Top Mach Studios, LLC

B-2A Spirit Stealth Bomber for Microsoft Flight Simulator 2020

User Manual

For Software Release V1.0.5

Disclaimer – Although the digital aircraft model for which this manual is written resembles its real-world counterpart, neither the model nor this manual can or should be used as a source of real-world information about the operation or maintenance of the corresponding aircraft and is a work of fiction. Additionally, this package is not endorsed by or supported by the Northrop Grumman Corporation or its affiliates, or by the United States Air Force, the United States Department of Defense, or the Government of the United States of America.

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- Our B-2 Spirit pilot and maintainer friends who’ve provided invaluable information.

And thank you to every member of the flight simulation community whose enthusiastic support, encouragement, and love of aviation and military aviation simulation kept us going. And a special thank you to our families and friends without whose support we couldn’t have persevered to make this model a reality.

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THE B-2A SPIRIT STEALTH BOMBER

Brought to you by Top Mach Studios, LLC

The B-2A Spirit stealth bomber presented a complex and exciting challenge for Top Mach Studios. It's taken us over a year and a half of laborious and painstaking work to render the B-2 well enough for us to feel ready to share it with the community. And we have a considerable road map of updates and upgrades to follow the initial release. One of the most interesting and unique aircraft ever developed, and in many ways well ahead of its time when it first rolled out of the hangar for public presentation on November 22nd, 1988 , the technologies and capabilities of the B-2 Spirit are still every bit as relevant today as when the aircraft was conceived back in the 1970s. While impossible within the scope of any desktop flight simulator to replicate the complexity and depth of operational and tactical systems found on the B-2A, we've endeavored to provide a highly immersive and satisfying experience that we hope represents what it might feel like to fly the Spirit. It has only been in the last few years that the USAF allowed any publicly available photographic and video footage from inside the cockpit of B-2 to become available. Prior to that it would have been exceedingly difficult to produce a reasonably accurate model of the aircraft that we'd have felt comfortable putting our logo on. We also received invaluable information, feedback, and encouragement from real world B-2 pilots and maintainers, within the limits of operational security. Also, somewhat fortuitously, during development of this model, new public video footage became available that enabled us to more accurately model the cockpit rear interior area and other features of the aircraft; prior to that there was only one publicly available in-flight cockpit footage video from the B-2 cockpit. Between the feedback from real world B-2 specialists and the new footage, development was set back at least two and a half months just so we could try to capture more of the visual essence and accuracy of modeled functionality within the B-2 cockpit. We hope the delay was worth the wait!

ABOUT THE B-2

The Northrop B-2 Spirit, also known as the "Stealth Bomber", is an American heavy strategic bomber, operated by the United States Air Force, featuring low-observable stealth technology designed to penetrate dense anti-aircraft defenses. A subsonic flying wing with a crew of two, the plane was designed by Northrop (later Northrop Grumman) as the prime contractor, with

Boeing, Hughes, and Vought as principal subcontractors, and was produced from 1987 to 2000. The bomber can deliver a wide variety of conventional and thermonuclear weapons, including up to eighty 500-pound class (230 kg) Mk 82 JDAM GPS-guided bombs, or sixteen 2,400-pound (1,100 kg) B83 nuclear bombs. The B-2 is presently the only acknowledged in-service aircraft that can carry large air-to-surface standoff weapons in a stealthy aircraft configuration.

The B-2 Spirit was developed to take over the USAF's vital penetration missions, allowing it to travel deep into enemy territory to deploy ordnance, which could include nuclear weapons. The B-2 is a flying wing aircraft, meaning that it has no fuselage or tail. It has significant advantages over previous bombers due to its blend of low-observable technologies with high aerodynamic efficiency and a large payload. Low observability provides greater freedom of action at high altitudes, thus increasing both range and field of view for onboard sensors.

Approximately 80 pilots are assigned to fly the B-2 at any one time. Each aircraft has a crew of two, a pilot in the left seat and mission commander in the right, and has provisions for a third crew member if needed. The B-2 is highly automated, and one crew member can sleep in a camp bed, use a toilet, or prepare a hot meal while the other monitors the aircraft, unlike most two-seat military aircraft.

A VERY SHORT HISTORY OF THE B-2'S DEVELOPMENT

In June of 1977, President Jimmy Carter cancelled the B-1A bomber program. Although much criticized at the time, one of the reasons for the cancellation was the need to concentrate the limited funds that were available on the development of air-launched cruise missiles. Another reason, unsaid at the time, was the desire to concentrate on the development of low observable aircraft that would be hard to detect by enemy radars and thus more likely to penetrate sophisticated defenses.

In 1978, the Carter administration secretly authorized the start of a stealth bomber program, termed the *Advanced Technology Bomber* (ATB). A bomber was sought which could replace the recently-cancelled B-1A in Air Force future plans and, in addition, also replace the B-52, which was by that time nearly a quarter-century old. The requirements were set by the needs of the Cold War--this aircraft would use low-observable technology to make it possible to penetrate unobserved for hundreds of miles into Soviet airspace with a full load of nuclear weapons.

In September of 1980, the USAF issued a request for proposals for an Advanced Technology Bomber (ATB). Since the costs and technological challenges both promised to be steep, collaborative efforts between different aerospace companies were encouraged. Two groups of competitors appeared-- Lockheed teamed with Rockwell and Northrop teamed with both Boeing and Ling-Temco-Vought. Northrop was responsible for the forward center body and cockpit, the leading and trailing edges, and the control surfaces, as well as for final assembly and the overall coordination of the project. Boeing was given responsibility for the aft center

section and the weapons pay, plus the outboard wing sections and the landing gear. Ling-Temco-Vought was given responsibility for the wing intermediate sections with their engine intakes and exhausts (LTV was subsequently acquired by Northrop Grumman). Final assembly would take place at Site 4, USAF Plant 42 at Palmdale, California.

There is much written about the painful, protracted, and expensive birth of the B-2A Spirit. The internet and several books written by knowledgeable parties can provide interesting reading about the Carter and Reagan era acquisition and development of the B-2A and the impact changing mission requirements and global politics had on the ultimate cost, development delays, and production run of this remarkable aircraft.

B-2A SPIRIT DESIGN AND SYSTEMS

The design that emerged was a pure flying wing, with no vertical rudders or fins. The wing leading edges run straight from the nose to the tips of the wing. The center body is thicker than the rest of the wing, and contains the cockpit, the weapons bays, and the electronics. Immediately outboard of the center body in separate bulges are the engines, two engines on each side. The forward leading edge of the wing is swept back at an angle of 33 degrees for both radar signal return mitigation and the requirement that a high subsonic speed be achieved, as well as by the need to locate the aerodynamic center close to the center of gravity. The length of the center body section was determined by the requirement that it had to be deep enough to accommodate the cockpit and the weapons bays, and this meant that it had to be a minimum length to avoid excessive drag at high subsonic speeds. Outboard of the center body section, the dimensions of the chord were set by the need to integrate the engines and their low-observable inlet and exhaust systems into the wing. The thick supercritical wing section accelerates the air to supersonic speeds over the wing.

The overall size of the aircraft was determined by radar test range research into aircraft sizes and shapes that minimized radar signal returns within the frequencies encountered from air defense radar units for an aircraft at the scale of a strategic bomber. Unlike almost any other aircraft built prior to the B-2A, the aircraft was built from the outside in, the shape and size revealed on the radar test range to create as small a radar cross section as possible, with the engineering team then forced to make everything fit inside without perturbing the shape or size of the outer body. The B-2 is also assembled with unusually tight engineering tolerances to avoid cracks and gaps as they could increase its radar signature. Because of this and many other unique requirements, the B-2A development program made use of a variety of new engineering and construction methods that had to be created and built specifically for the B-2 program by Northrop Grumman and its partners.

The B-2's low-observable, or "stealth", characteristics enable the undetected penetration of sophisticated anti-aircraft defenses and to attack even heavily defended targets. This stealth comes from a combination of reduced acoustic, infrared, visual and radar signatures (multi-spectral camouflage) to evade the various detection systems that could be used to detect and

be used to direct attacks against an aircraft. The B-2's stealth enables the reduction of supporting aircraft that are required to provide air cover, Suppression of Enemy Air Defenses and electronic countermeasures, making the bomber a "force multiplier".

To reduce optical visibility during daylight flights, the B-2 is painted in an anti-reflective paint. The undersides are dark because it flies at high altitudes (up to 50,000 ft (15,000 m), and at that altitude a dark grey painting blends well into the sky. It is speculated to have an upward-facing light sensor which alerts the pilot to increase or reduce altitude to match the changing illuminance of the sky. The original design had tanks for a contrail-inhibiting chemical, but this was replaced in production aircraft by a contrail sensor that alerts the crew when they should change altitude. The B-2 is vulnerable to visual interception at ranges of 20 nautical miles (23 mi; 37 km) or less.

Most of the surface of the B-2A is covered with a special elastomeric material which is designed to maintain a uniform conductivity over the surface to reduce reflections from joints or seams. Those areas which cannot by their nature be totally stealthy in their design (such as air intakes) are coated by radar-absorbent material (RAM), the composition of which is highly classified. RAM is a multi-layer sprayed-on elastomer which consists of an active element which converts radar energy into heat. The basic idea is to place a coating on the aircraft which is of the proper thickness so that the small reflection from the front face of the material is exactly cancelled out by a residual reflection from the rear face. A similar principle is used in coated optics for binoculars and telescopes to eliminate unwanted light reflections. Innovations such as alternate high frequency material (AHFM) and automated material application methods were also incorporated to improve the aircraft's radar-absorbent properties and reduce maintenance requirements. In early 2004, Northrop Grumman began applying a newly developed AHFM to operational B-2s.

Reportedly, the B-2 has a radar cross-section (RCS) of about 0.1 m2 (1.1 sq ft). The bomber does not always fly stealthily; when nearing air defenses pilots "stealth up" the B-2 via its penetration mode, a maneuver whose details are secret. The aircraft is then stealthy, except briefly when the bomb bay opens. The B-2's clean, low-drag flying wing configuration not only provides exceptional range but is also beneficial to reducing its radar profile. Without vertical surfaces to reflect radar laterally, side aspect radar cross section is also reduced. Radars operating at a lower frequency band (S or L band) are able to detect and track certain stealth aircraft that have multiple control surfaces, like canards or vertical stabilizers, where the frequency wavelength can exceed a certain threshold and cause a resonant effect.

To protect the operational integrity of its sophisticated radar absorbent material and coatings, each B-2 is kept inside a climate-controlled hangar (Extra Large Deployable Aircraft Hangar System) large enough to accommodate its 172-foot (52 m) wingspan. While deployed away from Whiteman AFB, B-2s are supported by portable, environmentally-controlled hangars called B-2 Shelter Systems (B2SS). The hangars are built by American Spaceframe Fabricators Inc. and cost approximately US$5 million apiece. The need for specialized hangars arose in 1998 when it

was found that B-2s passing through Andersen Air Force Base on Guam did not have the climate-controlled environment maintenance operations required. B2SS hangars are known to have been deployed to Naval Support Facility Diego Garcia and RAF Fairford.

There is no vertical fin. Unlike conventional aircraft, the B-2A is directionally neutral in yaw, which means that there are no aerodynamic pressures which would force it back to forward flight were it to yaw either left or right. Yaw control is provided by a set of Northrop-patented brake-rudders on the outer trailing edges of the wing. The very outermost pair of surfaces can split apart horizontally, one side moving up and the other side down. They can operate symmetrically as speed brakes and asymmetrically as rudders, and they are known as brake-rudders. The brake-rudders are the primary means of yaw control, but because of the boundary layer over the wing the surfaces are ineffective until they have moved at least five degrees from their neutral positions. In normal flight, the brake-rudders are set at the "5 and 5" position, that is, they are ordinarily slightly displaced so that they can be immediately effective when control is needed. However, open rudders are incompatible with stealth (especially from the rear), so the brake-rudders have to be locked shut when the B-2A is going into a combat zone. It is believed that differential engine thrust is used for yaw control when the B-2A is in full stealth mode. but the real means of control is classified.

The aircraft is inherently unstable, but is rendered stable by a quadruplex fly-by-wire system that can automatically manipulate flight control surfaces without direct pilot inputs in order to maintain aircraft stability. The flight computer receives inputs from pitot-static sensing plates, as opposed to pitot tubes which would negatively affect stealth; there are five groups of air data sensors located on the leading edges of the wing just ahead of the windshield. The flight control computer units were developed by General Electric. The B-2 is fitted with eight actuator remote terminals spread out along the wing span which receive their instructions from the GE flight control computer via a quadruplex digital data bus. The remote terminals issue analog commands to the actuators and control all of the necessary feedback loops. These provide input to the fly-by-wire system--the system compares air pressures to determine the angle of attack and the amount of sideslip. The flight actuation system incorporates both hydraulic and electrical servo-actuated components, and was designed with a high level of redundancy and fault-diagnostic capabilities.

The B-2A is powered by four General Electric F118-GE-11 non-afterburning turbofans, each rated at 19,000 lb.s.t. The F118 engine was based on the F101-X, a fighter engine originally derived from the F101 engine that powered the B-1 and its successor the F110. Compared with the F101, the F101-X had a smaller low-pressure spool which reduced the bypass ratio from 2:1 to 0.87 to 1. A lower bypass ratio engine was selected because it would need a smaller exhaust and inlet system than that of a high bypass ratio engine. The engines are seated in pairs in engine bays buried inside the wings just outboard of the central fuselage.

The engine inlets are set far back from the leading edge, thus shielding them from radar emissions coming from below. The inlet region resembles two supercritical wing sections in

series. The first is the area behind the leading edge, where the airflow accelerates to supersonic speed and is then recompressed to subsonic speed before being swallowed by the main inlet and the auxiliary boundary layer suppression scoop. The second supercritical section comprises the region from the inlet lip to the exhaust exit, where the flow is accelerated and recompressed once again.

The engine air intakes were a special challenge, since they are absolutely necessary but represent a ready source of unwanted radar reflections. One of the major problems is the danger that enemy radar signals might reach the whirling blades of the turbofan engines, producing reflections so intense that the enemy can not only readily detect the aircraft but can often even tell the type of aircraft that is present. Unlike in the F-117A, the intakes are not covered by radar absorptive grids. Instead, the engines are buried completely within the wing, and are fed by S-shaped inlet ducts which completely conceal the compressor faces from direct line-of-sight illumination by radar. RAM is used to cover the duct walls to suppress any radar energy that could bounce off the duct walls to reach the engines. As additional insurance, the lips of the air intakes are serrated in order to scatter enemy radar emissions, preventing them from being returned to their source. For maintenance, the engines are accessed via hatches in the underside of the aircraft. These hatches have serrated edges to suppress unwanted radar reflections.

Early wind tunnel testing showed that there was a certain amount of flow separation inside the highly curved intake duct, leading to a loss of power at low speeds. To prevent this, a pair of retractable auxiliary inlet scoops (EAIDs) were added to the upper wing surface, immediately above the engines. These open at low speeds to increase the air flow to the engines.

Ahead of each air intake inlet is a serrated slit-like auxiliary inlet which removes the turbulent boundary layer air, preventing it from entering the engine. This boundary layer air is then mixed with the exhaust to cool its temperature and reduce the infrared signature of the aircraft, part of its low observable systems.

An equally demanding challenge was presented by the engine exhausts. The B-2A engine exhausts are designed to minimize the infrared signature, making it more difficult for enemy infrared detection systems to pinpoint the aircraft. Since most long-range IR sensors such as the infrared search and track systems fitted to some fighters and the homing heads of IR-guided missiles operate by detecting the radiation from the hot gas and water vapor emitted by the engines, considerable work has gone into reducing the infrared signature of the B-2. One of these involves the cooling of the engine exhaust as quickly and efficiently as possible. The B-2 exhausts are built into the top of the wing, with the primary nozzles well ahead of the trailing edge. The engine exhausts feed into a pair of soft-lipped trenches, which flare outward. The engines are fitted with flow mixers that blend the hot core exhaust stream with the cold boundary layer air which is swallowed by the secondary inlets. The exhausts are wide and flat, so the perimeter of the plume is longer than the perimeter of a round exhaust stream, and mixing takes place more quickly. The interaction between the exhaust stream and the airflow

over the aircraft, at each side of the exhaust "trench", creates a vortex which cools the exhaust still further.

The B-2A has a crew of two, seated side by side on individual ACES II ejection seats, with the pilot on the left and the mission commander on the right. They are seated well to the rear of rather large windshields which fit flush with the surface of the center body airframe. The crew gain access to the crew compartment via a ventral hatch located to the port side of the nose gear bay door. In an emergency, the crew members eject upward through frangible panels in the roof of the aircraft. The mission commander is responsible for navigation and weapons delivery, but either crew member has the ability to perform the complete mission. Each crew station has four cathode ray tube color displays, with a flight data computer entry panel to the right and a set of throttles to the left

The navigation system for the B-2A initially combined two types of units, either of which is capable of navigating the aircraft on its own. However, greater accuracy is obtained when they operate in conjunction. One is a Kearfott inertial measurement unit and the other is a Northrop NAS-26 astro-inertial unit. The NAS-26 was originally developed for the Snark long-range cruise missile and is based on a stabilized electro-optical telescope which locks onto a pre-selected star even in cloudy daylight. The observation port for the system is to the left of the windshield.

At shorter ranges, infrared radiation emitted by the skin of the aircraft itself is a problem. This unwanted infrared radiation can be generated by reflected sunlight as well as by friction with the air passing over the skin of the aircraft. Infrared-absorbent paints are commonly used to absorb infrared light from sunlight, preventing it from being reflected from the surfaces. This results in an aircraft with an overall gray color. Heat generated by air friction cannot be affected by an absorbing paint, but coatings have been developed which change the emissivity of the surface, causing the infrared emission to take place in bands which are strongly absorbed by the atmosphere, making it less likely that a nearby detection system can see it.

The B-2A is capable of midair refueling, via a receptacle for a refueling boom that is installed in the upper fuselage behind the cockpit. In the interest of stealth, this receptacle rotates out of the way when not in use, presenting a smooth upper surface. At cruising altitude, the B-2A typically refuels every six hours, taking on up to 50 tons (45,000 kg) of fuel at a time.

The B-2A was equipped with the GM-Hughes Electronics AN/APQ-181 radar. The radar installation is designed to achieve Low Probability of Interception (LPI). LPI is achieved by using the least amount of energy required to detect and track the target, while encoding the signal to make it difficult for the enemy to distinguish it from random noise. There are two separate electronically-scanned antennae for this radar, one in each of the lower leading edges of the wings just outboard of the cockpit. There are 20 modes that the radar can use, including synthetic aperture radar mode and terrain following and terrain avoidance modes. There is a ground moving target indication mode that can detect vehicles on the ground and an air-to-air

mode that can be used during inflight refueling. Many features of this radar suite are still highly classified.

The B-2A does not have any defensive armament, relying instead on a Defensive Management Subsystem (DMS) to provide protection against threats. Lockheed Martin, Raytheon, and Honeywell have all provided components for the system. Although details of the system are largely classified, the primary component is believed to be the Lockheed Martin AN/APR-50 (sometimes known as ZSR-63). The APR-50 is designed to detect, classify, identify, and locate any hostile system that emits radio-frequency radiation. The system receives inputs from antenna distributed across the airframe, and the electronics system performs automated signal processing and analysis and presents real-time updates to the crew.

INTRODUCTION TO SERVICE AND UPGRADES

The B-2 was first revealed to the public on November 22, 1988, when AV-1 (82-1066) was unveiled at Palmdale. Taxi tests began on July 10, 1989. The B-2 finally made its first flight on July 17, 1989 from Palmdale, crewed by chief test pilot Bruce J. Hinds and Col. Richard Couch. It lasted 112 minutes and ended with a landing at Edwards AFB. After carrying out initial tests, AV-1 was used for radar cross section tests. In early 1993, AV-1 was placed in long term storage to await upgrading to full-service configuration prior to joining the operational fleet.

The first production B-2 (AV-1007 (88-0328) was delivered to Whiteman AFB in Missouri in December of 1993. By that time, it was clear that the initial production run would be far short of the 132 initially planned. A military review initiated by Defense Secretary Richard Cheney announced that the total B-2 buy would be drastically cut to 75, with the production rate being only 12 aircraft per year by the mid-1990s. In the aftermath of the collapse of the Soviet Union and the Warsaw Pact, in October of 1991, Congress froze the production plan at only 16 aircraft. In January of 1992, President George Bush announced that the administration would seek funds for only five more B-2s, bring total production to only 21 planes, including the six test aircraft. There are currently no plans for any more B-2A construction, so the fleet will be limited to only 21 planes and the B-2A will eventually be replaced by its successor, the B-21 Raider. Because of the limited production run, the B-2 is the most expensive aircraft ever built, with a price of nearly 2 billion dollars per aircraft, including research and development costs.

Terrain-following certification flights were undertaken by AV-4 in September 1996. By January of 1997, the B-2 had reached limited operational capability. The first 10 production B-2s (AV-1007 through AV-1016) were delivered as Block 10 aircraft between December 1993 and the end of 1995. The Block 10s were primarily used as trainers for pilots and ground crews. They all had a takeoff weight limited to only 305,000 pounds, had no terrain-following radar and did not have the ability to deliver any precision weapons.

Three new aircraft (1017-1019) were delivered as Block 20 aircraft in 1996. The Block 20 aircraft operate at a higher takeoff weight of 336,500 pounds, is cleared for terrain-following operations, and the DMS is operational in bands 1 to 3. The Block 20 upgrade also includes a

Global Positioning System (GPS) receiver with a special low-observable antenna. It replaces the astro-inertial unit for routine operations, although the AIU will be retained in use as an un-jammable backup. Block 20 also has an improved environmental control system. The Block 20 aircraft could carry B61 nuclear weapons, cluster bombs, and could deliver some types of precision-guided weapons. Starting in mid-1996, the five newest Block 10 aircraft (1012-1016) went through an upgrade program to bring them up to Block 20 status.

Block 30 B-2As are considered the definitive operational configuration. The Block 30 modifications include removal and replacement of all the aircraft's edges, including the leading edges and control surfaces. The RAM coating is of an improved type. Improved avionics software makes it possible to achieve a terrain-following mode as low as 200 feet. The DMS system adds Band 4, allowing crews to re-plan their mission in flight. The Block 30 is integrated with the transportable Air Force Mission Support System (AFMSS) which is designed to integrate the B-2 with other USAF operations all throughout the world. This replaces the Strategic Mission Development and Planning System (SMDPS), which was intended for the nuclear mission only and was never intended to be used outside the B-2's main base. The last two B-2As were originally built to Block 30 standards, with the first Block 30 B-2A being delivered in August of 1997. Earlier Block 10 B-2s were traded back to Northrop Grumman for retrofit into Block 20 and Block 30 standards on a planned, staggered schedule. By the end of 2000, all 21 B-2s were brought up to Block 30 standards.

THE B-2 IN SERVICE

The 509th Bomb Wing at Whiteman AFB in Missouri was the first wing to receive the B-2A. It became active on April 1, 1993 to receive the B-2. The 509th can trace its history back to the 509th Composite Group, which dropped the atomic bombs on Japan to end the Pacific War. The 509th had previously operated FB-111As at Pease AFB, New Hampshire, and had been inactivated when Pease was closed in 1988. The 509th (without equipment or personnel) then moved to Whiteman AFB, which was at that time also inactive. By the time that the 509th was resurrected at Whiteman, the USAF had replaced the term "Bombardment" with "Bomb". The operational units of the 509th BW were the 393rd Bomb Squadron and the 394th Combat Training Squadron. The first B-2A arrived on December 17, 1993. The B-2s have been regular participants in Red Flag exercises since 1995. In 1997, the USAF announced that B-2As had reached a limited capacity to carry and release conventional weapons. Also in 1997, the USAF declared the 509th capable of handling both conventional and nuclear missions.

In 2008, Northrop Grumman was awarded a contract to modernize the B-2's radar. the radar's operational frequency was shifted in order to avoid interference with other systems. The arrays of the radar were replaced to make the system into an active electronically scanned array radar. In 2010, it was made public that a new material had been developed to be used on the wing training edge engine exhaust, replacing previous material that had quickly degraded. In 2012 it

was revealed that a 10-year modernization of the B-2 would begin, concentrating on the replacement of outdated avionics and equipment.

The B-2A made its combat debut in Operation *Allied Force*, the NATO intervention in Kosovo. On March 24, 1999, two B-2As from the 509th BW at Whiteman AFB flew a 31-hour round trip mission against targets in Kosovo. This mission also marked the first use of the GBU-29/30 GPS satellite-guided JDAM "smart bomb" in combat. Although the bombers accounted for 50 sorties out of a total of 34,000 NATO sorties during the operation, they dropped 11 percent of all bombs.

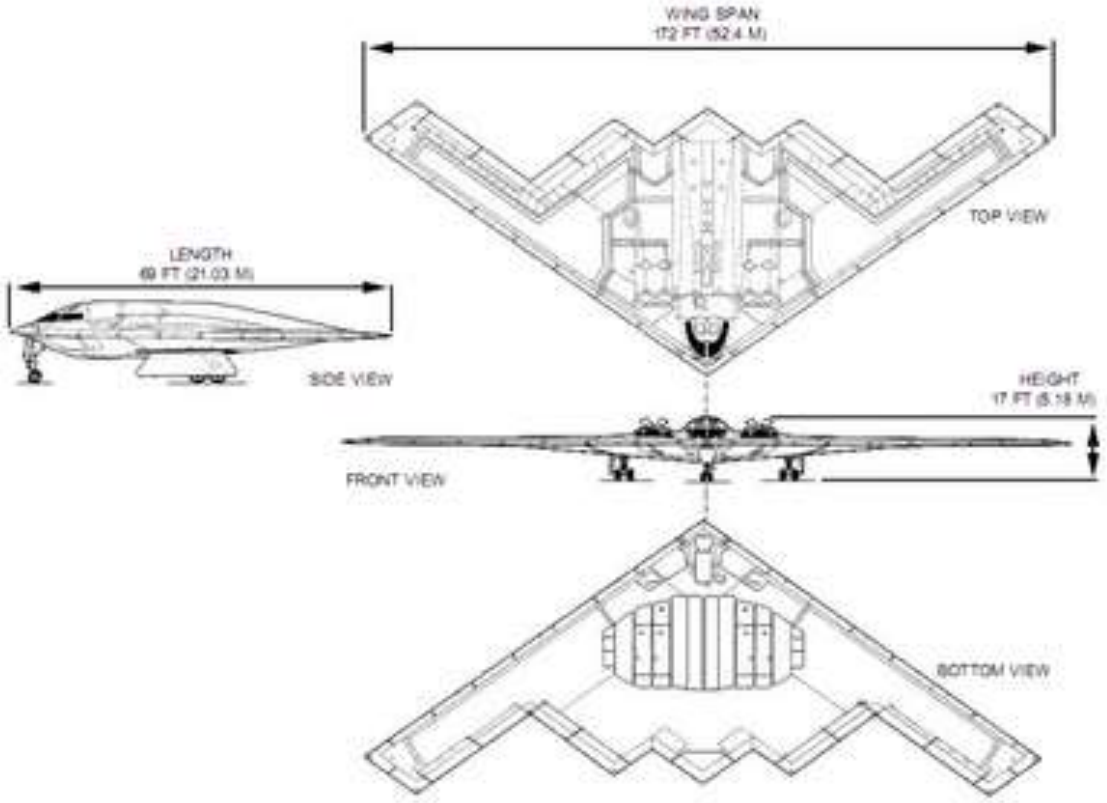
The B-2 holds the record for the longest air combat mission in history, when the Spirit of America entered Afghan airspace during a record-setting 44-hour+ non-stop flight in support of *Operation Enduring Freedom* in 2001. Supported by midair refueling, the B-2 flew from Whiteman AFB in Missouri, flying non-stop for over 44 hours before making a brief hot pit refueling stop and crew change at Diego Garcia, then flying back to Whiteman AFB, for a total of over 70 hours of continuous operation without an engine shutdown. Five other B-2s also flew sorties of comparable length during the same 3-day period, but Spirit of America still holds the record for longest non-stop flying mission.

In March 2011, B-2s were the first U.S. aircraft into action in *Operation Odyssey Dawn*, the UN mandated enforcement of the Libyan no-fly zone. Three B-2s dropped 40 bombs on a Libyan airfield in support of the UN no-fly zone. The B-2s flew directly from the U.S. mainland across the Atlantic Ocean to Libya; a B-2 was refueled by allied tanker aircraft four times during each round-trip mission.

On February 23, 2008, B-2A serial number 89 0127 AV-12 MSN 1012 “Spirit of Kansas” crashed on takeoff from Andersen AFB, Guam (509th BW, 393rd BS). Both crew members ejected safely, but the aircraft was destroyed. This was the first and, so far, the only B-2 lost. The estimated loss was $1.4 billion, which made it the most expensive crash in the history of the United States Air Force. The cause of the crash was determined to be moisture left in the aircraft's Port Transducer Units during air data calibration, which distorted the information being sent to the bomber's air data system. As a result, the flight control computers calculated an inaccurate airspeed, and a negative angle of attack, causing the aircraft to pitch upward 30 degrees during takeoff.

A total of 20 B-2s remain in service with the USAF, and the B-2 will remain in service until eventually replaced by its successor, the B-21 Raider.

AIRCRAFT SPECIFICATIONS (B-2A SPIRIT BLOCK 30)



General characteristics

Crew: 2: pilot (left seat) and mission commander (right seat)

Length: 69 ft 0 in (21.0 m)

Wingspan: 172 ft 0 in (52.4 m)

Height: 17 ft 0 in (5.18 m)

Wing area: 5,140 sq ft (478 m^2)

Empty weight: Approx. 158,000 lb (71,700 kg)

Maximum Takeoff Weight: 336,500 lb (152,200 kg)

Max Airborne Weight: 376,000 lb (170,600 kg)

Fuel capacity: 167,000 pounds (75,750 kg)

Powerplant: 4 × General Electric F118-GE-100 non-afterburning turbofans, 19,000 lbf (77 kN) thrust each

Performance

Maximum speed: 630 mph (1,010 km/h, 550 kn) at 40,000 ft (12,000 m) altitude / Mach 0.96+

Cruise speed: 560 mph (900 km/h, 488 kn) at 40,000 ft (12,000 m) altitude / Mach 0.85

Range: 6,900 mi (11,000 km, 6,000 nmi)

Service ceiling: 50,000 ft (15,200 m)

Wing loading: 67.3 lb/sq ft (329 kg/m^2)

Thrust/weight at MTOW: 0.225

Armament Includes:

2 internal bays for ordnance and payload with an official limit of 40,000 lb (18,000 kg); maximum estimated limit is 50,000+ lb (23,000 kg)

80× 500 lb (230 kg) class bombs (Mk-82, GBU-38) mounted on Bomb Rack Assembly (BRA)

36× 750 lb (340 kg) CBU class bombs on BRA

16× 2,000 lb (910 kg) class bombs (Mk-84, GBU-31) mounted on Rotary Launcher Assembly (RLA)

16× B61 or B83 nuclear bombs on RLA (strategic mission)

Standoff weapon: AGM-154 Joint Standoff Weapon (JSOW) and AGM-158 Joint Air-to-Surface Standoff Missile (JASSM)

2× GBU-57 Massive Ordnance Penetrator

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United States Air Force

Northrop Grumman, Corporation

NOTAMS (REALLY IMPORTANT STUFF TO READ FIRST)

MINIMUM HARDWARE RECOMMENDATIONS

This B-2A model is a large, complex, high-detailed model with large textures as well as complex customized flight control and instrumentation coding that may not function correctly without sufficient computing resources. We highly recommend minimum system specifications that meet or exceed the following:

CPU: 3.2GHz quad core processor or better

GPU: at least 6GB dedicated video memory, Nvidia 1060 GTX or AMD RX 580 or better recommended

RAM: 16.0GB minimum

Hard Disk: 2.8GB minimum hard disk space required for installation

Xbox Series X is recommended. The Series S may support the B-2A, but the lower processing and video RAM may cause unexpected / undesirable performance issues.

A dedicated control input device such as a joystick, yoke, or HOTAS type control device with dedicated rudder controls or alternatively an Xbox type compatible controller is strongly recommended, though keyboard flight control inputs are supported.

DISCLAIMERS ABOUT THE MODEL AND THIS MANUAL

We've done our best to replicate the B-2A, within the limits of the information available to the public and within the limitations of Microsoft Flight Simulator 2020 (MSFS2020) and MSFS2024, however, we make no claims, representations, or warranties about the accuracy or validity of any modeled systems or capabilities, or of any statements made about the real-world aircraft. This is not a true-to-life simulator of the B-2A, and any statements or programming choices we've made concerning performance, operations and procedures as incorporated in the model and described herein shall be considered fictional works and may not reflect real world aircraft data. This is a "scale" digital model, or replica, of the B-2A, with information used in its creation taken only from published, publicly available sources, and with its only purpose to be as a source of entertainment, exclusively for customers of the MSFS2020/MSFS2024 game environment, and is therefore not appropriate or intended for the purpose of training or simulation of real-world B-2A flight operations or systems familiarization. Additionally, this manual should only be used as a guide to using the Top Mach Studios, LLC model of the B-2A for MSFS2020/MSFS2024 and is in no way adequate to serve as a manual or guide to the operation of the real-life B-2A and its systems, nor is it an adequate source of information for real-world operation and maintenance of any aircraft sub-systems and components. Additionally, neither

the B-2A model, nor this manual are endorsed by or supported by Northrop Grumman Corporation, or its subcontractors or affiliates in the development and production of the B-2A, nor by the United States Air Force or the Government of the United States of America.

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Top Mach Studios will do its best to keep the product updated and resolve critical bugs as soon as possible. Updates are typically deployed as new installers/packages and will be available through the reseller channel from which you purchased the model. Installation of updates will depend on which point of purchase you used and the nature of the updates and instructions will be provided with each such update.

Top Mach Studios provides direct customer support via its Discord server support channels, which can be found on Discord by searching Top Mach Studios, LLC

MSFS SIMULATION LIMITATIONS AND LIMITATIONS OF THIS MODEL

The B-2 is a tailless aircraft. In order to maintain coordinated flight, the aircraft makes use of brake/drag-rudders and multiple independent control surfaces that prevent side slip and uncoordinated flight during turns, matched with a highly sophisticated and highly automated digital flight control system that maintains control of the aircraft while providing the pilot a conventional control input system and a relatively easy to fly aircraft. MSFS does not provide developers a way to reproduce this type of highly sophisticated control system. As such, we've modeled the flight control system and aerodynamics, as much as we could, to replicate the B-2s flying characteristics using our custom fly-by-wire module and with careful attention to the aircraft aerodynamics configuration files. Modeling a true tailless aircraft is also not currently possible in MSFS. Reducing vertical tail and rudder surfaces to zero values results in uncontrollable spinning / oscillation behavior. A small vertical tail and rudder is therefore modeled. In reality the B-2 is possibly more unstable and less forgiving than the flight model we've developed when past the margins of the flight envelope. However, we don't know whether this is true or no and without verifiable information in this regard, we've instead created a model that's forgiving and generally easy to fly and for which our custom fly-by-wire system prevents entry into potentially dangerous areas of the flight envelope.

WEAPON DISPLAY ADD-ON

The Microsoft in-game Marketplace does not permit the sale of any product that displays or otherwise incorporates weapons or weapons systems for either PC or Xbox product sales. To provide our PC customers with additional realism, we've prepared a free add-on modification that allows for weapons to be displayed in the weapon bays. The default load-out includes 8 x AGM-158 JASSM cruise missiles, and 8 X GBU-31 2000 lb guided bombs. This can be found on our Discord channel, on our web site, and on flightsim.to.

MODEL FEATURES AND CAPABILITIES

Custom Programmed Simulated Fly-By-Wire control system for virtually carefree flight control

- Auto-trim / pitch control
- G-Limiter
- Roll rate limiter
- Bank Limiter
- Pitch Angle Limiter
- Yaw limiter and Yaw Damping
- Highly resistant to departure from controlled flight throughout the flight envelope.
- Precision, stable high altitude flight control to 50,000 feet and above.
- Realistic control response and “feel” throughout the flight envelope
- “Poor man’s” terrain following system utilizing radar altimeter-controlled altitude hold
- Penetration Mode with Differential Thrust Control

Highly detailed fully custom 3D cockpit modeling and avionics suite with:

- Highly detailed modeling and texturing of cockpit, rear cabin, crew entry area, all control panels, and interior detailing developed with careful attention to real world reference photographs.
- Detailed ACES II ejection seat models
- Fully Functional MDUs (using fully customized instrumentation suite) including critical aircraft information displays, FLIR simulation, crew alerting system alerts, customized tactical top down radar type display, fuel management, electrical system status, etc…
- Robust crew alerting system messages system alerting on a variety of information, caution, and warning messages and associated sound effects including b****ing Betty/Brian alerts with acknowledge / mute functions on glareshield master warning, caution, and fire alerts panel.
- FLIR (forward looking infra-red) simulation using synthetic vision display with instrument overlays for night and low visibility flying
- Highly functional and customized Flight Management Computer (DEP) module with many features and functions for flight planning, instrument flight, navigation, and communication.
- Center Information Display unit with backup instrumentation, detailed custom-programmed moving map display, large format Crew Alerting System alerts
- Interactive Checklist System in Center Information Display that mirrors the detailed checklists found in this document.
- Canopy interior reflections and rain effects
- All buttons, knobs, and switches in the cockpit are animated and many are functional or emulate system functionality and drive crew alerting system messages.

- Full suite of essential autopilot and navigation controls.
- Detailed overhead panel with APU controls, engine management controls, lighting systems, and other details modeled as closely as the information we've gathered will allow.
- Full cockpit lighting system including night lighting and individual lighting controls modeled as closely to the real aircraft as possible.
- Numerous additional customized screens and gauges with realistic USAF style CAS messages and automated alerting system.
- Aerial refueling (refueling while airborne) using aerial refueling port switch when aircraft is flown within certain flight parameters.
- Animated pilot figurines with optional display positions including "self" view and co-pilot (mission commander) displayable in different poses.
- Rear Cabin details and "Easter Eggs" to explore.
- Custom "Electronic Flight Bag" tablet to manage sim configuration, weapons display, and moving map display configurations.

Detailed Custom 3D Exterior Model

- Highly detailed 3D exterior model.
- 21 detailed liveries representing all current and former B-2As in service.
- Detailed custom texturing of all main surfaces, weapon bays, wheel bays, and other surface and interior areas of the aircraft body.
- High detail landing gear, crew boarding, and weapon bay areas
- Animation of all key flight control surfaces with complex customized animation controls representing the B-2's complex flight control system.
- Detailed and fully animated landing gear and extension / retraction sequence.
- Animated and detailed crew entry tunnel and boarding ladder area
- Weapon bays modeled with cockpit-controlled door animations
- Optional stores configuration available to simulate loading and placement of 8 x GBU-31 2000 lb bombs and 8 x AGM-158 JASSM missiles (Available for PC customers with optional free weapons display update download).
- Custom dynamic visual effects including wing vapor effects, APU start and run effects, engine heat and smoke plumes, and others.
- Cold and dark visual modeling features (pilots displayed or hidden, remove before flight tags, etc…) that are user controlled from the EFB.
- Detailed and realistically modeled ground equipment for optional display from the EFB including: scaffolds, air start carts, ground power unit, munitions cart, munitions loader, fire extinguisher, and more.
- Animated air to air refueling slipway (cockpit switch controlled) with multiple custom accurately placed lighting objects and effects
- Pilot figures in pilot and co-pilot positions (can be optionally displayed when aircraft cold / dark).

- Full exterior Lighting Systems include custom landing and taxi lighting, navigation lights, and beacons; all modeled after the actual aircraft, with correct lighting positions and transparencies.
- Multiple custom cameras in cockpit and exterior views

Sound Pack from Echo19 Audio

- Highly realistic sound suite for exterior sounds based on B-2 and F118/F110 engine sounds, tuned with exacting attention to real-world B-2 exterior sound-scape.
- 3D Fly-By sound experience for fly-overs and exterior fly-bys. Experience the thundering sound experience of four huge military turbofan engines.
- Highly immersive interior sounds replicating sounds for all major systems and sub-systems and customer interactions within the cockpit environment
- Aural voice alerts and tones for a wide variety of Crew Alerting System alerts
- Wind and drag induced ambient and reactive sound effects for landing gear, weapon bay doors, speed brakes, high speed wind blast, and others.

Engine and Performance Modeling based on General Electric, Northrop Grumman, USAF, and other analyst estimated specifications

- Accurate weight and fuel quantities.
- Advanced fuel system employed including APU fuel burn, fuel dump, and aerial refueling emulation.
- Engine model tuned to realistic specifications for realistic thrust/weight ratio and performance across the flight envelope.
- Modeled fuel consumption in line with real world specifications at low and high altitudes. Range profile matches real world stated range estimates.
- Accurate fuel consumption and maximum range at all altitudes (not based on the default game turbine model, but customized to improve accuracy of turbine fuel consumption and thrust).
- Drag and lift model tuned to stated and estimated specifications for the B-2A.
- Mach 0.96+ maximum speed at altitude
- 500 KIAS low altitude terrain following flight possible (within game limits).
- Service ceiling modeled to 50,000+ feet.

THE SIMULATED COCKPIT AND GENERAL SYSTEMS DISCUSSION

COCKPIT OVERVIEW DIAGRAM / THE “BIG PICTURE”

The diagram above shows the cockpit layout. The numbered items are the various consoles and panels that contain instruments and controls for the B-2.

1. EFB (Electronic Flight Bag)
2. Left Upper Console
3. Left Lower Console
4. Left Auxiliary Console
5. Left Main Instrument Panel and Glareshield
6. Overhead Control Panel
7. Center Instrument Panel
8. Right Main Instrument Panel
9. Center Pedestal Console
10. Right Auxiliary Console
11. Right Upper Console
12. Right Lower Console
13. Ejection Seats

What follows is a summary description of each of the subpanels where functional controls or instruments can be found. If a subpanel lacks a description, this means that there is not a control or instrument in that subpanel that has functional importance within this model. This doesn’t mean it can’t be interacted with or explored as we’ve animated all cockpit controls and incorporated realistic behaviors where appropriate.

ELECTRONIC FLIGHT BOOK (SIMULATION CONFIGURATION CONTROL)

1. EFB Power Switch
2. G3000 Display Switch
3. G3000 Map Range Switch

SIM CONFIGURATION CONTROL SCREEN

INOP (Reserved for future expansion)
Options: Display options for the aircraft model
Map Menu (Generally non-functional – reserved for future expansion)

The **EFB OPTIONS** tab has the following notes to help with understanding when and how items will display:
- **AIRCREW**: display pilot figurines with optional positions for mission commander. To display or hide the pilot's head click on the torso of the pilot. To raise or lower the pilot's visor click on the visor area when the head is displayed. To hid or display pilot gloves, click on the right hand of the Pilot figurine or left hand of the Mission Commander figurine.
- **MSN Cmdr Pos**: Changes the display location of the mission commander (co-pilot) figurine.
- **Active MDUS**: Allows for freeze of one or the other side of the main panel displays to improve display performance on lower end computing devices. Improvement is modest.
- **RBF Tags and Wheel Chocks** – Displays a variety of remove before flight flags and tags when engines are off and aircraft is not moving on the ground. Weapon door and boarding ladder RBF tags will display when they are open. Wheel chocks will display with engines running.
- **Weapons** With the weapon mod installed (PC only) a weapon display option will appear in the EFB; weapon loading (all or nothing at this time) will load all sixteen stations with a mix of GBU-31s and AGM 158 cruise missiles and the weapon carts and munitions loader will display weapons.
- **Ground Equipment**: When external power is available (on an apron parking spot that supports external power – game limitation) and turned on in the cockpit, the ground power and air start carts will display in startup position and sound effects will play.

- Maintenance scaffolds will only display with engines are off
- Ground equipment will automatically shut off if the aircraft begins to move.
- In the Whiteman AFB scenery, a custom ground tug model will display if pushback is requested. The behavior is a little goofy when approaching the aircraft, but that's a game limitation apparently.

G3000 INTERFACE

The G3000 interface and map functions just as it will for other aircraft in the game and the aircraft autopilot and CDU planning pages are interoperable (with a handful of exceptions). We've included the G3000 for familiarity and for advanced flight planning and navigation that the custom DEP doesn't yet support at this time.

LEFT UPPER CONSOLE

ELECTRICAL SYSTEM SUBPANEL

Flight Control Battery Switch – Secondary battery
Utility Battery Switch – Used to enable DC power for APU startup and External Power startup
DC BTR – an additional battery switch (doesn't provide functionality to the model, but is animated)

External Power Button – When ground power is available (at designated MSFS apron parking spots) turn on Util Batt Switch and then press this button to get AC power to the aircraft.
Generator 1-4 Control switches: Electrical generators powered by engines 1-4.

COMMUNICATIONS CONTROL SUBPANEL

Master Comms Volume: Controls ATC volume.

LEFT CONSOLE

THROTTLE: Controls thrust to engines 1-4. Each lever is independently controllable (speed brake control switch animation not modeled at this time)

ALTN THROT Subpanel: Controls fine-tuned adjustments for engines 1-4. Push numerical button (will light when pressed) and then use INCR/DECR switches to increase or decrease thrust in small increments for a given engine.

LIGHTS Subpanel: Lighting controls for Pilot's side of aircraft

FLOOD CSL - Console Flood: Controls flood lighting for left console and left upper console
FLOOD LAPLT - Lap Light Flood: Controls flood lighting for the left main instrument console lighting fixture underneath the pilot's glareshield
PNL CSL - Console Panel Backlight: Left console and left upper console backlight brightness
PNL INST – Left main instrument panel backlight brightness control

ENGINE AUXILIARY INTAKE DOOR SWITCH: Controls the four engine auxiliary intake doors.

LEFT AUXILIARY CONSOLE

LANDING GEAR SUBPANEL

- Landing Gear Handle: Raise and lower gear. Extension locked out above 260 KIAS.
- Landing Gear Status: [NOSE, LEFT, RIGHT] Green when down and locked, Red when in transit or gear unsafe, Off when Gear retracted.
- Down Lock Override Switch: When on ground, this can be used to release the landing gear handle.

V-V (Vertical Velocity Indicator) Gauge: Displays aircraft climb or sink rate

FORWARD VISIBILITY LIGHTING AND BRAKE CONROLS SUBPANEL

- PKG BRK: Parking brake button, illuminated when set
- TAXI LT: Taxi lights. Three-way switch – off, dim (nose gear light fixture only only), bright (nose gear bright and main gear outboard light fixtures).
- LDG LT: Landing lights (inboard main gear light fixtures)

Anti-Skid: CAS message displays if not On

LEFT MAIN INSTRUMENT PANEL

1. **CENTER PRIMARY MULTI-PURPOSE DISPLAY UNIT** (X 1): A detailed description of PMDU and MDU functions can be found below

- PMDU Input Buttons (Arrow): Press buttons to select adjacent display items
- PMDU1 Brightness Knob (Arrow): Controls PMDU display brightness AND backup instrument brightness as well.

2 – 4. **SECONDARY MULTI-PURPOSE DISPLAY UNIT SCREENS** (X 3): A detailed description of PMDU and SMDU functions can be found below

- SMDU Input Buttons (Arrow): Press buttons to select adjacent display items.
- SMDU Brightness Knob (Arrow): Controls SMDU display brightness

5. **FLT DATA SUBPANEL**

- BARO command button: Updates baro pressure for aircraft altimeters
- CMD ALT command button: Sets the commanded autopilot altitude (can also be done from DEP RNAV autopilot menu)
- RALT SET command button: Toggles radar altitude mode for the autopilot (“poor man’s” terrain following system)

- A/S SET command button: Adjusts target Airspeed or Mach number for the Autothrottle system (can also be adjusted from the DEP RNAV Speed Menu)
- CRS SELECT knob: Selects autopilot heading bug (does not affect course bug)
- HDG SEL knob: Selects autopilot heading bug

Entries from FLT DATA subpanel number pad will display in the lower left corner of the Primary Flight Display page/screen. Pushing the respective FLT DATA subpanel command button will commit the entry made to the aircraft systems.

6. **BACKUP ARTIFICIAL HORIZON (ADI)**

7. **BACKUP AIRSPEED AND MACH INDICATOR**

8. **BACKUP ALTIMETER**

GLARESHIELD

1. **Master Warning Annunciator**: Illuminates when a warning CAS is triggered. Push button to silence aural alerting (when applicable)
2. **Master Caution Annunciator**: Illuminates when a caution CAS is triggered. Push button to silence aural alerting
3. **Master Fire Warning Annunciator**: Illuminates when fire is detected onboard the aircraft.
4. **AOA Indexer**: Illuminates when gear is extended and aircraft airborne. Yellow up Arrow = Angle of attack too low / below target. Green circle = On target angle of attack. Red Down Arrow = Angle of attack too high / above target.

5. **PEN Mode** Button: Enables penetration mode (see description below).
6. **APP Mode** Button: Enables autopilot approach mode when localizer or approach facility is active and autopilot is active.
7. **Whisky Compass**: Displays magnetic heading
8. **Fire warning and Suppression Panel**: Eng 1 – 4 fire warning buttons will illuminate if game simulated engine fire is active for a given engine.

OVERHEAD CONTROL PANEL

1. **L APU and R APU START / STOP**: Left and Right APU starter and stop Buttons
2. **ENG START & AUTO**: Engine 1-4 Starter Control Buttons & Engine Master AutoStart Control Button (black button next to the ENG START buttons)
3. **MOTOR**: Engine Motoring 1-4 Control Buttons
4. **STOP (ENG STOP)** Engine Stop Buttons
5. **OVERHEAD FLOOD LT**: Overhead Panel Floodlight Knob
6. **PEDESTAL**: Center Pedestal Backlight Control Knob
7. **CTR INST LIGHT**: Rear Cabin Flood Lighting Control Knob
8. **OVRHD**: Overhead Panel Backlight Brightness Control Knob
9. **CONSOLE FLOOD**: Center panel flood light (to be deprecated)
10. **EMERG**: Activates all annunciator lights in cockpit.
11. **A/R SLIPW & A/R FLOOD**: Aerial Refueling Slipway and Flood lighting Control Knobs.

12-14. **LIGHTS**: Aircraft Position and Anti-Collision lighting controls

15 & 16. **ENTRY HATCH OPEN & CLOSE**: Open/close outer hatch and ladder.

CENTER INSTRUMENT PANEL

CID (CENTER INFORMATION DISPLAY SCREEN) – For a more detailed description of CID screen displays see below

CID POWER: Turns CID display On / Off
BRT: Knob controls brightness of the CID Screen, the FUEL SYSTEM SUBPANEL, and also for the EFB tablet screen
BARO: Knob controls baro pressure setting for all aircraft altimeters

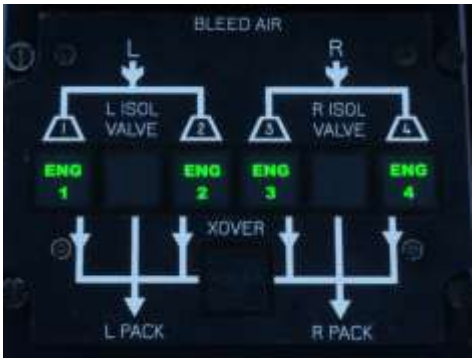
FUEL SYSTEM SUBPANEL

Aerial Refuel: See description below
Fuel Dump Switch: Lift red safety cover and switch to “Open” to dump fuel. See description below.
Fuel Tanks QTY and Status Displays: Shows fuel per tanks and totals
Center of Gravity Gauge: Shows aircraft center of gravity. Changes with fuel and ordnance loadings.

CENTER PEDESTAL CONSOLE

DEP: A description of DEP screens and functions is found below.

BLEED AIR SUBPANEL



Eng 1-4 Bleed Air Select Buttons: Are needed for engine starts and for ECS functions (sound effects, for example) to work.
R and L ISOL VALVE and XOVER VALVE: Buttons illuminate as well, but are not functional at this time.

OXY SUBPANEL: Switch positions will trigger CAS alerts if incorrectly configured.

Oxygen System Control Switch
Oxygen Mode Switch L, R

ECS SUBPANEL

Cabin Pack L, R: AirCon for cabin – triggers sounds and CAS messages depending on configuration.
Equip Pack L, R: AirCon / cooling for avionics / equipment – triggers sounds and CAS messages depending on configuration.
Cabin Pressure Dump: Dumps cabin pressure to ambient exterior pressure
Cabin Pressure Vent: Dumps cabin pressure to ambient exterior pressure (venting not modeled, just dump function)
Pitot Static Heat: Prevents air data port sensor icing

ANTI-ICE SUBPANEL

Windshield Anti-Ice L, R
Eng Anti-Ice

FCS MAINT: Triggers flight control surface auto-test (watch outside aircraft when active)

CLOCK: Shows local time

CABIN PRESSURE GAUGE: Shows cabin pressure. Cabin normal pressurization to 8000 ft. cabin altitude

EJECTION SEAT

Arm / Disarm Control: Arms or disarms the ejection seat firing system. Typically not armed until at the active runway ready for takeoff. Definitely not armed in the hangar.

REAR CABIN AREA OVERVIEW

14. **Toilet**
15. **Microwave**
16. **Interior Entry Pressure Door**

MULTI-PURPOSE DISPLAY UNITS AND FEATURES

The B-2 has 8 full color multi-purpose display unit screens (MDUs), a Center Information Display, and DEP screens, for a total of 11 different digital display screens, not including the digital display backup gauges. It's a lot of information across quite a few screens! Below is a description of the various MDU screens we've modeled. In our presentation of the MDU data labels in green next to a button indicate a functional (or future functional screen). White indicates inop / no functionality planned in V1 release or beyond. These other non-functional pages have no known publicly available reference images so we are leaving them inop at this time.

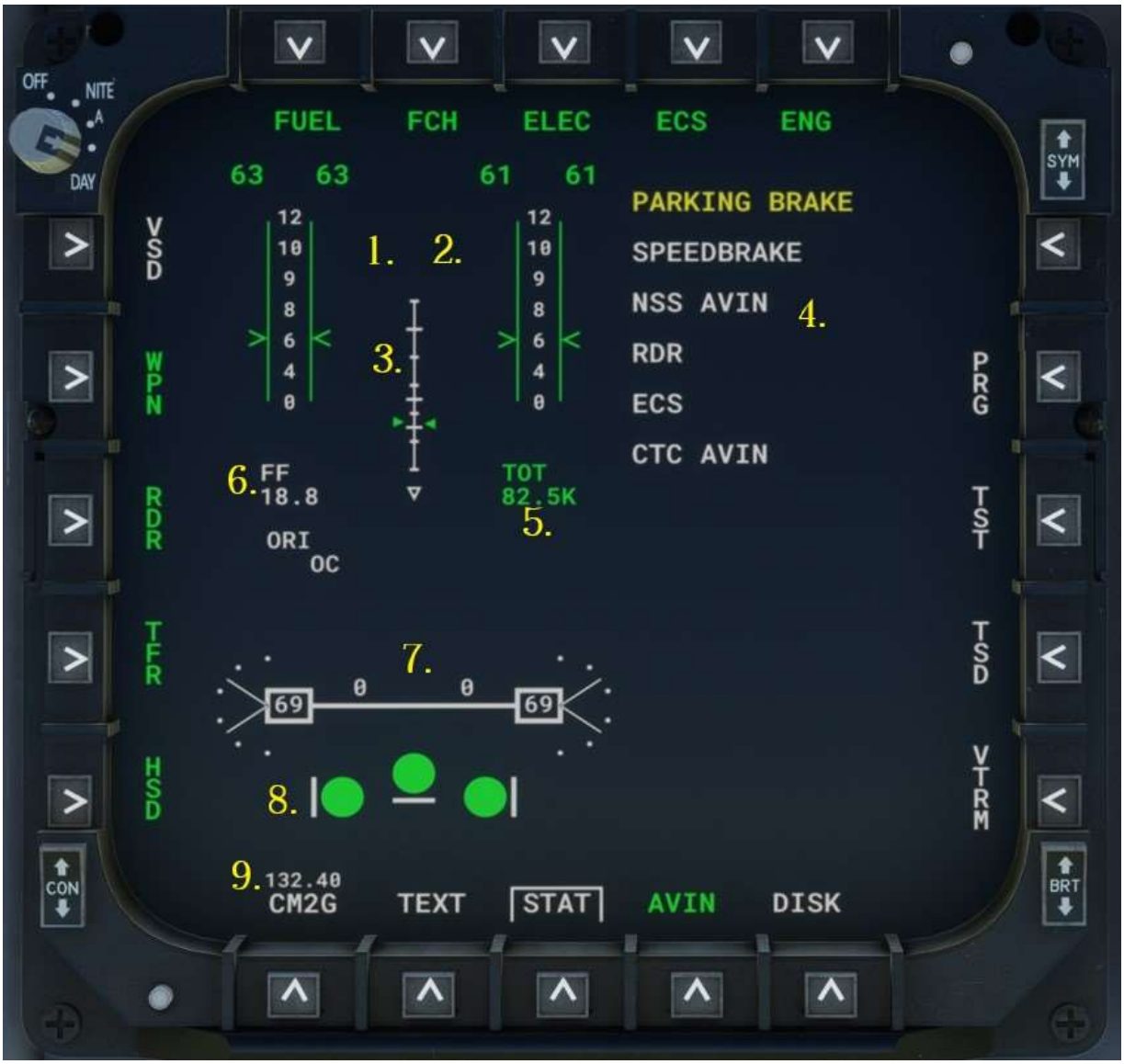
PRIMARY (CENTER) MULTI-PURPOSE DISPLAY UNIT

While it's most typical for the Primary Flight Display to be shown on the upper middle MDU, it's possible to display this on any (or none) of the MDUs. All MDUs are independent and can display any of the MDU pages, as desired.

NAV: (PRIMARY FLIGHT DISPLAY)

1. Autopilot status
2. Mach number
3. Heading Tape
4. Autopilot Heading Select
5. Heading and Bearing Indicator
6. Ground Speed KIAS
7. Airspeed KIAS
8. Autothrottle Target Speed
9. G Meter
10. FLT DATA Panel Entry (Pending)
11. Radar Altimeter (to 5000' AGL)
12. Slip Indicator
13. Current Nav 1 Radio Frequency
14. Angle of Attack Indicator, Degrees
15. Autopilot Target Altitude
16. Altitude ('MSL)
17. Glideslope (When localizer tuned)
18. Course Deviation (When localizer)
19. Bank Angle Indicator
20. Pitch Ladder
21. Climb-Dive Marker or Waterline
22. Flight Path Marker

STAT: AIRCRAFT SUMMARY STATUS PAGE



The STAT page displays summary information about engine output, control systems and other information.

1. Engines 1,2 N1 percentage
2. Engines 3,4 N1 percentage
3. Engine thrust and thrust delta information
4. Crew Alerting System messages
5. Total fuel on board
6. Current total fuel consumption (pounds per hour)
7. Control position indicator showing position of drag rudders diagrammatically and in degrees total deflection between upper and lower control surfaces.

8. Landing gear status (green = down and locked, red = in transit, no data = retracted)
9.Current Comm1 frequency

ENG: ENGINE OPERATING DATA PAGE

This screen shows a detailed list of engine operating parameters

T1 = Temperature at the inlet face (exterior ambient temperature)
N1 = Turbine N1 % RPM
N2 = Turbine N2 % RPM
TBT = Turbine Blade Temperature; measure of engine operating temperature
F F = Fuel Flow to engine in pounds per hour
PLA = Thrust lever position in percentage (0 – 100%)
O T = Oil Temperature in Celcius
O P = Oil Pressure in PSI
O L = % of Engine oil capacity (100% unless sim oil leak is triggered)
VIB = Engine Vibration (static / no function)
IGV = Duplicate of Oil Temperature
CDP = Duplicate of Oil Pressure
AI / … = Unknown – Static Data
EMSP (1-4) = Engine management system. FAIL when engines off, OK when running.
APU L and APU R = Percentage of APU turbine max RPM (0-100%)

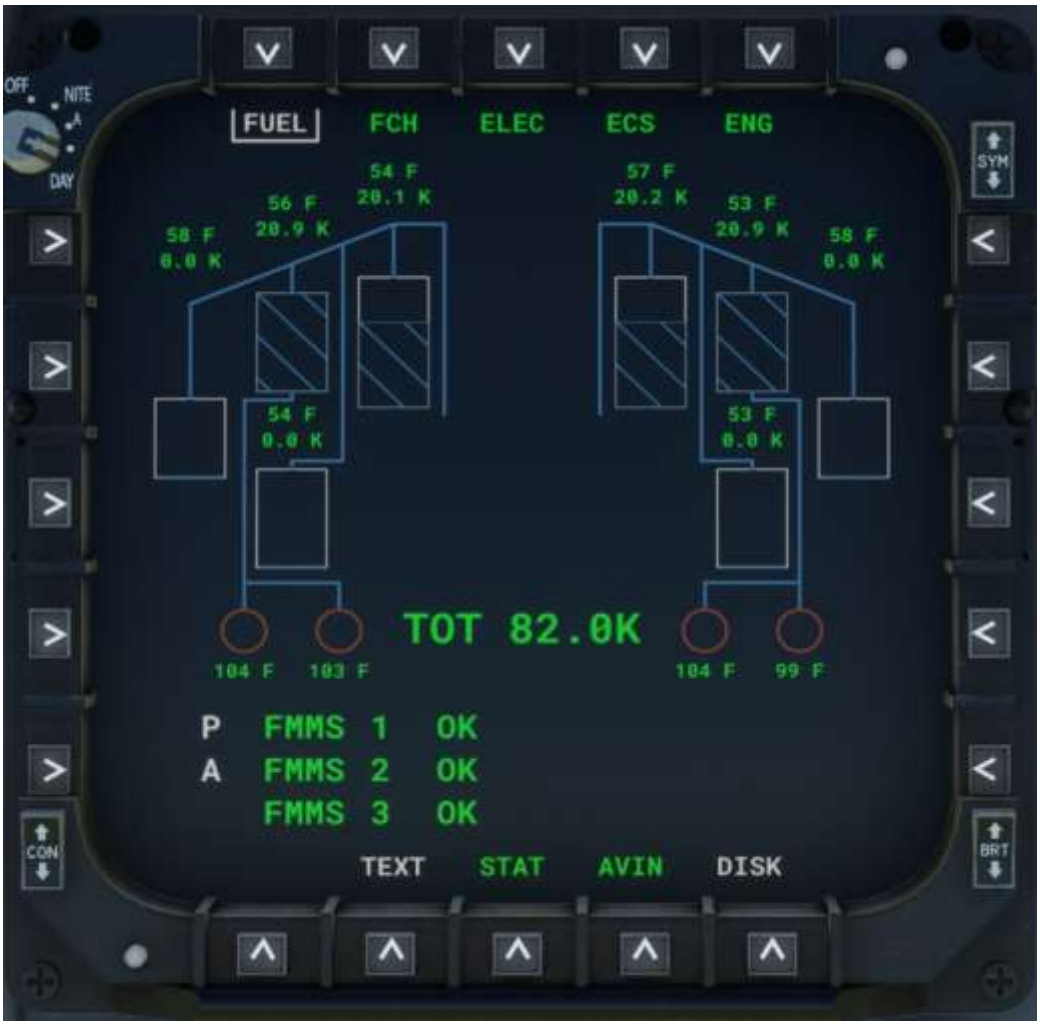
TFR: FORWARD LOOKING INFRARED SIMULATION

We don't have data concerning what is normally displayed in this page (Terrain Following Radar), so we've substituted a FLIR type simulation instead. Read below for our description of the autopilot driven "poor man's terrain following radar."

1. Airspeed Indicator KIAS
2. Heading Tape
3. Pitch Ladder
4. Climb / dive marker, flight path marker, and speed brake indicators
5. Course Deviation Indicator
6. Slip and Bank Indicator
7. Altitude (MSL)
8. Fuel

NOTE: The TFR / FLIR page is ONLY available to display in the pilot's left MDU due to sim limitations.

FUEL: FUEL SYSTEM INFORMATION PAGE

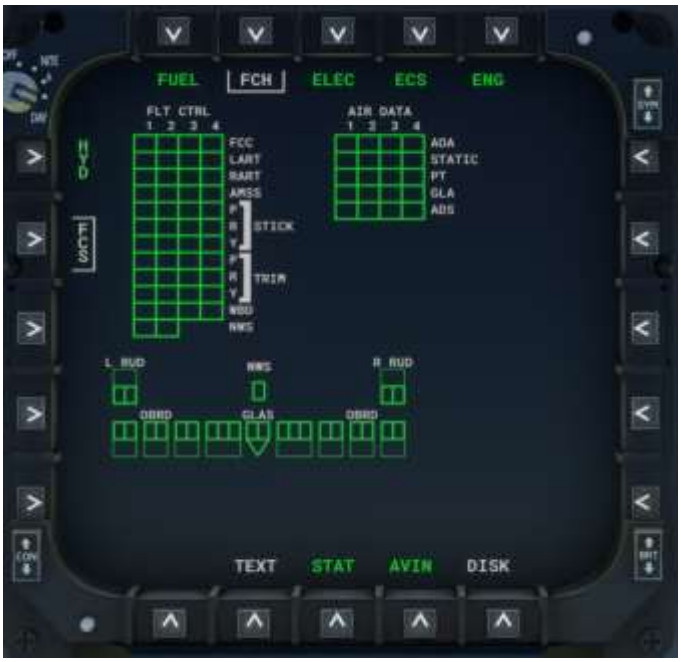


The fuel system display page has the following functional components:
Visual indicators for fuel quantity (blue hash marks on the rectangles)
Fuel system diagram
Fuel quantity in thousands of pounds within each of the eight fuel tanks
Total fuel quantity on board.
The remaining data is static and based on representative values.

FCH – HYD and FCS:

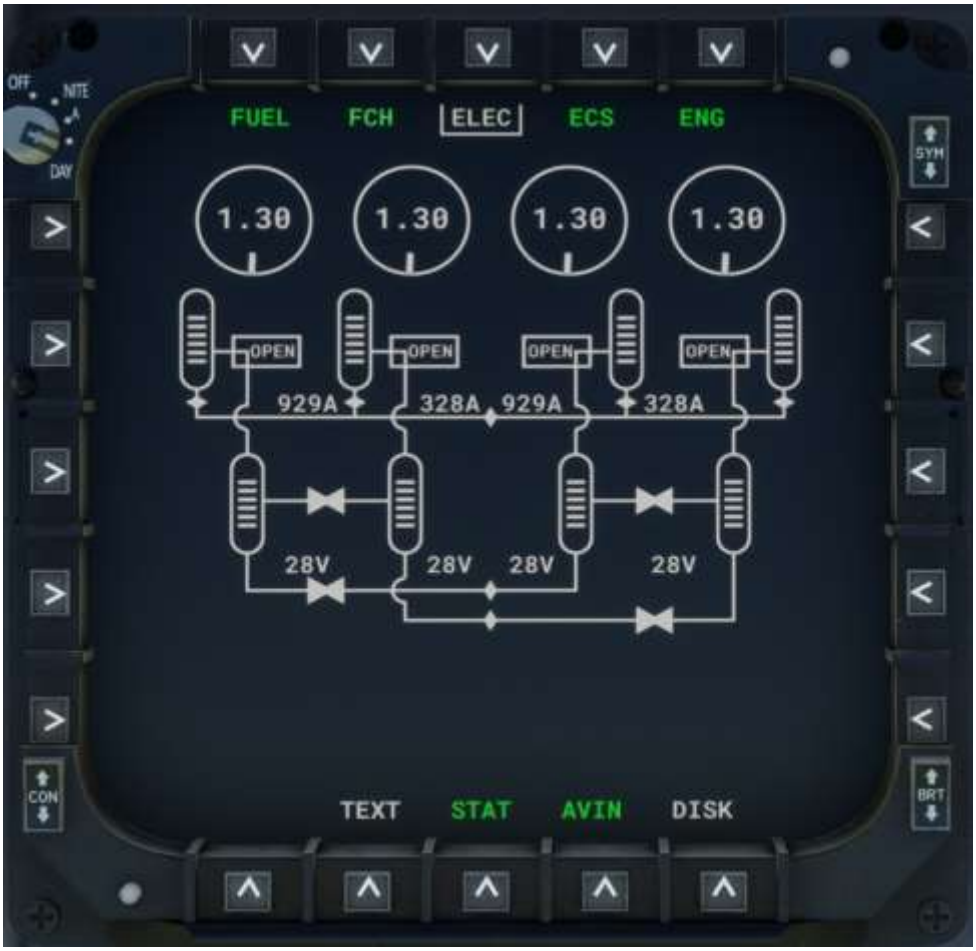
1. Engine / Hydraulic Line Number
2. Hydraulic Fluid Temperature F
3. Hydraulic Fluid Level
4. Hydraulic Fluid Temperature

FCS: FLIGHT CONTROL SYSTEM STATUS PAGE



This is static as this page shows the status (functional, degraded, failed) for the various flight control system control channels and air data sensors. We don't have a reasonable way to model display degraded state or failures of FCS control channels at this time.

ELEC: AIRCRAFT'S ELECTRICAL SYSTEM DIAGRAM AND STATUS



- Top 4 circles: Load on each generator

- Middle line: Load on each bus

- Bottom line: bus voltage (2 of these should read 28 and 2 should read 115, but can't due to a bug in the sim – read on)

- The open boxes would normally show where the bus tie breaker is open or closed for each generator, but it's inoperative at present for the reason noted below.

NOTE: There is a bug in the sim's electrical bus simulation that prevents us from displaying AC and DC bus voltages simultaneously, so the display can't be 100% accurate to the IRL aircraft.

ECS: ENVIRONMENTAL CONTROL SYSTEM STATUS

This page is static and is just for display purposes. Future functionality may be added at a later date.

RDR: Blank – placeholder for future update

WPN: PAGE IS INOP AT THIS TIME

HSD: HORIZONTAL SITUATION DISPLAY, AKA, HSI DISPLAY

This page shows navigation information related to aircraft position. The following is a detailed list of currently implemented features. Anything not listed is INOP and may be changed/included in a future update. Selected Autopilot Heading

1. Current Autopilot Heading Select
2. North Up/Track Up Display
3. Current Military Time Zone and Time
4. Commanded Course (VOR/TACAN course or AP Heading if HDG Lock active)
5. Ground Speed
6. ASL Altitude
7. Current Heading

8. Selected Range
9. Bearing/Range to next GPS waypoint
10. Course Arrow (Functional for GPS/VOR/ILS/TCN and AP Heading. If a localizer has been acquired, it will take priority over all other course information displayed.
11. Course Deviation Indicator – Shows deviation from desired GPS track or selected repeater
12. Opens Nav Page – Primary Flight Display
13. Opens Data Page – Displays detailed aircraft position and speed data
14. Shows Estimated Time of Arrival for Destination
15. Bearing to navigation signal repeater facility (VOR/TACAN/ETC…)
16. Range to navigation signal repeater / DME data

DATA: SUMMARY AIRCRAFT POSITION AND SPEED DATA

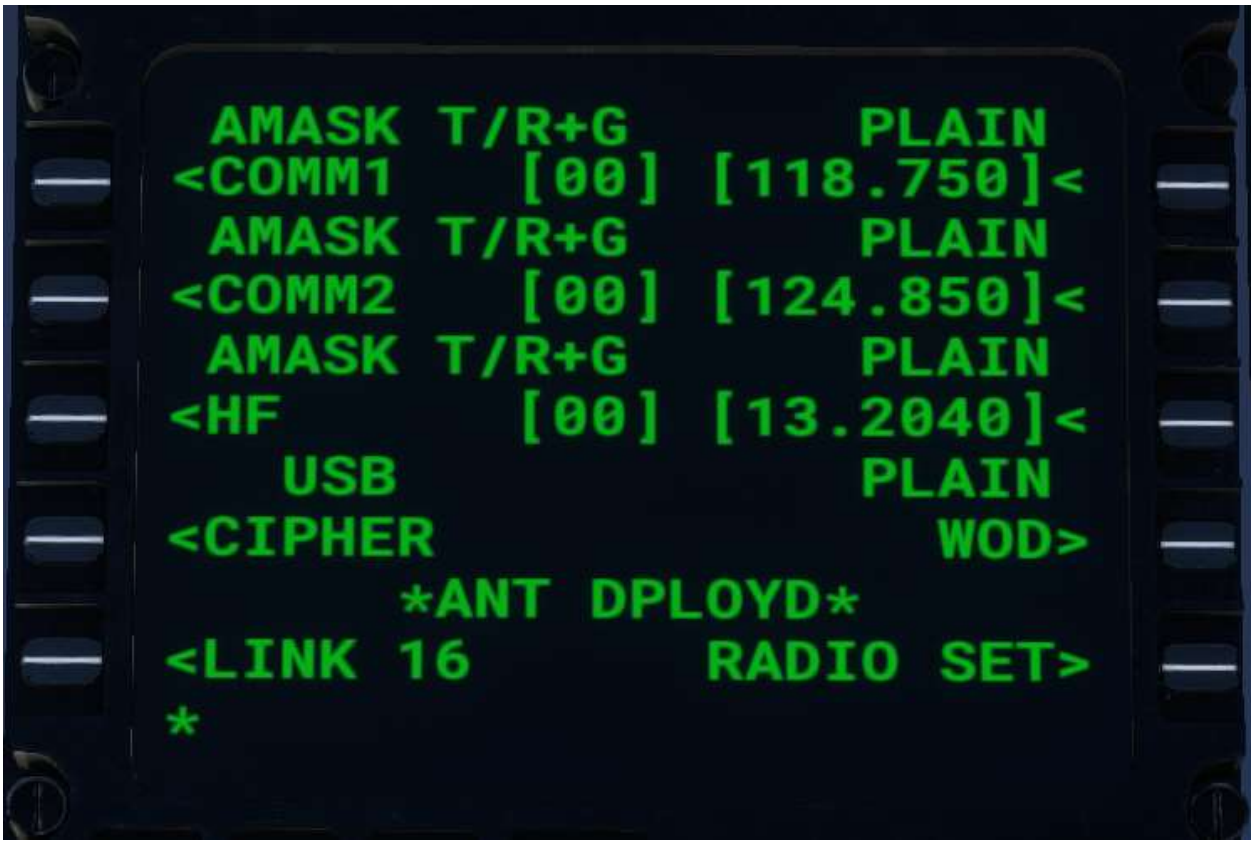
DEP: DATA ENTRY PROCESSOR (DEP)

The DEP is a combination of a keyboard and a high-performance Liquid-Crystal Display (LCD) that allows pilots to input and modify flight plans. It ties into the aircraft's Flight Management Computer (FMC).

The DEP, or CDU, for short, is the pilot's primary system for entering and modifying navigation data for the B-2. It also provides control for the weapons bay doors. Below is a list of pages and what you will see on each page.

1. Opens COMM/INDEX Page
2. Opens Navigation Page
3. Opens IFF Page
4. INOP (Currently opens RNAV Page)
5. Opens RNAV(Autopilot) Page
6. Opens Flight Plan Page
7. Opens Weapon Page
8. Opens COMM/INDEX Page
9. INOP
10. Increments Page or Selection
11. Decrements Page or Selection
12. Adds a space character to input

COMMS: RADIO COMMUNICATIONS PAGE



This page is used to enter your voice communications frequencies for the aircraft. Only the COMM1 and COMM2 lines are active on this page. All other information is for display only and is inoperable.

To enter the frequency:

1. Type the frequency into the number pad in the format XXX.XXX. You will see a printout of what is typed on the bottom line of the CDU display.
2. Press the index button to the right of the COMM channel you want to update. The carets pointed inward indicate that those lines take an input value. You will see the frequency update for the channel if the frequency you entered is valid.

NAV: NAVIGATION RADIO INTERFACE PAGE

This page is used to set departure and arrival airports, select departure and arrival procedures, as well as updating your TACAN channel.

To set your origin or destination airport, type the ICAO designator for your desired airport or waypoint, then press the corresponding index button for either ORIGIN or DEST on the CDU.

To update your TACAN channel, type the channel into the CDU (e.g. 33X, 12Y, etc) and press the right index button for the TCN line.

The departure and arrival pages will be described below.

NAV DEPARTURES PAGE:

Once you have an ORIGIN set in the NAV page, you have access to the Departures page.

To select a departure procedure, press the button next to the desired departure, then press the button for your desired airport. Once both of those are pressed, you will have the option to activate that departure.

If you wish to cancel what you have selected, just perform those steps in the reverse order. Press the Deactivate button, press the button for the selected airport, then press the button for the selected departure. You should then be able to reselect an updated departure.

NAV ARRIVALS PAGE:

Once you have a DEST set in the NAV page, you have access to the Arrivals page.

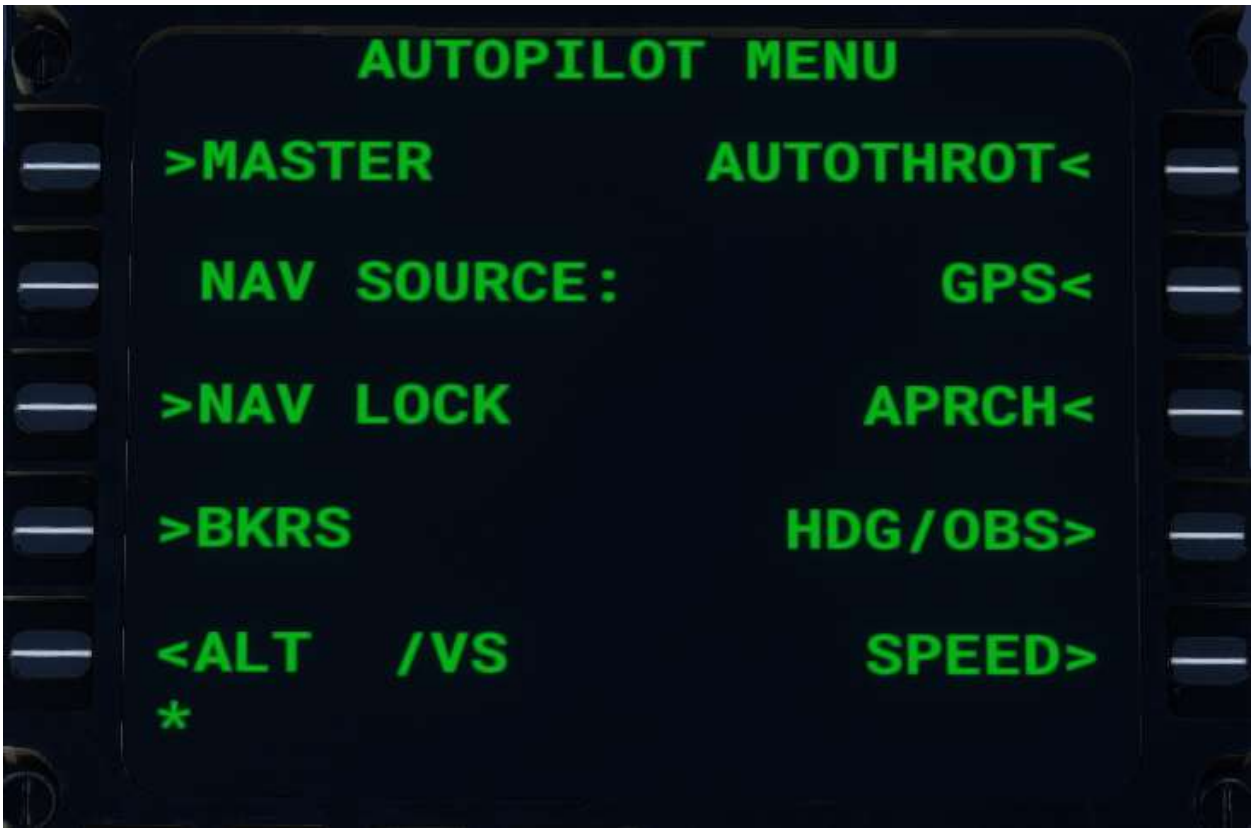
To select an arrival procedure, press the button next to the desired arrival, then press the button for your desired airport. If there is an enroute transition available for your selection, it will display below. Select the transition if available. Once everything has been selected, press the activate button to activate the procedure.

If you wish to cancel what you have selected, just perform those steps in the reverse order. Press the Deactivate button, press the button for the selected transition (if selected), then press the button for the selected airport. Finally select the button for the selected arrival. You should then be able to reselect an updated arrival.

IFF: TRANSPONDER PAGE

This page is used to set up your transponder. If a carat is pointed outward toward a button it is used for controlling the mode of the transponder. If it is pointed inward away from the button, it accepts the transponder code as an input. To set your desired transponder code, bring the transponder up to at least the STBY power level, then type in your code and hit the button next to the inward facing caret on the bottom left of the screen.

RNAV: AUTOPILOT MENU PAGE



This page sets various autopilot functions. If a carat is pointed inwards, it cycles a function (MASTER, AUTOTHROT, Selected Nav Source, NAV LOCK, APRCH, BKRS). If a carat points outward, the item has a submenu (HDG/OBS, ALT/VS, SPEED).

MASTER – Engages or Disengages Autopilot Master

AUTOTHROT – Enables or disables autothrottle

NAV SOURCE – Cycles the autopilots nav source between GPS, TCN, NAV1, or NAV2

NAV LOCK – Enables or disables NAV hold

APRCH – Enables or disables approach hold

BKRS – Enables or disables backcourse mode

AUTOPILOT SUBMENUS

HDG/OBS – Opens the menu for setting your desired autopilot heading or OBS course (including TACAN). Also includes the ability to activate heading hold mode.

To return to the Autopilot menu, press the RNAV button

ALT/VS – Opens the menu for setting your desired altitude and vertical speed, along with controlling ALT lock and VS lock

To return to the Autopilot menu, press the RNAV button

SPEED – Opens a menu for entering your desired autopilot airspeed. You can also switch between IAS/MACH from this menu.

To return to the Autopilot menu, press the RNAV button

FPLN: FLIGHT PLANNING PAGE

This page is used for creating or modifying your flight plan. To insert a waypoint, type in the ICAO for the waypoint and press the button next to the waypoint you want the new waypoint to be ahead of. For example, to add a waypoint between

MANSEQ and EED shown above, enter your new ICAO, then press the button next to MANSEQ.

To add a waypoint to the bottom of the flight plan, enter the ICAO, then press the button next to "-----". Keep in mind this will not function properly if a Destination airport is already selected from the Nav page.

To remove waypoints from the flight plan, first ensure no arrival or departure procedures are active (NAV button -> DEP/ARR menus). Press the minus (-) on the keypad, then select the button to the left of the waypoint you want to delete.

WPN: WEAPON BAY CONTROL PAGE

This page is used for opening and closing the weapon bay doors

CID (CENTER INFORMATION DISPLAY SCREEN)

SFID: BACKUP FLIGHT DATA

SFID page (supplemental flight information display) includes duplicates of primary flight, engine, and status page elements for quick or backup reference.

1. Mach Meter
2. Airspeed KIAS
3. Heading Tape
4. Primary Flight ADI (see Primary Flight Display Description Above)
5. Altitude (MSL)
6. Wind Vector
7. Vertical Velocity Indicator
8. Altimeter Baro Setting
9. Comm 1 Frequency
10. Key Engine Data

INFO: CREW ALERTING SYSTEM MESSAGES

Displays all currently active Crew Alerting System messages. For a list of CAS messages and logic please see the CAS Messages addendum below.

CTSD

Blank – No Function at Present

IFR: MOVING MAP

A typical moving map display with range, absolute elevation color reference, facilities display, and flight plan displays.

NOTES: Map MENU object pops up a menu, but that menu presently has no function in the IFR (but does have some effects on the HSD). This will be deprecated in a future update. Note that Flight plans entered from the G3000 interface will populate in this IFR map, and from CDU vice versa, EXCEPT for Direct to and custom waypoint entries from G3000, which will not display on the IFR map screen at this time. There may be other functionality that's not duplicated from G3000 derived plans to the IFR map screen.

TEXT: INTERACTIVE CHECKLIST PAGE

1. Items with a right facing arrow bring up sub-menu checklists.
2. As items are checked off in sub-menus, top level menus will show partially filled in when in progress and check marks upon checklist completion.
3. Up Arrow scrolls down a list and down arrow scrolls up.
4. A text version of this checklist (with some corrections as of this publication date) is appended below in this user manual.

AIRCRAFT HANDLING AND PERFORMANCE NOTES, LIMITS, AND GAME SETTINGS

AIRCRAFT ENGINE STARTUP OPTIONS

The B-2 engines are started similarly to commercial airliners. There are a handful of different ways to start up the engines. Below are instructions for each startup procedure.

The quick and easy way is to press the AUTO button found on the overhead panel next to the 4 engine start buttons. This is not a true to life startup procedure, but is designed to help with getting going quickly or for customers new to complex aircraft systems like this. But first, you'll need DC power (battery) to kick off the process – flip the UTIL BATT switch into the on position and then you're ready to go. The AUTO button is configured to complete the engine start flow by turning on APUs (which will allow starters to operate and powers up the aircraft avionics), opening the left and right bleed air isolation valves, engaging all 4 motor buttons (which spool the N2 RPM to minimum speed for engine ignition), and then activates the engine ignition switches (start buttons). You'll still need to turn off the APUs once engines have started, turn on the 4 engine electrical generators (if not already in the on position) open the 4 engine bleed air valves and close the ISOL valves and complete the other startup and pre-taxi checks (see checklists below).

The second option is the standard startup procedure. This process flow is as described above, except you'll do the button pushing. Set UTIL BATT on, make sure engine generator switches (4) are in the on position, and then push the left and right APU start buttons to spool up the APUs to generate AC power and power up the avionics. Once APUs are spooled up, open the left and right bleed air isolation valves found on the left side of the center pedestal, then push the Motor buttons on the overhead panel for the engines you are starting (4 total). Wait until N2 reaches 20% for the engines you are starting and push the respective engine start buttons. When N1% values have stabilized, turn off the APUs and continue your startup and pre-taxi checks (see checklists below).

The third option is for startup with external power. External power is only available at designated parking spots at airports that provide external power. When external power is available, the B-2 can be started without APUs (and the ground power unit and air start carts will be displayed in startup positions as well). The start procedure is the same as for standard start procedure described above *except* that after the UTIL BATT switch is turned on, you then press the EXT PWR button so that it's on and flowing AC power and you can then begin the startup procedure as above, but without turning on the APUs.

SPEED LIMITS

Though we don't have precise figures for the B-2A's speed limits, based on various sources we estimate the following. Mmo (maximum Mach number) is 0.96. A caution CAS message will display at 0.94M. An Overspeed CAS message and voice alert will play at 0.97M. VNe (Never exceed speed) is 525 KIAS. A CAS caution message will display at 500 KIAS. An Overspeed CAS Warning message and Overspeed Voice alert will play at 525 KIAS.

G-LIMITER

Sources indicate that the standard G limit is 2.5G. A CAS caution message and voice alert will play at 2.5G. At 3.0G a CAS warning message and repeating voice alert will play until load factor is decreased. The flight control system will limit G to no more than 3.33G. The aircraft is limited to -1.33 G by the flight control system.

BANK LIMITER

We've included a custom bank limiter that progressively decreases the available bank angle as the aircraft approaches stall speeds and prevents the aircraft from being rolled or banked into a fully inverted attitude at any speed. This prevents the aircraft from being flown into out of control or dangerous flight attitudes. We were informed that the real-world B-2 incorporates a bank limiting system into the FCS control logic that's dependent on the flight control computers indicating the maximum safe bank angle available for a given configuration, speed, attitude, etc, so this limit changes conditionally. Ours is much simpler in concept, but will help keep the aircraft out of trouble.

PITCH LIMITER

We've included a custom pitch limiter that prevents up or down pitch angles of greater than 45 degrees. The pitch limiter is set to +/-40 degrees and with continuous application of stick force can be pushed to +/-45 degrees.

AOA LIMITER (STICK PUSHER)

We've modeled a basic stick pusher model that will push the aircraft nose down if the Angle of Attack exceeds 13 degrees. This will happen with active stick deflection – momentarily overriding pilot pitch commands that would push the aircraft into a stall and also with passive increases in angle of attack as may happen in a power off climb without pilot control input.

FLAPS SYSTEM

The B-2 doesn't have conventional flaps. However, the beaver tail (center body control surface) and elevons will act as lift devices during takeoffs and approaches with landing gear down. The surfaces will deflect as speed increases during takeoff and as angle of attack increases and will provide enough additional lift to allow for takeoffs and landings at target speeds and angles of attack.

RADAR ALTIMETER AUTOPILOT ALTITUDE MODE (POOR MAN'S TFR SYSTEM)

At present there is not a way for us to model look ahead terrain following and feed this information into the autopilot system in MSFS. However, we are able to feed the radar altimeter data to the autopilot pitch hold system and this enables the aircraft to maintain a given altitude above the ground level by climbing and diving as terrain elevation changes. So, if you set the radar altimeter autopilot altitude hold system on and set the target altitude at 1000 feet above ground level, the aircraft will follow the contour of the earth, climbing and descending to maintain 1000 feet AGL. The modeled B-2 autopilot and pitch hold system is not highly responsive as a consequence of fairly severe limitations of what can be done with the native autopilot system. Additionally, because this system doesn't look ahead, but rather looks straight down beneath the aircraft, this greatly reduces the utility of this feature over highly varied terrain (steep mountains and valleys). This means the radar altimeter altitude hold will not respond quickly to changes in ground level and won't be aware of large increases in elevation over short distances ahead of you (like a high cliff face). While this makes for a smoother ride over flat or gently rolling terrain, this system will not work well over steep mountains and valleys or any highly variable terrain elevations. If you intend to use the system over very steep, highly mountainous terrain, you would be advised to set the system to a radar altitude hold of at least 3,000 feet AGL and maintain lower airspeeds to allow for the autopilot system to respond and correct accordingly (250 to 280 knots is a good target speed for this purpose). Flying in very high mountains with big elevation changes is dangerous with this system. You'll want to keep your eyes out the window or on the FLIR simulation to ensure the autopilot doesn't fly you into something. Over flat or gently rolling terrain, we've successfully used the system at speeds of 350 knots or greater with radar altitudes of 400 feet. Anything lower than this and you risk collision with terrain. Try it at your peril!

In real life, publicly disclosed documents show terrain following at speeds greater than 0.7M and terrain following as low as 200 feet AGL with most recent avionics upgrades (original spec was for 600 feet AGL) is possible. However, all evidence, and public remarks from pilots and maintainers, suggests the low altitude penetrating mission is no longer a typical part of the B-2 mission set. This may be evidenced indirectly by the successor B-21 which deleted the more complex rear control surface arrangement of the B-2, likely because it doesn't need the low altitude gust load alleviation system (GLAS) found on the B-2 due to mission changes.

AUTOTHROTTLE

The real B-2 doesn't have an auto-throttle system. Ours does… It works reasonably well and uses the game native autothrottle system. At high Mach numbers (above 0.9M), you'll see a slight deviation between the instrumented Mach number display and the Mach number the autothrottle system will maintain. This is due to the use of our customer Mach meter system, which is more accurate at high Mach numbers. This is nothing to be concerned about – just adjust accordingly as needed.

PITOT HEAT AND ANTI-ICING EQUIPMENT

Our B-2 model comes equipped with simulated pitot heat and anti-icing equipment. You will receive crew alerting messages if you fly into cold temperatures with this equipment turned off. We were not able to successfully trigger an icing event in our testing. But then we also couldn't trigger it in the Cessna 152 either, so maybe we're doing something wrong. Regardless, use it for the safety of the flight.

EXTERNAL POWER AND AIR START CART OPTION

The aircraft can be supplied AC ground power and started using the air start cart option as long as the aircraft is parked in a designated parking spot on an airport apron. This will avoid using the APUs to start the engines for situations where APUs are non-functional (or when fuel savings are important) or where there's a need to provide power to the aircraft without running the APUs, such as for maintenance and repair. This will become apparent when you are at a parking apron spot that provides external power. If you turn on external power and also enable the ground power unit and air start carts options in the EFB, you'll hear sound effects, and you'll be able to start up the engines without APUs.

LANDING GEAR EXTENSION AND SPEED LIMIT

The landing gear can't be extended from the retracted position when above 260 KIAS. The maximum landing gear extended speed is 310 KIAS and a CAS warning message and voice alert will play if this speed is exceeded with gear extended. On the ground the down lock override switch can be pressed to enable the landing gear handle to be raised; a CAS warning message and voice alert will play if done. This is only for emulation purposes as it's not possible to retract or otherwise force the landing gear to retract or collapse while on the ground, the intended purpose of this switch.

PENETRATION MODE (FEET WET AND STAYING STEALTHY)

The real-life B-2 Spirit has a system that allows the pilots to quickly put the aircraft into its combat low observable configuration at the push of a button. The details of how this works are classified. However, there is reasonable conjecture about some of what this might entail. It's thought that the control surfaces, particularly the outboard drag rudders are locked into a closed position and control deflections and aircraft banking are limited to ensure that the most-stealthy aspect of the aircraft is facing threat radar systems and control surfaces exposed to radar waves. Additionally, any active electromagnetic emitters would likely be silenced, in particular radios, non-passive radar modes, and so on would be disabled. Any protrusions from the aircraft surface including antennae, wing lights, and so on, would be retracted into the closed position. It's also likely that threat detection systems are enabled automatically to alert the crew and aircraft systems of enemy radar and other emissions and possibly enables jamming of various enemy electromagnetic systems. There are likely other passive and active measures taken while in penetration mode to ensure that the aircraft is very hard to detect. We've modeled a taste of this by enabling the penetration mode button on the glare shield. When pressed, the aircraft no longer has roll control and is locked into a level flight roll attitude.

Pitch control is retained. Heading directional control is facilitated by differential thrust control (described below). Additionally, the radar screen will be turned off. We haven't determined a way to disable outbound radio transmissions in the game; we would if we could.

DIFFERENTIAL THRUST CONTROL

When in penetration mode, aileron controls will be locked out and turns are managed with differential thrust control only. This prevents flight control deflections and changes in the aircraft attitude relative to radar signals that would increase the aircraft radar cross section. Differential thrust control is typically employed at higher altitudes. In low altitude terrain following flight, this would not be practical. To enable differential thrust-control one needs to enable multiple engine control on their HOTAS or keyboard. This can also be accomplished by interacting with the throttle levers in the virtual cockpit, though this is a little more challenging to accomplish. Slip rates of up to 1 degree per second are possible, allowing for slow but consistent directional changes without the use of banking. This can also be done while autopilot is enabled and as long as you haven't enabled an autopilot directional control mode, e.g. HDG mode or NAV hold mode. You can set an altitude hold mode for example and then steer the aircraft using differential thrust. Differential thrust control steering takes some practice, and is an interesting challenge.

EMERGENCY PROCEDURES

While we've not made an attempt to model or document any detailed emergency procedures, we have provided a significant list of crew alerting system (CAS) messages to keep you busy if you haven't followed checklists and standard procedures. There is a supplemental list of CAS messages with parameters and aural alert information attached to this document. This plane will bark at you if you're doing something wrong.

TAKEOFFS, APPROACHES, AND LANDING

Real world pilots call the B-2 easy to fly with exceptions for the landing approach and flare (there isn't a flare) as the aircraft generates a very large ground effect and vertical speed will decrease as the aircraft approaches the ground at a set angle of attack and airspeed. If the speed, angle of attack, and pitch angles are too high at landing the aircraft will float or balloon. This is modeled.

We don't know the exact recommended approach angles of attack for the real B-2. That information is not publicly available. What we have found out is that the B-2 makes its approach at around 135-140 knots (or slightly less depending on weight / loading). Max full stop landing weight is 311,500 lbs (this should be considered the emergency recovery weight). Normal maximum landing weights for all other landing procedures, such as touch and go's, is 270,000lbs. You'll need significantly higher pattern and final approach speeds to maintain target AoA values at high weights. At the inner marker and / or when the aircraft crosses the threshold the engines are idled and airspeed allowed to decay. There is no flare needed as the aircraft rate of descent will decrease as the aircraft gets close to the runway due to ground effect. When

landing lightly loaded, deploy 30 to 40% of the speed brakes to allow for higher engine rpms to be used, allowing for more rapid engine responses if a go-around is needed. We've found that in our model, maintaining an angle of attack of between 5 and 6 degrees is optimal during final approach and landing. During downwind and base leg, an angle of attack of 3 to 5 degrees with an airspeed of between 160 and 180 knots (depending on aircraft weight) is appropriate for maintaining a reasonable rate of descent enroute to final. As soon as the aircraft main wheels are on the ground, gently push forward on the stick to plant the nose gear on the ground (release forward pressure as soon as nosewheel touches down) and deploy speed brakes if they haven't automatically deployed. The B-2 has powerful brakes, negating the need for thrust reversing. The brakes get hot and in real life, after hard braking as may occur during a high gross weight landing, it can be many minutes before the brakes are cool enough to attempt another takeoff or landing.

APPROACH MODE (APP BUTTON)

You can activate approach mode for ILS or other precision approaches by activating autopilot, setting up the approach, and once established on the localizer or approach patch, pressing the APP button. The autopilot should take you down to around 500 feet AGL before you'll likely need to take over. The localizer tracking is somewhat inconsistent so you may find that the autopilot doesn't do a good of flying you right down to the runway.

ENGINE AUXILIARY INTAKE DOORS

The B-2 is equipped with auxiliary air intake doors that feed additional air flow to the engines during low-speed phases of flight. This is due to the shape of the engine inlets, with engines buried deep within the wings. In real life, the auxiliary doors allow for higher airflow to reduce the risk of engine stalls and to provide more thrust to the engines during takeoffs, climb-out, and approaches. In the sim, there isn't a performance penalty for not using the doors, but a series of CAS messages are displayed if the doors aren't deployed correctly. We've modeled three available settings for the doors: Open, Auto, and Closed.

There are some operating limitations to the doors that we're aware of:

The doors are limited to speeds of up to Mach 0.4. in Auto mode, the doors will close just before Mach 0.4 and open as the aircraft decelerates below Mach 0.4.

If the "Open" setting is selected and you accelerate past Mach 0.4, you will get a warning CAS alerting you to the condition. You should close the doors promptly.

If doors are left in the Closed setting, you will receive a caution if the engines are advanced past 80% N1 RPM during takeoff. This is a limitation of the engines with the doors closed. You should open them if you intend to takeoff without degrading your engine thrust.
When it's cold (less than 43F / 6C), during idle and taxi, the doors are closed. Engine anti-ice is enabled (you'll receive a CAS alert if you don't). This keeps the engine temperatures warm and

prevents induction icing conditions that can occur at low speeds in cold temperatures. One the aircraft is cleared for takeoff, the doors are opened by setting the system to Auto (this will trigger a CAS caution, which can be ignored as long as you depart shortly after clearance).

AERIAL REFUELING

The model can take on fuel while airborne by using the aerial refueling knob on the fuel system subpanel. Fuel will be onboarded at approximately 1100 gallons per minute (though you'll see faster rates at lower fuel volumes and lower rates when fuel is near max capacity – a quirk of the complex fuel system model that we haven't found a work around for at this time). You must fly between 8,000 and 29,000 feet and between 180 and 325 knots for fuel to be taken on. To open the AAR port, turn the knob to OPEN position. To begin fuel flow, turn the knob to OVRD – you'll see a "LATCH" message on the STAT page of the MDU when fuel is flowing. The B-2 model is also compatible with the Air Show Assistant Aerial Refueling option.

FUEL DUMP

Fuel can be dumped by lifting the fuel dump safety cover on the fuel systems control panel and selecting open. Fuel is dumped at a typical rate for large airliner sized aircraft.

CRUISE PROFILE AND RANGE

The USAF reports its range with ordnance load as approximately 6,000 nautical miles with reserves (6,900 mi; 11,000 km) or about 12.5 hours endurance. At cruising altitude of 40,000 feet (and above), the B-2 refuels about every six hours, taking on up to 50 short tons (100,000 lbs) of fuel at a time. The aircraft takes off at a maximum takeoff weight of 336,500 pounds and can then take on additional fuel, if needed, to reach its maximum airborne weight of 376,000 pounds. In our model, we find that at very high gross weights, the aircraft cruises efficiently between FL330 and FL360. As fuel is burned off, and particularly in combination with release of ordnance weight, the aircraft can be climbed to FL450 (and higher when very light) and fuel efficiency will become very good. Cruise Mach at high weights of 0.85 is a good target. At FL450 and above, Mach numbers of 0.9+ can be maintained with high fuel efficiency. During combat missions, the aircraft can be flown at 50,000 feet. Our maintainer friends, who've provided a lot of useful information about the B-2 say that the aircraft is typically recovered with at least 40,000 lbs. of fuel on board. During flight, the aircraft is aerial refueled well before there is any risk of a low fuel situation. Mission planning around fuel is VERY conservative.

CAMERA SETTINGS FOR THE SPIRIT

There are a number of custom cameras that can be used to view the Spirit, both from the cockpit and exterior views and in the showcase area under the fixed cameras section.

VR FUNCTIONALITY

The model supports VR headset usage. Most everything works as expected. In a subsequent update we'll finish configuring the yoke interaction points.

REAL WORLD MANEUVERING LIMITS AND NOTES (AFMAN B-2 REFERENCE DOCUMENT)

We've included a US Air Force reference manual concerning B-2 operations. No, we don't have a classified Dash-1 for the B-2 (though that certainly would permit a more realistic simulation of this fantastic aircraft); this document is publicly available. It's included as an addendum to this manual. It describes and prescribes a wide variety of operating limitations and conditions for various operations of the B-2. If you are keen on flying the B-2 closer to the real-world operating limits, take a look.

CAS (CREW ALERTING SYSTEM) MESSAGES REFERENCE

We've provided a reference for all of the Crew Alerting System messages that we've included with the B-2 model. This can be found below.

CONTACT AND SUPPORT INFORMATION

For support with your purchase, download, and installation, please contact the reseller channel from which you purchased the product (Microsoft Marketplace support).

For support with model features, bugs, or other related issues, please contact us on our Discord server via the B-2 related support channel.

Top Mach Studios Online Resources:

Web Site: www.topmachstudios.com

Discord: https://discord.gg/uqpvKjZC6t

Facebook: https://www.facebook.com/TopMachStudios

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TOP MACH STUDIOS, B-2A SPIRIT CHECKLISTS

INTERIOR INSPECTION (NO EXTERNAL POWER – ELECTRICAL SYSTEMS OFF) – PILOT

1. Personnel Equipment:
   a. Seat and Rudder Pedals – Adjust as desired
   b. Restraint harness and inertia reel – connect and check
   c. Helmet, Visor, oxygen mask – don and check fit
   d. Helmet communication cord and oxy hose – connect
   e. Oxy Control – Auto
   f. Oxy pilot / msn cmdr: norm, safety, test, back to norm
2. Eject Sequence Handle – Auto
3. Ejection seat arming handle – Armed
4. Clock – set and running
5. Throttles – Idle
6. Antiskid Switch – On
7. Landing Gear Lever – down
8. Down Lock Override - Norm
9. Parking Brake – Set
10. Landing light switch – Off
11. Taxi Light Switch – Off
12. Speed Brake Lever – Retracted / Closed Position
13. Pitot Static Heat Switch - Off
14. Cabin Pressure Gage – Check
15. Aerial Refuel Knob – Closed
16. Aerial Refuel Slipway and Flood Light Knobs – Off
17. EMERG COMM switches – IFF, UHF, ICS: NORM
18. COMM CHANNEL KNOB – COMM 1
19. POS LIGHTS – BRT
20. POS LIGHTS – FLASH
21. ANTI-COLLISION LIGHTS – OFF
22. Other exterior or interior lighting controls – Set knob / switch positions as desired
23. CABIN PACK SWITCHES - Off
24. EQUIP PACK SWITCHES – Auto
25. WINDSHIELD DEFOG SWITCH – Min
26. ANTI-ICE SWITCH Windshield – L Off, R Off
27. ANTI-ICE SWITCH Wing – Auto
28. CABIN TEMP – Auto (or as desired)
29. CABIN FLOW – As Desired
30. APU L and APU R – Off
31. CMD CG Switch – Norm
32. CG Limit – Set to 28

33. Fuel System Intcon L – Closed, Intcon R – Closed
34. Fuel System: Auto
35. Fuel System Manual Transfer Control Knobs – Off
36. Fuel System Manual Tank Fill Buttons – Off
37. Fuel dump Switch – Closed
38. Flight Control Battery Switch– Off
39. Util Battery Switch- Off
40. DC BTR Switch - Off
41. Generators 1,2,3,4 On

INITIAL CHECK / DC POWER ON

1. Confirm crew ready for DC power on
2. Util Battery Switch– On
3. Flight Control Battery Switch– On
4. DC BTR Switch – On
5. Landing Gear Down Lock Lights On (Green)
6. Parking Brakes – Verify Set

APU START

1. Verify ground crew and co-pilot ready for APU Start
2. APU L - Press Start Button and wait for light to illuminate
3. APU R – Press Start Button and wait for light to illuminate
4. Engine Bleed Air Left and Right ISOL Valves – Open / On
5. Adjust Cockpit lighting as needed
6. Cabin Pack Switches, L, R – On
7. Equipment Pack Switches, L, R - Auto
8. MDU and DEP screens brightness – set
9. CID Power On
10. Check battery voltages and electrical current in ELEC screen
11. Check Fuel Quantity
12. Hydraulic System – Verify Quantity, Temperature
13. CAS Switch (Fire and Warning Lights) – Test (no longer than 1 minute in test position)
14. CAS Switch – Arm
15. Entry Door / Ladder – Close
16. Crew Hatch - Close
17. Ordnance Bay Doors – Close
18. Engine Auxiliary Air Intake Doors – Auto

ENGINE START

1. Notify / confirm ground crew and any remaining ground equipment removed / clear
2. Throttles (4) to Idle
3. Press MOTOR buttons (4) and wait for N2 to reach 20% or higher

4. Press individual engine start buttons (4)
5. Check fuel flow at N2>20% for each engine (4)
6. Check Engine Parameters (N1, N2, Fuel flow, Temp, Oil Pressure, Oil Temp, Oil Quantity)
7. Check EMSP (4) - OK
8. Check Electrical System – Amperages and Voltages (ENG MDU page)
9. Close L, R Bleed Air ISOL valves
10. Open Engine Bleed Air Valves (4)
11. Wait a minimum of 30 seconds after final engine to be started has reached stable idle RPM and then turn off APUs L and R

BEFORE TAXI

1. Ordnance Bay Doors – Check Closed (ask ground crew to verify)
2. Engine Instruments – Check
3. Check Brake Accumulator Pressure
4. FCS – Check MDU page
5. Navigation equipment – Check
6. IFF – Verify function and transponder mode select in FMC
7. IFF Switch - Norm
8. FMC Programming – Verify plan / programming
9. Initial autopilot and autothrottle settings entered
10. Altimeters – Set barometric pressure and check field elevation on primary and backup altimeters
11. Verify fuel quantity and CG system settings
12. Gross Weight – check and verify same as provided on Flight Clearance form; MTOW 336.5K LBS
13. Eng Anti Ice - Auto
14. Windshield Defog Switch – As Required
15. Engine Auxiliary Air Intake Doors – Auto
16. If Ambient temp less than 43F Close Eng Aux Air Intake Doors During Taxi
17. ALTN SPD BRK – Norm
18. TRIM mode switch - Norm
19. A/R Slipway – Verify closed
20. Position Lights – Check Brt
21. Position Lights – Check Flash
22. Entry Door and Ladder - VERIFY Up and Closed (check light)
23. Crew Hatch – VERIFY Closed
24. Remove Wheel Chocks – Remove Headphones interconnect with ground crew
25. Signal Ground Crew with Taxi Lights – Steady to alert ground crew to clear the way for taxi, flashing the light to alert ground crew to re-establish intercoms.

TAXIING

1. Parking Brakes – Release
2. Verify Parking Brake light goes out
3. Brakes check – verify normal brake function and response
4. BIT FCS Maint button – press to engage built in flight control system test
5. Verify FCS function – no errors on FCS page on MDU
6. Speed Brake switch to full open and closed
    a. check speed brake extension and retraction
7. Check Oxy switch – Auto
8. Check Oxy regulator switch – Norm

BEFORE TAKEOFF

1. Anti-Collision Lights – Both
2. Position Lights - STDY
3. Landing Lights – On
4. Taxi Lights – Brt
5. Anti-Skid – Check On
6. Eng Aux Air Intake Doors –Auto
7. IFF Switch – Check Norm (in DEP enable desired mode)
8. Helmet Visors – Lower (additional protection against bird strikes causing windshield failure during takeoff)
9. CAS messages – status check
10. Pitot Static Heat On (no more than 63 seconds prior to takeoff to avoid Pitot Overheat)

TAKEOFF

1. Brakes - Depress and Hold
2. Heading Check
3. Annunciator and CAS – Status Check
4. Throttles – Intermediate thrust
5. Engine Data – Check
    a. Power level
    b. Fan RPM
    c. Engine TBT
    d. Core rpm
    e. Oil pressure
    f. Oil Quantity
6. CAS check
7. Brakes Release
8. Throttles – Maximum Thrust
9. Engine Performance – Check
10. Acceleration – Check

11. Rotation Speed – Check
    a. Rotation Speed b/w 125 and 145 Knots depending on A/C Weight
    b. Rotate to between 8 and 10 degrees nose up

AFTER TAKEOFF / CLIMB

1. Landing Gear – Up when aircraft clear of runway and safe climb speed reached
2. Taxi Lights – Off
3. Landing Lights – Off
4. Check Landing Gear Position indicator lights illuminate red during transition and off when gear fully retracted.
5. Check landing gear knob light out when gear retracted
6. Throttles – Set for Climb
7. Fuel Quantity and Flow indicators – Check
8. Cabin Pressure Gage – check
9. Altimeters – check barometric pressure settings
10. Above FL100, Maintain 280 KIAS until M0.77
11. Above FL180 set altimeters to 29.92
12. Autopilot – Engage when appropriate

CRUISE CHECKS

1. Engine & Instruments – CHECK
2. Fuel Quantity and CG – CHECK
3. Radios - TUNED and SET
4. Lights - AS REQUIRED
5. Cockpit Pressure – Check

AIR TO AIR REFUELING

Rendezvous:

1. Radio Contact – Established With Tanker
2. Altimeters – Set Barometer to Match Tanker
3. Descent (Ascent) Range – Compute
4. Descent (Ascent) – Initiate (Notify Tanker).
5. 70 Miles – Notify Tanker
6. Level Off – Notify Tanker
7. 25 to 21 Miles – Notify Tanker
8. 5- to 1-Mile Range Calls – Perform

Prep for Contact:

1. 1 Mile to Tanker – Decelerate
2. Check Engines
3. Check Cockpit Pressure

4. Check Oxygen System
5. Check Fuel State
6. Check Electrical
7. Turn Off Unnecessary EM emitters (Unneeded Comms, Nav, Radar, IFF, etc…)
8. Aerial Refuel Knob – Open
9. AR Flood Knob – As needed
10. AR Slipw Knob – As Needed
11. Anticollision lights – Off
12. Half Mile – Contact Tanker
13. Attain Pre-Contact Position – Stabilize

Contact:

1. Attain Contact Position – Stabilize
2. Contact Made – LATCH CAS
3. Monitor Refueling

Post Aerial Refueling:

1. Information – (position report, tanker off-load reports, etc…) Received from Tanker
2. Aerial Refuel Knob – Close
3. AR Flood and SLIPW Lights – Off
4. Anti Collision Lights – On (As Needed)
5. Altimeters – Reset to 29.92 (above FL180)
6. Comms, Nav, IFF, Radar and other EM emitters – On as needed
7. Check Engines
8. Check Cabin Pressure
9. Check Oxygen System
10. Check Fuel State
11. Check Electrical

DESCENT

1. Hydraulic System – Check Pressure, Temp, Qty
2. Electrical Power – Check
3. Engine Instruments – Check
4. CAS – Check
5. Fuel and CG – Check
6. Navigation and Communications – Set as desired
7. IFF / Transponder – Check on
8. Landing Data – Computed and checked
9. Altimeters – Set barometric pressure below transition altitude
10. Eng Anti Ice – Auto
11. Windshield Defog Switch – Windshield

12. Eng Aux Air Intake Doors - Auto
13. Helmet Visors – Lower
14. Interior Lighting – Set for Landing
15. Restraint Harness – On and checked

APPROACH AND LANDING

1. Altimeter – Check
2. Localizer Frequency – Check
3. Localizer Course – Check
4. Landing Gear Handle Dn – On Glideslope
    a. Check landing gear position lights illuminate green
    b. Check landing gear knob light illuminates
5. Landing Lights – On
6. Taxi Lights – On (BRT at night)
7. Speedbrake - Extend 50%
8. Approach AoA – 5 degrees
9. Approach Speed – B/W 150 and 175 kts depending on GW
10. Approach AoA – 4 to 5 degrees for 750 fpm descent rate on a 3 degree GS
11. Final Approach Speed – Approx. 135 to 150 knots depending on GW
12. Final Approach AoA – 5 to 6 degrees
13. Throttles idle at inner marker
14. Minimal Flare to avoid ballooning – Nose pitch approx. 4 to 5 degrees up at touchdown
15. AoA target 6 degrees at touchdown
16. Speedbrake full on touch down
17. Bring nose wheel down when safe
18. Apply wheel brakes until safe taxi speed.
19. Exit runway when able

AFTER LANDING

1. Landing Lights – Off
2. Taxi Lights – Check On (BRT at night)
3. Anticollision lights – Off
4. Position lights – BRT / FLASH
5. Transponder / IFF – OFF [how best to do this?]
6. Pitot Static Heat – OFF
7. ANTI-ICE SWITCH Windshield – L Off, R Off
8. Speed brake switch - Retract

PARKING / SHUTDOWN

1. Parking Brake – Set / On
2. Anti-Skid Switch - Off
3. Ground crew intercom – Connect

4. Wheel Chocks – Install
5. Taxi Light – Off
6. Anti-Collision Lights – Off
7. Position Lights – Off / Retr
8. Eng Aux Air Intake Doors - Close
9. Ordnance Bay Doors – Open
10. Bleed Air – Off
11. CABIN PACK SWITCHES – Off
12. Entry Door – Open
13. Throttles Idle
14. Engine Instruments – Check for normal Idle Operation
15. Engine Stop (4)
16. DC BTR Switch - Open
17. Ejection Seat Arming Lever – Disarm
18. Battery Flight Center Switch – Off
19. Battery Switch Upr - Off
20. Crew Hatch – Open

TOP MACH STUDIOS B-2A SPIRIT CREW ALERTING SYSTEM (CAS) REFERENCE

ALERTING MESSAGE TEXT	INFO	CAUTION	WARNING	SPECIFIC VOICE ALERT	NOTES
PULL UP			Below 3000 ft AGL, <-6000 fpm sink rate, speed > 180 knots IAS	WOOP WOOP, PULL UP PULL UP	
G FORCE		Load factor >2.5	Load Factor > 3.0	OVER G	
FUEL LOW		<15,000 lbs total fuel	<10,000 lbs total fuel	FUEL LOW	Warning can be silenced with master warning acknowledge button
AIRSPEED		Airspeed > 500 KIAS, Mach Number greater than 0.94			
OVERSPEED			Airspeed > 525 KIAS, Mach Number greater than 0.97	OVERSPEED	
LOW ALTITUDE		<1000 AGL, <-500 fpm sink rate, gear up		“ALTITUDE, ALTITUDE”	
HIGH ALTITUDE		Altitude > 51,000 feet	Altitude > 55,000 feet		
GEAR UP		Gear retracted, airspeed < 200 KIAS, Altitude <2000 Feet AGL		GEAR UP	
PENETRATION ON	Pen Mode On in Air		Pen Mode Active On Ground OR landing gear down		
PARKING BRAKE	Parking Brake On while on Ground	Throttle > 50% while on ground, or aircraft airborne			
GEAR UNSAFE	Gear in transit (cycling up or down)		Airspeed > 310 KIAS with gear extended	GEAR UNSAFE	
FUEL IMBALANCE		Fuel imbalance greater than 500 lbs between L/R sides of aircraft	Fuel imbalance greater than 2500 lbs between L/R sides of aircraft		
WEAPON BAY OPEN	Doors Open On Ground		Doors Open on Ground,		

	and Stationary or When in Air		Groundspeed > 15 knots		
AAR PORT OPEN	AAR Port Open		AAR Port Open in Penetration mode		
SPEEDBRAKE	Speedbrake deployed any percentage > 0				
ENTRY DOOR		Exterior Entry Hatch is Open			
ENG1 STARTING	Engine starter running				
ENG2 STARTING	Engine starter running				
ENG3 STARTING	Engine starter running				
ENG4 STARTING	Engine starter running				
ENG1 OUT			Airspeed > 8 knots and N1 < 15%		
ENG2 OUT			Airspeed > 8 knots and N1 < 15%		
ENG3 OUT			Airspeed > 8 knots and N1 < 15%		
ENG4 OUT			Airspeed > 8 knots and N1 < 15%		
ENG1 TBT		Turbine Blade Temperature > 920C	Turbine Blade Temperature >960C		
ENG2 TBT		Turbine Blade Temperature > 920C	Turbine Blade Temperature >960C		
ENG3 TBT		Turbine Blade Temperature > 920C	Turbine Blade Temperature >960C		
ENG4 TBT		Turbine Blade Temperature > 920C	Turbine Blade Temperature >960C		
ENG1 OVERSPEED			N1 > 101%		
ENG2 OVERSPEED			N1 > 101%		
ENG3 OVERSPEED			N1 > 101%		

ENG4 OVERSPEED			N1 > 101%		
ENG1 FIRE			Engine Fire Detected	ENGINE X FIRE	
ENG2 FIRE			Engine Fire Detected	ENGINE X FIRE	
ENG3 FIRE			Engine Fire Detected	ENGINE X FIRE	
ENG4 FIRE			Engine Fire Detected	ENGINE X FIRE	
GEN1 OFF		Eng 1 Generator switch Off and Eng 1 N1>15%			
GEN2 OFF		Eng 1 Generator switch Off and Eng 1 N1>15%			
GEN3 OFF		Eng 1 Generator switch Off and Eng 1 N1>15%			
GEN4 OFF		Eng 1 Generator switch Off and Eng 1 N1>15%			
BATT OFF		UTIL BATT Switch OFF when a/c power is on			
CAB PRESSURE LO					
CAB PRESSURE DIFF					
FCS			FBW module disabled		
PILOT SEAT DISARMED		Aircraft electrical power on and pilot ejection seat arming lever in disarm position			
COPILOT SEAT DISARMED		Aircraft electrical power on and pilot ejection seat arming lever in disarm position			
NSS AVIN	Aircraft electrical power on				No functional value - for display only
RDR	Displays when penetration mode off - Radar is active				When penetration mode is on, standard radar

					screen will be disabled
ECS	Aircraft electrical power on				No functional value - for display only
CTC AVIN	Aircraft electrical power on				No functional value - for display only
AC BUS			AC Bus switch off		
FUEL DUMP		Fuel dump switch in open position			
ANTI-SKID		Anti-Skid switch in off position, aircraft electrical systems on			
AFT DOOR		Interior entry/exit hatch is open			
CAB PRESSURE DUMP					
ENG AUX DOORS		If ambient temperature below 43f (6.1C) and doors are open. The eng aux doors caution when temps below 43 F should only display when: either ground speed is less than 30 knots (so confirming aircraft is taxiing and not taking off) and/or N1 <80%. and aircraft is on the ground	Doors in closed position below 50kts and N1 > 80% Doors in open position above Mach 0.4	Doors are set to auto (less than M0.4) or in manual open position	
EXT. POWER	Ext. Power Active				Only functions when aircraft is in a parking spot that supports ground power
ECS BL R		If eng 1 and 2 Bleed Air switches set to off in flight			
ECS BL L		If eng 3 and 4 Bleed Air switches set to Off in flight			

OXY	In Backup Mode	System Off Below 12000ft In Backup above 12000ft	System Off Above 12000ft		
CAB PACK R		Cabin Pack Switch L Off and Aircraft in Flight			
CAB PACK L		Cabin Pack Switch R Off and Aircraft in Flight			
EQUIP PACK R		Equip Pack Switch L Off and Aircraft in Flight			
EQUIP PACK L		Equip Pack Switch L Off and Aircraft in Flight			
PITOT HEAT		If ambient temperature below 43F (6.1C)			
ENG ANTI-ICE	If Anti-Ice ENG Switch is ON	If Anti-Ice ENG(EWS) Switch is Off and temp below 43F (6.1C)			
WSHLD ANTI-ICE L	If Switch L in RAIN or WSHLD				
WSHLD ANTI-ICE R	If Switch R in RAIN or WSHLD				
ENG OIL			Oil pressure below 30psi or Oil temp above 110C while engines running		
HYD	Parked on ground and engines off		(A:HYDRAULIC SYSTEM INTEGRITY, Percent) < 100 and aircraft is in motion (GS>0)		
LATCH	AAR refueling port knob is set open or overrid and aircraft within refueling parameters				Parameters: 8000 <ALT <29000 feet. 180 KIAS < Airspeed < 325 KIAS
MTOW		If on ground and total aircraft weight exceeds 336,500 lbs			

UNDERCOOL		Displays when undercool test switch is in on position			
FC BIT		FC BIT in Progress			Flight control surfaces will cycle for about 10 seconds and then BIT will automatically terminate
NUCLEAR			If both NUCLEAR Consent switches are Activated		
ENG	Displays when aircraft stationary on ground and all engines are off				
LANDING LT		when landing light switch is left on after gear retraction			
TAXI LT		when taxi light switch is left on after gear retration.			
WPN ARM	When conventional release enabled (CONV REL ENBL) switch is active on either side of cockpit				
L APU ON		when APUs are activated above 40,000 feet and/or greater than 250 KIAS	KIAS greater than 280, or in penetration mode		
R APU ON		when APUs are activated above 40,000 feet and/or greater than 250 KIAS	KIAS greater than 280, or in penetration mode		

AIR FORCE MANUAL 11-2B-2 VOLUME 3

BY ORDER OF THE
SECRETARY OF THE AIR FORCE

AIR FORCE MANUAL 11-2B-2,
VOLUME 3

30 OCTOBER 2020

Flying Operations

B-2 OPERATIONS PROCEDURES

COMPLIANCE WITH THIS PUBLICATION IS MANDATORY

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This volume establishes effective and safe operations of the B-2 and implements Department of the Air Force Policy Directive (DAFPD) 11-2, *Aircrew Operations*; DAFPD 11-4, *Aviation Service*; and Air Force Manual (AFMAN) 11-202V3, *Flight Operations*. It establishes the minimum Air Force operations procedures for personnel performing duties in the B-2. This publication applies to all civilian employees and uniformed members of the Regular Air Force and the Air National Guard operating B-2 aircraft. It does not apply to Air Force Reserve units and members. This publication does not apply to the United States Space Force. Ensure that all records created as a result of processes prescribed in this publication are maintained in accordance with Air Force Instruction (AFI) 33-322, *Records Management and Information Governance Program*, and disposed of in accordance with Air Force Records Information Management System (AFRIMS) Records Disposition Schedule (RDS). Refer recommended changes and questions about this publication to the Office of Primary Responsibility (OPR) using the AF Form 847, *Recommendation for Change of Publication*; route AF Forms 847 from the field through the appropriate functional chain of command. The authorities to waive wing/unit level requirements in this publication are identified with a Tier ("T-0, T-1, T-2, T-3") number following the compliance statement. See DAFI 33-360, *Publications and Forms Management*, for a description of the authorities associated with the Tier numbers. Submit requests for waivers through the chain of command to the appropriate Tier waiver approval authority, or alternately, to the Publication OPR for non-tiered compliance items. This AFMAN may be supplemented at any level, but all supplements must be routed to Air Force Global Strike Command, Standardization and Evaluations (AFGSC/A3TV) for coordination prior to certification and approval. When guidance in this manual duplicates, changes or conflicts with

already published information contained in other AFGSC manuals or lower designation, the **2**
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material in this manual takes precedence. The use of the name or mark of any specific manufacturer, commercial product, commodity, or service in this publication does not imply endorsement by the Air Force. Compliance with the attachments in this publication is mandatory.

SUMMARY OF CHANGES

This document has been substantially revised and must be completely reviewed. Primary purpose of revision is to change designation from AFI to AFMAN in accordance with DAFI 33-360. Additionally there were minor adjustments to tier levels, formatting and updating of references.

Chapter 1
INTRODUCTION

1.1. Overview. This manual prescribes procedures for operating B-2A aircraft under most circumstances. It is not a substitute for sound judgment. Procedures not specifically addressed may be accomplished if they enhance safe and effective mission accomplishment.

1.2. Roles and Responsibilities.

1.2.1. Commanders. Commanders at their respective tier levels are responsible for complying with guidance in this manual**. (T-1)**. B-2A flying unit wing commanders, delegated no lower than Operations Group Commander (or equivalent), are responsible for providing local operating guidance to supplement the requirements of this Manual**. (T-1)**.

1.2.2. Pilot in Command Authority. The pilot in command is responsible for, and is the final authority for the operation of the aircraft**. (T-1)**. Pilots will use best judgement to safely conduct flying operations**. (T-1)**.

1.3. Deviations. Deviations from these procedures require specific approval by the Major Command Director of Operations unless an urgent requirement or an aircraft emergency dictates otherwise. In that case, the pilot in command should take the appropriate action to safely recover the aircraft.

1.4. Waivers. Forward T-0, T-1 and T-2 waiver requests to the AFGSC, Director of Operations (AFGSC/A3) or Air National Guard (ANG/A3O) for coordination with HAF or external agencies or for approval. Waivers are valid for one year from the approval date. In accordance with DAFI 33-360, T-3 waiver authority may be delegated to group or squadron commanders. Information copies will be provided to AFGSC/A3T and ANG/A3D.

1.5. Instruction Changes. Guidance on suggesting revisions and recommending corrective action(s) is provided in DAFI 33-360. AFGSC/A3 will forward recommendations for changes to this volume to Headquarters Air Force Flight Standards Agency (HQ AFFSA/XOF) for Headquarters Air Force, Director of Operations (AF/A3) approval**. (T-2)**. **AFMAN11-2B-2V3 30 OCTOBER 2020 7**

Chapter 2
MISSION PLANNING

2.1. Duties.

2.1.1. The pilot in command of each aircraft and the designated flight lead are ultimately responsible for mission planning. **(T-3)**.

2.1.2. Crewmembers are personally responsible for maintaining adequate knowledge of system operations, normal, and emergency procedures. **(T-3)**.

2.1.3. The Weapons and Tactics Flight will provide supplemental planning information as necessary to effectively accomplish the assigned mission**. (T-3)**.

2.2. General Procedures.

2.2.1. Accomplish flight planning to ensure safe accomplishment of all phases of flight. As a minimum, flight planning includes takeoff/landing data, fuel requirements, target study/weapons delivery procedures/briefing (if applicable), formation procedures (if applicable), and chart preparation. Review bird advisory and bird hazard information in accordance with AFI 91-202, *The US Air Force Mishap Prevention Program*, and AFI 91-212, *Bird/Wildlife Aircraft Strike Hazard (BASH) Management Program*. **(T-3)**. Units should check the Avian Hazard Advisory System (AHAS) (**http://www.usahas.com**) and contact their base civil engineering wildlife expert or Air Force Safety Center BASH team for further information on times of increased bird activity. Consider and factor in foreseeable safety risks and risk mitigation factors in accordance with Operational Risk Management (ORM).

2.2.2. Standards. Groups may develop Operations Group Commander (OG/CC) approved group/wing standards. Operations Group Standards and Evaluations (OG/OGV) will review all standards to ensure standardization and compliance with AFI 11-series guidance and forward a copy to AFGSC/A3T**. (T-2)**.

2.2.3. The B-2 Weapons Attack Guide (WAG) is an aid for aircrews in mission planning and during flying operations. It does not relieve aircrew from compliance with Technical Orders (T.O.s) or flight regulations. Aircrew are responsible for ensuring information referenced from the B-2 WAG is current, complete, and accurate.

2.2.4. Mission Planning Time. Squadron commanders (SQ/CCs) will provide pilots sufficient time to mission plan**. (T-3)**. SQ/CCs should schedule no less than four (4) hours for mission planning when pilots have standardized/stereo products available ("show and go" flight profiles). SQ/CCs should schedule a minimum of eight (8) hours of mission planning for actual weapons deliveries, airshow/flyby profiles, or any non-standard mission. Unit operations supervisors (or higher) may make crew substitutions as long as the substitute crewmember is thoroughly briefed and understands all aspects of the mission.

2.3. Map/Chart Preparation.

2.3.1. Local Area Charts. A local area chart is not required if the unit in-flight guide includes jettison areas, divert information, controlled bailout areas, and provides sufficient detail of the local area to remain within assigned training areas. **8 AFMAN11-2B-2V3 30 OCTOBER 2020**

2.3.2. Enroute Charts. Pilots may use flight information publication (FLIP) enroute charts instead of maps on navigational flights within areas adequately covered by FLIP. These charts will be of sufficient scale to provide navigation and terrain/obstacle avoidance**. (T-3)**.

2.3.3. Supplemental Charts. Pilots flying under visual flight rules (VFR), inside military operating areas (MOA), or on military training routes (MTR) in the continental United States will supplement existing mission planning materials with either:

2.3.3.1. Mission Planning System (MPS) chart with the following overlay options selected: airports/heliports, airspace boundaries, airways, MTR, parachute jump and Special Use Area (SUA) boundaries**. (T-3)**.

2.3.3.2. Sectional Aeronautical Charts**. (T-3)**. **Note:** Use of sectional aeronautical charts in flight is not required.

2.3.4. Pilots flying outside the continental United States will follow gaining MAJCOM, theater or host nation guidance on mission planning. **(T-2)**. If no gaining MAJCOM, theater or host

nation guidance exists, use the best charts or overlay options available to comply with this manual's requirements**.**
2.3.5. MOA/Restricted/Warning Area Charts. Aircrew using a single Minimum Safe Altitude (MSA) will clearly annotate it on the chart. **(T-3)**. Aircrew will annotate all Minimum Safe Altitudes and associated constructs are annotated on the chart. **(T-3)**.
2.3.6. Minimum safe altitudes (MSA) and Route Abort Altitudes (RAAs) will be a minimum of 1,000 feet (2,000 feet in mountainous terrain) above the highest obstacle/terrain (rounded up to the next 100 feet) within the lateral limits of the route or operational area, but in no case less than five (5) nautical miles (NM) either side of planned route corridor**. (T-3)**.
2.4. Fuel Conservation. Manage aviation fuel as a limited commodity and precious resource. Design procedures for optimal fuel use and efficiencies throughout all phases of mission execution, to include ground operations, flight plans, power settings, and climb/descent profiles. Incorporate enroute tasks to make maximum use of airborne learning opportunities.
2.5. Briefing/Debriefing.
2.5.1. The aircraft commander (AC) or flight lead (FL) sets mission goals and objectives.
2.5.2. AC/FL will present a logical briefing to promote safe and effective mission accomplishment**. (T-2)**. AC/FL will brief contracts, roles, and responsibilities for all crew/flight members**. (T-2)**.
2.5.3. All flight members must attend the flight briefing unless previously coordinated with squadron supervision**. (T-3)**. Commanders will ensure that anyone not attending the flight brief receives a briefing on mission events and emergency procedures**. (T-0)**. If the interval from the initial briefing to takeoff exceeds 72 hours, commanders will ensure that a complete review and briefing is re-accomplished**. (T-3)**. All crews involved in a formation flight must attend a formation briefing**. (T-2)**.
2.5.4. AC/FLs will brief all items required by AFMANs and the flight crew information file (FCIF)**. (T-2)**. AC/FLs may use locally developed briefing guides that cover all AFI briefing requirements. Those items published in AFIs, Air Force Tactics, Techniques and **AFMAN11-2B-2V3 30 OCTOBER 2020 9**

Procedures (AFTTPs) Manuals, or squadron/wing standards and understood by all flight members may be briefed as "standard."
2.5.5. Alternate Mission. AC/FLs will brief an appropriate alternate mission**. (T-2)**.
2.5.6. Debriefing. AC/FLs will formally debrief every mission for all flight/crew members**. (T-2)**. After each mission, AC/FLs will review audio/visual mission recording media, if available**. (T-3)**. At a minimum, the debriefing should include safety of flight items, alibis to debrief items, an evaluation of the mission objectives, desired learning objectives, lessons learned, execution errors, deconfliction contracts, in-flight execution of flight member responsibilities, and mission/tactical employment priorities.
2.6. Unit Developed Checklists/Local Pilot Aids.
2.6.1. Except for -25 checklists, unit developed checklists may be used in lieu of flight manual checklists provided they contain all items (verbatim and in order) listed in the applicable checklist.
2.6.2. Units will produce a pilot aid that includes as a minimum:
2.6.2.1. Briefing guides.**(T-2)**.
2.6.2.2. Local radio and data link (VHF, UHF, HF, VSAT, and LINK-16) channelization**. (T-2)**.
2.6.2.3. Airfield diagram**. (T-2)**.

2.6.2.4. No radio (NORDO) procedures**. (T-2)**.
2.6.2.5. Impoundment procedures**. (T-2)**.
2.6.2.6. Fuel dump and weapons jettison areas**. (T-2)**.
2.6.2.7. Divert/alternate base information**. (T-2)**.
2.6.2.8. Recovery with ferried, retained, or hung weapons on board**. (T-2)**.
2.6.2.9. On-scene commander procedures**. (T-2)**.
2.6.2.10. Other information as deemed necessary by the unit, such as stereo flight plans, engine running crew change (ERCC), taxi-back procedures, local training areas, MOA or air traffic control assigned area (ATCAA) diagrams, alert procedures, and maintenance brevity codes.
2.7. Personal Equipment. Pilots should fly with adequate flight gear to ensure safe mission completion. Pilots will wear survival vests on all sorties utilizing combat step procedures from FENCE (firepower, emitters, navigation, communication, and electronic countermeasures)-IN to FENCE-OUT**. (T-3)**. Pilots will carry survival vests on ocean crossing flights**. (T-2)**. Crewmembers will wear gloves during engine start, takeoff, and landing**. (T-3)**. **10 AFMAN11-2B-2V3 30 OCTOBER 2020**

Chapter 3
NORMAL OPERATING PROCEDURES
3.1. Ground Communications. Pilots will brief ground crews as required**. (T-2)**. Use operational headsets to the maximum extent possible during all engine starts, pre-taxi checks, and when technicians perform tasks on the aircraft. Use hand signals as a last resort or if required during alert scrambles or combat operation.
3.2. Ground Visual Signals. When ground intercom is not available, use visual signals in accordance with **AFMAN 11-218,** ***Aircraft Operations and Movement on the Ground*****.** All signals pertaining to operation of aircraft systems should originate with the pilot. The crew chief will repeat the signal when it is safe to operate the system**. (T-2)**. Pilots will not activate any system that poses a danger to the ground crew prior to receiving proper acknowledgment from ground personnel**. (T-2)**.
3.3. Preflight.
3.3.1. Icing. Do not take off with visible icing (snow, frost, or ice) on any part of the aircraft**. (T-1)**.
3.3.2. Flight Control BITs (ABIT). Pilots will complete an ABIT of the flight control system (FCS) after performing any flight control (FC) memory reads**. (T-3)**. Pilots will not perform FC air event memory reads**. (T-3)**.
3.4. Taxi.
3.4.1. Minimum taxi interval is 500 feet.
3.4.2. Do not taxi with a reported runway condition reading (RCR) of less than 6 anywhere on the taxi route. Commanders will ensure that taxi routes are cleared to a minimum of 75 feet wide for taxi RCR purposes**. (T-2)**.
3.4.3. During normal operating procedures, maximum taxi speed is 15 knots groundspeed and 10 knots during turns or high gain operations. Refer to command guidance for taxi limits greater than 15 knots.
3.4.4. Taxi over arresting cables slower than 10 knots ground speed**. (T-3)**.
3.5. Takeoff.
3.5.1. Do not takeoff if any of the following conditions exist:
3.5.1.1. The RCR is less than 9 (can be waived by OG/CC).

3.5.1.2. Standing or pooled water is on the runway.
3.5.1.3. The computed takeoff roll exceeds 80% of the available runway**. (T-3)**.
3.5.1.4. The tailwind exceeds 10 knots (can be waived by OG/CC).
3.5.1.5. Any attitude indicator, heading indicator, or standby instrument is inoperative.
3.5.1.6. One or more engines are inoperative from the start of takeoff roll. During emergency evacuations and at the discretion of the wing commander or with higher headquarters approval, aircraft may takeoff with one or more engines inoperative. Under **AFMAN11-2B-2V3 30 OCTOBER 2020 11**

no circumstances should a crew take off with a computed takeoff distance that exceeds 95 percent of runway available.
3.5.2. Intersection takeoffs require OG/CC approval.
3.5.3. Runways must be cleared to 150 feet width (+/-75 feet of centerline). **(T-2)**.
3.5.4. Do not takeoff over any raised web barrier (MA-1A or 61QS11). Do not start takeoff roll or land prior to approach end cables. Commanders will ensure that takeoffs accomplished beyond approach end cables have 10,000 feet runway remaining, plus 1,000 feet overrun and still comply with applicable takeoff restrictions**. (T-2)**.

3.6. Formation.

3.6.1. Responsibilities. FLs are responsible for ensuring contracts, roles and responsibilities of each flight member are established, briefed, executed, and debriefed. If any flight member cannot meet their responsibilities, contracts or assigned tasks then they will immediately communicate that information to the FL**. (T-2)**.
3.6.2. Formation size is normally three aircraft or less, but can be as many as six aircraft.
3.6.3. Maintain a minimum of 500 feet vertical altitude separation between aircraft.
3.6.4. Notify air traffic control (ATC) when operating as a non-standard formation on flight plans, on initial ATC contact, and when contacting each subsequent controller. **(T-2)**.
3.6.5. Radio Procedures.
3.6.5.1. Except for wingman acknowledgement, preface all communications with the complete flight call sign. Transmit only information essential for mission accomplishment or safety of flight.
3.6.5.2. Make a “knock-it-off” (KIO) or “terminate” call in accordance with AFI 11-214, *Air Operations Rules and Procedures*. Any flight member may call KIO or terminate. All participants will acknowledge a KIO by repeating the call. **(T-2)**.
3.6.5.3. Acknowledge radio checks which do not require the transmission of specific data by individual flight members in turn (i.e., “2, 3”). Acknowledging indicates that the appropriate action is complete, in the process of completion, or the flight member understands.
3.6.5.4. All flight members will acknowledge the initial ATC clearance**. (T-2)**. Acknowledge subsequent ATC instructions when directed by lead.
3.6.6. Takeoffs.
3.6.6.1. Formation takeoff spacing is 1-minute minimum but can be waived to 30 seconds by the OG/CC. Nuclear training multi-ship minimum interval takeoffs (MITO) require OG/CC approval.
3.6.6.2. Use caution for wake turbulence on departure and adjust climb routing to avoid areas of potential wake turbulence. Appropriate fan headings should be flown for all MITO to account for preceding aircraft’s wake turbulence. If wake turbulence is encountered, smoothly adjust flight

path laterally to exit turbulence. Do not adjust throttles and use caution for G limitations. **12 AFMAN11-2B-2V3 30 OCTOBER 2020**

3.6.7. Join-Up/Rejoin.
3.6.7.1. Lead will ensure a minimum of 1,000-foot altitude separation between each aircraft for formation rejoins**. (T-3)**.
3.6.7.2. Instrument Meteorological Conditions (IMC). Until all wingmen report either visual or tied, FL will report passing every 5000 feet with current and planned rollout heading (if applicable)**. (T-2)**. Wingmen will echo their respective current altitudes and heading**. (T-2)**. Wingmen will not climb through preceding aircraft's altitude until visual or tied**. (T-2)**. Wingmen will delay turns until over the same point as the previous aircraft**. (T-2)**.
3.6.7.3. Visual Meteorological Conditions (VMC). Wingmen may use visual cutoff to expedite rejoins. Avoid flight through wingtip vortices and jet wash**. (T-1)**. If encountered, immediately decouple the autopilot (if engaged) and unload the aircraft to approximately 1G.
3.6.8. Formation Breakup. FL will not break up formation until each wingman has a positive fix with which to navigate (visual, INS, GPS, or TACAN), and a separate ATC clearance (if applicable)**. (T-2)**.
3.6.9. Changing Leads/Position Changes. See **AFTTP 3-3.B-2, *Combat Aircraft Fundamentals B-2***.
3.6.10. Formation Deconfliction.
3.6.10.1. General. FL will brief deconfliction contracts and ensure that all wingmen understand their responsibilities**. (T-3)**. Wingmen have the primary responsibility for safe separation and are responsible for executing the FL contracts.
3.6.10.2. Loss of Visual/Radar Lock. Use the following procedures if any flight member loses visual/radar contact within the formation:
3.6.10.2.1. Wingmen will call "blind/broke lock" when unable to monitor preceding aircraft's position**. (T-2)**.
3.6.10.2.2. After a blind/broke lock call from any formation member, lead immediately will communicate current heading and altitude and then repeat heading and altitude parameters every 1,000 feet until all formation members are tied or visual**. (T-2)**.
3.6.10.2.3. If there is not a timely acknowledgement of the original "blind/broke lock" call, then the flight member initiating the call will maneuver away from the last known position of the other flight members and obtain a separate clearance**. (T-2)**.
3.6.10.3. Broke Lock and Lost Communication. If a wingman becomes "broke lock" and is unable to contact the lead aircraft, the wingman will utilize all available communications devices on board the B-2 to establish contact with lead**. (T-2)**. Simultaneously, the wingman should take positive steps to ensure separation. If in straight and level flight, maintain established altitude separation and previously cleared flight path. If straight ahead and in a climb or descent, turn fifteen degrees away from lead's last known heading. If in a turn and in a climb or descent, roll out to obtain **AFMAN11-2B-2V3 30 OCTOBER 2020 13**

separation and ensure flight path clearance. If all attempts to regain contact with lead aircraft fail, attempt to contact ATC to obtain a separate clearance.
3.6.10.4. Mid-mission/Late Rejoins. Rejoining aircraft require radio contact, visual or radar contact, and 1,000 feet altitude separation before rejoining any formation**. (T-1)**. If applicable,

accept “military assumes responsibility for separation of aircraft” (MARSA) with ATC only after ensuring altitude separation.
3.6.11. Formation Air Refueling.
3.6.11.1. Initial Rejoin. Cross the rendezvous point in trail formation. If IMC, lead directs wingmen to move to echelon after the formation is rolled out behind the tanker(s)**. (T-2)**. If VMC and pre-briefed by FL, wingman may automatically assume echelon position with the tanker(s) in sight.
3.6.11.2. Visual Observation Position. Wingmen may move into visual observation position (VOP) in accordance with AFTTP 3-3.B-2 with the following restrictions:
3.6.11.2.1. Visibility is 2 NM or greater.
3.6.11.2.2. Tanker has cleared wingman to VOP.
3.6.11.2.3. FL has moved into the pre-contact position.
3.6.11.2.4. Aircraft will stabilize at 1,000 feet separation prior to proceeding no closer than 500 feet wingtip clearance. **(T-2)**.
3.6.11.3. Post Refueling Rejoins. After completing air refueling, lead moves to a two mile left 60 degree echelon position stacked down 2,000 feet from the air refueling base altitude of the lead tanker. **(T-2)**. After refueling, the number two aircraft stacks down 1,500 feet and assumes a trail position behind lead. **(T-2)**. Post refueling, number three stacks down 1,000 feet and moves to a trail position behind two. **(T-2)**. Lead will coordinate with the tanker lead for a larger altitude block, if required.
3.6.11.4. Comply with further formation air refueling procedures in accordance with Allied Tactical Publication (ATP)-3.3.4.2, *Air-to-Air Refueling*.
3.7. Air Refueling.
3.7.1. Air refueling operations are authorized along published routes/tracks. Random air refueling is authorized with air traffic control approval. After completing the rendezvous, maintain formation with the tanker. The tanker is responsible for navigation.
3.7.2. Air Refueling Restrictions.
3.7.2.1. Do not conduct air refueling with control stick steering engaged**. (T-2)**.
3.7.2.2. Do not conduct air refueling with an FCS CAUTION, except when necessary for safe recovery of the aircraft**. (T-2)**.
3.7.2.3. Do not conduct air refueling when encountering turbulence which, in the opinion of the pilot-in-command or boom operator, denies a safe margin of control of either aircraft or boom**. (T-2)**.
3.7.2.4. Do not conduct air refueling with less than four engines operating, except when necessary for safe recovery of the aircraft. Simulated engine out air refueling is permitted **14 AFMAN11-2B-2V3 30 OCTOBER 2020**

under Instructor Pilot (IP) supervision. Pilots will place no more than one throttle to idle to simulate the loss of one engine**. (T-2)**.
3.7.2.5. Do not conduct air refueling when the tanker has less than all engines operating, unless required for safe recovery of the aircraft**. (T-2)**.
3.7.2.6. Do not conduct air refueling when any flight control problems are suspected or encountered in flight which, in the opinion of the receiver aircraft commander, would deny a safe margin of control**. (T-2)**.
3.7.2.7. Do not conduct air refueling when tanker is unable to retract landing gear**. (T-2)**.

3.7.2.8. Discontinue air refueling after loss of all tanker disconnect capability, except during the following conditions: **(T-2)**.
3.7.2.8.1. During an emergency fuel situation (limit contact time to that required to obtain fuel).
3.7.2.8.2. Operational missions, operational readiness inspections (ORI), emergency evacuations or deployments/re-deployments (limit contact time to that required to obtain fuel).
3.7.2.9. Boom wet downs with jet propellant four (JP-4, emergency/alternate fuel) are acceptable as long as the total quantity passed does not exceed one percent of total fuel in tanks**. (T-2)**.
3.7.3. Breakaway Training.
3.7.3.1. The tanker pilot, boom operator, and receiver pilot will brief breakaway training prior to initiation**. (T-2)**. Commanders will ensure that the briefing includes when the maneuver occurs and who gives the execution command**. (T-2)**.
3.7.3.2. Do not accomplish breakaway training while in contact.
3.7.4. Boom Limits Demonstration.
3.7.4.1. Boom envelope demonstrations require IP supervision.
3.7.4.2. The boom operator and the receiver pilot will confirm normal disconnect capability prior to the start of the demonstration**. (T-2)**.
3.7.4.3. The receiver pilot will inform the boom operator when starting the demonstration, the limit demonstrated, and when terminating the demonstration**. (T-2)**.
3.7.5. Override Boom Latching Procedures Training. Override boom latching procedures require an instructor pilot. Pilots and boom operators will pre-brief procedures**. (T-2)**. Ensure that both tanker and receiver systems are fully operational**. (T-2)**.
3.8. Approaches and Landings.
3.8.1. Maximum bank angle in the traffic pattern is 45 degrees.
3.8.2. Landing Touchdown Zone. The normal touchdown zone for full stop and touch and go landings is 750 to 2,500 feet beyond the threshold on runway centerline. Pilots should consider a go-around for landings outside the normal touchdown zone. **AFMAN11-2B-2V3 30 OCTOBER 2020 15**

3.8.3. Autopilot. When flying coupled instrument approaches, disengage the autopilot no lower than decision height or minimum descent altitude.
3.8.4. Landings beyond approach end cables should be accomplished with at least 10,000 feet runway remaining plus 1,000 feet of overrun. When 1,000 feet of overrun are not available, reserve 1,000 feet of the runway to meet the minimum overrun requirements.

Table 3.1. Traffic Pattern and Landing Limitations and Restrictions.

Approach Type	Notes	Maximum gross weight	Maximum crosswind	Minimum Weather (ceiling/visibility)	IP Required	Night	Minimum RCR
Full stop landing	1	311,500	30	Approach mins	No	Yes	9
Normal low approach		300,000	N/A	Approach mins	No	Yes	N/A
Touch and go	2	270,000	20 25 (with IP)	500-1 1/2 (or non-precision minima whichever is higher) 300-1 (with IP)	No	Yes	9
Normal Master mode touch and go	2, 3	270,000	25	300-1	Yes	Yes	9
Simulated Engine Out Low Approach	4, 5	270,000	N/A	Note 6	No	Yes	N/A
Simulated Engine Out Touch and Go/Landing	5	270,000	25	Note 6	Yes	Yes	13

Approach Type	Notes	Maximum gross weight	Maximum crosswind	Minimum Weather (ceiling/visibility)	IP Required	Night	Minimum RCR

NOTES:

1. OG/CC approval required for full stop landings at gross weights exceeding 285,000.
2. Do not accomplish touch and go landings with any of the following:
   a. Any landing gear malfunction (gear door and nosewheel steering malfunctions)
   b. Any brake or anti-skid failure indications, any flight control caution or warning
   c. Center of gravity outside landing limits
   d. Runway length insufficient to abort a touch-and-go and stop in the remaining runway
   e. Any live or inert weapons on board
3. Accomplish normal master mode approaches without approach mode and without speed brakes extended.
4. Initiate low approach/go-around no lower than 200 height above touchdown.
5. Use four engines for non-briefed/unplanned go-arounds.
6. Weather required is 1,000 feet/2 miles visibility or circling minimums, whichever is higher.

3.9. Airshow/Flyby Profiles. The following are approved airshow/flyby profiles (see also AFI 11-209_AFGSC Supplement, *Participation in Aerial Events*):
3.9.1. Profile 1. Normal Pass--Straight Thru Pass. Profile consists of a 1,000 foot above ground level (AGL) (minimum altitude), clean configuration pass over the runway at 200 to 250 knots based on aircraft gross weight. If the show line is a non-runway environment then use 1,000 feet above the highest obstacle within 2,000 feet. Following the straight thru pass, the pilot will ensure that the aircraft climbout is in accordance with ATC instructions**. (T-1)**. If a high angle climbout is desired, this profile may be combined with the climbout portion of Profile 4.
3.9.2. Profile 4-Tear Drop Maneuver Pass. Profile begins via a straight run-in down the show line of the viewing audience at 200 to 250 knots, based on aircraft gross weight. Minimum altitude for this maneuver is 1,000 feet AGL. If the show line is a non-runway environment then use 1,000 feet above the highest obstacle within 2,000 feet. Upon completion of the straight run-in pass, track outbound approximately 1 nautical mile then execute a 240 degree turn away from the show line (rolling out momentarily at 90 degrees to the show line for clearing) so as to roll out directed towards show center tracking 30 degrees off runway or show centerline. At show center accomplish a turn away from show center and track outbound 30 degrees off runway or show centerline. All bank angles should be planned for 40 degrees (not to exceed 45 degrees)**. (T-2)**. Execute turns so as to fly no closer than 1,000 feet from the crowd line. If departing after this profile, at show center, execute a climbing turn at maximum continuous thrust at 40 degrees of bank away from the crowd line**. (T-2)**. Comply with climbout in accordance with ATC instructions.
3.9.3. Profile 5--360 Degree (Box Pattern). Profile consists of a 1,000 foot AGL (minimum altitude) **(T-2)**. Clean configuration pass over the runway at 200 to 250 knots based on aircraft gross weight. If the show line is a non-runway environment then use 1,000 feet **AFMAN11-2B-2V3 30 OCTOBER 2020 17**

above the highest obstacle within 2,000 feet. Following the straight thru pass, execute a turn away from the crowd line and fly a rectangular box pattern to a second pass at 1,000 feet AGL (roll out momentarily at perpendicular headings to the show line for clearing). All bank angles should be planned for 40 (not to exceed 45) degrees**. (T-2)**. At this time, the aircraft should execute a level pass and depart the area.

3.10. Chase Formation.

3.10.1. The OG/CC will approve preplanned B-2 chase flights.

3.10.2. Minimum chase spacing from a B-2 is 150 feet.

3.10.3. Chase aircraft will not fly directly over or under B-2 aircraft**. (T-2)**.

3.10.4. All aircraft in the chase formation use a common UHF frequency**. (T-2)**.

3.11. Reduced Lighting Training. Conduct reduced lighting training in approved airspace.

3.12. After Landing Procedures.

3.12.1. Weapons Bay Doors. Do not open the weapons bay doors until the aircraft reaches its final parking location and a ground observer is available**. (T-3).**

3.12.2. Fuel Distribution and Center of Gravity (CG). To allow auxiliary power unit refueling, manually adjust fuel so that each main tank fuel quantity is below 18,000 lbs, each inboard tank fuel quantity is below 19,400 pounds, and each outboard tank fuel quantity is below 14,300 pounds. Accomplish fuel adjustments after exiting the runway and prior to engine shutdown. Maintain CG within the flight CG envelope during taxi. To avoid fuel venting overboard, ensure the outboard tanks are below 14,300 pounds prior to engine shutdown following any preflight or alert cocking**. (T-3)**.

3.12.3. Unless maintenance requests otherwise, close auxiliary air doors and open the air refueling receptacle prior to engine shutdown**. (T-3)**.

3.12.4. Pilots will complete a post-flight walk-around inspection of the aircraft and weapons bays**. (T-3)**.

3.13. Hot Pit Refueling (HPR).

3.13.1. HPR certified pilots and ground crews may conduct HPR day or night.

3.13.2. HPR with a pentagraph requires a separate brake check area away from the refueling pits**. (T-3)**. HPR with R-11 or R-12A trucks does not require a separate brake check area.

3.13.3. Outgoing ERCC crews normally perform HPR. Do not ERCC adjacent to aircraft conducting HPR operations**. (T-3)**.

3.13.4. Do not conduct HPR if brake temperatures exceed 700 degrees Fahrenheit**. (T-2)**. After brakes cool to below 700 degrees, HPR is permitted.

3.13.5. Pilots will monitor aircraft CG during HPR because with the ground refuel panel powered, the flight management system does not monitor CG**. (T-2)**. The fuel panel fuel management switch position (automatic or manual) does not prevent exceeding CG limits.

3.13.6. Pilots will verbally confirm to the maintenance crew that hands, feet and knees are clear of all flight controls prior to commencing HPR**. (T-2)**. **18 AFMAN11-2B-2V3 30 OCTOBER 2020**

3.13.7. Do not perform any avionics operations or maintenance operations during HPR. Only transmit UHF/VHF if required for an emergency. Pilots will notify ground refueling crews prior to any radio transmissions**. (T-2)**.
3.13.8. Do not HPR if fuel was dumped during flight or if fuel is in the surge tank**. (T-2)**.
3.14. Fuel Minimums.
3.14.1. Normal fuel for recovery is 18,000 lbs. This is a general planning factor, and may be increased based on alternate requirements, follow-on missions, or other factors. If an alternate is required, fuel may be planned based on diverting to then landing at the alternate with minimum fuel – normal recovery fuel need not be applied.
3.14.2. Minimum fuel is 15,000 lbs. Crews will land at or above minimum fuel**. (T-2)**.
3.14.3. Emergency fuel is 10,000 lbs. If at any point in flight the AC/FL expects to land below emergency fuel, adjust the profile, divert and/or declare an emergency**. (T-3)**.
3.14.4. Remote or island destination (In accordance with AFI 11-202v3 AFGSC Supplement, *General Flight Rules*) fuel reserve is 30,000 lbs. If the remote or island destination requires an alternate due to weather, Commanders will ensure that the fuel reserve includes enough fuel for two (2) hours of holding**. (T-1)**. **AFMAN11-2B-2V3 30 OCTOBER 2020 19**

Chapter 4
INSTRUMENT PROCEDURES

4.1. Approach Category. The B-2A is designated as an approach category D aircraft. If the airspeed for a circling approach exceeds 166 knots, use category E at a minimum. **(T-1)**.

4.2. Simulated Instrument Flight Procedures. Synthetic ILS and Synthetic TACAN approaches require VMC**. (T-1)**. Visual glide path guidance required at night**. (T-1)**.

4.3. Flight in Precipitation/Icing Procedures.

4.3.1. Lightning Strike/Static Discharge. In the event of a known or suspected lightning strike or static discharge, terminate the mission and maintain below 250 knots calibrated air speed when practical.

4.3.2. Avoid thunderstorms laterally by 20 NM when below FL 200.

4.3.3. Avoid thunderstorms laterally by 40 NM when at or above FL 200.

4.3.4. When at or above FL 200, stay VMC when within 40 NM of any convective activity, not just thunderstorms, which have built above FL 200.

4.3.5. Avoid cruising at altitudes in IMC, or in areas of precipitation, that are within +/-5,000 feet or +/- 10 degrees Celsius of the forecast freezing level. Climb or descend through these areas as rapidly as is safely possible.

4.3.6. Do not climb or descend through forecast or reported icing conditions greater than light**. (T-2)**.

4.3.7. Do not cruise in any forecast or actual icing conditions**. (T-2)**.

4.3.8. Maintain Mach .65 or greater in icing conditions to minimize ice accumulation.

4.3.9. Minimize throttle movement with anti-ice/rain removal operating.

4.4. Area Navigation (RNAV)/ Reduced Vertical Separation Minimum (RVSM) Flight.

4.4.1. RNAV and global positioning system (GPS) approaches are not authorized.

4.4.2. RVSM Airspace. Airspace where RVSM is applied is considered special qualification airspace. Commanders will ensure that both the aircrew and the specific aircraft are approved for operations in these areas**. (T-2)**. All B-2As are approved for restricted operation within RVSM airspace as documented in **Figure 4.1** B-2A RVSM Envelope Limitations. Refer to the flight information general planning on the National Geospatial Intelligence Agency website (**https://www.nga.mil/ProductsServices/Pages/Aeronautical-Charts-and-Publications.aspx**) and the following guidance for additional RVSM requirements:

4.4.3. Required RVSM Equipment. Commanders will ensure that both altimeters (multipurpose display units, one display before each pilot, and the standby altimeter), the autopilot altitude hold function, the identify friend of foe (IFF) transponder altitude reporting (Mode C), and the flight control system (to include the air data ports and their heaters) are fully operational (defined as not more than single channel failed) before entry into RVSM airspace**. (T-2)**. Should any failures of this equipment beyond the allowable single channel **20 AFMAN11-2B-2V3 30 OCTOBER 2020**

failure occur, immediately notify ATC and coordinate further clearance. If failure occurs before entering RVSM airspace, request a new clearance so as to avoid this airspace, or request ATC special handling as a non-equipped aircraft.

4.4.3.1. Autopilot. The altitude hold function of the autopilot should be engaged throughout level cruise periods in RVSM airspace, except when special circumstances dictate, such as when turbulence procedures require disengagement. Report any aircraft deviations greater than 130 ft from the commanded altitude to maintenance.

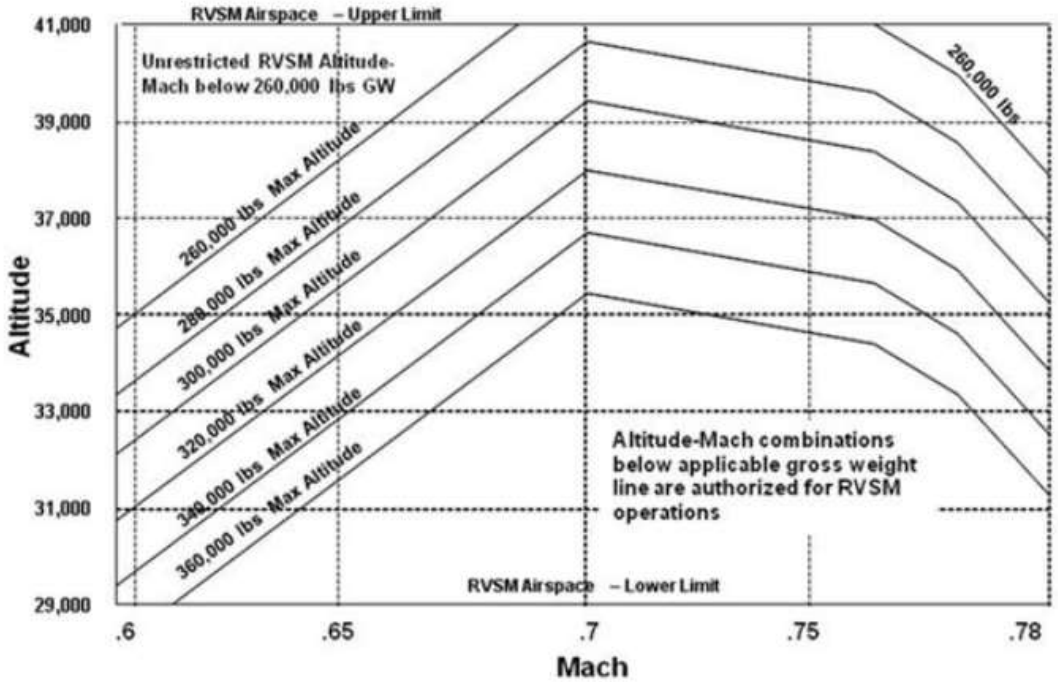
4.4.3.2. Altimeters. Crosscheck primary altitude displays with standby altimeter, before or immediately upon entry to RVSM airspace. After final level off in RVSM airspace the PIC will ensure that the readings of all altimeters are recorded (digital video recorder of both vertical situation displays) and retained for use in case of deviation**. (T-2)**.

4.4.4. RVSM Operations. Monitor systems and crosscheck altimeters on primary displays to ensure they agree +/- 10 ft. Aircrews should limit climb and descent rates to 1,000 feet per minute when operating in RVSM airspace to reduce potential effects on other aircraft's Traffic Alert and Collision Avoidance System (TCAS) operations, and to minimize risk of overshooting desired altitude during level-off.

4.4.5. Post Flight. Document in the AFTO Form 781A, *Maintenance Discrepancy and Work Document*, malfunctions or failures of RVSM required equipment, including failure of this equipment to meet RVSM tolerances.

4.5. B-2 Basic Area Navigation (BRNAV), Required Navigation Performance (RNP), North Atlantic (NAT) High Level Airspace (HLA). The B-2 aircraft is cleared for operations in basic area navigation (BRNAV), required navigation performance-10 (RNP-10), and NAT HLA.

Figure 4.1. B-2A RVSM Envelope Limitations.



NOTE: B-2 RVSM Restricted Operating Envelope.

PILOT OPERATIONAL LIMITATIONS AND RESTRICTIONS

5.1. Scope. This chapter adds B-2 aircraft limitations and restrictions to those specified in flight manuals and other portions of this manual and apply to all AFGSC aircrews.

5.2. Crew Requirements. The minimum crew for flight is specified in T.O. 1B-2A-1, *Flight Manual*. Waiver information for special situations is in **AFI 11-2B-2V1, *B-2 Aircrew Training*.**

5.3. General Limitations.

5.3.1. New/Modified Aircraft and Equipment. Pilots not qualified in the operation of new or modified aircraft equipment will not operate that equipment unless under the supervision of an instructor pilot qualified in that equipment**. (T-2)**.

5.3.2. Authorized Fuel Loads. Commanders will ensure that aircraft are loaded with standard fuel loads in accordance with T.O. 1B-2A-5-2, *Flight Manual Loading Data*. **(T-1)**.

5.4. Pilot and Aircraft Limitations.

5.4.1. Brief practice AFTTP 3-3.B-2 maneuvers or emergency procedures before the maneuver/procedure.

5.4.2. Do not practice compound simulated emergencies during critical phases of flight except those specifically authorized for Instructor Pilot Upgrade/Flight Instructor Course training.

5.4.3. After taking the appropriate action to rectify a malfunction, resume training only if the designated pilot in command determines no hazard to safe aircraft operations exists. In an actual emergency, terminate all training and emergency procedures practice.

5.4.4. Pilots must be combat mission ready to operate an aircraft loaded with nuclear weapons**. (T-1)**.

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Chapter 6
AIR-TO-SURFACE WEAPONS EMPLOYMENT

6.1. References, Authorities and Definitions. AFI 11-214 contains air-to-surface procedures applicable to all aircraft. Also, reference other applicable instructions, range guides, exercise or theater directives and Special Instructions (SPINS). This chapter specifies procedures applicable to B-2 operations.

6.1.1. Ensure all employment of actual weapons is properly authorized and cleared**. (T-0)**.

6.1.1.1. Authorization to employ weapons for training is given by the wing commander, typically by the 21-165 process. In combat, contingency operations and certain higher headquarters directed exercises, authorization is given via the Air Tasking Order (ATO), Execution Order (EXORD) or similar orders.

6.1.1.2. Aircrew must coordinate final target designation (if not previously received) and clearance to release with ATC, range agencies, and operational and/or tactical controllers (e.g., air operations center, joint terminal attack controller, tactical air control party, forward air controller) as applicable**. (T-0)**.

6.1.2. Units will ensure crewmembers are qualified and proficient, or properly supervised, prior to employing actual weapons**. (T-1)**.

6.1.3. Each training mission involving actual weapons will reference current range guidance and will coordinate number and type of weapons and assigned targets**. (T-3)**. Any exceptional arrangement or waiver for an actual weapons release will be documented in writing**. (T-3)**.

6.1.4. On test sorties, specific portions of this chapter may be waived by instructions contained in the operations order, test plan, or implementation message which directs the test.

6.1.5. Actual Weapon. Any high explosive, inert, or training munition. This includes any releasable store.

6.1.6. High Explosive Weapon. An actual weapon configured with live functioning fuses (i.e., having a live primer mated with electrical power) or high explosives. Planners and crews should be alert for differing usage of “live,” as in some instances it may be used by other agencies to denote an actual weapon (e.g., “live” vs. “virtual” or “simulated”). When appropriate, further clarify by describing the weapon as high-explosive.

6.1.7. Inert weapon. An actual weapon that does not have a functioning fuse or high-explosive. This includes weapons with functioning guidance systems, avionics, or propulsion. If a weapon is used with inert submunitions that will separate, it is still considered inert but care should be taken to ensure involved agencies know the submunitions will disperse and to describe any charges used in the weapon’s function.

6.2. General.

6.2.1. Do not release weapons if a release system, indicator, or weapon bay door malfunction exists, unless the malfunction is only a loss of redundancy which does not affect weapons accuracy or normal weapons release (e.g., single power drive unit controller failure)**. (T-2)**. **24 AFMAN11-2B-2V3 30 OCTOBER 2020**

6.2.2. Do not conduct simulated bomb runs, unusual maneuvers, or touch and go landings while carrying actual weapons**. (T-2)**.
6.2.3. Do not complete weapon unlock/release enable/release consent for weapons until the aircraft is on the range, cleared ***hot*** by the controlling authority, and weapons impact would be in the range danger area. When practicable in contingency operations, delay unlock, etc. until cleared and over water, empty or enemy territory**. (T-2)**.
6.2.4. Do not release weapons for training during an inflight emergency or with an engine shutdown**. (T-2)**.
6.2.5. Do not release weapons if the release exceeds or may result in exceeding technical order limits, CG limits, briefed track/timing tolerances, safe escape requirements, wingman deconfliction or fragmentation deconfliction**. (T-2)**.
6.2.6. Do not open weapon bay doors during flight with actual weapons on board other than for intentional release, jettison, or telemetry checks (if applicable)**. (T-2)**.
6.2.7. A range control officer, chase aircraft, or the B-2 flight mission management system may confirm releases. Pilots may conduct simulated bombing training after they release all actual weapons.
6.2.8. If communications are lost while on-range, immediately place release switches to the safe/off position. Do not accomplish further releases until establishing communications and receiving clearance to release. If communications cannot be established, the pilots will remain in range airspace and attempt to contact the appropriate air traffic control agency by all means possible**. (T-1)**. If communications cannot be established, then proceed in accordance with range procedures. During contingency operations, proceed in accordance with SPINS.
6.2.9. Do not operate in SIM mode when actual weapons are aboard the aircraft**. (T-2)**.
6.2.10. Do not practice simulated emergency procedures when actual weapons are loaded on the aircraft**. (T-2)**.
6.2.11. When conducting smart bomb rack assembly (SBRA) operations, do not delete targets or edit the release sequence (REL SEQ) with weapon interface units (WIU) on**. (T-2)**.
6.2.12. Aircrew must have a current copy of the B-2 Weapons OFP Compatibility Matrix (WOCM) when performing a guided weapon preflight. Refer to the OSK SharePoint™ site for the most current WOCM**. (T-3)**.

6.3. Off-Range Simulated Weapons Employment.

6.3.1. Pilots will minimize use of weapons doors in-flight during simulated weapons employment**. (T-2)**. Open weapons bay doors only for specific initial qualification or continuation training.
6.3.2. Do not “manually” rotate rotor launcher assemblies (RLA) in partial SIM without RLA installed**. (T-2)**.
6.3.3. When conducting nuclear training missions using the simulation mode, pilots may power off the simulated weapons and deselect the weapons display for departure. After **AFMAN11-2B-2V3 30 OCTOBER 2020 25**

completing all simulated weapons deliveries, pilots should safe any retained simulated weapons using the appropriate weapons checklist. Following completion of this procedure, pilots may power off any remaining simulated weapons and deselect the weapons display.

6.4. Weather and Navigation System Accuracy for Training Weapon Delivery. Unless range procedures are more restrictive, apply the following guidance.

6.4.1. Weather Guidance/Restrictions.

6.4.1.1. The B-2 is an instrument bomber and does ***not*** perform visual bombing.

6.4.1.2. VMC bombing procedures can be utilized to accomplish actual weapon releases if allowed by the applicable range regulation or SPINS.

6.4.1.3. Actual weapon releases in IMC and/or through an undercast are authorized if allowed by the applicable range regulation or SPINS.

6.4.2. Navigation System Accuracy Guidance/Restrictions. In accordance with AFI 11-214, Chapter 5, aircrew will confirm the accuracy of the aircraft navigation and weapon delivery systems.

6.4.2.1. Unguided Weapons.

6.4.2.1.1. GPS Moded-Out or Inoperative. Aircrew will utilize radar aiming, updates, and altitude calibrations to assess and manage navigation and weapon delivery system health and drift rate in accordance with checklist guidance. Additionally, aircrew must ensure that the navigation system drift rate is equal-to or less than tech-order specification (≤.25 nautical miles per hour or 25 feet per minute) and radar aim within 10 minutes of weapon release on a 0.8 nautical mile coherant map (CM)**. (T-2)**.

6.4.2.1.2. GPS Moded-In (GPS Figure of Merit (FOM) ≤ 3). If GPS FOM is ≤ 3, release is authorized if the aircrew utilizes a 0.8 NM CM map for radar aiming (offset aim point or target direct) while on the range to confirm the accuracy of the aircraft navigation and weapon delivery system. If radar aiming requires introducing buffers into the navigation solution, aircrew will mode-out the GPS and utilize “GPS moded-out or inoperative” guidance. Aircrew will ***not*** release unguided weapons with ***both*** buffers and GPS moded-in the navigation system**. (T-2)**.

6.4.2.1.3. GPS Moded-In (GPS FOM ≥ 4). If GPS FOM is ≥ 4, aircrew will mode-out the GPS and utilize “GPS moded-out or inoperative” guidance. Aircrew will ***not*** release unguided weapons with ***both*** buffers and GPS moded-in the navigation solution**. (T-2)**.

6.4.2.2. Guided Weapons.

6.4.2.2.1. GPS Moded-Out or Inoperative. Do ***not*** release**. (T-2)**.

6.4.2.2.2. GPS Moded-In. If GPS FOM is ≤ 3, release is authorized. If GPS FOM is ≥ 4, withhold**. (T-2)**.

6.4.2.2.3. INS-only weapons may be released if allowed by the applicable range guide. Set the failed weapon mode for SBRA training weapons to “withhold.” **26 AFMAN11-2B-2V3 30 OCTOBER 2020**

6.5. Hung Weapons Procedures.
6.5.1. General. A hung store should be accompanied by a WEAPON caution on the STAT page and a HUNG STORE message on the weapons bay display. Record the Weapons display and note the offending weapons station. If required to swap stores management processors (SMP) for any reason (e.g., to exit bomb (BMB) mode), expect the HUNG STORE message to rescind, even though the hung store condition still exists. If the crew does not suspect that a store is resting on the weapons bay doors, safe weapons and return to base following range and in-flight guide procedures**. (T-2)**.
6.5.2. Recovery. If recovering with hung weapons, accomplish the abort/post-release checklist and return directly to base or other suitable landing base, avoiding over-flight of populated areas. Accomplish air refueling only if necessary for aircraft recovery.
6.6. Jettison Procedures. Pilots will jettison weapons only if, in the opinion of the pilot in command, retention of stores would adversely affect the safe recovery of the aircraft**. (T-2)**.
6.6.1. Mission Planning. Use conventional weapon delivery software (CWDS) and a 235 millisecond (ms) release interval to calculate jettison stick lengths and ensure they are within limits set by range guidance. Calculate data and plan to jettison at the lowest practical altitude.
6.6.2. If a store is suspected to be resting on weapons bay doors:
6.6.2.1. Ensure no IPs will be sequenced to preclude entering BMB mode.
6.6.2.2. Place STACAN on the intended impact point and set course to intended release heading.
6.6.2.3. Intercept the course inbound to the STACAN.
6.6.2.4. Ensure SMPs are ***not*** in BMB mode, decouple roll, and open weapons bay doors manually at "Weapon Range at First Release", calculated using CWDS.
6.6.3. Jettisoning all stores in a bay. If deemed necessary for the safe recovery of the aircraft, accomplish the steps below first. Then, jettison all remaining stores from a selected bay by accomplishing the WEAPONS JETTISON - SELECTIVE checklist in T.O. 1B-2A-34-2-1, *B-2 Non-nuclear Weapons Delivery Manual*. Designating either rack on a side will designate both racks on that side.
6.6.3.1. Ensure no IPs will be sequenced to preclude entering BMB mode.
6.6.3.2. Place STACAN on the intended impact point and set course to intended release heading.
6.6.3.3. Intercept the course inbound to the STACAN.
6.6.3.4. Ensure SMPs are ***not*** in BMB mode, decouple roll, and press jettison button at "Weapon Range at First Release" plus 0.5 NM.
6.6.4. After a successful jettison with suspected or known hung munitions, do not accomplish any further weapons delivery activity (peacetime). **AFMAN11-2B-2V3 30 OCTOBER 2020 27**

6.7. Exercise Participation.
6.7.1. B-2 crews may fly in penetration master mode during peacetime training missions that comply with current security directives.
6.7.2. B-2 pilots will comply with all other training rules/SPINS including external lighting, IFF, squawks, and altitudes. **(T-1)**.
6.7.3. The OG/CC may waive these restrictions in accordance with the appropriate classification guide. **28 AFMAN11-2B-2V3 30 OCTOBER 2020**

Chapter 7
ABNORMAL OPERATING PROCEDURES

7.1. General. This chapter contains procedures to be followed when other-than-normal situations occur. They do not replace or supersede procedures contained in the flight manual.

7.1.1. Accept no aircraft for flight with a malfunction which denies the crew the ability to safely operate in all phases of flight or any malfunction that, if airborne, would require mission termination.

7.1.2. Once a malfunctioning system is isolated and/or the fault corrected, do not use that system again unless use in a degraded mode is justified by mission priority or required for recovery. Do not conduct ground or in-flight troubleshooting after completing flight manual emergency procedures**. (T-3)**.

7.1.3. Fuel Dumping. Only conduct fuel dumping in order to reduce aircraft gross weight for safety of flight. When circumstances permit, dump over unpopulated areas above 8,000 feet AGL. Annotate fuel dumping in the AFTO Forms 781A. If conditions permit, advise the appropriate air traffic control agency of altitude and location and when the operation has been completed.

7.1.4. Brake and Nosewheel Steering (NWS) Malfunctions. Do not taxi the aircraft with a brake system malfunction**. (T-2)**. Do not taxi with a nose wheel steering malfunction with the exception of using nose wheel steering override, or differential braking to clear the active runway**. (T-3)**. After clearing the runway, the pilots will stop until the malfunction can be cleared**. (T-3)**. If nosewheel failure occurs in-flight and cannot be cleared or reset, aircrews may taxi the aircraft clear of the runway using NWS Override or differential braking and stop until the malfunction can be cleared.

7.1.5. Release Faults. When conducting actual weapons releases for training, if an aircrew receives a REL CON: FLT in flight and cannot clear this fault, do not attempt to release weapons**. (T-2)**. Terminate all bombing activity, and write the fault up for maintenance actions upon landing. The crew should attempt to clear the fault by cycling the REL ENBL switches or swapping and/or performing a SMP CDE.

7.2. Ground Aborts. Delayed aircraft may join a flight at a briefed rendezvous point or fly a briefed alternate mission. Flight leads will advise the appropriate agencies of applicable changes after a ground abort**. (T-3)**.

7.3. Takeoff Aborts.

7.3.1. When a takeoff is aborted and hot brakes are suspected or computed, taxi to the hot brake area, declare an emergency, and follow technical order procedures. Reference the B-2 Brake Energy Limit Chart in T.O. 1B-2A-1 and comply with local guidance**. (T-1)**.

7.3.2. Pilots will recalculate takeoff data and brake energy data prior to follow-on takeoffs after an abort**. (T-2)**.

7.4. Air Aborts. Local guidance such as the Go/No Go guidance published in the B-2A In Flight Guide may further dictate specific causes for mission abort. **AFMAN11-2B-2V3 30 OCTOBER 2020 29**

7.4.1. Pilot shall abort missions for any of the following:
7.4.1.1. Bird strike/FOD. **(T-3)**.
7.4.1.2. Over-G. **(T-3)**.
7.4.1.3. Flight control system anomalies (see local guidance). **(T-3)**.
7.4.1.4. Engine flameout/stagnation. **(T-3)**.
7.4.1.5. Boom strike. **(T-3)**.
7.4.1.6. Confirmed or suspected fuel leaks. **(T-3)**.
7.4.2. Do not conduct training events such as air refueling (except when required for safe recovery of the aircraft), actual weapons releases, dissimilar air training activity, or practice patterns/landings after an air abort**. (T-3)**.
7.5. Radio/Identify Friend or Foe (IFF)-Selective Identification Feature (SIF) Failure. Comply with local procedures for radio failure. Immediately notify controlling agencies if the IFF is inoperative, and provide accurate position reports for separation from other traffic**. (T-3)**.
7.6. Lost Wingman Procedures. During climbs and descents, if visual and/or radar contact is lost, flight leads should use all means to ensure proper formation spacing (lateral and vertical). Wingmen immediately will call blind/broke lock when unable to monitor preceding aircraft's position**. (T-2)**. After a blind/broke lock call, lead will broadcast heading and altitude every 1,000 feet until all formation member are either tied or visual**. (T-2)**.
7.7. Spatial Disorientation/Unusual Attitudes.
7.7.1. Practice unusual attitude recoveries are prohibited in flight**. (T-2)**.
7.7.2. Nose High Recovery Procedure. To recover from a nose high attitude, add power as required, establish a bank angle of no more than 60 degrees, lower the nose to a minimum minus three degree pitch attitude, then return the aircraft to level flight in both pitch and bank.
7.7.3. Nose Low Recovery Procedure. Recover from a nose low attitude by reducing power and extending speedbrakes as necessary, rolling wings level, then increasing stick back pressure to return the aircraft to level flight.
7.8. Armament System Malfunctions.
7.8.1. After complying with technical order procedures and guidance, pilots will comply with local guidance**. (T-3)**.
7.8.2. For training missions, do not rotate a hung weapon from the release position. **(T-2)**.
7.8.3. If an inadvertent release occurs, accomplish post release checklist actions to ensure switches are in the safe/off position. Do not accomplish any further weapons deliveries (actual or SIM). If no weapons remain on the aircraft, any non-weapons related training may be accomplished. **30 AFMAN11-2B-2V3 30 OCTOBER 2020**

7.9. In-flight Practice of Emergency Procedures.
7.9.1. A simulated emergency procedure is any procedure that produces an effect which closely parallels an actual emergency. Retarding a throttle to simulate the drag of a flamed out engine would be an example of such a practice.
7.9.2. Do not practice aborted takeoffs except in a simulator**. (T-2)**.
7.9.3. Do not shut down an engine in flight to simulate an emergency**. (T-2)**.
7.9.4. Simulated engine out refueling with an engine in idle is permitted as part of syllabus training with an IP.
7.9.5. Practice stalls and approach to stalls are prohibited inflight**. (T-2)**.
7.10. Search and Rescue Combat Air Patrol (SARCAP) Procedures. During an aircraft mishap, immediately attempt to locate survivors and initiate rescue efforts.
7.10.1. Knock off maneuvering and the pre-briefed mission.
7.10.2. Establish a SARCAP commander.
7.10.3. Notify controlling agencies of the situation, and change squawk as necessary.
7.10.4. Mark the last known position of survivors using any navigation means available.
7.10.5. Remain above the highest ejection altitude.
7.10.6. Deconflict with other aircraft to prevent mid-air collision.
7.10.7. Revise BINGO fuels or recovery bases to maintain maximum SARCAP coverage.
7.10.8. Relinquish SARCAP operations to designated rescue forces upon their arrival.
7.10.9. Follow briefed or local procedures after the arrival of designated rescue forces. **AFMAN11-2B-2V3 30 OCTOBER 2020 31**

Chapter 8
LOCAL OPERATING PROCEDURES

8.1. General. This chapter is reserved for unit local operating procedures. In accordance with DAFI 33-360, the paragraph method is the only authorized way to supplement an AFMAN and added material should be arranged according to the basic publication. Units composed of dissimilar aircraft may publish guidance in a single, stand-alone local operating instruction instead of supplementing this AFMAN. Added or stand-alone procedures should not be less restrictive than those contained elsewhere in this volume. This chapter is not intended to be a single source document for procedures contained in other directives or regulations. Avoid unnecessary repetition of guidance provided in other established directives; however, reference to those directives is acceptable when it serves to facilitate location of information necessary for local operating procedures. This chapter is authorized to be issued to each B-2 pilot. Units may supplement the following paragraphs for local operating guidance:

8.2. Section A. Introduction/Purpose.
8.3. Section B. Applicability.
8.4. Section C. Ground Operation.
8.5. Section D. Flying Operations.
8.6. Section E. Weapons Employment.
8.7. Section F. Abnormal Procedures.
8.8. Section G. Command and Control.
8.9. Section H. Fuel Requirements.
8.10. Section I. Divert Instructions.
8.11. Section J. Jettison Areas (instrument/visual flight rules).
8.12. Section K. Controlled Bailout Areas.
8.13. Section L. Local Weather Procedures.
8.14. Section M. Approved Alternate/Other Missions.
8.15. Section N. Unit Standards.

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Deputy Chief of Staff, Operations **32 AFMAN11-2B-2V3 30 OCTOBER 2020**

Attachment 1
GLOSSARY OF REFERENCES AND SUPPORTING INFORMATION
References
AFPD 11-2, *Aircrew Operations,* 31 January 2019
AFPD 11-4, *Aviation Service*, 12 April 2019
AFI 11-209 AFGSC Supplement *Participation in Aerial Events*, 8 February 2019
AFI 11-214, *Air Operations Rules and Procedures*, 8 July 2020
AFI 11-215, *Flight Manuals Program,* 25 March 2019
AFI 33-322, *Records Management and Information Governance Program,* 23 March 2020
AFI 91-202, *The US Air Force Mishap Prevention Program*, 12 March 2020
AFI 11-202V3 AFGSC Supplement, *General Flight Rules*, 9 July 2019
AFI 91-212, *Bird/Wildlife Aircraft Strike Hazard (BASH) Management Program*, 31 May 2018
AFMAN 11-2B-2V1, *B-2 Aircrew Training,* 20 August 2020
AFMAN 11-202V3, *Flight Operations*, 10 June 2020
AFMAN 11-218, *Aircraft Operations and Movement on the Ground*, 5 April 2019
AFTTP 3-3.B-2, *Combat Aircraft Fundamentals - B-2*, 31 July 2015
ATP-3.3.4.2, *Air-to-Air Refueling*, 26 April 2019
B-2A *Inflight Guide,* 1 Dec 2017
B-2A *Weapons Attack Guide*, 1 October 2015
DAFI 33-360, *Publications and Forms Management*, 1 December 2015
T.O. 1B-2A-1, *Flight Manual*, 10 March 2014
T.O. 1B-2A-34-2-1, *B-2 Non-nuclear Weapons Delivery Manual*, 31 January 2007
T.O. 1B-2A-5-2, *Flight Manual Loading Data,* 8 January 2008
Adopted Forms
AF Form 847, *Recommendation for Change of Publication*
AFTO Form 781A, *Maintenance Discrepancy and Work Document*
Abbreviations and Acronyms
AC—aircraft commander
AFGSC—Air Force Global Strike Command
AFI—Air Force instruction
AFMAN—Air Force manual **AFMAN11-2B-2V3 30 OCTOBER 2020 33**

AFPD—Air Force policy directive
AFTTP—Air Force tactics, techniques, and procedures
AGL—above ground level
AHAS—avian hazard advisory system
ATCAA—air traffic control assigned airspace
ATO—air tasking order
BASH—bird/wildlife aircraft strike hazard
BINGO—pre-briefed fuel state for recovery
BIT—built-in test
BMB—bomb mode
BRNAV—basic area navigation
CBRN—chemical, biological, radiological and nuclear
CC—commander
CG—center of gravity
CHUM—chart update manual
CM—coherent map mode of B-2 radar
CT—continuation training
CWDS—conventional weapon delivery software
deconfliction—removal or mitigation of collision risk
DVR—digital video recorder
DRU—direct reporting unit
EOR—end of runway
ERCC—engine running crew change
EXORD—execution order
FAF—final approach fix
FC—Flight Controls
FCIF—flight crew information file
FCS—flight control system
FENCE—firepower, emissions, navigation, communications, expendables
FIC—flight instructor course
FL—flight lead
FLIP—flight information publication **34 AFMAN11-2B-2V3 30 OCTOBER 2020**

FOA—field operating agency
FOM—figure of merit
G limitations—limits on the demands placed on aircraft load factor
GPS—global positioning system
HAS—hardened aircraft structure
HE—high explosive
HF—high frequency
HLA—high level airspace
HPR—hot pit refueling
IAF—initial approach fix
IFF—identification friend or foe
IFR—instrument flight rules
IMC—instrument meteorological conditions
IP—instructor pilot
IPUG—instructor pilot upgrade
IQT—Initial Qualification Training
JDAM—joint direct attack munition
JP-4—Emergency/Alternative jet fuel normally used by US Navy and Marine Corps
KIO—knock-it-off
LINK-16—data link system
MARSA—Military Assumes Responsibility for Separation of Aircraft
MITO—Minimum Interval Takeoff
MOA—military Operating Area
MOPP—mission oriented protective posture
MNPS—minimum navigation performance specifications
MPS—mission planning system
ms—millisecond
MSA—minimum safe/sector altitude
MTR—military training route
NAT—North Atlantic
NM—nautical mile
NORDO—no radio **AFMAN11-2B-2V3 30 OCTOBER 2020 35**

NWS—nose wheel steering
OFP—Operational Flight Program
OG—operations group
OPR—office of primary responsibility
ORM—operational risk management
ORI—operational readiness inspection
RAA—Route Abort Altitude
RCR—runway condition reading
REL SEQ—release sequence
RLA—rotary launcher assembly
RNAV—area navigation
RNP—Required Navigation Performance
RTB—Return to Base
RVSM—reduced vertical separation minima
SARCAP—search and rescue combat air patrol
SBRA—smart bomb rack assemblies
SIF—selective identification feature
SILS—synthetic instrument landing system
SMP—stores management processors
SPINS—special instructions
STACAN—synthetic TACAN
SUA—special use airspace
SQ—squadron
TACAN—tactical air navigation
TCAS—traffic alert and collision avoidance system
T.O.—technical order
UHF—ultra high frequency
VFR—visual flight rules
VHF—very high frequency
VMC—visual meteorological conditions
VOP—visual observation position
VSAT—voice satellite/very small aperture terminal 36 AFMAN11-2B-2V3 30 OCTOBER 2020

WAG—weapons attack guide
WIU—weapons interface unit
WOCM—Weapons Operation Flight Program Operational Flight Capability Matrix
Terms
Actual Weapon—Any high explosive, inert, or training munition. This includes any releasable store.
Alarm Black—Attack is over and contamination or unexploded ordinance is known or suspected.
Alarm Red—Immanent attack by air, missile, or ground forces.
Inert weapon—An actual weapon that does not have a functioning fuse or high-explosive. This includes weapons with functioning guidance systems (e.g., LGB seekers/tail kits), avionics and/or propulsion. If a weapon is used with inert submunitions that will separate, it is still considered inert but care should be taken to ensure involved agencies know the submunitions will disperse and to describe any charges used in the weapon's function.
Blind—No visual contact with the friendly aircraft/ground position; opposite of visual.
Broke Lock—Loss of radar contact with element or aircraft; opposite of tied.
High Explosive Weapon—An actual weapon configured with live functioning fuses (i.e., having a live primer mated with electrical power) or high explosives. Planners and crews should be alert for differing usage of "live," as in some instances it may be used by other agencies to denote an actual weapon (e.g., "live" vs. "virtual" or "simulated"). When appropriate, further clarify by describing the weapon as high-explosive.
Hung Weapon—A live or inert weapon that does not separate from the aircraft following an attempted release.
Inert Weapon—An actual weapon that does not have a functioning fuse or high-explosive. This includes weapons with functioning guidance systems (e.g., LGB seekers/tail kits), avionics and/or propulsion. If a weapon is used with inert submunitions that will separate, it is still considered inert but care should be taken to ensure involved agencies know the submunitions will disperse and to describe any charges used in the weapon's function.
Live Weapon—Actual munitions containing a primary explosive charge (JDAM, Mk 84, etc.).
Tied—Positive radar contact with element or aircraft.
Weapon—Any live, inert, or training munitions. **AFMAN11-2B-2V3 30 OCTOBER 2020 37**

Attachment 2
AIRCREW OPERATIONS IN CHEMICAL, BIOLOGICAL, RADIOLOGICAL, AND NUCLEAR (CBRN) THREAT ENVIRONMENT

A2.1. General Information. Potential use of CBRN weapons against friendly airfields presents a serious threat to flying operations. Although the most effective way for aircrews to avoid this threat is to be airborne before those weapons are detonated or dispersed and then land at a field that has not been contaminated, all personnel must be prepared to operate from a field that has come under CBRN attack. Each air base should publish detailed CBRN procedures. The following information is for use when base-specific procedures are unknown or incomplete.

A2.2. CBRN Environments. Counter-CBRN actions can be grouped into environments. Chemical and Nuclear environments result from clouds or rain of minute droplets of agents dispersed from a munition or sprayed as an aerosol. The nuclear environment is within range of any direct effect from a nuclear detonation. The radiological environment's hazard is radioactive dust that can originate as fallout from a detonation or from dispersal of radioactive material without a nuclear detonation--a dirty bomb. Procedures in all environments except nuclear are similar--use procedures and protective gear to avoid skin contact with or inhalation/ingestion of agents or particles.

A2.3. Mission Preparation. Determine the CBRN status at planned launch, recovery and divert bases. Know the current Mission Oriented Protective Posture (MOPP) level for relevant sectors of the launch airfield. Plan ground ops to minimize the time between leaving shelter and takeoff. If available, use other aircrew members to perform preflight duties to minimize flight crew exposure. Arming and End of Runway (EOR) procedures may be conducted in the hardened aircraft shelter (HAS) or other non-standard location.

A2.4. Travel To/From the Aircraft and Aircraft Preflight. Step in the appropriate protective ensemble and carry other protective gear as required. If possible, travel to and from the aircraft in an enclosed vehicle to prevent contamination from agents or dust settling from the air. If travel on foot is unavoidable, choose a route that takes maximum advantage of available overhead cover (sun shades, buildings, etc.). If the aircraft is contaminated, ensure maintenance has accomplished spot decontamination and avoid contaminating your person during preflight. Take steps to avoid bringing contamination into the aircraft on helmet bags, map bags, etc. In a potential CBRN environment, keep aircraft buttoned up as much as possible when outside protective shelter. Post-mission, if there is any suspicion of aircrew contamination process through an aircrew contamination control area.

A2.5. Ground Operations during Alarm Red (or Theater Equivalent).

A2.5.1. Before Taxi Out and After Taxi Back. If Alarm Red occurs while the crew is outside the aircraft or in the chocks, shut down and exit the aircraft (if appropriate), take cover and don appropriate MOPP. This may require use of the ground crew mask. A hardened facility such as a Hardened Aircraft Structure (HAS) provides optimum protection. Ensure the safety of supporting ground crew; use hand signals if necessary.

A2.5.2. Ground Operations Outside the Parking Spot. Maintain contact with supervisor of flying, air traffic control, command post, etc., to remain aware of ground hazards and command direction. If Alarm Red occurs while on the ground outside the chocks, there are **38 AFMAN11-2B-2V3 30 OCTOBER 2020**

two primary options. The first option is to taxi into a hardened structure. If a hardened structure is not available, a hangar or flow through should reduce exposure to settling airborne agents. Use caution to not damage the aircraft or nearby people and things. Shut down and close structure doors when able. The second option is to launch for survival contingent on fuel state, arming status, proximity to runway, nature of attack, etc. If shelter or takeoff is not possible, try to get out of the taxi flow. In extremes, especially if there is no protective mask available, select 100 percent oxygen and consider turning off the environmental control systems and/or shutting down to avoid bringing agent/dust into the aircraft. Leave the aircraft buttoned up and await assistance.

A2.6. Airborne.

A2.6.1. Contamination. Becoming contaminated by chemical or biological agents, while airborne, is very unlikely. If chemical agent contamination occurred prior to takeoff, flight will dissipate the agent to some degree, but will not achieve complete decontamination. Flights of at least two (2) to four (4) hours are recommended, and lower altitudes are more effective than higher altitudes. Fly with the aircraft configured (gear and speedbrakes extended) as long as possible to maximize the airflow in and around as many places as possible. There is no simple guidance for biological contaminants. If suspected, maintain maximum protective posture. If radioactive dust contamination is suspected, take measures to avoid getting the dust on bare skin, breathing it in (protective masks work for this) or getting it into your mouth. Seek decontamination assistance after landing.

A2.6.2. During the Mission and Return to Base (RTB). Use command and control agencies to maintain awareness of command intent and the status of primary and alternate landing locations. Do not attempt to land during Alarm Red situations unless there is no other option. Follow command directions and hold or divert. If holding, try to wait until Alarm Red is terminated. When able, obtain updates on airfield status, ground hazards, de-arm and taxi routing. If landing in Alarm Black, expect a contaminated environment and MOPP 4. Droplet settling following a chemical or biological airburst attack can take up to one (1) hour. If you believe the aircraft was contaminated before takeoff or while airborne, notify command and control.