Combined Maritime Forces. DDG-1000 will establish and maintain surface and sub-surface superiority, provide local air defense, and incorporate signature reduction to operate in all threat environments. DDG-1000 will have seamless Joint Interoperability to integrate all source information for battlespace awareness and weapons direction."

But with no guns (yup, still unusable until further notice) and fewer VLS cells than even an *Arleigh Burke*, these huge ships will probably be placed somewhere that they won't get hurt, but also where they won't be able to do anything terribly useful.

The Navy's prescription for staying out of trouble continues: "After a comprehensive review of *Zumwalt* class requirements, the Navy decided in November 2017 to refocus the primary mission of the *Zumwalt* class Destroyers from Land Attack to Offensive Surface Strike [hunting down other ships… – ed]. The funding requested in PB 19 will facilitate this change in mission and add lethal, offensive fires against targets afloat and ashore. These changes include integration of SM-6 capability, Maritime Strike Tomahawk Integration, and organic cryptologic collection equipment (SPECTRAL). In order to maintain the required radar signature, an upgrade in off-board platform communications to the Network Tactical Common Data Link (NTCDL) is also required, paired with the SPECTRAL system.

The Advanced Gun Systems will remain on the ships, but in an inactive status for future use, when a gun round that can affordably meet the desired capability is developed and fielded."

So, for the moment, the DDG-1000 is still a nearly-unarmed behemoth, probably too big to risk losing anywhere near real combat.

DDG-1000 Combat System: Perhaps Ready in 2020, But Not Sonar…

In May 2019, according to DDG-1000 Program Manager Capt. Kevin Smith, the DDG-1000's unique, orphan, *Zumwalt*-only Raytheon-designed combat system was mounted on the ex-*Paul F. Foster* (DD-964), being used as the Self-Defense Test Ship. In April 2019, after it conducted a few tracking exercises, the *Paul F. Foster* fired the first Evolved Sea Sparrow Missile, demonstrating the *Zumwalt* combat system can see incoming threats and use ESSM to protect the ship. The combat system had previously only been tested at a ground facility at Wallops Island, VA.

Also according to Capt. Smith, "It's been a long road as far as getting through the combat integration at Wallops Island. We learned a lot: we did six tracking exercises there, and now we're on the Self Defense Test Ship and we're going through all our unmanned firing testing. And then the plan is, we have an SM-2 (Standard Missile) risk-reduction firing (on the *Paul F. Foster*); when we get that done, we're going to move over to the lead ship and fire our first SM-2 off the lead ship probably in the '20 timeframe."

Smith said he expects DDG-1000's "final delivery" in September 2019 (when it will technically become a warship), though work will still remain to bring the SM-2 live-fire capability to the ship in 2020 (meaning, "but stay away from combat!").

Smith also said early work at Wallops Island and on the *Paul F. Foster* reduced risk in some warfare areas. But, "under water, for the sonar system, we didn't have a lot of land-based test sites to go … test a lot of the systems. So we're doing it on the ship for the first time," which according to Smith presents more risk than for systems which could be tested on land.

Teal Group suggests that without a functional/tested sonar, the DDG-1000 might also want to stay away from water….

DBR Flaws Require ECPs

In March 2019, the US Navy's FY20 procurement budget discussed DBR flaws and provided funding for the Dual Band Radar under MDAP/MAIS Code P40A/DC020.

As a result of DBR land based testing at the Wallops Island Engineering Test Center (WIETC), limitations were identified in Dual Band Radar (DBR) performance that directly impact CVN-78 and DDG-1000 class readiness. These limitations require ECPs to correct the performance areas of the radar for Air Traffic Control and Integrated Combat Systems (e.g., False Clutter Tracks, Short Range Tracking, General Tracking, Slow Air Tracking, Waveform Scheduling, and code stability).

Additional limitations will be identified during CVN-78/DDG-1000 Shipboard Activation, Integration and At-Sea Testing.

The Prime Contractor and Government Technical Team have documented critical radar issues that require correction via ECPs in FY17-FY24. Funding for these ECP efforts increased starting in FY18 due to the engineering and technical complexity of the change proposals needed to satisfy combat system qualification requirements. DBR was reviewed by an Independent Review Team (IRT) chartered by the Under Secretary of Defense (Acquisition, Technology and Logistics) to assess specific CVN-78 systems. The IRT recommended that the Navy establish infrastructure and mechanisms to accelerate the acquisition of spares for DBR and develop a repair capability for DBR parts from the Fleet.

DBR Special Test Equipment and Infrastructure funding from FY19-FY24 provides for, (1) test equipment and support for a repair depot for assemblies and subassemblies for DBR components, including the Common Array Power System (CAPS) and Common Array Cooling System (CACS); (2) resolution of system obsolescence that will degrade system Ao; and, (3) establishment of product support engineering infrastructure. The additional DBR sustainment and infrastructure efforts will facilitate the transition of material sparing support of DBR to NAVSUP.

Funding is also required to establish the In-Service Engineering Agent (ISEA), Original Equipment Manufacturer (OEM) production services and support for Configuration Management. Funding also implements the DBR Life Cycle Sustainment Plan (LCSP) and infrastructure, Diminishing Manufacturing Sources and Material Shortages (DMSMS) Plan, associated hardware and software obsolescence mod kits, procurement of Engineering Change Proposals (ECPs), associated logistics products and on-board allowance requirements to enable system operation. Production Support is also required to assist with DBR Combat System Integration and Technical Documentation.

Current Developments: AN/SPY-6 AMDR

Flight III *Arleigh Burke*s Begin Construction; AMDR IOC Planned for 2023

In May 2018, the first Flight III *Arleigh Burke* guided-missile destroyer, the USS *Jack H. Lucas*, began construction at Huntington Ingalls Shipbuilding in Pascagoula, MS. The *Louis H. Wilson Jr.* is also under contract. In September 2018, ten new Flight III ships were approved for construction by the Navy – the *Ted Stevens*, *Jeremiah Denton*, and eight other unnamed ships.

The SPY-6 radar is up to 30 times more sensitive than the older AN/SPY-1D radars, but requires much more power. The Flight III destroyer will have a new power plant that converts 4,160-volt AC power into 1,000-volt DC power.

In early 2019, the US Navy expected the SPY-6 to achieve initial operational capability (IOC) in 2023. The Flight III *Arleigh Burke* guided-missile destroyers will have the Baseline 10 system.

AMDR BMD Developmental Testing Complete

In January 2019, the SPY-6(V)1 AMDR completed the final round of developmental testing after tracking its 15th ballistic missile target, locating and tracking targets launched from the Navy's Pacific Missile Range Facility.

AMDR LRIP Begins: $400 Million for Three Systems

In March 2019, the US Navy awarded Raytheon a $402.6 million contract modification for three low-rate initial production (LRIP) SPY-6 AMDR systems to be deployed on DDG-51 Flight III destroyers. Work will be performed in Marlborough, MA, and is to be completed by March 2023.

Current Developments: EASR & EXI

EASR Systems-Level Testing Begins

In March 2019, Raytheon announced the SPY-6(V)2 EASR had completed subsystem testing. Mounted on a 100-foot tower at the Navy's Surface Combat Systems Center at Wallops Island, VA, the rotating radar array will undergo systems-level tracking of aircraft through the end of the year. The SPY-6(V)2 cleared tests in Hawaii in February 2019.

According to US Navy Cpt. Jason Hall, Program Manager for Above Water Sensors, Program Executive Office Integrated Warfare Systems, "Going from 'cold steel' to a fully calibrated radar in less than one year is no small feat, but that's exactly what we accomplished with EASR…. The scalable building block architecture developed for AN/SPY-6(V)1 enabled EASR to rapidly complete subsystem testing. We are making great strides toward delivering SPY-6 capability across the fleet."

In June 2019, EASR systems-level testing began at Wallops Island.

Teal Group Evaluation

Dual Band Radar (DBR)

Our DDG-1000 Forecast History

In mid-2008, the Navy "officially" reduced the DDG-1000 program from seven (originally 32) to three ships. With construction of two ships well underway in early 2015, it looked like at least two Raytheon ***AN/SPY-3 Multi-Function Radar (MFR)*** suites would be built. The third ship had been laid down, and we also forecast at least funding would be provided for a third radar suite (even if it was never built).

Whether the DDG-1000 ever sailed at all was still somewhat uncertain. As a technology demonstrator for a land-attack mission now mostly covered by UAVs with precision bombs and missiles, the DDG-100 has long been a pointless and extremely expensive exercise, albeit a very cool one. In the salad days of ever-increasing defense budgets, well, heck, why not? Even this analyst would someday love to see the huge tumble-home hull 21st century pocket battleship at sea. Who wouldn't? But it is a stupid idea, especially now that the Flight III *Arleigh Burke*s are funded and will provide new development challenges for the genuinely vital BMD mission. The DDG-1000 is a giant, possibly stealthy (unless one has eyes, or a UAV with EO/IR sensors, or a submarine with a sonar) ship with two 6" guns, with underpowered radars more suitable for auxiliary use on an aircraft carrier – which will in fact be their first application. And the DDG-1000 now won't even have the full *carrier* radar suite!

By mid-2013, with sequestration in place and the Navy likely to become rational and fund necessary projects like JSF and UCAV, and maybe some sailors, Teal Group believed there was a significant chance the DDG-1000 would eventually be cancelled outright. In the March 2014 budget, funding levels were already dropping. Our forecast assumed the Navy would build two ships and use already-awarded third ship funding to cover some of the cost overruns on testing of the first two: if we use Northrop Grumman's recent new-class LPD-17 disaster as a guide, any all-new ship class is due for years of additional delays to service, even after being laid down and then launched. We thought DDG-1002 could still be lying in the yard in a decade, a huge rusting hulk. DDG-1000 and DDG-1001 could be re-classified as a technology development program for high-power weapons and technologies at sea (with its 78 MW power generation capability).

The Navy apparently agreed with us, and in September 2015 reports indicated the Department of Defense was considering terminating funding for the *Lyndon B. Johnson* (DDG-1002) during construction. However, other reports claimed the program shutdown costs and contract termination penalties would be so high that cancellation could cost as much as completion. DDG-1000 has become yet another less than useful program continued due to contracts written in favor of industry (see JSF…), despite decades of developer delays that only received more and more money from the Navy. Why are the delays not grounds for contract termination?

But we should also remember, these are big and noble-looking ships, and huge rusting hulks (and the corresponding wasted expense) are difficult to hide. In April 2016 in Bath, Lawrence Pye, a Maine lobsterman, told the Associated Press that on his radar screen the 610-foot long DDG-1000 looked like a 40- to 50-foot fishing boat. But it is actually 100 feet longer, displaces much more (15,000 vs. 8-9,000 tons), and towers over the DDG-51 class destroyers. The DDG-1000 is essentially a "pocket battleship" in size.

By December 2015, the Pentagon had apparently decided in favor of keeping the third ship, despite the fact that the ship class's mission was still very uncertain. There have been suggestions of use for special operations because of the ship's stealth. But why not unload those SOF forces from an actual 40- to 50-foot boat, rather than a massively expensive battleship with two popguns – now without the follow-on munition types originally planned for a 30-ship fleet, and long since replaced in its land attack purpose by much less vulnerable UAVs?

Additionally, despite its surface radar stealth, there has been suspiciously little written about the DDG-1000's resistance to mines and diesel submarines, or its EO/IR signature and detectability by the current generation of longer-range naval and UAV EO/IR systems, and long-range fighter-bomber IRSTs. You can't hide a battleship in the fog today. Teal Group suspects a pocket battleship that generates 80 MW of power is about as hot above and about as loud underneath the surface as, well, a pocket battleship.

With an untried tumblehome hull, Teal Group fears the DDG-1000 will never come near the littorals in a real combat situation. It is just too big and expensive to lose, and it could potentially turn turtle and sink from a single torpedo, especially considering its reduced manning for damage control (143 crew vs. 323 aboard the much smaller *Arleigh Burke*s…). While experts today generally agree that thorough Navy testing of the unique hull has shown an ability to survive weather and high seas, very little is known about its resistance to sinking and capsize when damaged (especially in high seas). At least there would be fewer lives lost, but many more than aboard UAVs.

DDG-1000 Status

By mid-2019, the *Zumwalt* story had only gotten weirder.

In August 2018, the 2019 defense authorization bill clarified what counts as a "battle force ship" in the US Navy. Apparently (egads!), a warship now needs to have a functioning combat system – which the *Zumwalt*s still (in mid-2019) do not have. So, DDG-1000 and DDG-1001 were removed from the battle force ship count, and will not be added back on until they complete a combat system activation in San Diego.

In January 2019, the US Navy commissioned the second *Zumwalt* class Destroyer, the USS *Michael Monsoor* (DDG-1001). The third and last, the USS *Lyndon B. Johnson*, was launched in December 2018 and will be commissioned in 2022.

In August 2018, the *Monsoor* was still at the Bath Iron Works yard in Maine, after it was determined that the main turbine engine needed to be replaced after engine blades were damaged during ship's acceptance trials.

In March 2019, the US Navy's FY20 budget discussed the DDG-1000, and managed to sound pretty unimpressed. PE# 0204202N DDG-1000 introduced the ship with the hope that it would achieve at least a "credible" presence, but to us DDG-1000 and its ungainly brothers sound like the kids no one wants to hang out with, and also like the kids that will never be trusted with a truly important task. With no guns (yup, still unusable until further notice) and fewer VLS cells than even an *Arleigh Burke*, these huge ships will probably be placed somewhere that they won't get hurt, but also where they won't be able to do anything terribly useful. "The Advanced Gun Systems will remain on the ships, but in an inactive status for future use, when a gun round that can affordably meet the desired capability is developed and fielded."

In May 2019, according to DDG-1000 Program Manager Capt. Kevin Smith, the DDG-1000's unique, orphan, *Zumwalt*-only Raytheon-designed combat system was mounted on the ex-*Paul F. Foster* (DD-964), being used as the Self-Defense Test Ship. In April 2019, after it conducted a few tracking exercises, the *Paul F. Foster* fired the first Evolved Sea Sparrow Missile (ESSM), demonstrating the *Zumwalt* combat system can see incoming threats and use ESSM to protect the ship. The combat system had previously only been tested at a ground facility at Wallops Island, VA.

Capt. Smith also said early work at Wallops Island and on the *Paul F. Foster* reduced risk in some warfare areas, but, "under water, for the sonar system, we didn't have a lot of land-based test sites to go … test a lot of the systems. So we're doing it on the ship for the first time." Meaning, the DDG-1000 might be able to defend itself from aerial threats, but it may be awhile before it should go anywhere near the water….

Our DDG-1000 & DBR Forecasts

Our funding forecast is thus highly speculative. By rights, with any kind of budgetary responsibility, the two lame duck DDG-1000s already launched should not continue in service for long, even if they are useful test ships (they will be extremely expensive test ships). Their time and their mission passed a decade ago when armed UAVs successfully took over the land attack mission with much greater range and survivability. The third ship should never be launched. Our persnickety forecast assumes this.

However, with 20+ years experience at Teal Group, this analyst would not be surprised to see one (or maybe two) ships still at sea in a decade, possibly with the other two (or one) ships launched and quickly mothballed. There is even the possibility the Navy will find a mission for these behemoths, if only as spectacular lookers for showing the US flag during port visits (somewhat more survivable, and much cooler-looking, than the even bigger aircraft carriers).

If more than one ship does remain in service, our out-years ***Dual Band Radar (DBR)*** forecasts will more than double for RDT&E and Upgrade & Support funding (though the money may go for a new radar suite, or indeed continuing high-power radar testing).

Caveat

We should add one caveat, however. A few years ago, the DDG-1002 looked likely to mount an experimental form of electro-magnetic railgun, probably replacing one of the two Advanced Gun Systems (planned for retrofit after commissioning). If that happened (looking less likely in id-2019), there is a slim possibility that the three DDG-1000s could suddenly become the most valuable ships in the world.

With stealth and more power than any other surface combatant in any Navy*, if railgun or laser technology advances to where these "sci-fi" weapons actually work, stealthy laser battleships with massive electrical power shooting down every aircraft and ballistic missile in sight at the speed of light may become the future of naval warfare. Of course, a nuclear-powered ship would be the ultimate solution for maximum power generation, but to the imaginatively-minded, the cool-looking *Zumwalt*s could reign over a solid decade of aircraft/missile-zapping pocket battleship science fiction success. This future is not currently in our forecast, but watch this space….

**For comparison with the DDG-1000's reported 78 MW electrical generation capability (from four gas-turbine generators; this power is also the sole source of power for the propulsion motors, so power available for sensors and weapons will be much less while underway), the Flight I/II DDG-51 destroyers provide only a reported 7.5 MW of* *power. Four 750 KW diesel generators aboard the Freedom class LCS-1 generate 3 MW of power. The AMDR radar is planned to require much more power – 30-31 MW peak power – than the Flight I/II AN/SPY-1 Aegis radar, which requires only about 5 MW peak power. The nuclear reactor in a US submarine or aircraft carrier may generate up to about 165 MW, which would also make these good platforms for high-power weapons.*

AN/SPY-6 AMDR

AMDR: Different Program, Real Future

Unlike the DBR, the ***Air and Missile Defense Radar (AMDR)*** had been an increasingly very well-funded program, with more than $90 million per year for RDT&E in FY08 and FY09, more than $160 million in FY10, and $200-350+ million planned annually from FY11-FY16 (except for only $150 Million in FY12).

In the March 2014 budget, RDT&E funding dropped significantly, but remained substantial ($194/125/145/247/100 million in FY13/14/15/16/17). This is the kind of funding that results in a real production radar suite, earlier planned for the CG(X) next generation cruiser and now for an ongoing Flight III *Arleigh Burke* procurement, as well as future ship classes as a follow-on to Aegis BMD. The DBR is not a BMD radar system, originally intended instead for the again-anachronistic land-attack DDG-1000 mission (the massively more powerful land-attack Missouri battleships were retired in the 1990s after reactivation near the end of the Cold War).

In early 2013, the Navy planned AMDR to enter system development in March 2013 for the S-band ***AMDR-S*** radar and ***Radar Suite Controller (RSC)*** after demonstrating all of its technologies in a relevant environment. A new X-band ***AMDR-X*** radar will be developed under a separate program at a later date, with AMDR initially using an upgraded AN/SPQ-9B radar in its place.

In October 2013, Raytheon was awarded a $385.7 million contract for EMD through LRIP of the AMDR-S and RSC for the Flight III *Arleigh Burke* (DDG-51) class destroyers, beginning with DDG-118/119, with the ship itself to be funded in 2016. The contract includes options which, if exercised, would bring the cumulative value to $1.6 billion.

Protests followed from Northrop Grumman and Lockheed Martin – the producer of a whole generation of Aegis radars for the *Arleigh Burke*s and other ships. In early February 2015, the Navy was reportedly still re-evaluating bids from Raytheon, Lockheed, and Northrop, but by 2016 Raytheon AMDR development had restarted, with testing of a production representative face from the S-band volume search radar to begin in Hawaii in late 2016.

In May 2018, the first Flight III *Arleigh Burke* guided-missile destroyer, the USS *Jack H. Lucas*, began construction at Huntington Ingalls Shipbuilding in Pascagoula, MS. The *Louis H. Wilson Jr.* is also under contract. In September 2018, ten new Flight III ships were approved for construction by the Navy – the *Ted Stevens*, *Jeremiah Denton*, and eight other unnamed ships.

Our AMDR Forecast

With the long-term DDG-51 contract in June 2013, the Navy for the first time set a definite date for AMDR production, for the first Flight III *Arleigh Burke* (DDG-119), to be funded in FY16. In the March 2014 Navy budget, planned AMDR RDT&E funding was to drop from $235 million in FY16 to $100 million in FY17, to only $43 million in FY18 – perhaps an overly optimistic hope that AMDR development would be completed in time for DDG-119 construction.

But as we forecast in early 2015, the Flight III ships are in many ways new ships themselves. Though they do have a guaranteed future, unlike the DDG-1000 class, we foresaw continuing delays. 2016 or 2017 was even more absurdly optimistic for a production AMDR system, even just the AMDR-S. The Navy has until very recently planned “initial capability” of a partial AMDR for March 2023, based on a system development to be awarded in late 2013 (to either Lockheed Martin, Raytheon, or Northrop Grumman).

With a big new fleet of Flight IIA *Arleigh Burke*s, the potential removal of one nuclear carrier group from service, and sequestration, we anticipated a pause in destroyer production before the Flight IIIs are ready or in fact needed. The long protests and delays in AMDR EMD have also further delayed AMDR development.

By the February 2016 budget, the Navy had switched plans for the first AMDR for the Flight III/SPY-6 configuration. The radar systems were to be executed via Engineering Change Proposals (ECP) as they will not ready in time for scheduled ship construction.

In early 2019, the US Navy expected the SPY-6 to achieve initial operational capability (IOC) in 2023. The Flight III *Arleigh Burke* guided-missile destroyers will have the Baseline 10 system. In March 2019, the US Navy awarded Raytheon a $402.6 million contract modification for three low-rate initial production (LRIP) SPY-6 AMDR systems to be deployed on DDG-51 Flight III destroyers.

Teal Group’s AMDR forecast includes continuing high (but not massive) levels of RDT&E funding beyond the end of the decade, with the first AMDR production system to be built around 2020 – but this could easily slip further right. Note that once production begins, the Navy has funded Flight III *Arleigh Burke*s at the rate of two ships per year, continuing.

EASR & EXI

New EASR & EXI Programs

The ***Enterprise Air Surveillance Radar (EASR)*** will modify an existing radar technology (the AMDR…) to meet the air surveillance requirements for multiple ship classes, including forward-fit for the CVN-79+, LHA(R), and LX(R) classes, and potential back-fit to CVN, LHA, and LPD classes. EASR will be one sensor in a suite that is designed to meet the performance needs for ship self-defense, situational awareness, and air traffic control. EASR will replace the Volume Search Radar (VSR) in the CVN-78 class Dual Band Radar (DBR) system and the AN/SPS-48/49 radar systems in numerous ship classes.

The US Navy also plans to procure a separate X-band radar to compliment the EASR for both future carriers and large deck amphibious warfare ships.

In August 2016, the US Navy awarded Raytheon a $92 million contract to develop EASR, planned as the volume air search radar initially for the new *Gerald R. Ford* class aircraft carriers (CVN-78) beginning with the *John F. Kennedy* (CVN-79), and future big deck amphibious warships beginning with the planned LHA-8.

Following the EMD phase, there are up to $723 million in contract options to support 16 ship sets of the radar – 6 fixed-face for the *Ford* carriers and 10 for amphibious ships. If all the options are exercised the program is set to run through 2026.

In March 2019, Raytheon announced the AN/SPY-6(V)2 EASR had completed subsystem testing. In June 2019, EASR systems-level testing began at Wallops Island, Virginia.

Enterprise X-Band Illuminator (EXI) funding will develop an X-band illuminator compatible with the EASR radar and Combat System suite. Funding will also integrate a missile illuminator for future CVN applications as well as other ship classes.

Our EASR Forecast

The new EASR radar will have much in common with the AMDR, reportedly varying as an AMDR would if smaller versions were developed for different platforms than the Flight III DDG-51 BMD destroyers. In a sense, the EASR is supposed to be just that – AMDR modified for other ships, but as smaller and less expensive systems.

However, the long-standing lovefest for "modular" systems that save money by being, well, genuinely modular, almost never works out as planned. Half-sized systems typically cost almost as much as the original full-size versions (and in fact, very few planned "modular" systems are ever produced in different sizes). Thus, Teal Group expects an AMDR-derived EASR will unlikely cost the $45 million planned in August 2016 contract options (16 radars for $723 million). Our EASR unit cost forecast is for closer to $120-200 million, compared with $320-420 million AMDRs (when including related C4I).

We forecast initial production around 2020, probably for the CVN-79, followed by radars for LHA-6, LPD-28, and a retrofit system for CVN-78. But with three different platforms, there is a definite likelihood of delays. In our forecast, we have assumed the radars will be ready for the ships themselves, but this may not be the case, especially not for all of them. Our EASR production forecast will very likely shift at least a year or two to the right.

The first *new* ship class in our forecast period that should receive an EASR radar suite is the LH(X), especially if development of this LPD-17-based class goes ahead (quickly) on schedule. But again, delays for any new ship class are almost guaranteed. Our forecast again is very optimistic.

Next decade, after AMDR and EASR have been proven aboard several ship classes, we foresee the possibility of major production for several new classes, as well as for retrofit to nearly all the US Navy's non-Aegis amphibious warfare ships and aircraft carriers.

In June 2019, the US Navy released the final request for proposals (RfP) for the next-generation guided-missile frigate (FFG(X)) – which now is a very different (and even larger) beast than planned in 2016. In addition to the COMBATSS-21 system, the FFG(X) will primarily mount government-furnished equipment (GFE) for all its major sensors and systems. A fixed-face Raytheon Enterprise Air Surveillance Radar (EASR) will be required as the primary air search radar for all FFG(X)s (see *Littoral Combat Ship (LCS) & Frigate (FFG(X)) Radar & C4I* report for LCS/FFG(X) program details and FFG(X) EASR forecasts).

Note that our EASR forecast does not include the eventual, separate and still uncontracted, next-generation X-band radar intended to compliment the EASR for both future carriers and large deck amphibious warfare ships. Current plans for most new Navy warships, including the Flight III *Arleigh Burke*s, and LHA-6 and LPD-17 classes, include Northrop Grumman's AN/SPQ-9B (see report) still being used on many platforms.

Sea Change in the Naval Radar Market

Shocker: AMDR to Supplant SPY-1

Within the space of just a couple of years, Raytheon has taken the vast majority share of future new-build naval radars from Lockheed Martin. Until October 2013 when Raytheon won the EMD contract for AMDR, Lockheed's AN/SPY-1 Aegis system was the 800-pound gorilla of naval radar, aboard nearly all new US Navy surface combatants and an increasing number of international Aegis warships. But following more than a year of protests by Lockheed and Northrop Grumman, Raytheon was confirmed for AMDR development for future *Arleigh Burke* class destroyers, with AMDR to supplant the SPY-1 aboard the new Flight III version from DDG-119 onward.

With Raytheon's win of EASR EMD in August 2016, Raytheon also took away the future radar market for what had been called "non-Aegis ships" – essentially every other large warship other than destroyers and cruisers, including aircraft carriers and large amphibious ships.

Combined with a few legacy DBRs and MFRs on aircraft carriers and the lame duck DDG-1000 class, essentially every new major US warship for the next decade at least is now planned to have a Raytheon radar as its primary radar system – not a Lockheed Martin Aegis radar.

This is a major sea change from only a few years ago, when the SPY-1 and Aegis looked to have swallowed the naval radar market whole.

With EASR derived almost entirely from AMDR, and with DBR essentially dead already, EASR/AMDR will essentially be one major radar program.

Raytheon to Surpass Lockheed Martin in FY24

Lockheed Martin will continue to garner hundreds of millions of dollars annually for Aegis upgrades and support. There are more than 100 ships currently in service with Aegis, and in mid-2019 not a single AMDR/EASR in service. But with hundreds of millions of procurement dollars soon to be spent annually for AMDR/EASR, in less than a decade Raytheon may surpass Lockheed Martin as the dominant world naval radar producer.

According to our forecasts, assuming AMDR/EASR go ahead relatively on schedule, Raytheon's total funding for DBR/AMDR/EASR will exceed Lockheed Martin's total funding for SPY-1/Aegis for the first time in FY24 – with $1.91 billion versus $1.57 billion – and Raytheon will likely hold this lead for at least a decade.

Funding Forecast

RDT&E (FY19$ Millions)	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28
All RDT&E										
DBR	6.0	4.0	4.0	6.0	4.0	2.0	4.0	2.0	4.0	2.0
DBR C4I	18.0	22.0	18.0	16.0	12.0	8.0	10.0	8.0	8.0	10.0
AMDR	180.0	140.0	120.0	110.0	140.0	120.0	130.0	150.0	160.0	150.0
AMDR C4I	120.0	190.0	130.0	90.0	70.0	40.0	50.0	60.0	90.0	80.0
EASR	50.0	60.0	45.0	50.0	40.0	50.0	60.0	45.0	65.0	70.0
EASR C4I	42.0	66.0	56.0	50.0	44.0	58.0	48.0	42.0	54.0	56.0
Total RDT&E	**416.0**	**482.0**	**373.0**	**322.0**	**310.0**	**278.0**	**302.0**	**307.0**	**381.0**	**368.0**

Procurement (FY19$ Millions)	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28
Production										
AMDR	—	—	260.0	240.0	420.0	630.0	630.0	420.0	420.0	420.0
AMDR C4I	—	—	160.0	160.0	300.0	450.0	450.0	300.0	300.0	300.0
EASR	—	80.0	160.0	70.0	80.0	150.0	150.0	150.0	150.0	225.0
EASR C4I	—	80.0	160.0	80.0	90.0	160.0	160.0	160.0	160.0	240.0
Upgrade & Support										
DBR	34.0	20.0	12.0	14.0	10.0	12.0	10.0	8.0	6.0	6.0
DBR C4I	30.0	18.0	24.0	22.0	14.0	18.0	16.0	14.0	12.0	10.0
AMDR	—	—	—	40.0	40.0	50.0	70.0	90.0	80.0	100.0
AMDR C4I	—	—	—	50.0	60.0	70.0	90.0	100.0	120.0	120.0
EASR	—	10.0	30.0	20.0	24.0	40.0	50.0	45.0	50.0	60.0
EASR C4I	—	—	20.0	40.0	40.0	50.0	40.0	40.0	50.0	65.0
Total Procurement	**64.0**	**208.0**	**826.0**	**736.0**	**1,078.0**	**1,630.0**	**1,666.0**	**1,327.0**	**1,348.0**	**1,546.0**
Total DBR/AMDR/EASR	***480.0***	***690.0***	***1,199.0***	***1,058.0***	***1,388.0***	***1,908.0***	***1,968.0***	***1,634.0***	***1,729.0***	***1,914.0***

Production Forecast

User (Platform)	Through 2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	Total
DBR												
USN (DDG-1000 class)	3	—	—	—	—	—	—	—	—	—	—	2
USN (CVN-78)	1	—	—	—	—	—	—	—	—	—	—	1
Total DBR	**4**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**4**
AN/SPY-6 AMDR												
USN (DDG-51 Flight III)	—	—	—	1*	1	2	3*	3*	2	2	2	16
EASR#												
USN (LHA-8)	—	—	—	1	—	—	—	—	—	—	—	1
USN (LPD-28/LX(R) class)	—	—	—	1	—	1	—	1	1	1	1	6
USN (CVN-78 class)	—	—	1	—	1**	—	1	—	—	—	1	4
USN (Undetermined)	—	—	—	—	—	—	1	1	1	1	1	5
Total EASR	**—**	**—**	**1**	**2**	**1**	**1**	**2**	**2**	**2**	**2**	**3**	**16**

**Each year includes one ECP/retrofit system for DDG-119/120/121*
***Retrofit to CVN-78*
#See Littoral Combat Ship (LCS) & Frigate (FFG(X)) Radar & C4I report for FFG(X) EASR forecasts

July 2019