

## **B-2 SPIRIT ADVANCED TECHNOLOGY BOMBER**



### **Air Force ACAT IC Program**

Total Number of Systems:	21
Total Program Cost (TY\$):	\$44,700M
Average Unit Cost (TY\$):	\$1,175M
Full-rate production:	N/A

### **Prime Contractor**

Northrop Grumman Corporation

### **SYSTEM DESCRIPTION & CONTRIBUTION TO JOINT VISION 2020**

The B-2 builds on *technical innovation* and advancements in weapon delivery accuracy and low observable technologies to enhance the *Joint Vision 2020* operational concept of *precision engagement*. The aircraft also supports the concept of *dominant maneuver* through its ability to reach targets worldwide and to penetrate air defenses with minimal supporting forces.

The B-2 *Spirit* bomber is an all-wing, two-crew aircraft designed for worldwide conventional and nuclear weapon delivery missions. Propelled by four F-118 GE-100 turbofan engines, the bomber has twin side-by-side weapon bays, capable of carrying a total of approximately 44,000 pounds of weapons. The B-2 incorporates technologies that provide low observable (LO) characteristics; i.e., low radar cross-section as well as low infrared, visual, and acoustic signatures. Avionics include a multi-

mode radar, Global Positioning System (GPS), a Defensive Management System (DMS) for radar warning functions, and a Terrain Following/Terrain Avoidance (TF/TA) system.

Operational aircraft deliveries to the Main Operating Base at Whiteman AFB, MO began in 1993, and Initial Operational Capability was reached in April 1997. Block 30 final version aircraft deliveries have now all been completed, and the 509<sup>th</sup> Bomb Wing now operates two squadrons of eight aircraft each. The remaining five aircraft are assigned either for test purposes or as “pipeline” aircraft undergoing depot level maintenance. For nuclear missions, the B-2 can carry and deliver the B-61 and B-83 type gravity nuclear weapons. Table 1 lists the conventional weapons that can be carried by the B-2.

**Table 1. Conventional Weapons Carried by the B-2**

<b>Weapon</b>	<b>Type</b>	<b>Quantity Carried</b>
GBU-31 (principal weapon)	GPS-guided Joint Direct Attack Munition (JDAM) with 2,000-pound Mk-84 warhead or BLU-109 penetrator warhead	16
GBU-37	GPS-guided 4,700-pound penetration weapon	8
Mk-82	500-pound general purpose bomb	80
Mk-84	2,000-pound general purpose bomb	16
CBU-87/89/97	Cluster bombs	34
M-117	750-pound general purpose bomb	34
Mk-62	500-pound sea mine	80
AGM-154	Joint Standoff Weapon (JSOW) (currently being integrated and tested)	16

**BACKGROUND INFORMATION**

A combined DT&E/IOT&E program for the B-2 began at Edwards AFB, CA in 1989. Dedicated AFOTEC IOT&E test team pilots conducted system assessments during operationally realistic DT&E flights. In addition, a series of test flights was conducted against individual threat systems and an integrated air defense system to evaluate survivability. IOT&E ended in July 1997.

The B-2 only partially met operational requirements at the conclusion of IOT&E. The aircraft had significant operational utility for selected missions although several sub-systems failed to meet expected performance levels or their development had not been completed at that time. Table 2 summarizes IOT&E results.

**Table 2. B-2 IOT&E Findings**

Critical Operational Issue (COI)	IOT&E Finding
Rapid Strike	Met requirements only for pre-planned missions (because of Mission Planning System (MPS) deficiencies). Generation and launch times not met.
Sustained Operations	Did not meet requirements for Mission Capable Rate (MCR) or Sortie Generation Rate (SGR).
Mission Survivability	Met requirements with adequate mission planning, tactics, and support package. Defensive Management System (DMS) unsatisfactory.
Weapons Effectiveness	Met requirements.
Reliability, Maintainability, and Deployability	Did not meet requirements because of poor LO reliability/maintainability and need for environmental shelters at deployed locations.

IOT&E was followed by FOT&E (Phase I) conducted by AFOTEC at Whiteman AFB through December 1998. This was followed in turn by an ongoing Force Development Evaluation (FDE). FDE identifies deficiencies, assesses operational effectiveness and suitability, assists in the development of tactics, and re-evaluates the B-2 against changing operational needs. The 72nd Test and Evaluation Squadron, Air Combat Command conducts FDE in fiscal year increments. FDE began in January 1999 and will continue for the foreseeable future. The first FDE period (January-December 1999) contained the Operation Allied Force (OAF) period. FOT&E and FDE activities leveraged normal training operations as additional data gathering opportunities.

Since the end of IOT&E, the B-2 development program has focused on upgrades aimed at correcting deficiencies found in testing, as well as enhancements to the aircraft's original capabilities. Post-baseline upgrades initiated to date address the following:

*Deficiencies:*

- Mission Planning System (MPS) – Faster computers and software upgrades to improve usability and reduce planning time.
- Defensive Management System (DMS) – Improvements in recent P1.1 aircraft software and Mission Data File (MDF).
- Low Observable (LO) reliability and maintainability – Improved materials, faster cure times, improved application techniques, and better management of maintenance actions. Began programs for Alternate High Frequency Materials (AHFM), Advanced Top Coat system, and improved durability tiles. Tailpipe repair efforts continue as well as efforts to extend material life of outer mold line. LO verification tools and technical data improvements are being pursued.
- Terrain Following/Terrain Avoidance (TF/TA) system – Improvements in recent P1.1 aircraft software.
- Auxiliary Power Unit (APU) and Environmental Control System (ECS) – Block 30 modification to allow APU to drive ECS while using external electrical power.

- Deployability – Initiated acquisition program to obtain deployable shelters for LO maintenance and environmental protection.

*Capability Upgrades:*

- Integrate Joint Standoff Weapon (JSOW) and incorporate Generic Weapon Interface System (GWIS).
- Integrate Enhanced GBU-28 weapon delivery capability.
- Integrate 500-pound JDAM (Mk-82) and develop Smart Bomb Rack Assembly (SBRA).
- Integrate SATCOM secure voice, Have Quick II, and data communications capabilities.
- Add Link 16, Center Instrument Display, and In-flight Re-planner.
- Integrate Joint Air-to-Surface Standoff Missile (JASSM).

The above initiatives are in various stages of completion and some are suffering from near-term funding shortfalls. Additional enhancements planned within the Five Year Defense Plan include:

*Future Upgrades:*

- Add MILSTAR EHF/SHF survivable SATCOM capability.
- Enhanced Digital Engine Controller (EDEC).
- Add Demand Assigned Multiple Access capability to SATCOM Radio.

The B-2 was added to the Annual T&E Oversight List for Live Fire Test and Evaluation in May 1995. DOT&E decided the requirements of Section 2366, Title 10, United States Code did not apply because the program was not expected to proceed beyond low-rate production. The Air Force initiated an LFT&E program that relied on modeling and simulation. However, the modeling and simulation was not completed and an Air Force assessment of B-2 vulnerability to live fire has yet to be accomplished.

**TEST & EVALUATION ACTIVITY**

Force Development Evaluation activity in FY00 concentrated on evaluating a new aircraft software release (Version P1.1) and an associated mission planning system software upgrade (Version 2.0). The FDE effort is focused on evaluation of corrections to areas that were found to be deficient at the conclusion of IOT&E and FOT&E (Phase I). Additionally, flight tests to evaluate Joint Standoff Weapon delivery capabilities and the new Generic Weapon Interface System were conducted.

Planning continued for the first deployable shelter evaluation, now scheduled for November 2000.

**TEST & EVALUATION ASSESSMENT**

B-2 OT&E progress is based on a review of FDE reports and discussions with test force personnel. An assessment is provided for each of the five Critical Operational Issues: Rapid Strike;

Sustained Operations; Mission Survivability; Weapons Effectiveness; and Reliability, Maintainability and Deployability.

**Rapid Strike:** This area is now satisfactory except for time to generate and launch, still being impacted by LO maintenance time. In IOT&E, AFOTEC assessed this area as meeting user requirements but for pre-planned missions only. Limitations of rapid strike capability resulted from immaturity of the Mission Planning System consisting of the Air Force Mission Support System (AFMSS) combined with a Common Low Observable Autorouter (CLOAR) and B-2 unique software. Rapid strike capabilities were also affected by the time to generate and launch the B-2. These times did not meet requirements due to the LO repair time (discussed below).

As a result of cumulative improvements, mission planning performance has improved so that planning time is no longer a bottleneck. AFMSS B-2 version 2.0 enables planners to achieve the required 8-hour planning timeline for a wartime mission. The latest CLOAR Version 3.2.1 contains improvements that make it a usable tool for the first time, provided care is taken to constrain potential route choices and to choose proper optimization settings. Improvements are still needed in a number of areas (e.g., printed products). However, overall MPS performance is now satisfactory.

A total of 29 FOT&E and FDE generation exercises have been conducted to date. Only 6 of the 29 exercises generated the required number of aircraft in the allotted time. The latest exercises, conducted in FY00, did meet requirements and represent improvements over the times predicted during IOT&E. However, LO maintenance timelines must be further improved to comply with the Operational ORD. The Passive Thermal Protection System (PTPS) panels are a constraint for nuclear mission generation due to the time required to install the PTPS frames into each aircraft.

TF/TA system improvements are incorporated in P1.1 aircraft software introduced in early 2000. Following IOT&E, operation was cleared down to 600-foot Set Clearance Plane (SCP). Low-level flight has now been demonstrated in development testing down to the ORD level of 200 feet SCP in clear weather and 400 feet SCP in light rain. Improvements resulted from changes to software that controlled radar illumination of the terrain and eliminated potential radar blind spots in turns. Operational testing of TF/TA improvements has not yet been performed.

Weapon System Reliability (WSR), which measures the probability that an aircraft will function correctly to reach the target and release weapons, is satisfactory. Based on current failure rates, WSR for the nuclear mission is estimated as between 96 and 99 percent, compared to a requirement of 88 percent. For a conventional mission, WSR is estimated to be between 82 and 90 percent for a 30-hour mission. In Operation Allied Force, B-2's demonstrated a WSR of 98 percent for 30-hour conventional missions.

**Sustained Operations:** This area did not meet user requirements in IOT&E. LO materials on the B-2 required high amounts of maintenance and had a time-consuming repair process with long cure times. This reduced the time aircraft were available for operational use, which kept Mission Capable Rates (MCRs) below the requirement. These problems increased the amount of time it took to prepare the B-2 for its next combat flight, reducing the number of sorties that could be flown in a given period. During IOT&E, the B-2 was rated incapable of achieving the required Sortie Generation Rate (SGR) due to unreliability and difficulty in maintaining the aircraft's LO system. The ability to sustain combat operations in a deployed environment was also identified as a problem area due to the causes cited above.

This area still does not meet requirements. There have been improvements in the past two years, but they are insufficient to meet the formal requirements of the ORD. A comprehensive program to test and install new and improved LO materials, improve repair processes, reduce cure times, and develop new diagnostic tools has begun. Only a few of these improvements have reached the operational unit. Those improvements, coupled with better management of LO maintenance, have led to only a moderate increase in mission capable rates.

Mission Capable Rate during FY00 has averaged about 39 percent, compared to the ORD requirement of 60 percent. Although this is better than the 32 percent experienced in FOT&E, the improvement is not statistically significant and the most recent six months have seen a decline back to about 33 percent. Factors contributing to this recent decline include manning issues and technical issues (e.g. aft deck cracks, nozzle bay doors, windshield tape, and over-G technical data shortcomings) impacting overall LO maintainability and aircraft availability. If LO maintenance is not included in the MCR calculation, the FY00 rate was 71 percent, declining to 68 percent for the past six months. The using command, Air Combat Command, has recently reduced their standard for B-2 MCR to 50 percent (including LO) and 80 percent (not including LO; no ORD requirement exists for MCR without including LO).

Sortie Generation Rate for deployed operation has not been measured directly. However, turnaround times seen in training missions and during OAF indicate that the ORD requirement is unlikely to be met.

**Mission Survivability:** The Defensive Management System (DMS) is still unsatisfactory. However, in IOT&E and FOT&E, AFOTEC assessed the B-2 as being survivable against the projected threat on the assumption that appropriate mission planning, force packaging, and tactics are employed.

Force Development Evaluation survivability testing in FY00 was focused on evaluating improvements to DMS. DMS is designed to identify and locate unknown threats that pop up during a mission. During earlier testing the DMS was found to be operationally unsatisfactory. Problems included inaccurate information, a cluttered display, and an excessive workload to operate the system.

Cumulative changes to the operational software have corrected a number of DMS deficiencies found during IOT&E. The most recent software release (P1.1) and changes to the Mission Data File (MDF) have led to reduction of false detections and improvement in identification and location performance. However, the system still does not meet all requirements and a large list of deficiencies remain uncorrected. Analysis of operational test results is still incomplete, and training on the new software has been impeded by a lack of test range access. There is no current plan or funding identified to enhance the B-2 DMS further. Although DMS does not provide the originally planned capability, the Air Force indicates the system's deficiencies do not prevent planning and executing B-2 missions.

**Weapons Effectiveness:** Weapon delivery effectiveness is satisfactory. However, the total weapon delivery rate of the B-2 has been constrained by Mission Capable Rates and Sortie Generation Rates. The B-2's weapon delivery accuracy partially compensates for shortfalls in Sortie Generation Rate and deployability (see below), but the full target kill potential of the B-2 has yet to be reached.

Testing of the B-2 indicates that all requirements for carriage and release of nuclear and conventional weapons have been demonstrated, except for JSOW, which is still undergoing test. Accuracy requirements have been met for all conditions except for high-altitude retarded releases and

releases not employing GPS. During OAF, the B-2 confirmed it is a highly accurate bombing platform that exceeds expectations for JDAM weapon delivery accuracy.

In development testing, four JSOWs have been released from the B-2. These launches revealed a number of anomalies with B-2 software and data transfer to the missile. Two of the JSOWs did not achieve required accuracy. However, the most recent launch in September 2000 appears to have been successful and accurate.

**Reliability, Maintainability, and Deployability:** This area is still unsatisfactory because of poor LO material reliability/durability and poor LO maintainability. In IOT&E, AFOTEC rated this area as not meeting user requirements because the reliability of the LO system was unsatisfactory and the amount of maintenance effort to sustain the aircraft (all systems) was excessive. The most significant limitation was LO maintainability. A large number of B-2 LO unscheduled maintenance events, combined with the lengthy time and excessive manpower required to repair LO discrepancies, reduced aircraft availability. Additionally, the curing of LO materials was a major determinant of the time it takes to complete LO maintenance action. These materials include sealants (used to fill gaps between panels), adhesives, and tapes to cover the joints.

B-2 deployability also did not meet requirements. The B-2 must be able to deploy to forward locations to reduce transit times and achieve a high sortie rate. The capability to deploy was not demonstrated in IOT&E. Obstacles to deployment included the requirements for extensive support equipment, the need to protect the aircraft from rain intrusion, and a requirement for environmentally controlled shelters for use during LO maintenance at deployed sites. In the FOT&E period, deployability capabilities were partially demonstrated by small deployments to Andersen AFB, Guam. These deployments showed that aircraft shelters and extensive support equipment (e.g., ground power and air conditioning units) will be required to support deployed operation.

Force Development Evaluation assessment during FY00 shows that some aspects of maintainability have improved significantly, although still falling short of requirements in some areas. LO maintenance still has the greatest impact. Total Maintenance Man-Hours per Flight Hour (MMH/FH) are now 53, compared to 120 in IOT&E and 73 in FOT&E. Some of the improvement since IOT&E has resulted from a change in the way in which maintenance man-hours are calculated. LO MMH/FH represent 38 percent of the total.

A serious LO maintainability concern is that maintainers still cannot be certain their repairs are effective in returning aircraft radar signature to required levels. A high percentage of aircraft sent to the test range are found to exceed the required radar cross-section. In part, this is because there are no diagnostic tools available to the organizational level maintenance team to verify repairs. A program has been initiated to acquire LO Verification Equipment (LOVE). However, no improvement has occurred in availability of LO verification tools in the past year.

Extensive changes to LO materials and techniques are being introduced on the B-2 in order to reduce repair times. Expectations are high for the Alternate High Frequency Materials (AHFM) program. This program replaces conductive tape surface treatments with sprayed magnetic radar absorbing material. This change is expected to eliminate or reduce repair times for extensive areas of the aircraft. AHFM flight testing was recently completed and data reduction is being accomplished.

Overall reliability of B-2 sub-systems has not improved significantly. The Mean Flying Hours Between Unscheduled Maintenance are now 0.22, compared to the ORD requirement of 0.31 and values

of 0.23 and 0.27 observed in IOT&E and FOT&E, respectively. Reliability of critical systems has improved slightly as demonstrated by the Break Rate, which counts the number of mission-essential system failures in 100 sorties. Break rate is now 7 percent, compared to 12 percent in IOT&E and 10 percent in FOT&E.

Deployability has not yet been operationally assessed. Delivery of the first deployable shelter for evaluation has slipped to November 2000. This will be a prerequisite to further deployment testing, at which time additional deployability capabilities (e.g., support equipment, spares) need to be evaluated. No deployment tests are planned within the next year.

## **CONCLUSIONS**

Improvements to the B-2's effectiveness and suitability continue to occur slowly over time. As a result, DOT&E's assessment has changed little since last year. As demonstrated in Operation Allied Force, the aircraft has proven to be an effective delivery platform for precision-guided munitions. Based on DOT&E's review of battle damage assessment reports furnished by the U.S. Air Force Europe Warrior Preparation Center, the B-2 with JDAM demonstrated the highest rate of target destruction of any aircraft/weapon combination used in the war. Once it has been successfully launched it can reliably reach and attack targets anywhere in the world.

In the past year, testing has revealed improvements to mission planning, terrain following, and non-LO maintainability. However, many areas still need improvement: LO maintenance, LO verification, Defensive Management System, Mission Capable Rate, and deployability. Operation Allied Force highlighted these deficiencies as well as some additional upgrade needs (e.g., secure voice and data communications and autothrottles). Because of these issues, the Air Force has postponed declaration of B-2 full operational capability.

A continuing program of OT&E will be required to assess further improvements and sustainment upgrades planned over the forthcoming years. Major advancement is not expected until LO improvements and shelters are delivered and tested, and deployability is attained.