Black Bom

The B-2's tortured acquisition program

USAF's new bomber seems to have survived 2011's budget battles, but a dark specter still hangs over it: the ghost of the B-2 program, begun more than 30 years ago.

Of course, the B-2 bomber has notched outstanding combat success in numerous air campaigns. Fears of revisiting the B-2's brutally truncated acquisition process, however, continue to exert an eerie influence on bomber politics.

"What we must not do is repeat what happened with our last manned bomber," then-Secretary of Defense Robert M. Gates warned in 2009. "Looking ahead, it makes little sense to pursue a future bomber—a prospective B-3, if you will—in a way that repeats this history."

Deputy Secretary of Defense Ashton B. Carter likewise said the goal for future programs is to "ensure that we do not find ourselves, after spending billions on development, with a system we can't afford to produce."

The next bomber's critical design trade-offs still have to be made. Will it focus on high subsonic flight versus an option for supersonic dash? What type of weapons and sensors will it carry? Will it operate mainly with an onboard or remotely located crew?

The 20 B-2s in service are still central to the plans of most regional combatant commanders. That's one of the biggest reasons why the Air Force has fought hard to start a new program for a penetrating bomber, with serious dollars in the 2012 budget.

There are clearly lessons to be learned from the B-2's development program. Are the skeletons rattling in the closet relevant today or blown out of proportion?

Based on the B-2's cautionary tale, senior defense leaders seem to believe that the trick to keeping the next bomber on track depends on not reaching too

The B-2 bomber **Spirit of Missouri** *lands at Whiteman AFB, Mo.*

ber Blues

By Rebecca Grant

casts a shadow even today.

far with technology development. "By the time the research, development, and requirements processes ran their course, the aircraft, despite its great capability, turned out to be so expensive—$2 billion each in the case of the B-2—that less than one-sixth of the planned fleet of 132 was ever built," Gates said in 2009.

Of course, the B-2s cost $2 billion apiece *because* only 21 were built. Had the originally planned 132 been built, although the total program price would have been higher, unit cost would have been far less. This false cause and effect has been like a millstone around the stealth bomber's neck ever since the program was halted.

The technologies for the B-2 included stealth, precision attack, electronic countermeasures, and sophisticated mission planning. All these were deemed essential due to the leap in Soviet air defense capabilities, the premier threat of the day. The attempt to build a stealth bomber was a natural evolution from high volume research on stealth and other precision attack technologies in the 1970s.

Officials as far back as the Nixon Administration conceived a stealth fighter—which led to the F-117—and got industry thinking about a stealth bomber. Ronald Reagan's 1980 election brought in Caspar W. Weinberger as SECDEF and put even more emphasis on invigorating national military capabilities. Soon after Weinberger was sworn in, reporters asked what surprised him most about the Pentagon.

"The principal shock was to find out, through daily briefings, the extent and the size of the Soviet buildup and the rapidity with which it had taken place—in all areas, land, sea, and air," Weinberger replied.

He became a staunch supporter of the B-2.

USAF photo

DOD photo

Tacit Blue, Northrop Grumman's stealthy battlefield control technology demonstrator aircraft on one of its 135 flights, which began in 1982.

Even given its high national security priority, USAF took a fairly conservative acquisition approach to the stealth bomber. By mid-1980, service officials approved a competition for an advanced strategic penetrating aircraft known by the acronym ASPA. The secret contest pitted Lockheed and Northrop against each other for the third time in less than seven years. They'd already gone head-to-head on the highly secret F-117 stealth fighter and the one-off battlefield control technology demonstrator aircraft known as Tacit Blue but nicknamed the Blue Whale for its fat curves.

New Design Components

The B-2's flying wing design was logical. It was the brainchild of a group of Northrop designers who agreed that for all-around survivability, the flying wing came closest to the radar engineer's ideal shape: an infinite flat plate. The Northrop team's principal innovation was to introduce curvature. The combination of flat flying wing and curved surfaces allowed engineers to predict and control the amount of radar energy returned from the B-2. (The Lockheed competitor, also a flying wing, relied somewhat more on faceted surfaces like those on the F-117.)

All this assumed the B-2 would fly its mission at high altitudes, 50,000 feet and above. This maximized stealth properties and gained efficient range and payload. A bomber flying at high altitudes diminished the effectiveness of the Soviet Union's air defense radars and stood the best chance of getting around the centrally controlled Soviet interceptor fighters. With smart mission planning, B-2 pilots could avoid most of the dangers of Soviet airspace and reach their targets in a way that the B-52, with its blazing radar-reflective signature, could not hope to match.

The B-2 was also pushing the envelope in precision weapons targeting. Unlike the F-117, the B-2 would incorporate advanced mission systems designed especially for it.

"It had a very sophisticated radar that took [synthetic aperture radar] images at high-fidelity resolution to go identify targets, with an electronic defensive system to be incorporated," as well as "four engines instead of two," said retired Lt. Gen. Richard M. Scofield, who spent eight years as the Air Force's B-2 program manager. He started in the job as a colonel in 1983 and rose to become a two-star general in the same position.

For the F-117, off-the-shelf systems were used wherever possible. For the B-2, however, "all the components were basically new design," recalled Scofield. In fact, the B-2 would be the first aircraft to carry Global Positioning System guided bombs as its standard weapons and later was first to employ the now-ubiquitous Joint Direct Attack Munition, or JDAM, in combat. In that sense, it was a pathfinder for USAF's combat fleet.

The Air Force was treating the bomber program with an urgency reminiscent of the Manhattan Project. Even so, systems engineering risk reduction was a key part of the program from the beginning.

Northrop was awarded the contract on Nov. 2, 1981. Configuration freeze of the entire design was scheduled for summer of 1983. Northrop at first proposed a brisk schedule with first flight in December 1986. As a backup, however, Weinberger restarted the B-1 program canceled under President Jimmy Carter.

To be safe, the Air Force added a year to the original production schedule, specifically for risk reduction. That pushed the first flight deadline to late 1987. After that, the program was slated to ramp up to peak production of 30 aircraft per year. On that schedule, the B-2 would reach initial operational capability with the Air Force in 1990.

Northrop Grumman photo

The B-2 was designed and built with a 3-D, integrated database. It required engineering and computation that were, at the time, utterly state of the art.

Then, Strategic Air Command, responding to a new threat analysis, changed the game. It added a second combat mission profile—flying low on the deck—and required the B-2 to now achieve speeds near Mach 1 at low altitude.

Back at the drawing board, Northrop's engineers reviewed the B-2's design.

"Everything was going along fine until we got to the aeroelastic analysis," said James Kinnu, who managed the program for Northrop from 1981 until 1985. The idea behind aeroelastic analysis was to test loads and structures in wind tunnel models, derive the results, and use the data to design actuators swift enough for the hydraulic controls.

When the data were in, they showed that the control surfaces worked fine in the smooth air at high altitude, but at low altitude, they would become saturated in strong gusts and fail.

"My airplane just blew up on me," Kinnu recalled telling his boss.

"It turned out to be a much tougher environment than they thought," said Scofield. The problem was severe because both pitch and roll were handled by trailing edge surfaces. To fix this, two more "sawtooth" planform features had to be added to the tail.

On top of the problems at 200 feet, there was the requirement for speed. SAC's insistence that the B-2 now fly at high subsonic speeds on the deck increased the proportional response from the gust loads.

By the spring of 1983, when he joined the program, "they'd pretty much decided that they had to redesign the planform to add the additional flight-control surfaces and beef up the structure," Scofield recalled. It fell to him to take the news to the then-Chief of Staff, Gen. Charles A. Gabriel.

"The first briefing I had to give on the program was to General Gabriel to say we're going to change the airplane," he said.

"If that's what we have to do to have a good airplane, that's what we'll do," Gabriel said.

Northrop's flight control manager, a specialist named Al Meyers, came up with a gust load alleviation system to quell it. Quick response by the flight controls would allow the B-2 to compensate for gusts.

The technical fix was extensive but elegant. It was also expensive—with estimates for the redesign running close to $2 billion.

Northrop Grumman photo

B-2s under construction at Northrop's Pico Rivera plant in California. The facility was subjected to the highest security measures.

Even though inadequacy of the flight controls forced the redesign, engineers took advantage of the reopened configuration to make other beneficial changes, including improvement of the center body shape with the sawtooth trailing edge. That put flight-control surfaces well aft of the center of pressure. Other changes included a symmetric W-shaped air inlet and a symmetrical exhaust. The cockpit also moved forward.

Nuclear Hardening

Ultimately, SAC had to take other steps to keep up with the threat environment. Although the redesign yielded a better airplane, the lesson learned was not to lock in a bomber design until those who will fly it are comfortable that its technology meets upcoming threats.

Another cost driver for the B-2 was its nuclear mission. SAC had no choice at the time but to opt for both nuclear and conventional capability.

Making the B-2 a survivable nuclear bomber was an extremely difficult process because designers had to learn how to harden stealth coatings against radioactive effects. None of the previous stealth programs had taken hardening to the level demanded for the B-2.

Originally, designers had theorized about flying around the "atomic cloud" caused by earlier missile detonations, for example. With the design change, there would be no chance of staying up at high altitude and avoiding some areas of radiation. The B-2 had to be ready to "go low" on the deck through an atmosphere full of radiation or cope with the shock waves from its own nuclear bombs on egress from the target. While the B-2 relied on low observable technology to get into the target area, it depended on structural strength to survive the blast from its own nuclear weapons or those of nuclear-tipped Soviet air defense missiles in order to get home.

Thus, the effect of radiation on the B-2's unique composite structure and radar absorbent material had to be taken into account.

This was uncharted territory. "None of the materials we used on Tacit Blue made it to the B-2," said airframe designer Irving T. Waaland. "They hadn't been developed for the nuclear environment."

Nuclear hardening actually involved several different, nasty scenarios. First there was predetonation dust. The detonation itself gave off gamma-neutron radiation. Next, a massive thermal wave of great intensity could sweep over the aircraft and scorch everything inside it. Then came electromagnetic pulse, or EMP, the result of exoatmospheric gamma rays interacting with the magnetic field.

"We had to make sure coatings, crew, and systems survived," said engineer John Mall, who worked on the problem for Northrop. The principal challenge was testing the stealth coatings to find the ones that could do their stealth "jobs" and still survive the spate of nuclear blast effects. That meant a lot of time and journeying to test facilities where Mall and his team would fry various low observable materials at 10 times solar power and measure the effects.

Sometimes, materials that passed the test still had to be discarded because they were too toxic to use in large-scale

***The B-2* Spirit of Georgia.**

Illustration © Zaur Eylanbekov/*Air Force* Magazine

production. Southern California's air quality management district enforced strict environmental compliance for the Pico Rivera plant, underlined by inspections, fines, and at one point, a lawsuit.

"Environmental compliance drove us nuts," recalled Mall.

Ultimately, the B-2 team found the right materials for vital systems such as the cockpit. It had a passive thermal protection system and a windscreen with "a quick-reacting photochromic that reflected thermal waves back," said Mall. The process had been developed especially for the B-2 by one of the program's suppliers.

"About the only thing that was not rad-hardened was the anti-skid system" of the brakes, Waaland later jested.

Another aspect of the B-2's development was the intense secrecy shrouding the program.

Here, USAF seems inclined to follow the B-2 model. While the existence of the next bomber program is no secret, USAF has already tucked it away from view as a Special Access Program, meaning that only those with the highest clearances and bomber-specific security slots will know much about it.

In theory, so-called black world acquisition streamlines the process and lowers cost. Yet here again the B-2 program offers a cautionary tale. It, too, was a totally classified program, but heavy secrecy actually imposes heavy costs. All the management, labor, and accounting procedures integral to any major program were required for the B-2, but every single person had to have a security clearance. Nor was this just a secret program; there were numbered levels of security and access, and thousands of workers at every skill level had to be cleared.

"One of the biggest struggles was manning up and getting the right people," said Kinnu. Top talent came from programs such as the space shuttle and from around the pool of Southern California's aerospace industry. Even so, clearances often took months, slowing the overall project. New workers stayed on the program payroll while awaiting clearances. The B-2 security structure included complete document control, as well as background checks, physical access control, and measures to keep the plant work environment secure. Subcontractors also had to follow the tight standards for the black program.

Cruel Math

Kinnu and Waaland later estimated that security alone added between 10 percent and 20 percent to the overall B-2 program cost, a figure consistent with that for the F-117 program.

Despite all this, B-2 program managers tried to hold to the schedule for first flight in 1987. They didn't make it. The B-2 rolled out of its hangar in Palmdale, Calif., in November 1988 and took to the skies on July 17, 1989.

Despite the major technology hurdles, the B-2 didn't spend an inordinate amount of time in development. Not quite eight years passed from contract award until first flight.

Trouble hit the B-2 at the typical place: the transition between flight test and low-rate production. The next three B-2s made their first flights at the rate of one per year in 1990, 1991, and 1992. Test and development of the pilot cadre was slow as a result.

Mission systems proved to be a risky area. One of the program's worst flubs came well into the flight-test program, when the aircraft failed a summer 1991 stealth test. The Air Force rushed to explain the test results to the handful of congressional members and staff cleared to know. The test by itself was not an insurmountable problem, but the signs weren't good—especially with pressure mounting for a national budgetary "peace dividend," given the rapid decline of Russian military capability after the Soviet Union went out of business in 1991.

"I am not closing the door on the B-2," Democratic Sen. James J. Exon of Nebraska warned in 1991, "but I wish to send a very loud and very clear signal that they had better get their act straightened out or the program will die a fast, rather than a slow, natural death."

Crumbling congressional support was a bigger blow than the collapsing Soviet Union. The denouement of the cost tragedy came in just a few months. The bipartisan support that guided the B-2 from contract award to flight test fell apart completely under President George H. W. Bush.

Bush's Secretary of Defense, Dick Cheney, had already trimmed the buy from 132 to 75 in April 1990. In January 1992, he decided not to fund any more than the 15 production aircraft then in the works or with parts on long-lead purchase. President Clinton later added funds to turn a test article into the 21st operational aircraft.

The cruel math hit hard. The final tally for the B-2 program at the end of production was a hefty $44.2 billion. More than half—$23.4 billion—had been sunk into costs for research and development, while another $18.5 billion went to production; half-a-billion more went to military construction.

The nation clearly did not get a full return on the massive B-2 development program, but a complicated lesson from the B-2 is that conquering a major technology challenge can pay off handsomely in indirect ways.

The B-2 achieved the revolutionary goals of applying low observable technology to a bomber-sized aircraft, while incorporating avionics for precision weapons missions. More than 20 years later, that's an achievement still unmatched by any other program or air force. ■

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