ARCHIVED REPORT

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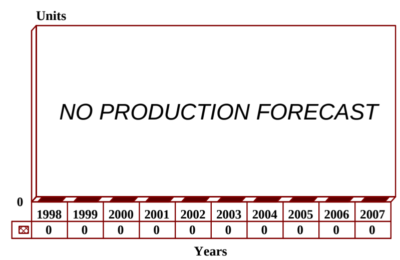
APQ-181 (B-2 Radar) - Archived 11/99

Outlook

- Production for 21-bomber fleet complete
- Logistics support developing
- Congressional fleet expansion attempts turned back

10 Year Unit Production Forecast
1998-2007



Orientation

Description. Airborne multi-mode radar.

Sponsor
US Air Force
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Contractors
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Status. In production, ongoing logistics support.

Total Produced. 21 shipsets have been built.

Application. B-2.

Price Range. Price is approximately US$13 million each, US$26 million per shipset of two radars.

Technical Data

	Metric	US
Dimensions		
Shipset weight:	953 kg	2100 lb
Shipset volume:	1.5 m^3	52.5 ft^3

Antenna weight:	261 kg	575 lb

Characteristics

Frequency range:	12.5 to 18 GHz (K Band)
Radars per shipset:	2
Units (LRU) per radar:	5
Modules per shipset:	82
Data bus:	MIL-STD-1553

Design Features. The APQ-181 is made up of a five-unit "radar string" which includes the antenna, transmitter, receiver/exciter, radar signal processor and radar data processor. A shipset consists of two complete radar strings. To maximize mission success, either antenna can be connected to either radar string and units from either string can be interconnected. The antennas do not transmit simultaneously.

The antennas are located in a cavity behind a large radome eight feet outboard of the aircraft centerline and below the leading edge of the wing. Antenna boresight is approximately 20^o off axis from the aircraft centerline. Patterns overlap sufficiently to allow single radar operation if one system fails.

The transmitter, receiver/exciters and radar signal processors are located in openings in the side walls of the nose wheel well. The radar data processors are located on the aft wall of the nose wheel well.

The antenna is electronically steerable in azimuth and elevation and features a monopulse feed design with fractional beamwidth angular resolution. A motion sensor subsystem (MSS) compensates for aircraft movement during Synthetic Aperture Radar (SAR) operation. The antenna has a monopulse feed and is steered in two axes.

Each transmitter is self-contained and is similar to the APG-63, APG-65 and APG-70 gridded traveling wave tube, liquid-cooled rf amplifier.

The receiver/exciter combines rf waveform generation, detection and received signal frequency down-conversion. It digitizes the received signal stream and performs pulse compression to enhance range resolution. Some circuit modules are interchangeable with the APG-70 and APG-71 fighter radars.

The core signal processing modules are functionally interchangeable with those of the APG-65 radar. It is fully programmable and carries mode-unique software in a 50 Mbit bulk memory. Throughput is 7.1 MOPS.

The MIL-STD-1750A Radar Data Processor (RDP) is a dual-unit CPU Airborne Computer Instruction Set Architecture general-purpose computer. It is the command controller for all radar units and serves as the radar terminal on the avionics data bus. It produces beam steering commands for the beam steering computers at the antennas. It has a throughput of 2.5 MOPS. Most of the RDP modules are interchangeable with the Hughes APG-70 and APG-71 radars.

The antenna is a unique design for the B-2 and spurred the development of new manufacturing processes to meet the stringent requirements of a low observable platform. It is important that the radar transmissions or antenna reflections do not give away the presence of the airplane.

The monopulse feed network is made up of an electronically scanned array, a beam steering controller, and power supplies. The array itself is approximately 36" X 24". The need for extremely tight manufacturing tolerances to support low observability prompted (then) Hughes to implement a high-speed machining process not previously used for antenna component manufacture.

There are 85 machined plates per antenna with 4,600 individual tolerance features. By using a Hughes/ Matsuura 800DC-EXIS High Speed Machining center, the process can achieve ± 0.0005 to ± 0.010 inch tolerances and produce a plate in four and half hours (versus 50 hours for standard machining). There is a drastic reduction in out-of-tolerance parts.

Hughes developed a technique for injection-molded metalized plastic centerfeeds. The 30 percent glass reinforced thermoplastic centerfeeds are metalized through a special process which creates a unit that is 35 percent lighter and 75 percent less expensive to produce. This process can also be used to produce interconnecting waveguides. The process is also used on the radars for the first 15 aircraft, but would be applied to follow-on production.

Operational Characteristics. The B-2 radar has 21 distinct operating modes, including pulse, pulse Doppler, and two built-in tests for fault detection and failure isolation to LRU level. The radar supports search, detection, track, penetration, and synthetic aperture radar operation. Each mode has two sets of software, one for the radar data processor and one for the radar signal processor.

The modes support the following functions:

- Precision position and velocity update measurement to support autonomous navigation
- A radar altitude mode
- Terrain following
- Hazard avoidance
- Variable resolution synthetic aperture target location and identification
- Ground mapping
- Precision weapons delivery

Operational modes can be selected by the aircrew or initiated on demand by the B-2 mission control computer. The low probability of intercept operation is achieved through a series of classified operational modes.

A typical mission may be accomplished by a flight of three B-2s (two in the lead, one trailing) which will make a coordinated attack. One of the lead airplanes will use the ALQ-181 SAR capability to acquire an image of the target area. This image is correlated with reconnaissance imagery that will have been prepared before time. Aim points are selected and matched with GPS coordinates. This three-dimensional, non-optical targeting information will make it possible for the B-2 to achieve near-laser-guided precision results with launch and leave weapons. The trailing bomber will use the radar to do real-time bomb damage assessment and make a follow-up attack, if needed. A three-ship mission will be able to hit up to 32 targets at one time.

The Air Force demonstrated that interim B-2 aircraft could carry and deliver unguided Mk 84 bombs or the precision-guided Global Positioning System (GPS) aided munition (GAM) in the conventional role or B-83/ B-61 nuclear weapons in the nuclear role. Reports of flight tests and demonstrations indicated the GAM to be an effective all-weather weapon in attacking fixed targets with near-precision accuracy. In one demonstration, 3 B-2s destroyed 16 targets using 16 GAMs dropped from over 40,000 feet. In addition, the interim aircraft have automatic terrain-following capability as low as 600 feet and some of the capabilities of the planned defensive management system. All of these results were heavily dependent on the radar.

According to Air Force officials, the demonstrated capabilities are more than adequate to perform the mission defined for the interim configuration when operating from Whiteman Air Force Base, the B-2's main operating base. The APQ-181 has proven able to deliver Joint Test Articles (JTAs) which contain depleted uranium and simulate the weight and balance of an operational nuclear weapon. Tests validated the ability of the system to deliver a deep-penetrating B61-11. The bomber has also dropped four 2,000 lb BLU-109 versions of the Joint Direct Attack Munition (JDAM). In a high altitude test targeting two of the near-precision weapons at the same point, the two bombs followed one another "into the same hole," a first for launch and leave weapons. These weapons combine GPS capability with the B-2's targeting capability.

Variants/Upgrades

No variants have been specifically identified, but a series of pre-planned software upgrades are expected, especially to support the conventional precision munitions delivery capability being installed in the B-2 fleet.

Program Review

Background. Hughes Aircraft Company and Westinghouse Electric Corporation competed for the original Advanced Technology Bomber radar development contract. The antenna design, considered a high technical risk item, began in 1982. In 1983 Hughes identified the need for unique manufacturing technology applications in creating the low radar cross section antenna.

The radar hardware Critical Design Review was held in 1985. The Air Force and Hughes committed to the special manufacturing process and the first complete radar string was delivered to the system integration laboratory in mid-1986. It demonstrated system level operation under mode control software and was delivered to Edwards Air Force Base for installation in a modified KC-135 avionics testbed.

Hughes noted that the radar collected recognizable synthetic aperture imagery on the first flight. All other modes reportedly worked as designed the first time. This performance reportedly continued through three and a half years of testing. By January 1991, the test radar had flown 165 development flights for 650 hours of flight operation time.

B-2 Air Vehicle #3, the avionics dedicated test aircraft, was the first to fly with an operational radar and used to evaluate the radar and navigation avionics. A/V #1 and

#2 had been dedicated to flight characteristics, low-observability and structural flight testing. Air Vehicle #4 was be devoted to avionics and weapons tests.

In late 1991, the Pentagon acknowledged that results from some of the low observability tests of the B-2 were below-spec. This drew severe criticism from Congress, as well as threats of funding termination.

By early 1992, the Air Force was admitting that many of the original specifications had been too stringent and unrealistic. They admitted that the airplane could never meet all specifications at all frequencies, but questioned the validity of having such stringent specifications instead of establishing realistic operational and performance requirements.

In the FY93 budget, the Air Force changed its request from 75 (already down from 132) to 20 aircraft and noted that the B-2 would be employed in a sustained conventional mode. The 20 would give the Air Force the ability to field two squadrons of eight operational aircraft, a near doubling of operational capability beyond the authorized 15 aircraft. Funding considerations favored authorizing the additional five aircraft. Total program cost would be US$44.4 billion, the Air Force said. Congress approved the change.

On August 6, 1993, the Air Force announced that engineers had found a cost-effective solution to the B-2 stealthiness problem. The effort developed a new diagnostic capability that could be used for all low observable platforms.

The FY94 budget request continued funding for the remainder of the B-2 procurement. Congress approved the full requested amount; but set a variety of restrictions and certifications that must be met before the funds can be obligated.

The FY95 Defense Authorization and Appropriation saw full funding of the requested amount, and the Senate Armed Services tried to provide US$150 million to the program to preserve the capacity to produce additional B-2s beyond the authorized 20. Although debate was heavy, procuring more than the authorized 20 bombers was rejected in conference. Congress did direct the Secretary of Defense to study whether or not there is or would be a bomber capability shortage in the near-, mid-, or long-term, and report the conclusions to Congress. The report presented to Congress found that the bomber industrial base did not require more B-2 bomber production to survive.

The Pentagon's FY96 budget request did not ask for additional B-2 bombers. The Pentagon, supported by various studies, said that the need was greater for more precision munitions and a variety of conventional upgrades to B-2s, B-1Bs, and B-52s. Undaunted by this, the House of Representatives added advanced funding for 20 more B-2s to both the Authorization and Appropriations bills.

The Senate did not recommend further B-2 production, and the Air Force began lobbying hard against more of the bombers. Their position was that supporting the unwanted planes would make it necessary to curtail or kill wanted programs in the future, including the F-22 and C-17. The Administration decided to use the money put toward possible advance procurement of more B-2s into converting the prototype aircraft into an operational bomber, bringing the fleet to 21 aircraft.

In debating the FY97 Defense Authorization, Congress focused on the conventional munitions delivery modifications to the B-2, authorized an increase of US$212.0 million to accelerate integration of PGMs and to provide enhanced communications, information data link capability, and improved conventional weapons accuracy for the existing fleet.

With the tenacity of the Energizer Bunny, in FY98 the House again put money into the budget for 20 more B-2s. The Senate did not, and the Air Force came out strongly against the added bombers, noting that this would devastate modernization plans in all other areas. The Senate has no such addition in its version of the appropriation legislation, and President Clinton said he would veto any appropriation bill with the added airplanes in it.

In the FY99 Defense Appropriations bill submitted by the House of Representatives, Congress recommended that the current force of bombers be supported with a sustained series of investments that will provide warfighters with high leverage combat capabilities in a wide range of contingencies through the remainder of the force's useful life. The House appropriations panel recommended development of a carefully phased and funded investment plan to upgrade and sustain the B 2 as well as the rest of the bomber force structure. Members found that DoD planning regarding future bomber production inadequate and recommended that the Pentagon develop a plan for replacing the current force over time.

Accordingly, the Committee directed the DoD to present to the Congress no later than March 1, 1999, a comprehensive plan for the future long-range bomber force. This plan should be based on the findings and recommendations of the Long-Range Air Power Panel and should be comprised of two parts. The first should describe the integrated and phased investment plan the Panel recommended to upgrade and sustain the existing Long Range Air Power force structure, with particular emphasis on those upgrades needed to fully leverage the potential of the B-2. The second part should describe

DoD's plan to replace the existing bomber force structure over time, including planned investment for such a system and timeliness associated with production of additional aircraft.

Aircraft stealthiness and maintenance problems. At nearly the same time, the GAO released a report (NSIAD-97-181) which noted that the B-2 program cost appears to have stabilized; the Air Force reported a total estimated B-2 acquisition costs (development, procurement, and military construction) decrease from US$44,946 million in early 1995 to US$44,754 million in early 1997. The estimated cost declined even though Congress added new requirements to the B-2 program and provided additional funds of US$734 million in FY95, 96 and 97. Air Force officials advised GAO that the US$44,754 million reported to Congress was understated by US$89 million, which meant that two of the test aircraft would not be fully upgraded to block 30, making them less than fully capable. Through FY97, Congress appropriated about 96 percent of the US$44,754 million estimated total cost.

The GAO report went on to note that although the cost estimate had not changed substantially since 1995, it could increase if the flight test program were extended beyond March 1998 and identifies more performance deficiencies than predicted during the remaining portions of the acquisition program, making unplanned development and procurement activities necessary to better maintain the B-2s' low-observable features.

On April 1, 1997, the Air Force declared that interim B-2s had achieved initial operational capability. But the Air Force decided it was unrealistic to plan on deploying the interim aircraft to forward operating locations because of difficulties in maintaining low-observable characteristics at the B-2's main operating base. Also, officials were reviewing specific B-2 deployment requirements and working to resolve related problems by the time the B-2s are scheduled to be fully capable in 1999.

According to the Air Force, the interim B-2 is supposed to be capable of participating in nuclear or conventional warfare either from its main operating base at Whiteman Air Force Base, Missouri, or from a forward operating location outside the continental United States.

While the B-2's performance met requirements for initial operations, the aircraft would be unable to meet intended deployment requirements because some low-observable features require substantial maintenance and the aircraft are more sensitive to climate and moisture than expected. As a result, the Air Force eliminated the deployment requirement for interim aircraft and began evaluating potential actions to allow deployment when fully capable aircraft are delivered.

The Air Force decided it was unrealistic to deploy the B-2 without shelters. Some low-observable materials require lengthy maintenance in an environmentally controlled shelter after each flight. In addition, B-2s must be kept in shelters because of their sensitivity to moisture, water, and other severe climatic conditions. Air Force operational requirements for the B-2 intended for both the interim and fully capable B-2s to be capable of deploying to forward operating locations, without shelters, in all types of weather and climates.

The operational test report for the interim aircraft stated that tests showed that some low-observable materials on the aircraft were damaged each time the aircraft flew and that repair of those materials accounted for 39 percent of the 80 maintenance man-hours per flight hour. This is about three times greater than the next largest contributor to maintenance man-hours, which is aircraft structures. The current goal for total maintenance man-hours per flying hour is 60 hours, and the ultimate goal is 50 hours.

The actual B-2 maintenance man-hours per flying hour at Whiteman Air Force Base averaged 124 hours over 12 months ending in March 1997. During operational testing of the interim configuration, low-observable materials took from 30 to 80 hours to repair and cure, and the processes required a shelter with a temperature and humidity controlled environment for proper curing.

Problems with low-observable materials affected the percentage of time the B-2 was partially or fully capable of completing a mission, which was significantly less when low observability was considered. When low observability was not considered, the mission-capable rate was 66 percent for a 12-month period ending March 1997. However, when low-observability problems were considered for the same period of time, the rate dropped significantly to 26 percent.

Testing indicated that exposure to water or moisture can damage some of the low-observable enhancing surfaces on the aircraft. Further, exposure to water or moisture that causes water to accumulate in aircraft compartments, ducts, and valves can cause systems to malfunction. If accumulated water freezes, it can take up to 24 hours to thaw and drain.

Air Force officials said it is unlikely that the aircraft's sensitivity to moisture and climates or the need for controlled environments to fix low-observability problems will ever be fully resolved, even with improved materials and repair processes. Therefore, if B-2s are to be deployed, some form of aircraft sheltering at a forward operating location will likely become a requirement in the future.

Air Force test officials stated that maintenance of low-observable features is an issue that requires significant further study and that the percentage of maintenance hours required to repair low-observable materials would increase even more before they are reduced. They said technological improvements in materials and repair processes will be required.

Air Combat Command considers low-observable maintainability to be its number one supportability issue, and the Air Force has efforts underway to develop new materials, procedures, and support equipment. It is currently changing some materials on the aircraft to improve durability and reduce repair times. It has also established procedures to monitor conditions of low-observable materials on the operational aircraft and developed a model that characterizes the operational impacts of material degradations so that repairs can be prioritized relative to the operational requirements of the B-2s.

The USAF deployed two B-2 Spirit bombers and about 200 airmen from the 509th Bomb Wing at Whiteman Air Force Base, Mo., to Andersen Air Force Base, Guam, from March 23 to April 3, 1998. The deployment was part of an Air Combat Command-sponsored exercise and represents the first time B-2s deployed to and conducted sustained training operations from a forward location.

This Global Power exercise was intended to demonstrate the wing's and the aircraft's ability to deploy and operate from locations throughout the world. During the deployment, the aircrews conducted a series of weapons drops at a bombing range in the Northern Marianas and flew low-level missions, while ground crews sharpened their skills at maintaining and arming their aircraft in an unfamiliar environment.

This was one of a series of exercises and deployments to prove-out the new bomber's capabilities and maintainability. Other deployments have included Red Flag exercises, a long-flight mission to Chile, and the Paris Air Show.

Funding

Current funding is from the B-2 R&D and production lines. Radar funding is not broken out separately.

Recent Contracts

No radar-specific contracts are recorded.

Timetable

Month	Year	Major Development
	1986	B-2 full-scale development began
Jan	1987	First radar test flight (on KC-135 test bed)
	1988	Radar production contract
Jul	1989	First B-2 flight
	1991	First flight of radar-equipped B-2 (AV#3)
Jun	1990	B-2 Block I flight tests completed
	1992	Approval of final fleet funded
	1992	Integrated avionics test flights began
	1996	Flight testing completed
Apr	1997	B-2 IOC (Interim aircraft)
Apr	1998	Two bombers deployed to Anderson AFB, Guam
	1999	Planned full B-2 IOC

Worldwide Distribution

This is a **US** only program.

Forecast Rationale

The B-2 radar is based on proven hardware, is software-driven, and incorporates a new, extremely demanding, antenna production technique needed for the bomber's low observable characteristics. It has many of the features that may become typical of future airborne radars. Because of the nature of the B-2 mission, this radar has to be far more stealthy than the F-22's APG-77.

The technological advances of the ALQ-181 are noteworthy. Because of the nature of radar, stealth design is heavily dependent on the ability to predict how a signal will react when it strikes any surface on the airplane, including the radar antenna. Designers developed a unique antenna manufacturing process for economically producing the exacting tolerances needed to prevent the antenna from revealing the presence of the aircraft to air defense systems, especially from the front quadrant. The manufacturing processes developed for the ALQ-181 have proven valuable and will be applied to radar manufacturing in the future. One special technique, the injection-molded metalized plastic process, is being considered for future upgrades for the F/A-18 radar.

The success of the development is the result of good software design and using proven hardware whenever possible. The multiple mode program will form the basis of a variety of operational spin-offs into other sensors on other platforms. The B-2 and F-22 radars have created a baseline next-generation airborne radar.

The market for the APQ-181 is completely dependent on the B-2. The program has been legislatively capped at 20 shipsets, plus spares. The full 20 aircraft procurement has been approved (becoming 21 with the first article airframe brought up to operational standard). Hughes produced the fleet requirement during the original production run and added the remaining radars and spares to the existing line. The Air Force has already ordered a significant number of spare and repair parts, and LRUs. As the bombers enter the fleet, a continuing logistics support requirement will exist.

Although Congress, especially the House National Security Committee, pushed for an additional 20 B-2 aircraft, their efforts came to naught. The Pentagon did not want to have to reprogram any of its funds from other programs for the new bombers, and the Senate continued to turn thumbs down on the addition. Although the idea has resurfaced in the FY98 defense package when the House added US$331 million as a down payment on additional bombers, the Senate did not include a similar addition in its version of the legislation, and the White House said it would veto an appropriation bill with the additional B-2s included. In the FY99 defense funding debate, Congress seemed to have given up acquiring more of the bombers in lieu of developing a plan to upgrade the entire bomber fleet.

The GAO report on stealthiness problems came at a time that favored opponents to adding more to the fleet. The Air Force had all of the bombers it wanted, needed, and could afford to maintain, and although the report brought up some negative features of the early aircraft, from the engineering standpoint these findings are not all that surprising. The B-2 surfaces were produced with some of the original low-observable manufacturing techniques, and the nature of low observability means that problems such as this are to be expected.

Although the B-2 was criticized as a result of this report, the Pentagon and the Air Force would not willingly give up F-22s for more B-2s. A major effort has helped the service overcome many of the criticisms by developing a more effective and reasonable maintenance program that could support the B-2 in operation. This has borne fruit, and the bombers have become more able to deploy in the real world with fewer of the original problems. This has nearly defused the Congressional effort to force more airplanes on the Air Force. Instead, the lawmakers are taking a more reasonable approach and pushing for a sensible upgrade and replacement plan for the entire bomber fleet.

Ten-Year Outlook

No further production is expected.

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