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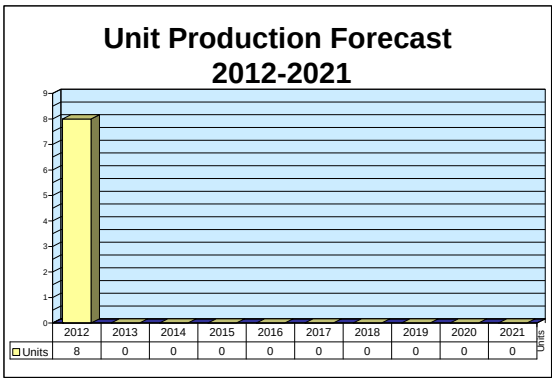
APG-77(V)

Outlook

- The final F-22 Raptor, the APG-77s radar's sole platform, was delivered in 2012
- The U.S. Congress has considered lifting the F-22 export ban in order to extend production
- The APG-77's upgrade market will provide limited future funding



Orientation

Description. Multimode AESA fire control radar.

Sponsor
U.S. Air Force
AF Systems Command
Aeronautical Systems Center
Wright-Patterson AFB, OH 45433
USA
Tel: + 1 (216) 787-1110
Web site: http://www.wpafb.af.mil

Status. In production.

Application. Lockheed Martin F-22 air superiority fighter.

Price Range. Because of the interconnectedness of the avionics system, it is difficult to determine prices of individual equipment. The estimated average cost of an APG-77 is $4.8 million to $5.4 million per aircraft.

Contractors

Prime

Northrop Grumman Electronic Systems	http://www.es.northropgrumman.com, 1580-A W Nursery Rd, Linthicum, MD 21090 United States, Tel: + 1 (800) 443-9219, Email: ES_Communications@ngc.com, Prime

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Contractors are invited to submit updated information to Editor, International Contractors, Forecast International, 22 Commerce Road, Newtown, CT 06470, USA; rich.pettibone@forecast1.com

APG-77(V)

Technical Data

	Metric	U.S.
Dimensions		
Antenna diameter (approx)	1 m	3 ft
Characteristics		
Frequency	8 to 12 GHz	
Power per antenna module	10 w	
Estimated MTBF	2,000 hours	
Radar subassemblies	AESA antenna	
	Radar support electronics unit	
	Array power supply unit	
	Aircraft installation kit	
	Coolant distribution manifold	

Design Features. The APG-77(V) radar for the F-22 is based on the successful APG-66/68/80(V) family of fire control radars. It interfaces with the AMRAAM missile to support day/night and all-weather missions. Aircraft equipped with the fire-and-forget missile can attack targets at beyond visual range.

The active electronically scanned array (AESA) is a fixed, active array consisting of more than 2,000 low-power X-band transmit or receive modules that are electronically scanned or "steered," with no mechanical movement. The separate transmitter and receiver for each radiating element results in increased agility, low radar cross-section, and wide bandwidth. Lower life-cycle costs offset the system's increased complexity, weight, and procurement costs.

Phase shifting is fast, and a lower level of energy is radiated by the side lobes, eliminating the spillover common to feed horn/reflector antennas. This makes the radar less detectable and reduces ground clutter.

The APG-77(V) does not have a main processor of its own. Instead, two central integrated processors (CIPs), which can each process 700 million instructions per second with growth capacity up to 2,200 million, integrate the radar with other sensors and the electronic warfare systems on the F-22.

ESM sensors will use small antennas mounted in the front, along the wingtips, and in the rear. The system will also take advantage of some signals from the radar antenna. The sensor will link to a powerful central processor. Electronics countermeasures (ECM) jamming energy can be transmitted through the AESA antenna and can be powerful enough to "fry" the electronics of enemy sensors.

Operational Characteristics. The APG-77(V) was tailored for air superiority and strike fighter missions. It provides all-weather, air-to-air, and air-to-ground capability, with advanced electronic counter-countermeasures (ECCM) capabilities. Increased processing power and integrated avionics will allow the APG-77 to increase operational modes in the future. The following are some of the current operational modes:

Advanced Air-to-Air Modes

- RANGE-WHILE-SEARCH (RWS). RWS mode processing provides air-to-air, all-aspect target detection, even in heavy clutter. The radar displays synthetic video on a clutter-free scope when presenting airborne targets, even those flying close to the ground. Ground-moving targets are eliminated by selective filtering and logic. There is a Spotlight mode to scan a small, pilot-selected volume to facilitate the detection of a desired target at the earliest possible time.
- VELOCITY SEARCH WHILE RANGING (VSR). This mode gives maximum detection-range performance against closing, nose-aspect targets out to 160 nautical miles in both uplook and downlook situations. Through advanced processing within the Advanced Pilotage System Program, an innovative Alert/Confirm mode is activated to achieve a low rate of false alarm, while extending the range capability of the radar beyond the RWS mode.
- TRACK-WHILE-SCAN. This mode was designed to help a pilot cope with numerically superior forces. To maximize situational awareness and firepower, TWS can track up to 10 targets. Target tracks are displayed for up to 13 seconds after a missed detection before the track file is terminated. This mode has proved effective in multitargeting situations.
- SINGLE-TARGET TRACK (STT). This mode can be entered from any of the air-to-air search modes by using the side-stick controller and

throttle grip. It provides a dependable, accurate track, displaying target parameters and the tactical engagement geometry. The STT submode provides track data to support cueing for short-range and beyond-visual-range air-to-air missile shots. It also provides gun-sight envelope solutions for short-range gunnery modes.

- SITUATIONAL AWARENESS MODE (SAM). This provides the pilot with an interleaved search and track capability. SAM provides high-quality tracking on one or two targets while searching for other targets in an independent, pilot-selected scan volume. Track accuracy makes this mode ideal for accurate air-to-air missile cueing and all beyond-visual-range (BVR) target engagements.
- TRACK RETENTION THROUGH THE NOTCH (TRTN). This feature is automatically activated in the track phase for STT and SAM. It allows active tracking when the target is maneuvering into the same Doppler filter as main beam clutter and when the target amplitude is such that the radar can no longer distinguish the target from clutter. The radar will automatically "coast" for a few seconds, until the target emerges from the clutter region.

Advanced Strike Modes

- ENHANCED REAL BEAM GROUND MAP (GM). This mode generates a map for navigation and target detection out to 80 nautical miles. It was enhanced with a monopulse mapping technique that sharpens map features for hard targets both off-boresight and on the nose. Both direct and offset weapons delivery are possible. A Freeze option stops radar emissions and allows the aircraft to approach the target radar-silent. An extended map mode provides a 4:1 resolution improvement and map expansion.
- DOPPLER BEAM SHARPENING (DBS). When a target of interest is displayed on the ground map at 10-, 20-, or 40-nautical-mile scale, DBS1 mode gives an accurate map of a selected area with an 8:1 azimuth resolution improvement. A resolution of 64:1 is possible with DBS2 mode. This mode gives off-boresight weapons the improved resolution needed for precise launch data. The Freeze option is available.
- SEA. This will detect seaborne targets in medium and low sea-state clutter. It is similar to the GM mode, but the radar processor integrates more radar samples to produce a map better tailored for maritime surveillance. Slower scan rates and additional samples increase sea-target detection performance. The Freeze option is available.
- FIXED TARGET TRACK (FTT). This mode can automatically maintain an accurate track on a stationary target for fix-taking and weapons delivery. FTT is accessible from the GM, GM EXP, SEA, SEA EXP, and DBS modes. Slow-moving targets can be acquired from GM or SEA modes using FTT mode.
- GROUND MOVING TARGET INDICATION (GMTI). This detects moving targets such as cars, trucks, tanks, other military vehicles, ships, and taxiing aircraft on land or sea out to 40 nautical miles. GMTI mode can also be used to detect moving surface targets in high sea-states. The Freeze option is available.
- GROUND MOVING TARGET TRACK (GMTT). This mode automatically maintains an accurate track on a moving vehicle (land or sea) for weapons delivery. It is available only from the GMTI mode. Moving targets detected in GMTI can be acquired and tracked using GMTT.
- BEACON (BCN). In this mode, the radar detects a beacon transponder for fix-taking and air-to-ground weapons delivery offset. It can also be used for tanker rendezvous. The Freeze option is available.

The advanced, combined radar/ESM/ECM system will be a fast-moving ISR platform with the ability to datalink to ground troops, if needed. By including the system in the design from the beginning, aircraft stealthiness is ensured. The system will have the power and ability to shut off computers, cut off cell phones, and disrupt most electronics systems.

The advanced capabilities of the APG-77, along with the radar's ability to transmit and receive data, give the F-22 an expanded role on the battlefield. In recent exercises, the radar was able to perform as an airborne control system. It was able to send information about enemies to friendly units, increasing the effectiveness of friendly forces.

APG-77(V)

APG-77 equips the F-22 Raptor.

Source: Lockheed Martin

Variants/Upgrades

Automatic target recognition capability and an interface with an infrared search-and-track system have been implemented, as have a variety of preplanned performance improvements, especially air-to-ground mode improvements. Many upgrades are being accommodated via software changes instead of reworking or replacing hardware.

Planners are studying ways to leverage new software from other company sensors, such as the APY-6(V), into next-generation sensors, including the APG-77(V). Such advancements may prove valuable in attack variants of the aircraft.

Block 5. The addition of a third central processor makes further performance/operational enhancements possible. This processor is based on a targeting refinement from the B-2, one that uses a GPS-aided targeting system.

Electronic Countermeasures. AESA apertures allow new radars to function as jammer transmitters as well as radar sensors. A jammer transmitter offers a more discrete and surgical form of self-protection jamming. It also may be powerful enough to damage or destroy enemy electronics.

APG-77(V)1. The latest variant of the APG-77 equips Lot 5 F-22s. It improves the radar's ability to carry out search and targeting missions.

F-22 Increment 3.1. The F-22 Increment 3.1 upgrade provides a new map interface board for the fourth generation APG-77(V)1 radar. This allows use of the APG-77's synthetic aperture radar (SAR) feature.

Program Review

In 1991, the Lockheed/Boeing F-22 was selected as the Advanced Tactical Fighter (ATF) to replace U.S. Air Force F-15 aircraft. Procurement was originally planned to total 750 fighters but the number was reduced to 648 units. Faced with shrinking budgets and competition from other programs, the USAF eventually reduced the number of F-22s to be purchased to 187.

The F-22's radar, the APG-77(V), is based on proven designs, as engineers applied what they had learned from developing and producing other radars to create a successful family of modular systems.

Flight Tests Begin

Flight-testing of the APG-77 began 1997 on board a modified Boeing 757-200 testbed aircraft. In 1998, Northrop Grumman delivered an APG-77 to Boeing's F-22A Avionics Integration Laboratory for formal flight-testing. These tests allowed designers to demonstrate radar performance as well as identify anomalies in the system before the complete avionics suite was tested on board the aircraft. The APG-77s used in these tests included Block 1 software. The entire avionics suite was installed on board a test F-22 in 1999.

Block 2 software was delivered to Boeing in 1999 after it had completed 2,000 hours of laboratory testing. Block 2 encompassed radar, mission, inertial reference system, pilot vehicle interface, and cockpit display software for flight testing.

Block 3 avionics software was delivered in 2000, to be evaluated in the flying testbed. Previous success with the testbed prompted officials to consider making a low-rate initial production (LRIP) decision without full testing of Block 3 on an actual F-22.

The first upgraded APG-77(V)1 radar was delivered in early 2005 for testing. Upgraded software combined with the new radar offered an enhanced air-to-air capability. The new sensor was expected to undergo testing at Edwards AFB, California, during the summer of 2005. The APG-77(V)1 successfully completed flight-test certification in March 2007.

In September 2005, a Northrop Grumman team used an APG-77 and a Common Data Link (CDL) modem emulator to transmit and receive high-data-rate communications signals over the air. Line-of-sight communications at long distances for both air-to-air and air-to-ground applications were proved with test data. This technology breakthrough will enable both communication and imagery data transmission via advanced AESA radars and CDL modems.

Raytheon Takes Away a Potential Market

In 2007, the U.S. Air Force began a project to replace the aging APG-70 radars on its F-15E Strike Eagles with AESA radars. The APG-77 competed against an AESA radar from Raytheon. Raytheon won the competition in November 2007, preventing the F-15 upgrade program from being a source of new sales for the APG-77.

Northrop Grumman achieved a key milestone in April 2007 with the delivery of the 100th production radar for the U.S. Air Force's F-22 Raptor. Designated the APG-77(V)1, the 100th radar was part of the Lot 6 deliveries.

Northrop Grumman demonstrated the ability to generate high-resolution, in-flight synthetic aperture radar (SAR) maps using the APG-77 radar in February 2008 on board a BAC 1-11 test aircraft. The test flights were the first phase of a planned multiyear contract with Boeing to incorporate SAR capability into the F-22 fleet in support of future air-to-ground requirements.

Capped at 187 Raptors

In April 2009, Secretary of Defense Robert Gates ignited a firestorm of controversy when he announced at a press conference that the Pentagon would not support the purchase of more than 187 F-22s. This move essentially ended production in 2012. In concert with the recommendation, the FY10 budget justification documents submitted to Congress in May 2009 recommended stopping production at 187 aircraft.

Many members of Congress, however, were not willing to let the F-22 die. Still, President Barack Obama has vowed to veto any bill that includes funding for F-22s beyond the 187 requested by the Pentagon. Some members of Congress therefore began to consider lifting the export ban of the F-22. They believed that allowing other countries to purchase the aircraft would extend production, giving the U.S. more time to debate whether to purchase additional aircraft.

While there are opponents to the F-22 export ban, issues regarding sale of the aircraft remain. The U.S. might want to develop an export version of the aircraft to address these issues. Some experts believe such development could take up to three years to accomplish, meaning development would be completed after Lockheed Martin shut down the F-22 production line. Additionally, the most advanced features that would be removed from the export version are the features most prized by future international customers.

APG-77(V)

Funding

U.S. FUNDING

	Prior QTY	Prior AMT	FY11 QTY	FY11 AMT	FY12 QTY	FY12 AMT	FY13 QTY	FY13 AMT
Procurement (U.S. Air Force)								
F-22 Raptor	179	32,165.6	0	157.2	0	104.1	0	0

Source: U.S. Air Force FY13 Budget Estimates, Aircraft Procurement, Air Force, Volume 1, Feb 2012

Notes: All dollars are in millions of dollars.
Funding for the F-22 covers all aspects of the procurement program, including the APG-77 radar.

The budget reflects an 187-aircraft procurement profile (the 187 total includes 6 Production Representative Test Vehicle (PRTV) II aircraft, 179 production aircraft, and 2 previously procured EMD aircraft funded in the RDT&E phase).

Contracts/Orders & Options

The APG-77 is included as part of the F-22 sensor suite. Northrop Grumman produces the radar and is a subcontractor to Lockheed Martin, the F-22 prime contractor.

Timetable

Month	Year	Major Development
	FY89	Prototype sensor fabrication completed
Apr	1991	ATF source selection
Aug	1991	EMD contract awarded
Apr	1993	Preliminary Design Review
Dec	1994	Avionics Critical Design Review
Nov	1997	First APG-77 flight test on board 757
May	1998	First F-22 flight test
Aug	2001	Low-rate initial production
	2004	Start of full-rate production
May	2005	First F-22 delivered to an operational squadron
Dec	2005	F-22 IOC
Mar	2007	APG-77(V)1 completes flight test certification
May	2007	100th APG-77 delivered by Northrop Grumman
Apr	2009	Secretary of Defense Gates says Pentagon will request only 187 F-22s
	2012	Projected final deliveries of F-22 Raptors

Worldwide Distribution/Inventories

The F-22 is a **U.S.**-only program.

Forecast Rationale

The APG-77 radar is a purpose-built, integral part of the Lockheed Martin/Boeing F-22's sensor suite. The fate of the aircraft directly affects the future of the radar.

Cancellation/Foreign Export Ban/End of the Line

The United States Air Force, the sole operator of the F-22, placed its final order for the aircraft in 2009. The U.S. government had canceled all further procurement of the fighter jet.

With no future manufacturing of the F-22 slated domestically, the APG-77 radar would have to rely on international sales to secure its continued production. However, the U.S. has banned export sales of the F-22, thereby putting an end to the radar's use in new-build aircraft.

Forecast International does not believe that the F-22 will be made available for the export market, capping production at 194 aircraft (including engineering and manufacturing development, or EMD, units).

The final F-22 was delivered in 2012.

Upgrade

Some potential value lies in the APG-77's upgrade market. While the F-22's production will end at 194 aircraft, the USAF will want to maintain the technology of its advanced fighter jets. This will result in a sequence of capability upgrades to the APG-77 radar over the coming years.

A current F-22 Mod program, the Increment 3.1 upgrade, calls for a new map interface for the APG-77(V)1 radar. The modification will give the F-22 pilot the ability to utilize the APG-77's synthetic aperture radar (SAR) feature, allowing the selection of targets from a radar-driven, high-fidelity, high-definition black-and-white image.

Ten-Year Outlook

ESTIMATED CALENDAR YEAR UNIT PRODUCTION

Designation or Program	High Confidence					Good Confidence			Speculative			
	Thru 2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total
Northrop Grumman Electronic Systems												
APG-77 <> United States <> Air Force <> F-22A												
	186	8	0	0	0	0	0	0	0	0	0	8
Total	186	8	0	0	0	0	0	0	0	0	0	8