

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\$):	\$2,100
Full-rate production:	N/A

Prime Contractor

Northrop Grumman Corporation

SYSTEM DESCRIPTION & CONTRIBUTION TO JOINT VISION 2010

The B-2 *Spirit* bomber is a “flying wing” aircraft with a two-pilot crew. The multi-role aircraft can be configured for delivery of conventional or nuclear weapons, and with in-flight refueling can reach targets anywhere in the world. It is powered by four F118-GE-100 turbofan engines and has twin, side-by-side weapon bays capable of carrying a total of approximately 44,000 pounds of weapons. The B-2’s low observable (LO) characteristics provide a low radar cross-section, as well as reduced electromagnetic, infrared visual and acoustic signatures.

B-2 aircraft are based at the Main Operating Base (MOB) at Whiteman AFB, MO. By the end of CY99, sixteen aircraft in the final Block 30 configuration will have been delivered. For Single Integrated Operational Plan missions, the B-2 can carry and deliver B-61 and B-83 type nuclear weapons. The principal conventional weapon is the near precision, 2,000-pound, Global Positioning System (GPS)-guided GBU-31 Joint Direct Attack Munition (JDAM) with MK-84 general-purpose warhead or BLU-109 penetrator warhead. Additional conventional weapons include:

- GBU-37 - GPS-guided 4,700-pound penetration weapon (limited inventory B-2 unique weapon).
- Mk-82 - 500-pound general-purpose bomb.
- Mk-84 - 2,000-pound general-purpose bomb.
- CBU-87/89/97 - Cluster bombs.
- M-117 - 750-pound general-purpose bomb.
- Mk-62 - 500-pound sea mines.

The AGM-154 Joint Standoff Weapon is currently being integrated and tested on the B-2.

The B-2 builds on *technological innovations* and advancements in weapon delivery accuracy and low observable technologies to enhance the *Joint Vision 2010* operational concept of *precision engagement*. B-2's long range and capability to penetrate air defenses and deliver large weapon loads anywhere in the world contribute to the concept of *dominant maneuver*.

BACKGROUND INFORMATION

Operational testing of the B-2 was conducted within a combined DT&E/IOT&E program at Edwards AFB, CA, beginning in 1989 and continuing through June 1997. AFOTEC evaluated five Critical Operational Issues (COIs) for their final IOT&E report:

- Rapid Strike.
- Sustained Operations.
- Mission Survivability.
- Weapons Effectiveness.
- Reliability, Maintainability, and Deployability.

IOT&E test results showed that the B-2 only partially met operational requirements at that time, but had significant operational utility for selected missions. The Air Force's Initial Operational Test and Evaluation final report rated two of five COIs (Sustained Operations; Reliability, Maintainability, and Deployability) as not meeting user requirements. Two of the three COIs rated as meeting requirements carried qualifying conditions that seriously limited the full satisfaction of requirements. For example, the IOT&E report said survivability requirements were met, but only with adequate mission planning, (which at that time was not adequate), force packaging, and tactics. The Rapid Strike requirement was met only for pre-planned missions. Tests also showed that numerous Measures of Effectiveness and Measures of Performance did not meet the user's operational requirements.

During IOT&E, immaturity of several sub-systems precluded a final evaluation of effectiveness and suitability. In particular, the following major areas were found to not meet requirements and require additional development/OT&E:

- Mission Planning System (MPS).
- Defensive Management System (DMS).
- Low Observable reliability and maintainability.
- Deployability.
- Auxiliary Power Unit (APU) and Environmental Control System (ECS).
- Terrain Following/Terrain Avoidance (TF/TA) System.

Additionally, survivability testing for several threat types was incomplete at the end of IOT&E.

As IOT&E ended, operational testing transitioned to FOT&E (Phase I), conducted in conjunction with operational and training flights by the Air Combat Command operational wing at Whiteman AFB. DOT&E approved the FOT&E test plan on August 10, 1998. Starting in 1998 and subsequently, the Air Force corrected some deficiencies identified during IOT&E and FOT&E, and established programs to correct other high priority deficiencies.

The B-2 Live Fire Test and Evaluation program was initiated in May 1995 when the aircraft was placed under DOT&E live fire oversight. The scope of the LFT&E program is limited to modeling and simulation, along with data from past tests. This approach takes into account current plans for the B-2 program not to proceed beyond low-rate initial production. The Air Force was to prepare a vulnerability assessment based on past tests with modeling and simulation. The modeling and simulation was not completed, and the Air Force has not yet submitted their assessment.

TEST & EVALUATION ACTIVITY

Residual test requirements were partially addressed during FOT&E (Phase I). The test program evaluated Critical Operational Issues, Measures Of Effectiveness, and Measures Of Performance that were similar to those evaluated in IOT&E, but focused on evaluating the aspects of the B-2 weapon system found to be deficient at the end of IOT&E. FOT&E concluded in December 1998 and AFOTEC published a final report in April 1999.

Air Combat Command is conducting an additional Force Development Evaluation (FDE) phase of ongoing evaluation for B-2 hardware, software, and tactics development and evaluation. This activity began in January 1999. FDE is expected and programmed to continue throughout the life of the aircraft.

B-2 combat experience during the NATO Kosovo air campaign (March-May 1999) contributed real-world data to augment the findings of Follow-on Operational Test and Evaluation and Force Development Evaluation. These Operation Allied Force (OAF) missions expanded the data base on weapon delivery performance of the B-2 when flying from the Main Operating Base to overseas targets

and returning to the Main Operating Base. Operation Allied Force did not provide data to evaluate deployability.

TEST & EVALUATION ASSESSMENT

Follow-on Operational Test and Evaluation and Force Development Evaluation have showed gradual improvements to the B-2's effectiveness and suitability since the end of IOT&E. The progress and results from recent B-2 OT&E are presented and discussed below for each Critical Operational Issue, followed by observations on the B-2's performance during Operation Allied Force.

Rapid Strike: Overall, this area is now rated as satisfactory despite the need for improvements in several subsystems. B-2's capability to rapidly strike targets anywhere in the world has improved during the past year. In earlier testing, a major impediment to the B-2 meeting user requirements for rapid strike was the Mission Planning System (MPS). Lengthy planning times using earlier versions of the Mission Planning System constrained B-2's rapid response to pre-planned targets. Recent releases of MPS software and the acquisition of faster MPS IV computers reduced the time required to prepare mission plans. Automatic route planning for threat avoidance employing the Common Low Observable Autorouter (CLOAR) remains unsatisfactory. Workarounds are available for CLOAR autorouting. These include a software program called OPUS and human analysis of routes. Pending improvements to CLOAR, the time to select survivable routes for the B-2 depends on the threat scenario. Total mission planning times for the B-2 are now approaching the required peacetime and wartime values.

The B-2 Terrain Following/Terrain Avoidance system has been cleared for operation down to 600-foot Set Clearance Plane. A software change to fix a "turn-transition" problem cited at the end of IOT&E was incorporated. However, the evaluation of the system was not completed in FOT&E because of limited opportunities for low altitude operations. Low altitude operations are not in the conventional concept of operations and are seldom practiced. Limitations on the Terrain Following/Terrain Avoidance system would mainly affect Single Integrated Operational Plan missions and are not considered to have critical impact on the B-2's conventional operational capability. DT&E testing has been conducted for the Terrain Following/Avoidance system down to the required 200-foot Set Clearance Plane (400 foot in rain), employing the next release (P1.1) of aircraft software. P1.1 software is now undergoing FDE.

The B-2's rapid strike capability is limited by the small number of available aircraft and low Mission Capable Rates (discussed below). However, the aircraft and its supporting systems have matured to the point that the B-2 can meet operational tasking for combat operations.

Sustained Operations: This area is still not meeting user requirements, principally because the required Mission Capable and Sortie Generation Rates for the B-2 are still not being met. Both rates are heavily influenced by the reliability and maintainability of Low Observable materials on the B-2. These materials require extensive maintenance man-hours and have a time-consuming repair process with long cure times. Low Observable maintenance activities increase the amount of time it takes to prepare the B-2 for its next combat flight, reducing the number of sorties that can be flown in a given period. The B-2's capability to sustain combat operations in a deployed environment is also still rated a problem area due in part to the causes cited above.

Survivability: B-2 survivability is satisfactory for conditions where appropriate mission planning, tactics and support packaging are available. Survivability test sorties during FOT&E and Force Development Evaluation provided data on additional threat systems. These data are used to update

templates used by the Mission Planning System. Test and training flights, together with modeling and simulation, have aided in developing and assessing tactics.

The principal limitation to B-2 survivability is unsatisfactory DMS performance. DMS, which is intended to detect, identify, and locate potential threat systems, does not correctly identify threats or provide accurate location information. A slight improvement resulted from using a modified threat data file. However, DMS remains unreliable as a basis for in-flight decisions to employ tactics or alter routes. DMS software changes now being developed are designed to improve situational awareness, although they will not provide the originally envisioned capability.

Weapons Effectiveness: The B-2 is a highly accurate bombing platform that meets user requirements for weapon delivery accuracy. Additional testing during FOT&E and Force Development Evaluation has added to the database of accuracy scores. The B-2's unique GPS-Aided Targeting System (GATS) provides a capability to target guided weapons using the aircraft's radar. GATS can also be used to refine target coordinates provided from external sources, thus improving the weapon impact accuracy compared to a bomb-on-coordinates mode. The combat-proven combination of B-2 (with GATS) and JDAM represent a major advance in all-weather conventional bombing effectiveness.

Reliability, Maintainability, and Deployability: Reliability and maintainability of B-2 systems other than LO systems are satisfactory. LO reliability and maintainability remain unsatisfactory, having improved only modestly during FOT&E and FDE periods. Deployability still does not meet operational requirements.

Low Observable reliability and maintainability are still challenging. The wing continues to experience high failure rates of LO systems, including several cases of damage from static discharges. Many improvements to the materials and processes for LO maintenance were initiated upon the discovery of these problems in earlier testing. These included materials with easier application techniques, faster cure times, and longer shelf lives. Programs for improved diagnostic tools were also initiated. However, only a few improvements have reached the operating wing. The wing has achieved improvement in the number of maintenance man-hours required for LO, but this has resulted mainly from additional experience in managing repairs. The use of a computer model called the Low Observable Combat Readiness Model for LO maintenance prioritization and planning contributed to lowering LO maintenance man-hours. However, the Low Observable Combat Readiness Model sometimes has large errors in estimates of the aircraft signature resulting from LO discrepancies and should not be used to estimate aircraft signature.

The Environmental Control System and Auxiliary Power Unit are still inadequate to keep power on the aircraft while cooling the cabin and avionics. A Block 30 mode allows the Auxiliary Power Unit to drive the Environmental Control System while using external electrical power, but the systems are still unsatisfactory, particularly in hot and humid environments. Extra support equipment is required to cool the aircraft for ground operations.

The Mission Capable Rate for the B-2 (including all systems) does not meet requirements. If LO systems are not considered, the Mission Capable rate meets requirements. Maintenance Man-Hours per Flight Hour (MMH/FH) for non-LO systems improved during FOT&E and Force Development Evaluation. However, some of the improvement (about 20 percent) resulted from ways the Air Combat Command counted these hours. LO systems are still the main contributor to high maintenance time and reduced Mission Capable Rate. Despite the improvements in non-LO systems' reliability and

maintainability, the B-2 still has several hundred high priority deficiencies awaiting correction or funding.

The following table summarizes results for B-2 performance measures during IOT&E and for more recent FOT&E and FDE periods. Note that some measures for the FDE period cannot be directly compared to earlier values because sorties during Operation Allied Force were of much longer duration. In particular, longer duration sorties contributed directly to changes in Mission Capable Rate, Maintenance Man-Hours per Flight Hour (all systems and LO), Break Rate and Utilization Rate. These performance measures will be re-evaluated at the conclusion of FDE.

The listed requirement of Sortie Generation Rate assumes relatively close (in-theater) basing and therefore short sortie duration. However, the original required Sortie Generation Rate of 0.55 cannot currently be achieved even with short duration missions. Turnaround times must be significantly reduced to obtain the required rate.

B-2 Performance Measures

Performance Measure	Requirement	IOT&E (through July 1997)	FOT&E (through Dec 1998)	FDE (through July 1999) (includes OAF sorties)
Mission Capable Rate	60 percent	33 percent	32 percent	43 percent
Mission Capable Rate (without considering LO)	None	74 percent	70 percent	69 percent
Maintenance Man-Hours per Flight Hour (MMH/FH) (all systems)	54	119.8	72.8	32.11
Maintenance Man-Hours per Flight Hour (LO)	No requirement	37.11 (31 percent of total MMH/FH)	24.57 (34 percent of total MMH/FH)	14.03 (44 percent of total MMH/FH)
Mean Flight Hours Between Unscheduled Maintenance	0.31	0.23	0.27	0.30
Break Rate (Major Discrepancies per 100 Sorties)	No requirement	12.2	10.6	17.34
Weapon System Reliability	0.88	0.83 to 0.88 (Nuclear mission) (From model only)	0.90 to 0.98 (Nuclear mission) (From model)	0.98 (OAF results)
Utilization Rate (Flight Hours per Aircraft per Month)	None	31.1	26.8	55.6
Sortie Generation Rate (Sorties per Aircraft per Day)	0.55 (Deployed)	0.16 (From MOB) (From model only)	Not available	0.14 (From MOB) (OAF sorties)

As noted above, deployability still does not meet operational requirements. Evaluation was based on two wing deployments to Guam during the FOT&E period. Major obstacles to deployability are the need for shelters to perform LO maintenance and requirements for extensive support equipment. Acquisition of deployable B-2 maintenance shelters is underway. Delivery of the first deployable shelter is planned for 1QFY01. Despite the success of B-2's operating from the Main Operating Base during Operation Allied Force, deployability is still a critical necessity if the B-2 is to achieve expected response times and Sortie Generation Rates.

LFT&E:

B-2 vulnerability analysis was briefed to DOT&E in May 1998. At that time, several items needed resolution. The B-2 program office has subsequently provided the material requested at the May 1998 meeting, but has not completed the analyses described in the approved Test and Evaluation Master Plan. DOT&E has reviewed the data provided and will prepare a draft report to Congress and advise the Air Force of our findings. A coordinated B-2 LFT program should be continued under the B-2 Sustainment Program, providing information required to identify B-2 vulnerabilities in the conventional missions role and appropriate design modifications to reduce identified vulnerabilities.

OPERATION ALLIED FORCE (OAF):

B-2 employment during OAF was extremely successful, considering that missions were flown from the Main Operating Base, requiring 30-hour average sortie durations. However, the B-2's success did not disprove earlier reports by DOT&E or the General Accounting Office. The B-2 essentially fulfilled the expectations of IOT&E and earlier FOT&E. One area where B-2s performed significantly better than predicted was in the area of mission planning. As noted above, mission planning times have improved recently (but deficiencies remain for developing routes through dense threat areas). DMS also showed some improvement resulting from manipulating the threat data files to optimize performance.

All aircraft launched on OAF missions were believed to meet LO signature requirements at the time of launch, based on estimates from the Low Observable Combat Readiness. Since the end of OAF operations, two aircraft that were sent to the Periodic RCS Surveillance Mission range did meet signature requirements.

B-2s during Operation Allied Force flew 49 sorties, 45 of which entered the combat area and released weapons over their targets. Three of the 49 sorties were recalled or cancelled en route, leading to an overall 98 percent mission success rate. The sorties took place over a period of 60 days, and were flown by the wing's six available aircraft. This resulted in a Sortie Generation Rate of approximately 0.14 sorties per aircraft per day, slightly less than predicted by AFOTEC models during IOT&E.

Of the 682 weapons intended for release, 656 were successfully released for an overall weapon release probability of 96 percent. Of those weapons not released, roughly half were traceable to aircraft problems and the remainder were traceable to weapon reliability problems. The aircraft related problems were detected and corrected after the twenty-fourth mission and did not recur. Reports of B-2 effectiveness, estimated by battle damage assessment, stated that B-2s damaged a higher percentage of their targets than any other aircraft participating in combat operations. The 509th Bomb Wing's post-war analysis indicated the B-2 damaged or destroyed over 80 percent of its assigned targets on the first pass.

CONCLUSIONS

The B-2's operational effectiveness and suitability have improved incrementally as the aircraft has matured. Its performance in OAF was admirable considering sorties were flown against targets 5,000 nautical miles from the Main Operating Base. The missions confirmed the OT&E results that showed the B-2/JDAM combination is extremely effective. However, B-2's target kill effectiveness and survivability will be significantly enhanced if remaining deficiencies are corrected. Emphasis should continue toward improvements in Low Observable maintainability and verification, correction of CLOAR and Defensive

Management System deficiencies, and demonstration of the ability to forward deploy. The ability to deploy will raise Sortie Generation Rates.