FLIGHT MANUAL

USAF SERIES AIRCRAFT

F-22A RAPTOR

INCREMENT 3.2

AIRCRAFT 91-007 AND ON

LOCKHEED MARTIN AERONAUTICS COMPANY
THE BOEING COMPANY
PRATT & WHITNEY

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SUPPLEMENTAL NOTICE

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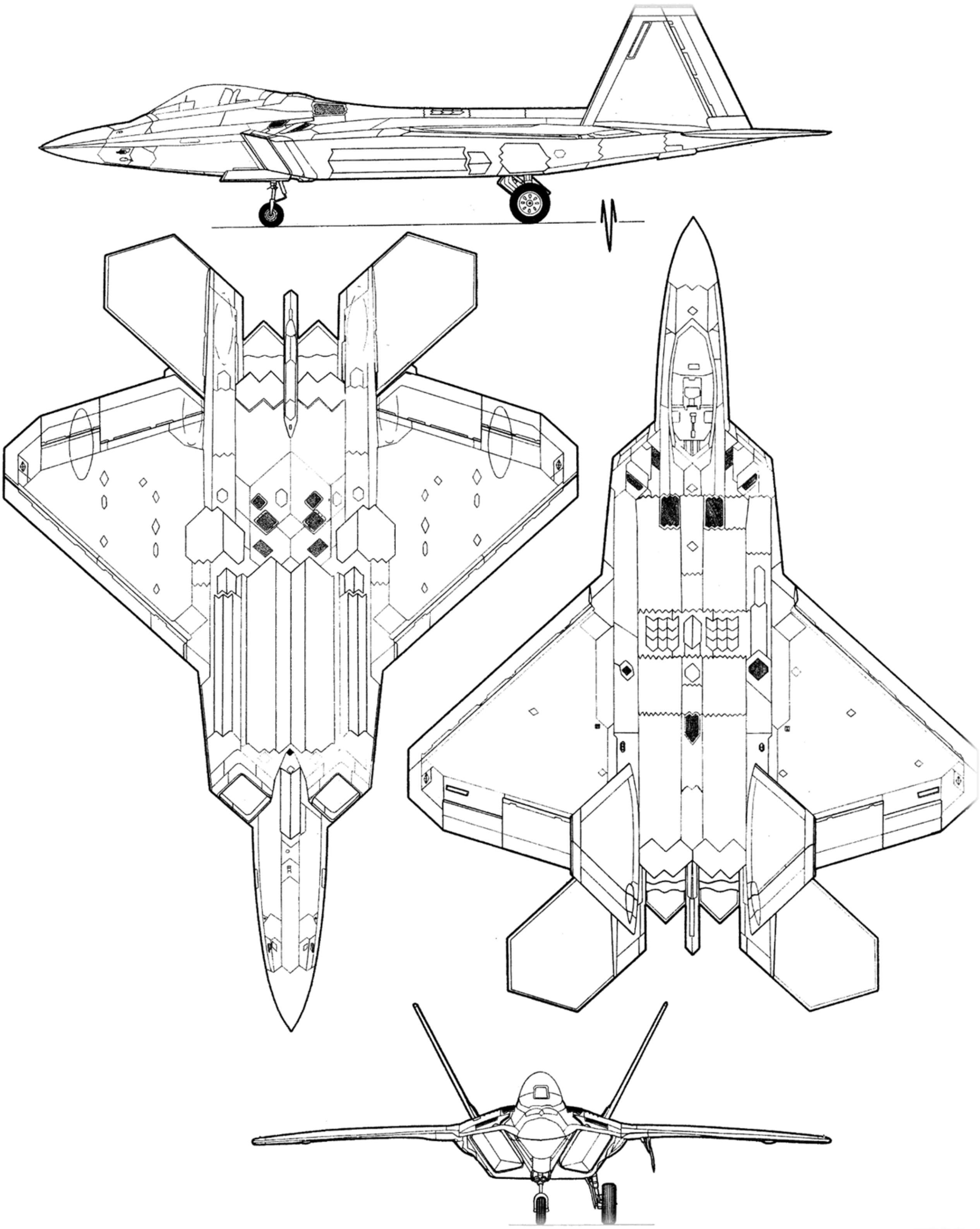
F-22A RAPTOR



THE AIRCRAFT

The F-22 Raptor is one of the newest fighters in the U.S. Air Force fleet. It offers a combination of stealth, speed, maneuverability, and robust warfighting capabilities. A suite of sensors and highly-lethal weapons guarantee air dominance, supporting the mission at hand.

The F-22, a critical component of the Global Strike Task Force, is designed to project air dominance, rapidly and at great distances and defeat threats attempting to deny access to our nation's Air Force, Army, Navy and Marine Corps. The F-22 cannot be matched by any known or projected fighter aircraft.

A combination of sensor capability, integrated avionics, situational awareness, and weapons provides first-kill opportunity against threats. The F-22 possesses a sophisticated sensor suite allowing the pilot to track, identify, shoot and kill air-to-air threats before being detected. Significant advances in cockpit design and sensor fusion improve the pilot's situational awareness. In the air-to-air configuration the Raptor carries six AIM-120 AMRAAMs and two AIM-9 Sidewinders.

The F-22 has a significant capability to attack surface targets. In the air-to-ground configuration the aircraft can carry two 1,000-pound GBU-32 Joint Direct Attack Munitions internally and will use on-board avionics for navigation and weapons delivery support. In the future air-to-ground capability will be enhanced with the addition of an upgraded radar and up to eight small diameter bombs. The Raptor will also carry two AIM-120s and two AIM-9s in the air-to-ground configuration.

Advances in low-observable technologies provide significantly improved survivability and lethality against air-to-air and surface-to-air threats. The F-22 brings stealth into the day, enabling it not only to protect itself but other assets.

The F-22 engines produce more thrust than any current fighter engine. The combination of sleek aerodynamic design and increased thrust allows the F-22 to cruise at supersonic airspeeds (greater than 1.5 Mach) without using afterburner -- a characteristic known as supercruise. Supercruise greatly expands the F-22 's operating envelope in both speed and range over current fighters, which must use fuel-consuming afterburner to operate at supersonic speeds.

The sophisticated F-22 aerodesign, advanced flight controls, thrust vectoring, and high thrust-to-weight ratio provide the capability to outmaneuver all current and projected aircraft. The F-22 design has been extensively tested and refined aerodynamically during the development process.

The F-22's characteristics provide a synergistic effect ensuring F-22A lethality against all advanced air threats. The combination of stealth, integrated avionics and supercruise drastically shrinks surface-to-air missile engagement envelopes and minimizes enemy capabilities to track and engage the F-22. The combination of reduced observability and supercruise accentuates the advantage of surprise in a tactical environment.

The F-22 will have better reliability and maintainability than any fighter aircraft in history. Increased F-22 reliability and maintainability pays off in less manpower required to fix the aircraft and the ability to operate more efficiently.

GENERAL DATA

Primary function: air dominance, multi-role fighter

Contractor: Lockheed-Martin, Boeing

Power plant: two Pratt & Whitney F119-PW-100 turbofan engines with afterburners

and two-dimensional thrust vectoring nozzles.

Thrust: 35,000-pound class (each engine)

Wingspan: 44 feet, 6 inches (13.6 meters)

Length: 62 feet, 1 inch (18.9 meters)

Height: 16 feet, 8 inches (5.1 meters)

Weight: 43,340 pounds (19,700 kilograms)

Maximum takeoff weight: 83,500 pounds (38,000 kilograms)

Fuel capacity: internal: 18,000 pounds (8,200 kilograms);

with 2 external wing fuel tanks: 26,000 pounds (11,900 kilograms)

Payload: same as armament air-to-air or air-to-ground loadouts; with or without two external wing fuel tanks.

Speed: Mach two class with supercruise capability

Range: more than 1,850 miles ferry range with two external wing fuel tanks (1,600 nautical miles)

Ceiling: above 50,000 feet (15 kilometers)

Armament: one M61A2 20-millimeter cannon with 480 rounds,

internal side weapon bays carriage of two AIM-9 infrared (heat seeking) air-to-air missiles

and internal main weapon bays carriage of six AIM-120 radar-guided air-to-air missiles (air-to-air loadout)

or two 1,000-pound GBU-32 JDAMs and two AIM-120 radar-guided air-to-air missiles (air-to-ground loadout)

Crew: one

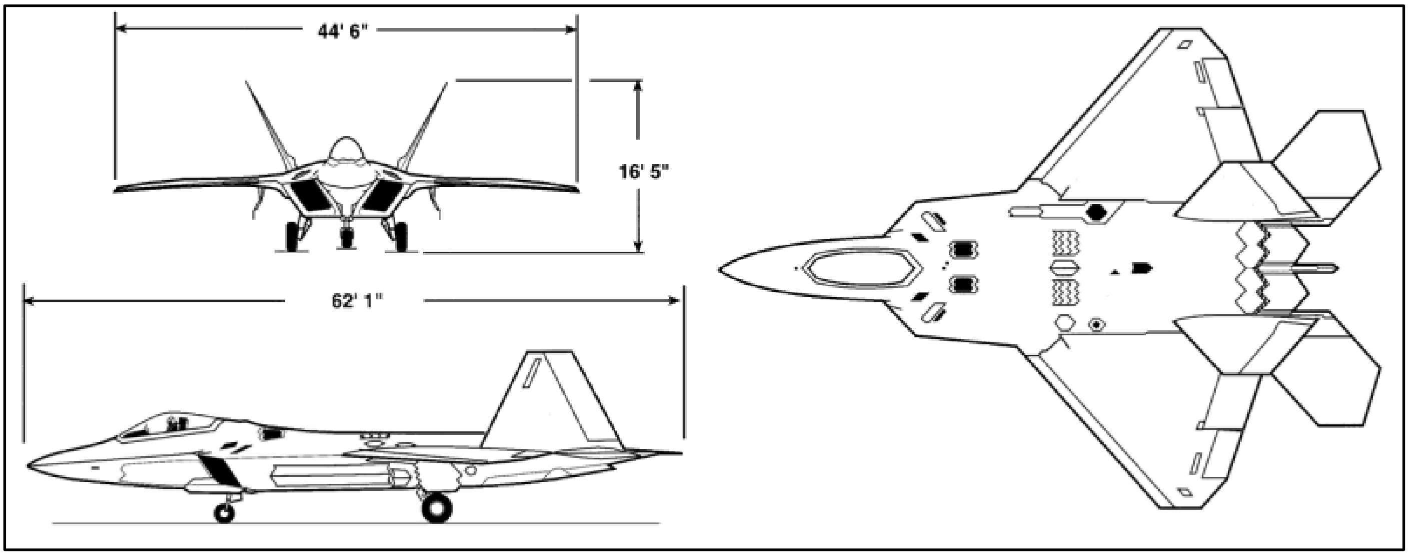
Unit cost: $143 million

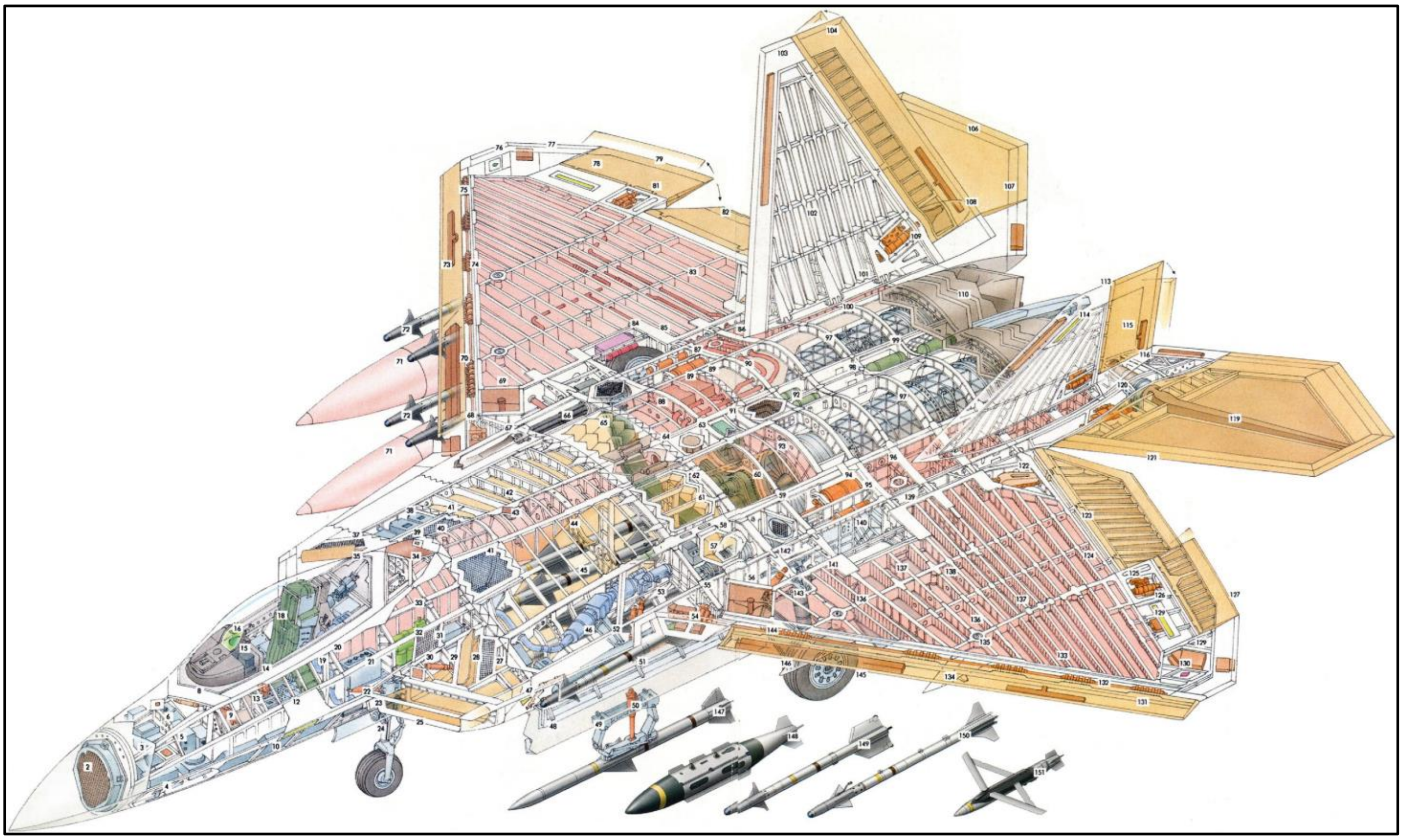
Initial operating capability: December 2005

Inventory: total force, 183

(Current as of September 2015)

GENERAL DATA





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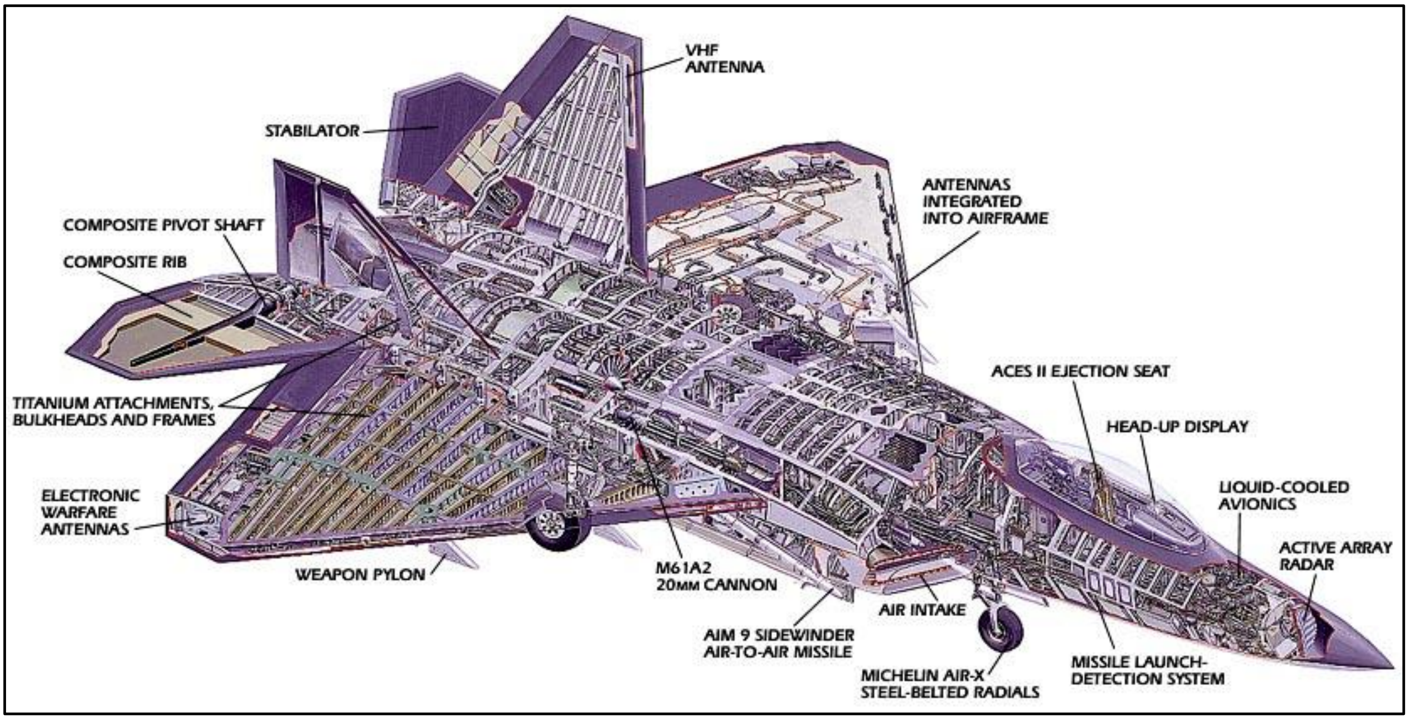
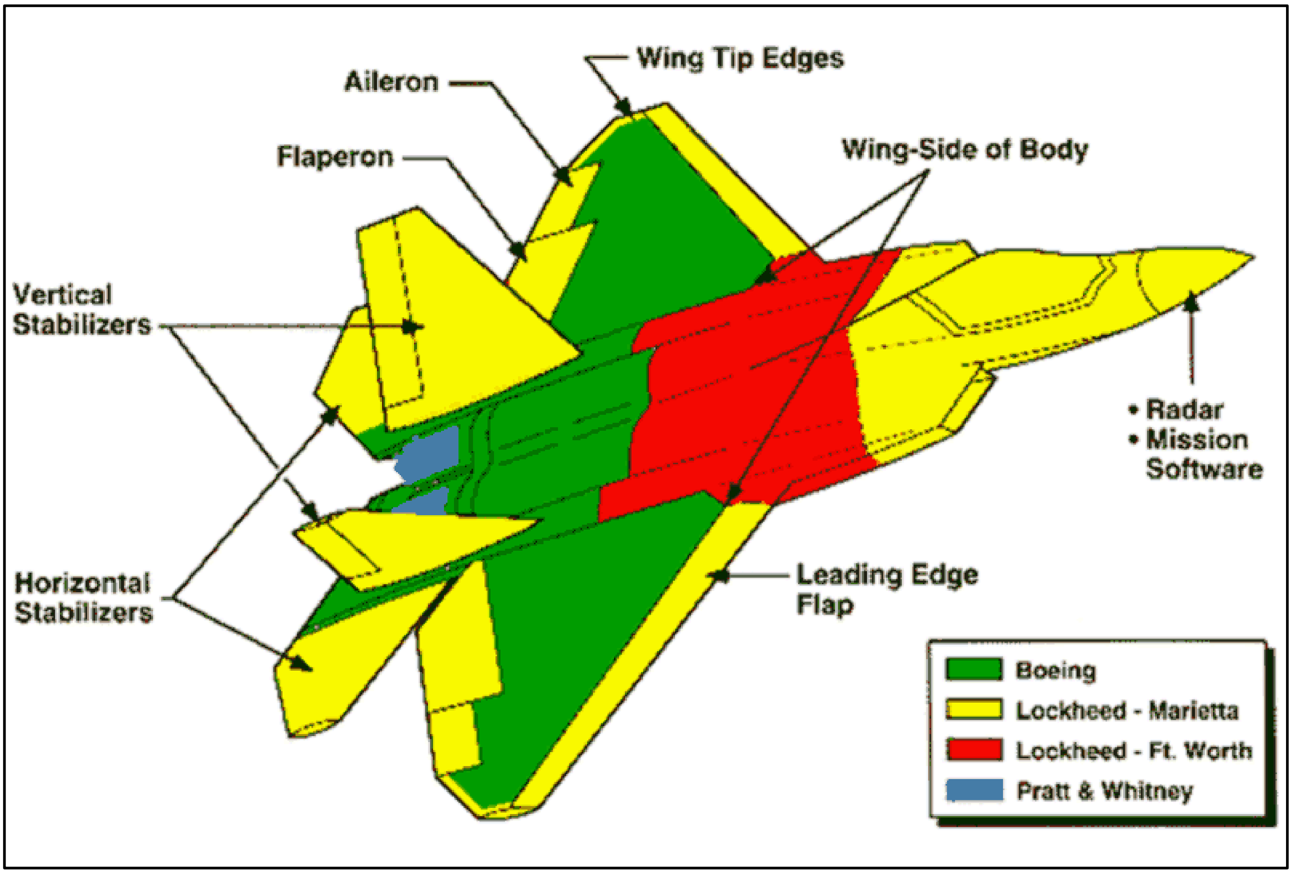


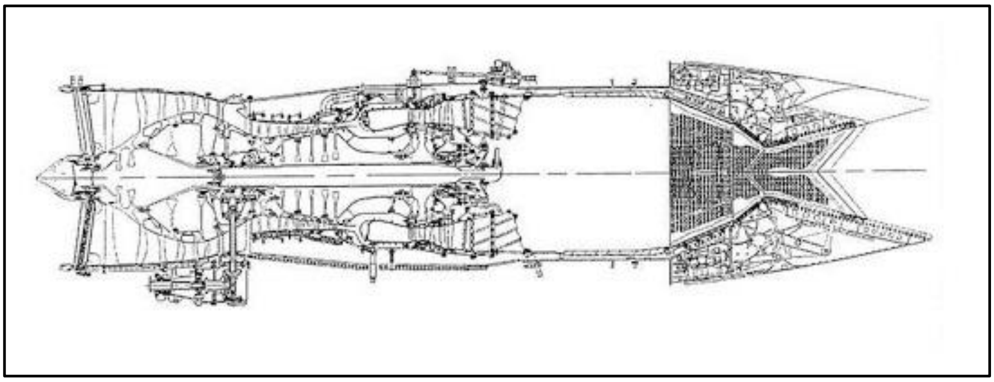


AIRCRAFT COCKPIT

ENGINE F-119-PW-100

This is a low-bypass-ratio, mixed-flow afterburning turbofan being developed for the Air Force’s new F-22 fighter. The engine will enable the F-22 to supercruise (cruise supersonically without afterburning).

The F119 engine develops more than twice the thrust of current engines under supersonic conditions, and more thrust without afterburner than conventional engines with afterburner. The F119 can push the F-22 to supersonic speeds above Mach 1.4 even without the use of afterburner, which gives the fighter a greater operating range and allows for stealthier flight operation.



Each F-22 is powered by two of these 35,000-pound-thrust-class engines. By comparison, the engines powering the Air Force's current F-15 and F-16 fighters have thrust ratings ranging from 23,000 to 29,000 pounds.

The F119’s component designs push the state-of-the-art to give it exceptional performance; it should also provide exceptional reliability.

The F119 is equipped with a 2-D thrust-vectoring nozzle to enhance the F-22’s maneuverability. The engine’s full authority digital engine control is integrated with the aircraft’s flight control system. Further, this will be the first operational engine in which the low- and high-pressure spools rotate in opposite directions. All compressor and fan stages are integrally bladed. The fan’s first-stage blades are also hollow to save weight and enable the engine to respond more rapidly to throttle changes. The F119’s float wall combustor design should reduce the problems that are typically associated with thermal stresses in combustor liners.

Engine maintenance improvements have been designed into the F119 based on lessons learned from previous engines. For example, almost none of the line replaceable units that are external to the engine are stacked on top of one another, fasteners are standardized, and key portions of the external plumbing are flexible hosing. The engine’s main case is split at the fan and at the compressor to permit rapid access to those components. Overall, the engine has 40 percent fewer parts than the F100). P&W has predicted that engine deployments will require 75 percent less airlift and will require 220 pieces of relatively compact ground support equipment, compared with the 400 pieces required by the F100-PW-229. F119 maintenance personnel will use electronic tech manuals, replacing approximately 85,000 pieces of paper that would have been required with traditional manuals. In addition, electronic updating of these manuals will save extensive flightline maintenance manpower, compared with traditional methods. Using the F100-PW-220 as a baseline, P&W expects shop visit rates to be reduced 74 percent, unscheduled engine removal rates to be reduced 33 percent, and maintenance man hours per flight hour to be reduced 63 percent.

Features

▪ Integrally bladed rotors: In most stages, disks and blades are made from a single piece of metal for better performance and less air leakage .

▪ Long chord, shroud less fan blades: Wider, stronger fan blades eliminate the need for the shroud, a ring of metal around most jet engine fans. Both the wider blades and shroudless design contribute to engine efficiency .

▪ Low-aspect, high-stage-load compressor blades: Once again, wider blades offer greater strength and efficiency .

▪ Alloy C high-strength burn-resistant titanium compressor stators: Pratt & Whitney's innovative titanium alloy increases stator durability, allowing the engine to run hotter and faster for greater thrust and efficiency .

▪ Alloy C in augmenter and nozzle: The same heat-resistant titanium alloy protects aft components, permitting greater thrust and durability .

▪ Float wall combustor: Thermally isolated panels of oxidation-resistant high cobalt material make the combustion chamber more durable, which helps reduce scheduled maintenance .

▪ Fourth-generation full-authority digital electronic engine control (FADEC): Dual-redundant digital engine controls - two units per engine, two computers per unit - ensure unmatched reliability in engine control systems. The same experience that introduced full-authority digital control to fighter engines works with the aircraft system to make engine and aircraft function as a single flight unit .

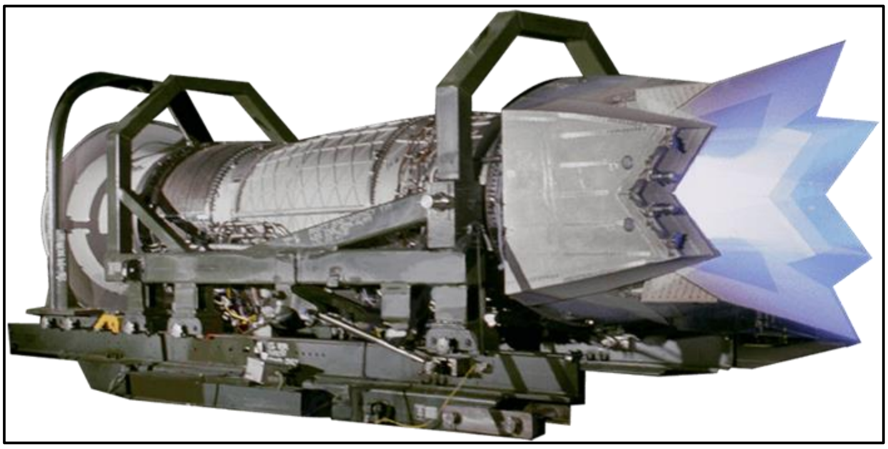
▪ No visible smoke: Reduces the possibility of an enemy visually detecting the F-22 .

▪ Improved Supportability: All components, harnesses, and plumbing are located on the bottom of the engine for easy access, all line replaceable units (LRUs) are located one deep (units are not located on top of one another), and each LRU can be removed with just one of the six standard tools required for engine maintenance.

F119/F-22 Engine Nozzle

The F119 engine nozzle for the F-22 is the world's first full production vectoring nozzle, fully integrated into the aircraft/engine combination as original equipment.

The two-dimensional nozzle vectors thrust 20 degrees up and down for improved aircraft agility. This vectoring increases the roll rate of the aircraft by 50 percent and has features that contribute to the aircraft stealth requirements



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Heat-resistant components give the nozzles the durability needed to vector thrust, even in afterburner conditions.

With precision digital controls, the nozzles work like another aircraft flight control surface. Thrust vectoring is an integrated part of the F-22's flight control system, which allows for seamless integration of all components working in response to pilot commands.

The nozzle is manufactured at Pratt & Whitney's West Palm Beach facility, home to the company's military engine design and prototype construction.

Airframe-Mounted Accessory Drive

Built by Boeing, the F-22 Airframe Mounted Accessory Drive (AMAD) transfers shaft power from the Air Turbine Starter System (ATSS) to the Fl 19 engines for engine starts, and from the engines to a generator and hydraulic pumps for the electrical and hydraulic systems. The AMAD transmits power required by the high-performance F-22 throughout the flight envelope and incorporates a highly reliable lubrication system that services the AMAD-mounted generator and ATSS as well as gearbox components.

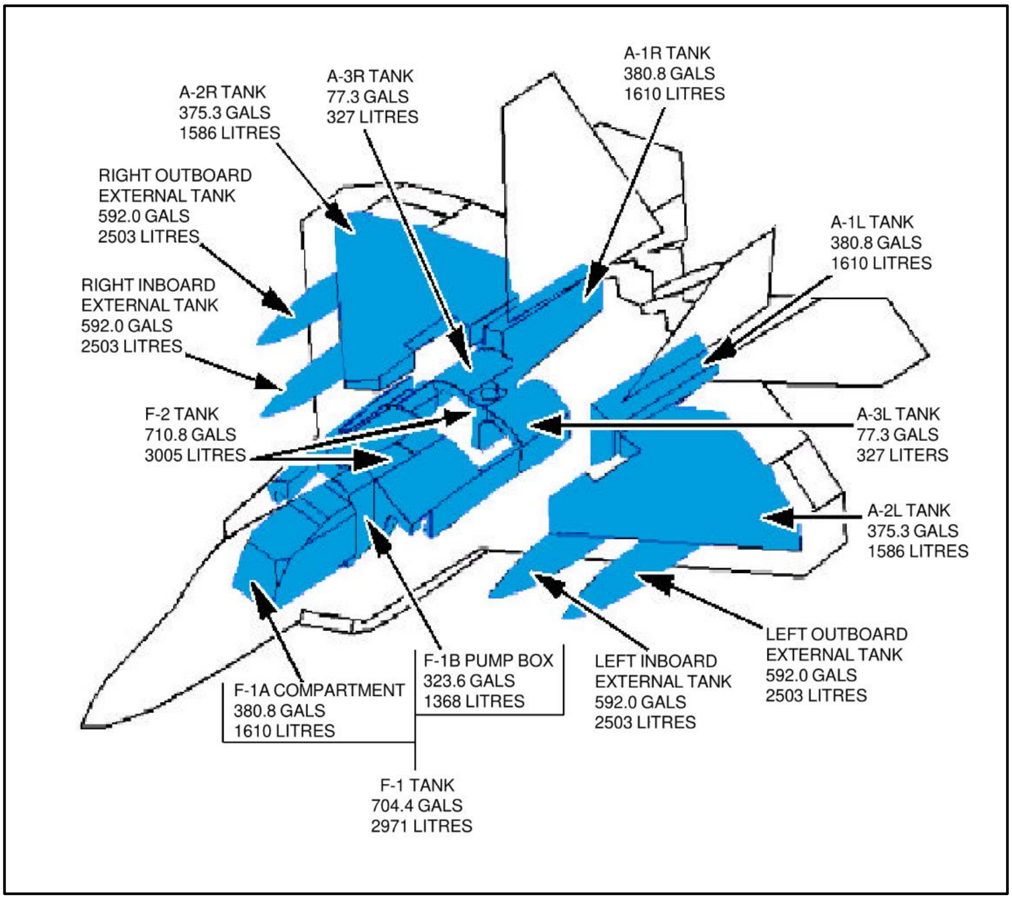
Auxiliary Power Generation System

The F-22 is equipped with a hybrid APU (auxiliary power unit) made by Allied Signal for Boeing. Called an APGS (auxiliary power generation system), it is started by bursts of compressed air. This permits it to start far more quickly than ordinary APUs that have a typical jet engine startup procedure (because they are small turbine engines) and it permits the APGS to start and run briefly at high altitudes where the air would be too thin for a normal APU to start.

APUs are designed to provide power for ground starts and A/C operation independent of ground power, and to provide a power backup source in flight. The APGS can be used to ground start the F-22 but its main emphasis is fast starting backup power for in-flight emergencies. The compressed air and jet fuel fast start looks and sounds a lot like the old propellant cartridge based Coffman “shotgun starter” systems used on WW II era piston aircraft, but the APGS is a true gas turbine engine APU that packs a lot of power output (450 HP) into a pretty small package (220 pounds) and unlike a typical APU, it can be producing that power in 5 seconds and start at high altitude if need be.

The Allied Signal G-250 APU that forms the core of the APGS system is regarded as being one of the most compact and highest power density APUs in the industry. Incidentally, if the two stored compressed air charges fail to start the APGS, the compressed air can be restored by tapping hydraulic pressure bleed-down from the F22’s hydraulic system which might be good for two attempts if, in the absence of external hydraulic power, the hydraulic pressure was full. And if *that* fails, there’s actually a hand pump in the cockpit that can pump up the system. The physical effort required to pump up the system manually for one restart attempt has been compared by pilots to doing 150 pushups, but it would permit the startup of the F-22 even if every stored energy source, with the exception of jet fuel, on the aircraft were exhausted.

FUEL SYSTEM



There are eight fuel tanks on the F-22, including one (designated F-1) in the forward fuselage behind the pilot's ejection seat. The others are located in the fuselage and the wings. The F-22 runs on JP-8, a naphthalene-based fuel with a relatively high flash point.

The F-22 has single-point ground fueling, and it can be refueled without the need for ground power. It also has a Xar-built air refueling receptacle on the top side of the aircraft in the mid fuselage directly behind the cockpit. It is covered by two butterfly doors that have integral low-voltage lights to aid in night refueling.

The F-22 also has an On-Board Inert Gas Generation System (OBIGGS) that inverts the fuel tanks as the fuel is depleted. Fuel in itself is not as explosive as the fumes are. By filling the tanks with inert nitrogen as the fuel is used, the fumes are suppressed, and the chance of explosion, such would occur if the fuel tanks were hit by gunfire, is nearly eliminated.

NOTE: All quantities in US gallons and liters.

NOTE:

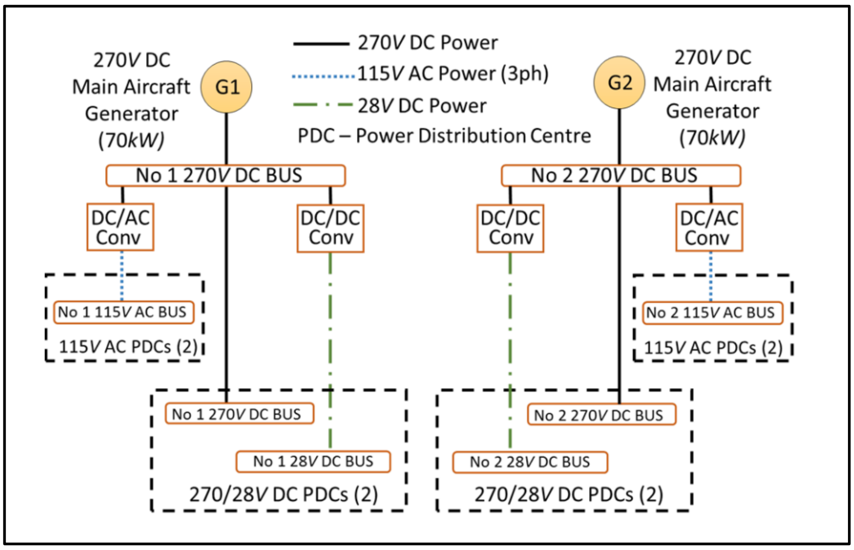
Total fuel: 5,450 gallons, 23,043 liters

Fuel weight: 36,515 lbs.

Fuel type: JP-8.

ELECTRICAL, HYDRAULIC, AND ARRESTING SYSTEMS

The F-22 using as many switched reluctance (SR) generators. Although the electric power is generated at 270Vdc, this aircraft is fitted with electric loads requiring 115Vac and 28Vdc, which are supplied through PECs. Figure bellow, shows the F-22 power generation and distribution systems.



A similar architecture has been also implemented on the Lockheed Martin F-35 (i.e. single engine combat aircraft), that was launched in 2015. For redundancy purposes, an 80kW double channel SR generator is adopted.

The F-22 uses a Smiths Industries 270-volt, direct current (DC) electrical system. It uses two 65 kilowatt generators. The hydraulic system includes four 72 gallon-per-minute pumps and two independent 4,000 psi systems.

The F-22 has an arresting hook in an enclosed fairing between the engines on the underside of the aircraft. This hook is deployed in an emergency to stop the aircraft by means of hooking on to a wire strung out across the end of a runway. These barrier engagements work very similar to the arresting gear of an aircraft carrier.

While the F-22 has an arresting hook, it cannot land on an aircraft carrier, as the F-22 does not have the heavier structure necessary to withstand the stresses of a carrier landing. The shape of the arresting hook is not compatible with low observable design, and that is why the fairing and doors are required.

Landing Gear

The F-22 utilizes tricycle landing gear, with the standard two main gears (each with a single tire) and a single-wheel, steerable nose landing gear assembly. The nose gear retracts forward, and main gear retracts outward.

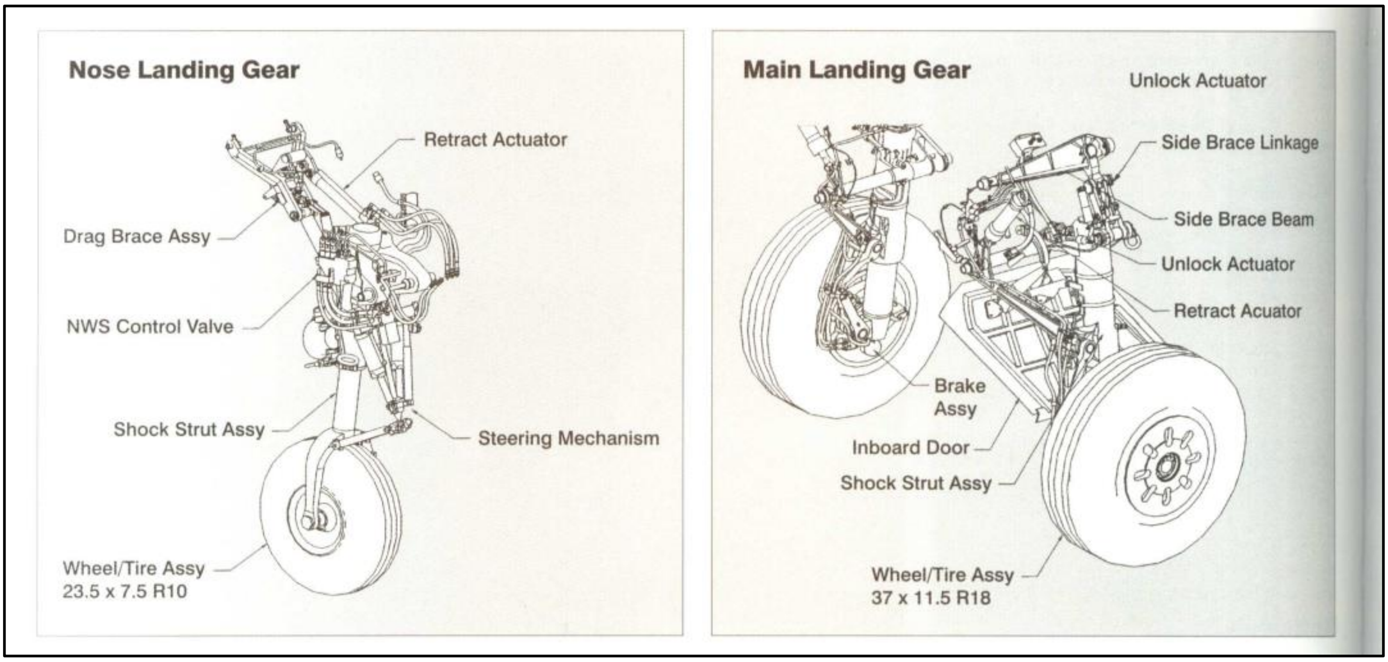
The landing gear assemblies utilize AirMet 100, which provides greater strength and corrosion protection and are made by Menasco. The main gear uses a dual-piston design and are sized not to withstand a collapsed gear or flat tire landing.

The aircraft's AlliedSignal-made carbon brakes are always in anti-skid mode, which means the pilot has one less thing to remember to activate. The pilot applies pressure on the brakes by using the rudder pedals, but only after the F-22's weight-on-wheels sensor engages upon landing.

The nosewheel is a direct drive system, that is hydraulic force is applied to the nosewheel pivot to turn it. The nose gear is mechanically driven to align itself correctly before retraction.

As a safety precaution, the nosewheel clamshell doors and the lower inboard landing gear doors are physically linked to the landing gear itself. If an emergency blowdown is required, the doors will open when the gear comes down. Also, the gear down and locked indicators in the cockpit are battery operated, so if all other systems malfunction, the pilot still has a way of knowing whether his landing gear is down.

The tires on the F-22 are Michelin Air-X steel belted radials. Goodyear Bias-ply tires were also qualified for the aircraft.



Integrated Vehicle Subsystem Controller (IVSC)

The Integrated Vehicle Subsystem Controller (IVSC) is the system responsible for aircraft integration, control and diagnostics.

Environmental Control System

The F-22 uses a totally integrated environmental control system (ECS) that provides thermal conditioning throughout the flight envelope for the pilot and the avionics.

The five basic safety critical functions the ECS must take care of include: avionics cooling; adequate air to the pilot; canopy defog; cockpit pressurization; and fire protection.

Air Cycle System

The air cycle system takes bleed air from engines (which comes in to the system at between 1,200-to-2,000 degrees Fahrenheit) and cools it down in the Primary Heat Exchanger (PHX) to approximately 400 degrees. From the heat exchanger, the air is fed into the air cycle refrigeration package (ACRP). The air must be dry, so the system also includes water extractors.

The air, when it comes out of the ACRP, is now chilled to approximately 50 degrees Fahrenheit. The flight-critical equipment, the systems that are for keeping the aircraft -flying, are cooled by this air. This air is also fed into the Normal air-Garrett-built On-Board Oxygen Generating System (OBOGS) to provide breathable oxygen to the pilot, to operate the Breathing Regulator/Anti-G (BRAG) valve on the pilot's ensemble, to provide canopy defogging, and cockpit pressurization.

Liquid Cooling System

Unlike other fighter aircraft, the F-22 uses liquid cooling, rather than air cooling for the mission avionics. The F-22 is breaking ground in liquid cooling and the environment in which it works. Resistance to high temperature and durability were the driving factors in the liquid cooling design. AlliedSignal is the primary supplier of the liquid cooling equipment.

The closed-loop liquid cooling system is divided into two loops, one forward and one aft. These systems use brushless, DC current motor pumps that are connected for redundancy. Polyalphaolefin (PAO) is the medium used in the liquid cooling system.

The forward loop is for cooling the Mission Critical Avionics and keep them at a comfortable (for them) 68 degrees F. The PAO passes through the Vapor Cycle System and a filter and is routed to the Avionics and then out to the wings to cool the embedded sensors.

From there, the now-warm PAO coolant enters the aft loop, which allows it to pass by the air cycle machine, which cools that system by receiving transferred heat. The PAO then is routed to the fuel tanks, where the heat is dumped. No coolant gets mixed with the fuel however, as this is a closed-loop cooling system. The fuel in the tank is only used as a heat sink.

Thermal Management System (TMS)

The Thermal Management System (TMS) is used to keep the fuel cool. The Air-Cooled Fuel Cooler (ACFC) takes air from the boundary layer diverter between the inlet and the aircraft's forward fuselage. Hot fuel passes through the heat exchanger and is cooled. Greatly simplified, this is essentially blowing on hot soup to cool it down enough to eat it.

Fire Protection

Fire protection is provided for the aircraft's engine bays, the Auxiliary Power Unit (APU), and for dry bays, such as the landing gear wells, the side-of-body cavities, the Linear Link less Ammunition Handling System (LLAHS), the On-Board Inert Gas Generation System (OBIGGS), left and right ACFCs, and ECS bay.

The aircraft uses infrared and ultraviolet sensor for fire detection and Halon 1301 for fire suppression. The Halon 1301 is the only ozone-depleting chemical on the F-22, and efforts are underway to find a replacement suppressing chemical. Space provisions have already been included for this new agent up to a chemical that requires 2.5 times the volume of the Halon.

F-22 Avionics

- **F-22 Role and Mission**

The F-22 will replace the F-15 as the U.S. Air Force's next generation air superiority fighter. With a first look, first-shoot, first-kill capability it will maintain U.S. air supremacy in air-to-air and air-to-ground roles in the 21st century. It will deploy a wide mix of missiles and stand-off weapons which, under the guidance of the Integrated Avionics System (IAS), will provide the pilot with robust lethality and mission survivability.

- **IAS Hierarchical Functional Design**

Behind this first-look, first-kill capability is the F-22's ability to establish superior situational awareness concerning target detection, location, identification, and lethality. The IAS provides the pilot situational awareness well Beyond Visual Range (BVR). Data fusion from multiple sensors is used to achieve long-range detection, high confidence BVR-Identification (BVRID) and highly accurate target tracking for BVR weapons employment and/or threat avoidance. The IAS directly contributes to increased survivability by providing threat warning and countermeasures against threat systems.

This first-look, first-kill requirement depends on the ability to collect data from multiple onboard sensors, to develop a highly accurate track file on enemy targets, and to do so before the F-22 is detected by enemy sensors. Each target track file is continually and automatically updated without pilot intervention. Targets receive increasingly tighter tracking accuracies as they penetrate a series of tactical engagement boundaries surrounding the F-22 as shown in Figure .1 From outermost inward, these "globes" are called (1) Situation Awareness Initial Track/ID, (2) Engage/Avoid Decision, (3) BVRID Initial AMRAAM Launch, (4) Initial Threat Missile Launch, and (5) Threat Missile Lethal Envelope. The globe boundary concept, inherent in the tactical software design, supports both (1) efficient sensor usage and (2) automated sensor tasking. It provides the pilot adequate time to make tactical decisions (such as engage, avoid, commit weapons, or expend countermeasures) instead of controlling sensors.

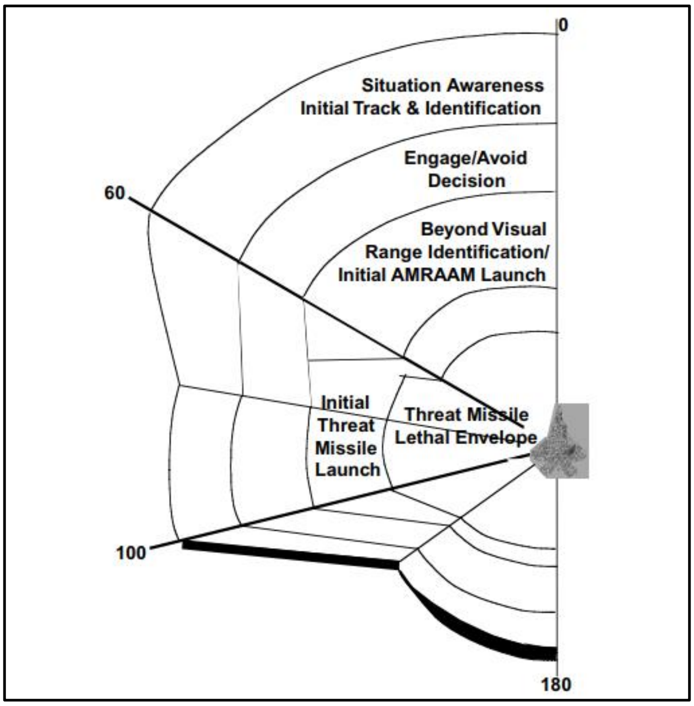


Figure .1

All multisensory information must be fused or correlated into a consistent, valid, integrated track file. This is done automatically by the sensor track fusion algorithms and the “smart” sensor-tasking algorithms which are tailored to support each globe boundary’s requirements. The integrated track file is then presented to the pilot on the integrated offensive, defensive, and area-wide situational awareness tactical displays.

Mission Software (MS/W) serves as the central controller of IAS operations, interfacing to all sensors, processors, pilot controls, and displays. It manages, coordinates, and supports the overall integrated capability to search, detect, track, identify, employ weapons, and expend countermeasures against airborne or ground threats. MS/W accomplishes this through a hierarchical functional tree consisting of three principle levels: the integrating functions level, the decision-aiding functions level, and the mission functions level (see Figure .2).

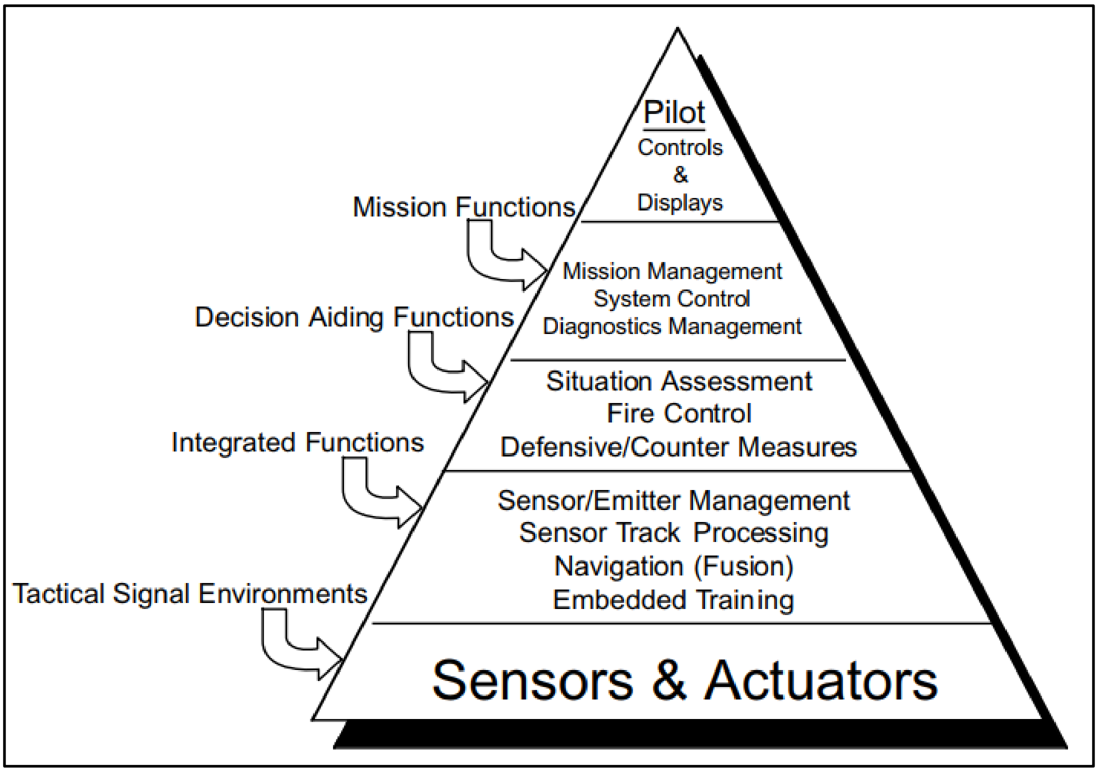


Figure .2

First, situation assessment is done on the target track relative to the pilot’s own ship threat and targeting environment. Consistent and timely information is continuously updated on the overall own ship situation, allowing the pilot to make key decisions to engage or avoid targets of interest. Second, fire control assessment calculates missile launch the envelopes against designated targets and controls launch and post-launch weapon support throughout the engagement. Finally, continuous assessments are made of the F-22’s defensive tactical situation to assist the pilot in managing defensive countermeasures. These decision-aiding functions provide the pilot consistent and reliable tactical information to support war fighting decisions without the need to control individual sensors or correlate target track information in the heat of battle. At the top level of the mission software hierarchy, mission functions control all avionics hardware and software and status the health of the IAS. These functions handle mission planning and system reconfiguration should hardware failures occur. Being at the top level of control for the IAS, the mission functions are the primary interface between the IAS and the pilot, who interacts with the IAS via Controls and Displays.

- **Integrated Avionics Architecture**

The F-22 avionics architecture is characterized as a common, modular, highly integrated system. These characteristics result in increased performance, reliability, availability, and affordability. It is the first fully integrated avionics system in U.S. military aircraft, supplanting the federated architectures of the past.

The F-22 does not employ traditional, single-function "black boxes" to perform basic avionics functions such as navigation, communications, threat warning, and fire control. Instead, these functions are implemented with common, programmable modules which are software-configured to process many different functions. This architecture not only allows increased mission effectiveness, but also allows significant flexibility in basic avionics design through: robust, fault-tolerant reconfiguration capabilities, higher reliability, easier supportability, higher availability, lower weight, extended growth capability, and lower acquisition and life cycle cost.

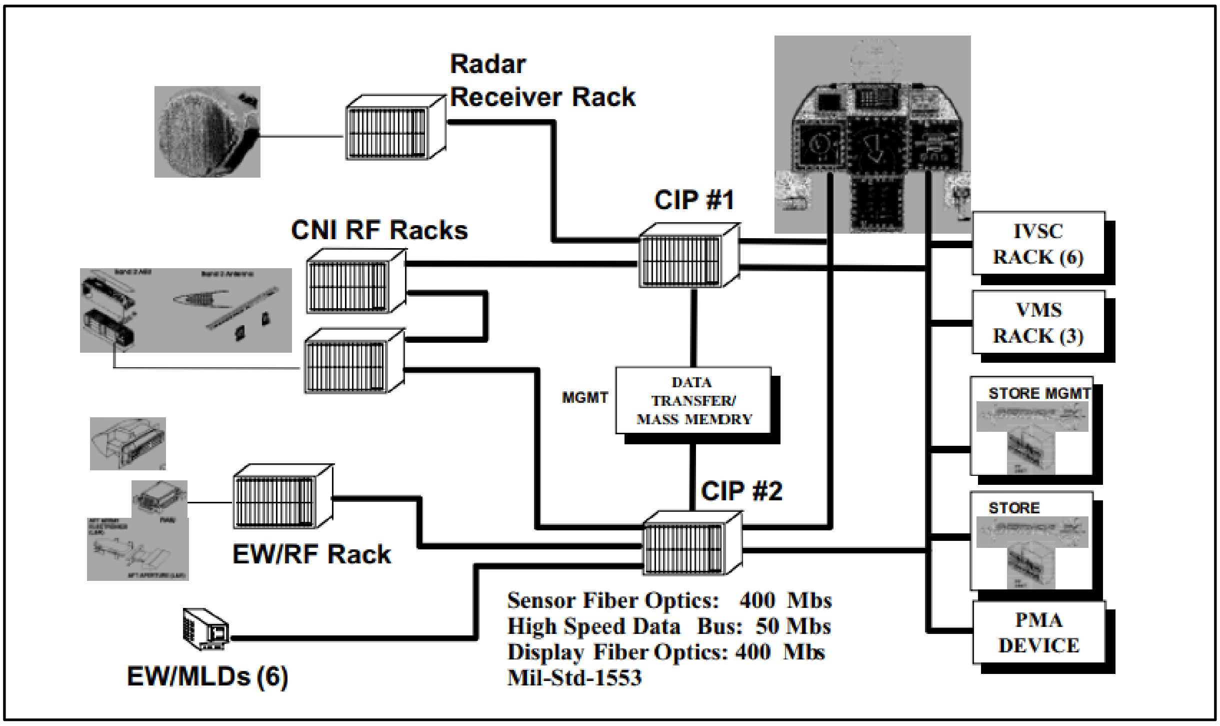


Figure .3

The IAS's system design features an interconnected set of high-speed, modular subsystems which use Standard Electronics Module Size E (SEM-E) modules. The core processing architecture is a distributed, parallel processing design that employs common, general purpose digital processor modules to perform all avionics functions. A common operating system is distributed on all core processing SEM-E modules to provide maximum flexibility and to support additional modules for new applications or for technology insertion. IAS software, written mostly in Ada, is being built and integrated under a multiblock process to reduce development and integration risk. Each software block provides an increase in F-22 functional capability.

Block 0 provides basic flight systems for initial flight qualification testing. Block 1 provides single-sensor threads of the IAS system. Block 2 provides multiple-sensor threads. Finally, Block 3 provides full F-22 functionality.

The IAS is partitioned into several interactive systems of antennas, sensors, processors, pilot interfaces, and high-speed interconnects (see Figure .3). The primary subsystems are Core Processing (consisting of two Common Integrated Processors, or CIPs), Electronic Warfare (EW), Radar, Communications/Navigation/Identification (CNI), Inertial Reference System (IRS), Stores Management System (SMS), and Controls and Displays (C&D).

By using low observable (LO) antennas and arrays, the sensors receive, measure, and extract both radio frequency (RF) and non-RF signals. Raw data are preprocessed, digitized, and routed to the CIPs via 400 Mbps fiber optic buses. Using digital and signal processor modules, the CIPs process raw data into sensor-level track reports which in turn are processed by sensor-track fusion algorithms residing on other digital and signal processor modules. Sensor-level reports are then combined into a single integrated track file and sent to the cockpit displays via fiber optic lines. The two CIPs are connected to one another via a 50 Mbps fiber optic High-Speed Data Bus (HSDB). Finally, the avionics architecture also features Mil-Std-1553 buses to interconnect to other aircraft systems.

- **Common Integrated Processor (CIP)**

The Common Integrated Processor (CIP), developed by Raytheon Systems Company, provides the memory, I/O, data, and signal processing capability required for the IAS. It has an open, expandable architecture supporting radar, EW, CNI, mission software and Controls, and Displays processing requirements. The F-22 core processing system uses two installed CIPs (with growth space for a third). Each CIP contains 66 SEM-E slots in two rows. Due to the wide utilization of common modules, only 13 unique CIP module types are utilized. To provide for additional growth, each CIP is about two-thirds populated.

- **CIP LRM Types**

The Dual Data Processing Element (DDPE) is the backbone of the CIP’s digital processing capability. Each DDPE has two independent, 32-bit, 25-MHz Intel 80960 (i960®) microprocessors on each side of a SEME module. Each side of the DDPE operates as a general-purpose computer executing Ada code. The DDPE module is Liquid Flow-Through (LFT) cooled, weighs 1.2 lb and is connected to the CIP backplane by a standard connector which uses 332 electrical pins and 4 fiber optic and two coolant connections. The IAS employs13 DDPEs to support radar, EW, CNI, and MS/W functions. Currently, product improvement programs plan to replace the Intel i960® with a state-of-art processor in 2005. The Dual Signal Processing Element (DSPE) is a generic signal processor that executes mathematically intensive functions such as the state matrix multiplications used in Kalman filter propagation and Fast Fourier Transform (FFT) algorithms used in radar signal processing. Each DSPE uses two independent pipelines to perform high bandwidth signal processing. Each individual SPE can execute a fixed-point instruction within one 25 MHz clock cycle and can operate at up to 18 operations per instruction. The DSPE consumes nearly 80 W of power, resides on a Liquid Flow-Through (LFT) cooled SEM-E module, and is connected to the CIP backplane by a standard connector (332 electrical pins and 4 fiber optic and two coolant connections). The IAS employs 9 DSPEs to support radar, EW, and MS/W functions.

The DPE/Mil-Std-1553 I/O Port (DPE/1553) features a Data Processing Element (DPE) on side A and a Mil-Std-1553 I/O interface port on side B. The Global Bulk Memory (GBM) is a memory complex available to modules residing on the CIP backplane. Each GBM features 12 Mbytes of available bulk memory, consumes about 60 W of power, resides on a Liquid Flow-Through Cooled (LFT) SEM-E module, and is connected to the CIP backplane by a standard 360-pin connector.

The Gateway module (GWY) provides a bi-directional communications path between Parallel Interface (PI) bus segments within a CIP. The GWY module also provides communications between two CIPs via the fiber-optic HSDB.

The Low Latency Signal Processor (LLSP) uses a Texas Instruments SMJ320C31 (C-31) processor to provide the interface between the CNI front end and the CIP backplane via a fiber optic line. It performs low latency signal processing for the CNI system.

The Graphics Processor/Video Interface (GPVI) features a fiberoptic interface to the cockpit MultiFunction Displays (MFDs). One side of the GPVI module is a standard DPE, the other side performs graphics processing and I/O, generating up to 30 frames per second and supporting up to two MFD displays simultaneously.

The Non-RF Signal Processor (NRSP) is an Infra-Red (IR) signal processor that includes a pipeline processing structure optimized to perform IR impulse-response high-pass filtering, two-dimensional windowing for spatial filtering, data normalization, and thresholding for IR sensors. One NRSP can support up to three Missile Launch Detectors (MLDs).

The Data Encryption/Decryption Device (KOV-5) is an integrated Communications Security (COMSEC) unit housed in a SEM-E module. It can perform any 2 of 17 different COMSEC, data encryption, data decryption, cryptographic functions. The KOV-5 supports encryption/decryption functions of voice, text, data, and communications links. The encryption/decryption engine is National Security Agency (NSA) certified. The IAS employs 5 KOV-5 modules to support various crypto functions.© 2001 by CRC Press LLC Voltage Regulator modules (VR) receive 270 VDC aircraft power and output 5 VDC and ————————————5.2 VDC to the CIP backplane.

The User Console Interface (UCIF) is a two-sided LRM featuring a DPE on side A and UCIF hardware on side B. The UCIF is a nonproduction module which supports instrumentation and access to the CIP I/O backplanes during integration and test activities.

The Fiber Optic Transmit/Receive Network Interface module (FNIU) provides low latency, high bandwidth communications between a CIP processing cluster and the sensors. The FNIU supports bi-directional communications to the Parallel Interface bus or directly into the GBMs at the rate of 400 Mbps to the GBMs.

- **CIP Buses**

The CIPs interconnecting communications paths consist of both internal and external buses. These communications paths are depicted in Figure .4.

The Parallel Interconnect (PI) Bus is a 32-bit, error-correcting, parallel, digital data bus that facilitates data and control exchange between modules within the CIP at a peak rate of 50 Mbytes per second. Each CIP contains three PI bus segments connected in a “triangle” by three Gateway modules. Each segment supports 22 modules. To optimize communications, subsystem processing (such as radar or EW) is usually clustered into modules within the same PI bus segment.

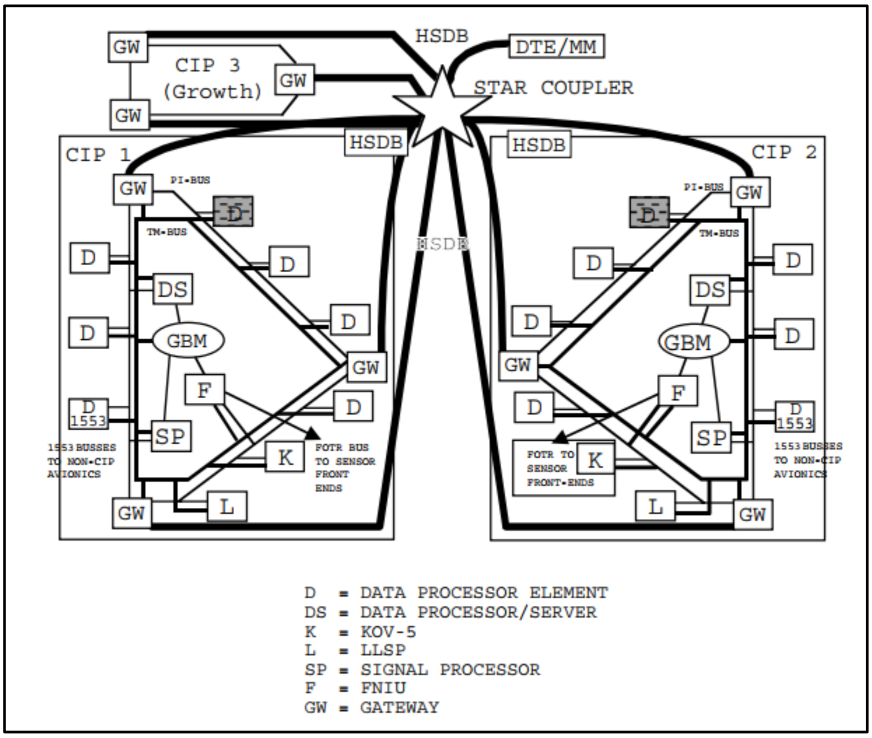


Figure .4

The Test and Maintenance (TM) Bus, like the PI bus, contains three segments connected by the Gateway modules. The TM bus is a 6.25 MHz bus primarily used for diagnostic monitoring of each module’s health without interfering with either the PI bus or the internal processing within each module. The TM bus also supports fault reporting, isolation, and system reconfiguration. Via the TM bus, spare modules, typically DDPEs, can be commanded to reconfigure to maintain functionality lost due to a failed module. The High-Speed Data Bus (HSDB) is a fiberoptic bus which provides 50 Mbps data transfer rate between the CIPs and the Data Transfer Cartridge or Mass Memory unit.

The Fiber Optic Transmit-Receive (FOTR) Bus supports low latency, high bandwidth (400 Mbps) data communications between the CIP and the sensors.

The Mil-Std 1553 Bus provides I/O communications to standard interfaces such as weapons and aircraft flight control systems.

- **CIP Software**

The CIP software has a layered architecture which provides a common set of utilities for the CIP application software and handles data transfer integrity and security. It consists of two principle software packages, the Avionics Operating System (AOS) and the Avionics System Manager (ASM). The layered architecture with AOS and ASM as an intermediary between the hardware and applications is shown in Figure .5.

The AOS provides operating system services to embedded avionics applications running on the CIP. The AOS resides and executes on each DPE-based module. It supports a multilevel secure execution environment in which multiple application programs may run and process concurrently at different security levels. This is enforced by the AOS Privilege Control Tables (PCTs) which require that data at a given security level not be processed by a program at a lower security level. Communications between application programs is restricted to those that are allowed by the PCT. The AOS provides four basic capabilities within the CIP: control of Ada application programs, control of the I/O interfaces to the DPE modules, debug capability, and PCT security access authorization.

The Avionics System Manager (ASM) is the central resource manager for the CIP, featuring three basic services: (1) system control, (2) module management, and (3) file services. It assigns global resources, such as memory and processing elements, to the application programs. ASM is also responsible for maintaining CIP health status, performing reconfiguration around failed modules, providing file management functions between applications and the DTC/MM, providing GBM file allocation services, and coordinating startup and shutdown of CIP functions.

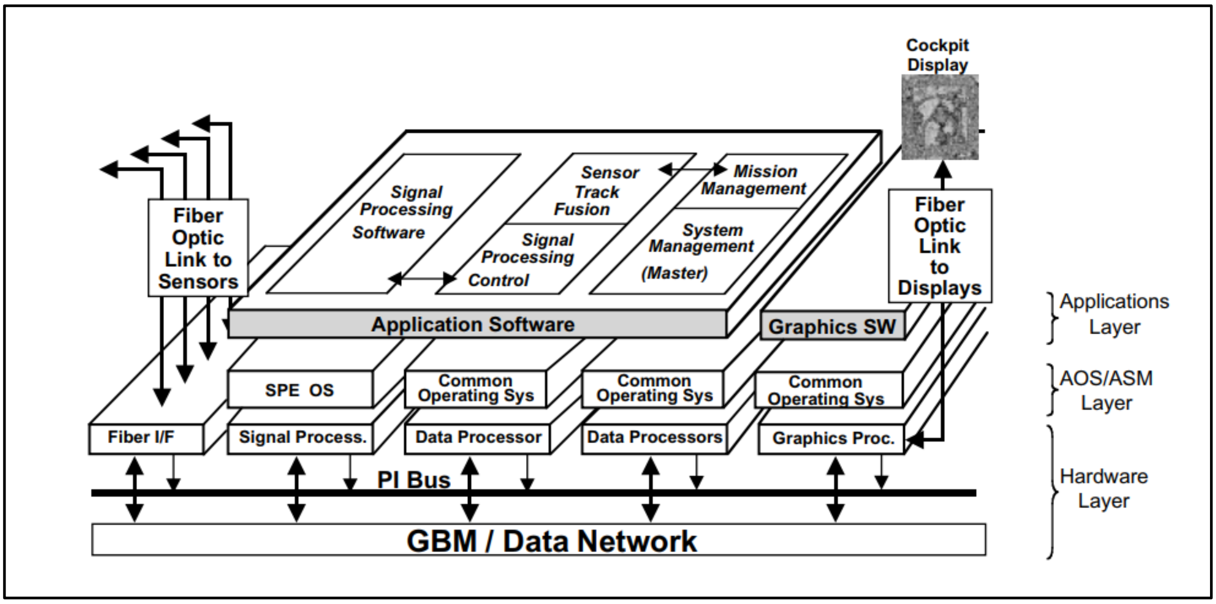


Figure .5

CIP Signal Flow

The sensor front-ends preprocess RF and non-RF data, converting raw sensor data into blocks of digitized data that are sent, via 400 Mbps FOTR lines, to the FNIUs. The FNIU modules route the raw digitized data to the GBM modules in real time for temporary buffering and storage. The data are then extracted over the Data Networks (DN) by either the DPE or the SPE modules for further processing and refinement.

To reduce PI bus overloading, the GBM also supports intermediate buffering of data between the processors or between processing tasks on a processor. Processed data are then sent out on the PI bus to be further processed by other higher-order functions on other DPEs and SPEs. Once these DPEs and SPEs complete the higher-order functional tasks, the data are again sent on the PI bus to the GPVI modules, transferred to graphic format, and sent via FOTR lines to the cockpit displays.

This signal and data flow approach reduces bus loading and potential throughput problems. Sensor data are sent nearly real-time via FOTRs to GBMs and on through the “backdoors” via the DN bus to the processors. Only after the processors have completed their operational tasks on sensor data is the PI bus involved.

APG-77 Radar

The F-22’s APG-77 radar is an advanced multimode, multitarget interleaved search/track, all-weather, fire control radar. Developed by Northrop Grumman, it incorporates the following design features: Active Electronically Scanned Array (AESA), low observability (LO), electronic counter-countermeasures (ECCM), and low probability of intercept (LPI). These features give the F-22 radar a major leap in combat capability. The main array, mounted in the nose radome, is composed of hundreds of Transmit/Receive (T/R) modules. Beam switching is performed by controlling each T/R module’s phase characteristics,

thus, accomplishing a summed beam pattern of all T/R modules. These T/R modules are designed to operate for over 16,000 hours failure-free. The T/R module application features an extremely fault tolerant design, where the system can lose numerous T/R modules before minimum required performance is affected. The system can continue to effectively operate with loss of even more T/R modules, however at reduced transmit power levels.

- **Communication, Navigation, Identification (CNI)**

The F-22 CNI subsystem performs standard military communications, navigation, and identification functions. Developed by Lockheed-Martin Tactical Aircraft Systems (LMTAS) and TRW Military Electronics and Avionics Division, its primary functions consist of UHF/VHF secure and clear voice, Have Quick IIA, GPS, TACAN, ILS, MK XII Identification-Friend-or-Foe (IFF), JTIDS receive, and the Intra-Flight Data Link (IFDL). Like the CIP, the CNI architecture is also highly integrated and uses common SEM-E modules with diverse CNI functions sharing common hardware components. This integrated approach requires time-sharing and multiplexing of assets or system reconfiguration between mission phases (landing vs. engagement operations, for example).

1 .Low observable apertures and arrays;

2 .External Aperture Electronics (EAE) units (located near the arrays for low noise amplification),

3 .RF filtering and switching; the Antenna Interface Unit (AIU) (to interface all RF lines to/from the

RF/Preprocessor racks;)

4 .RF/Preprocessor Integrated Avionics Racks (IARs) which house SEM-E modules for RF transmission, reception, and processing;

5 .Interphone/Intercom subsystem for voice communication and synthesis; and

6. CNI digital processing LLSP and KOV-5 LRMs resident on the CIP

The RF/Preprocessor IARs consist of a pair of three-bay, SEM-E modular, liquid-cooled racks and the LRMs which perform CNI RF processing. The two IARs were originally fully redundant and identical, but to save weight each IAR is now more specialized. However, aircraft mission-critical functions such© 2001 by CRC Press LLC as UHF/VHF communications, ILS, TACAN navigation, or MK XII IFF transponder can be supported from either rack.

The CNI SEM-E modules which comprise the CNI IAR racks are as follows:

1 .Eight L-Band tunable receivers with selectable IF bandwidths to support TACAN, MK-XII transponder, Mode S ATC, IFDL, and JTIDS receive.

2 .Two 5-channel tunable L-Band receivers with common local oscillators used to support direction

finding.

3 .One L-Band transponder Carrier Generator/Power Amplifier (CG/PA) used to support low duty cycle pulse modulation of RF transmit power for MK XII IFF transponder and TACAN functions.

4 .One Interrogator CG/PA used to provide low duty cycle RF pulse modulation for MK XII interrogate. This CG/PA is used as a backup for MK XII transponder and TACAN in the event of an L-Band Transponder CG/PA failure.

5 .Four UHF/VHF single-channel tunable receivers which support U/VHF voice communications,

ILS, and growth satellite communications.

6 .Two UHF/VHF CG/PAs for supporting U/VHF transmit.

7 .One GPS Receiver Processor to provide a complete decoded GPS navigation solution.

8 .Two RF/FE controller LRMs which support all RF asset control, multiplexing, timing references, and reconfiguration.

9 .Four Pulse Narrowband Processor (PNP) LRMs used to support L-Band programmable pulsed signal decoding such as TACAN, MK XII IFF transponder, and interrogate, and Mode SATC. The PNP LRM also supports A/D conversion of the U/VHF communications and ILS navigation.

10 .One Pulse Environment AOA Processor (PEAP) LRM to convert measured pulse phase and magnitude data into a calculated Angle of Arrival (AOA) via algorithms which use real-time calibration data and prestored array characteristics.

11 .Two CNI Bus Coupler LRMs to provide a FOTR bus interface to the FNIU module within the CIP.

12. One IFDL Mod/Synth LRM to provide the waveform generation, signal modulation and demodulation, and relative navigation processing for the F-22-to-F-22 Intra-Flight Data Link system.

Other SEM-E modules are the Air-Combat Maneuvering Instrumentation (ACMI) transceiver which provides ACMI signal modulation and demodulation; the Ovenized crystal oscillator LRM; a 5-volt backup battery LRM used to maintain system crypto keying and clocks with main power off; and various RF and digital power supply LRMs which provide up to seven different voltages required by the CNI system components.

Electronic Warfare (EW)

The EW subsystem provides Radar Warning (RW), Missile Launch Detection (MLD), and chaff and flare countermeasures. RW was developed jointly by Lockheed Martin Missiles and Fire Control, Lockheed Sanders, and LMTAS. It provides airborne and ground-based radar emitter detection, tracking, identification, and location to the mission software system for integrated target tracking. The Missile Launch Detector also provides a passive IR capability to detect, declare, track, and report missile launches to mission software.

The defensive countermeasures function is responsible for timing and deploying chaff and flares. Deployment of countermeasures is programmable for fully automatic, semiautomatic, or manual.

The EW architecture, like the CIP and CNI, is an integrated architecture using common SEM-E modules. The EW subsystem employs resource sharing of common hardware components to perform the simultaneous search, detection, RF and non-RF measurement, signal analysis, direction finding, identification, and tracking of RF and non-RF signals. This integrated approach requires time and resource sharing of these common modules.

The EW subsystem is comprised of seven major components:

1 .Low observable apertures and arrays;

2 .Array Electronics (AEs) units near the arrays for low noise amplification, RF filtering, and switching;

3 .Remote Antenna Interface Unit (RAIU) to interface all RF lines to/from the EW RF racks;

4 .EW RF Integrated Avionics Racks (IARs) which house SEM-E modules for RF, reception, and processing;

5 .Six Missile Launch Detector sensors;

6 .The countermeasures controller and dispenser units to dispense MJU-7 and -10 standard flares, MJU-39 and -40 flares developed specifically for the F-22, and RR-170 and -180 chaff bundles, and

7 .The CIP based DDPE, DSPE, NRSP, and GBM LRMs.

The EW RF IAR consists of a SEM-E modular liquid-cooled rack and the LRMs which perform the EW RF reception and processing. The EW SEM-E modules which comprise the EW RF IAR rack are as follows:

1 .Six Narrow-Band Receiver (NBR) LRMs with selectable IF bandwidths to support signal analysis,

emitter tracking, and emitter direction finding processing.

2 .Six NBR Local Oscillator LRMs to tune the NBRs.

3 .Six Pulse Measurement Units to extract RF characteristics from the NBR for signals analysis.

4 .Four Wide-Band Receiver (WBR) LRMs to support wideband detection and acquisition of emitters in the environment.

5 .Six signal frequency down converter LRMs to convert RF signals into a base frequency band.

6 .Nine power supply LRMs to convert 270 V power to /————————9 , ١٥————————/and /————————5 V.

7 .One WBR asset controller LRM.

8 .One NBR asset controller LRM.

9 .Two RF Delay LRMs to support hand-off of signal analysis for direction finding processing.

10 .One Reference Oscillator LRM for supplying a common local oscillator to the NBR and down converter LRMs.

11 .One CIP Interface (CIPI) module to interface digitized EW information onto the CIP fiber optic FOTR bus.

12 .One Data Converter LRM to reformat digitized RF data into pulse descriptor words for CIP processing.

13 .Three Measurement Control Processor (MCP) LRMs to support timing and synchronization of receiver assets.

14 .One Data Distribution Network (DDN) to provide DF triggers for supporting signal direction finding and angle binning to support pulse de-interleaving.

15 .Two Compressive Receiver (CR) LRMs to support high probability of intercept against high priority signals.

16 .One Array-RAIU Controller Interface (ARCI) to control RF line switching and filtering in the RAIU.

The EW RF IAR racks perform RF to digital conversion and then send the raw digitized information to the FNIU fiber optic interface module in the CIP for RF sorting, signal characteristic measurement, signal identification, and emitter tracking.

- **Stores Management System (SMS)**

The SMS monitors, controls and statuses countermeasures, launchers, weapon bay doors, and the F-22 armament (AIM-9, AIM-120, gun). It also controls emergency jettison of stores. The SMS consists of two rows of SEM-E modules, two AIM-9 power supplies, a gun control unit, and the SMS Controller.

- **Inertial Reference System (IRS)**

Developed by Litton Guidance and Control, the IRS is an advanced laser ring gyro with a common processor with flight controls. It provides position and rate information to the IAS mission software to support target location calculations.

- **Controls and Displays (C&DS)**

Unlike today's generation of fighters, the F-22's tactical displays are not dedicated to providing sensor only information such as radar-only displays. Instead, the F-22 has four active-matrix liquid-crystal Head-Down displays (HDD) and a Head-Up display (HUD) to provide highly integrated information concerning the overall tactical situation. The middle HDD, or Tactical Situation Display (TSD), is an 8 ×8 in. color display that provides the pilot with current situational awareness and enhanced navigational information, including location of airborne friendlies and threats, own ship heading, navigational waypoints, etc. The left 6 × 6 in. color HDD, or Attack Display, provides the pilot with the current offensive tactical situation and is tailored for weapons employment including target selection and offensive and defensive missile engagement ranges. The right 6 × 6 in. color HDD, or Defensive Display, provides the pilot with the current defensive tactical situation and is tailored for assessing threat capability against the F-22 and includes location and identification of airborne and ground-based engagement systems, missile engagement ranges, and countermeasures selection. The lower 6 ×6 in. color HDD provides status of aircraft expendables, stores, engine performance, and external doors status.

- **Avionics Software**

The software that provides the avionics system's full functionality is composed of approximately 1.7 million lines of code. In addition, 90 percent of the software is written inAda, the DoD's common triservice high-order computer language. Exceptions to the Ada requirement are granted only for special processing or maintenance requirements. When the first Raptor made its first flight in September 1997, it carried only 20 percent of the final software load that will be required for the full avionics' suite.

The avionics software is to be integrated in three blocks, each building on the capability of the previous block.

- **Block 1** is primarily radar capability, but Block 1 does contain more than 50 percent of the avionics suite's full-functionality source lines of code or SLOG and provides end-to-end capability for the sensor-to-pilot data flow. The fourth EMD F-22 will be the first raptor to have a full avionics suite, and at this writing, it was scheduled to fly in late 1999.

- **Block 2** is the start of sensor fusion. It adds radio-frequency coordination, reconfiguration, and some electronic warfare functions. Block2 is to be integrated into the F-22 in late 1999

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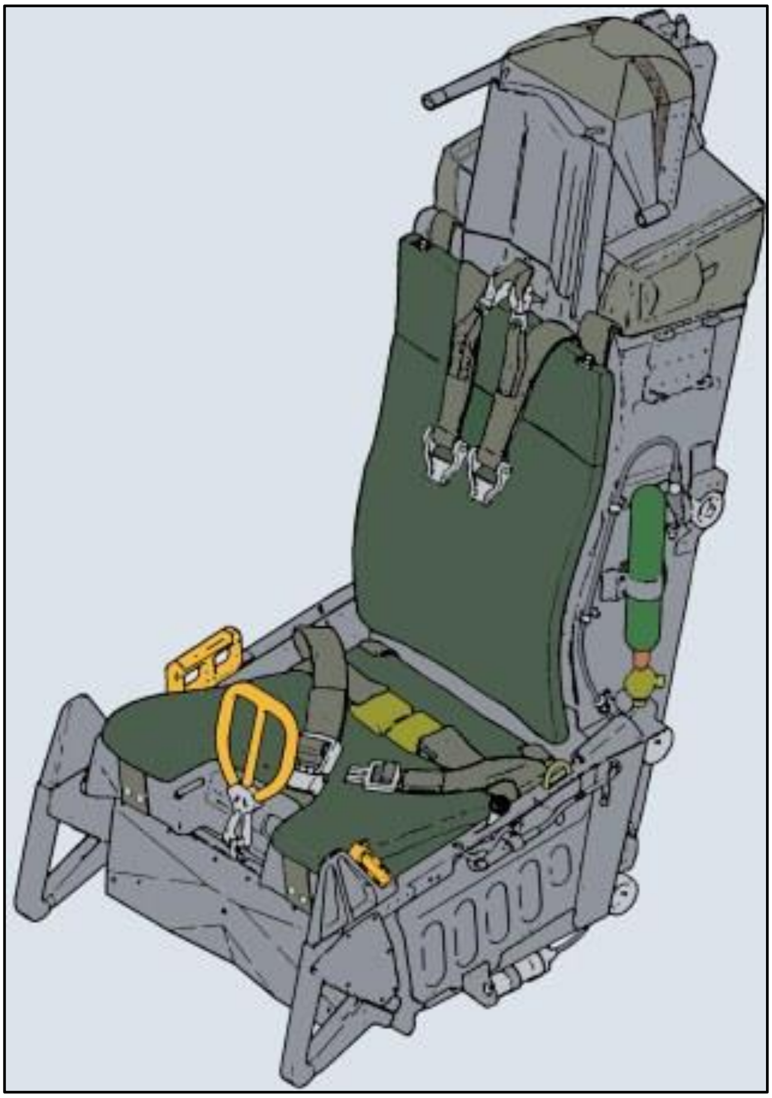
- **Block 3** encompasses full sensor fusion built on electronic warfare and CNI functions. It has an embedded training capability and provides for electronic counter-countermeasures (ECCM). It is scheduled to be integrated into the aircraft in the spring of 2000. Block 3.1, which adds full GBU-32 JDAM launch capability and joint tactical information distribution system (JTIDS) receive-only capability, will be integratedinApril2000.

The proposed Block4 software will be post-EMD. Itis scheduled to be integrated on the IOC F-22s in 2005 and will likely include helmet-mounted cueing, AIM-9XSidewinder missile integration, and JTIDS send-only capability

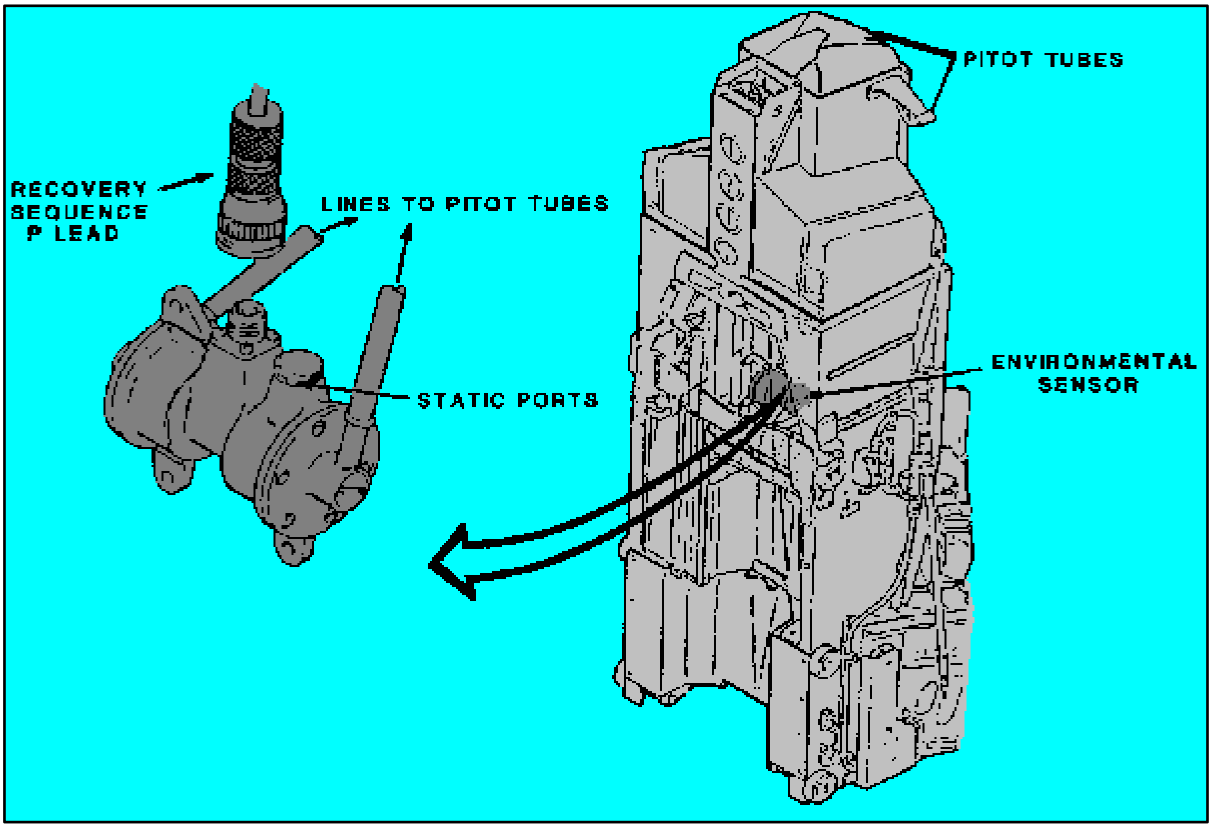
ACES II Ejection Seat

The "advanced concept ejection seat," or ACES II as it is called, is designed to provide safe escape at aircraft speeds from 0 to 600 knots equivalent airspeed (KEAS) (at sea level) and from ground level to 50,000 feet. Safe escape is achieved through special features and controlled event timing. The seat provides three modes of operation that are required to get the correct elapsed time from the start of the ejection to the recovery of the crewmember under all escape conditions. The increased performance capability of this system has greatly improved the survivability of aircrews during escape from aircraft under adverse conditions throughout the flight envelope. Because of this, the ACES II system has become the standard USAF seat that is used in most of the modern aircraft in the Air Force inventory. In this unit we'll cover the ACES II system.



The ACES II seat system uses both conventional and advanced technology to recover the ejecting crew member. The heart of this system lies in post-ejection, and it is at this point that all events are electronically controlled. To give you a better understanding of the ACES II system, we'll discuss each component individually. In addition, you will be provided with some important information regarding system safe tying. This will include ground safety devices, maintenance safety pins, and grounding of the seat.

Imagine flying along on a dark rainy night--500 feet above the ground--traveling at over 10 miles per minute. Suddenly, an emergency develops and you know you must get out of that plane immediately. In situations like this, our aircrew members rely on the escape system for their survival. Needless to say, ejection success or failure depends upon equipment reliability and how well you have done your work. The failure of just one critical component can result in the loss of an aircrew. Keep this thought in mind as we discuss the individual components that make up the ACES II system. Let's get started by looking at the environmental sensor.



Environmental sensor. The purpose of the environmental sensor is to sense seat airspeeds and altitude and send this information to the recovery sequencer. As the seat travels up the guide rail, pitot tubes located on both. Sides of the headrest are exposed to the airstream. As you can see in figure 1, a static port on the environmental sensor monitors the pressure. Pitot and static pressure inputs are sensed by the speed and altitude transducers in the sensor. The transducer outputs are in turn applied to the sequencer for selection of prier recovery mode.

Recovery Sequencer. The recovery sequencer contains logic circuitry to interpret the inputs from the pitot and static inputs from the environmental sensor. The inputs allow the sequencer to select an ejection sequence that provides the best recovery means for the full range of escape conditions.

Three modes of ejection are possible. The mode selected depends on altitude and airspeed. These possibilities are:

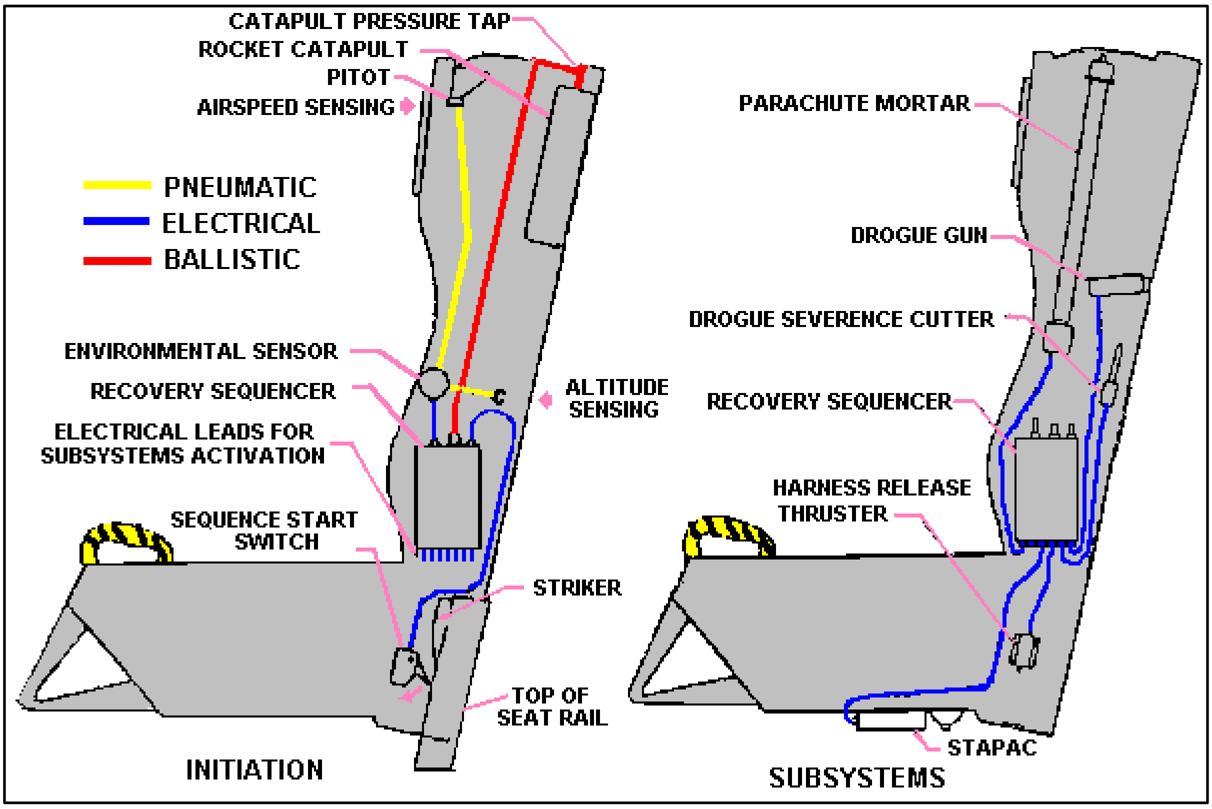
Mode 1 (low altitude/low speed) --selected during ejections at low speeds below 250 knots (1 knot equals 1.15 miles per hour) and at low altitudes below 15,000 feet. In mode 1 the drogue parachute does not deploy.

Mode 2 (low altitude/high speed) --selected during ejections at high speeds above 250 knots and at low altitudes below 15,000 feet.

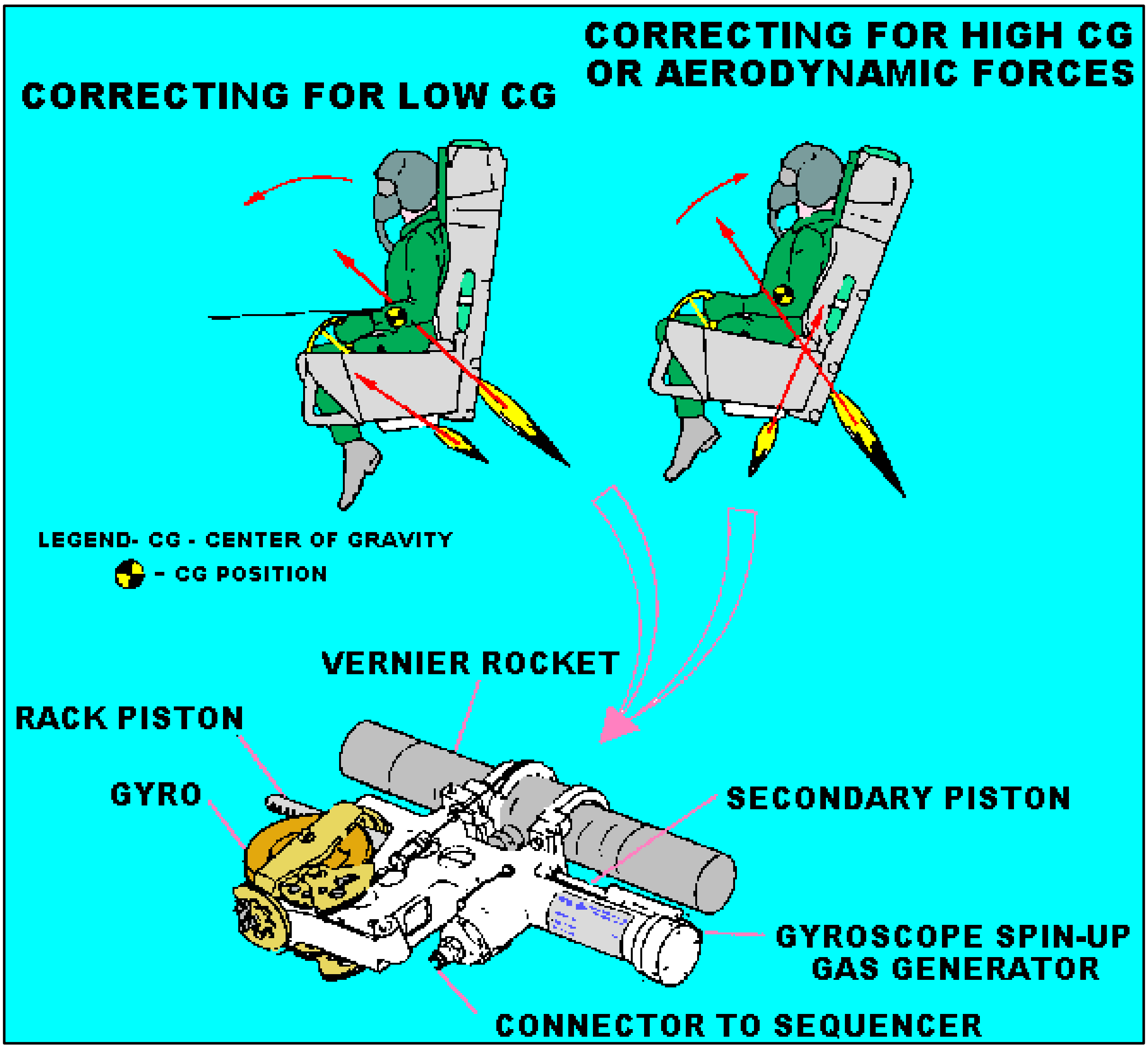
Mode 3 (high altitude/low or high speed) --selected during ejections at high altitudes above 15,000 feet and high or low speeds.

The recovery sequencer gets the necessary electrical power from four thermal batteries located within the sequencer. Two of these batteries are gas-fired by the rocket catapult and charge capacitors that send the electrical signals to fire the other two thermal batteries when the proper altitude parameters are reached. These batteries provide the power to operate the timing circuits. They also provide electrical initiation signals that actuate subsystem ballistic devices. The thermal batteries are dormant and there is no electrical input or output from the recovery sequencer until bleed-off pressure is provided by the rocket catapult. Once activated, information concerning speed and altitude is gathered and interpreted, and the time delays are selected. However, no post-ejection events will occur until the sequence start switch is closed.

A battery indicator window is used to determine the serviceability of the thermal batteries. A white indicator indicates the batteries are serviceable, while a red indicator sticking through the window indicates that the thermal batteries have been fired and specific technical order instructions must be followed for seat removal.

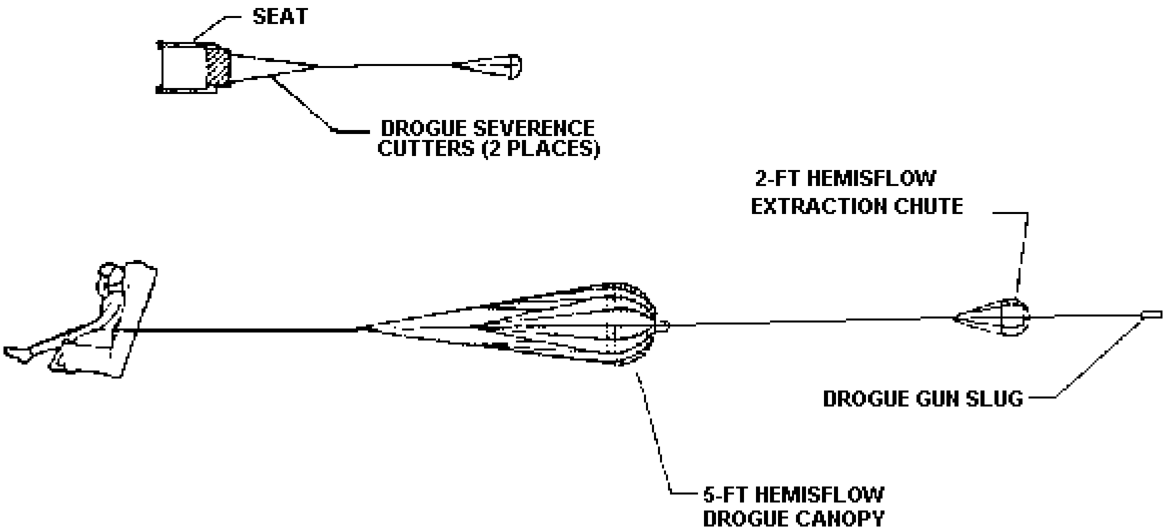


Sequence start switch. As you see in previous page figure, this switch is located near the lower right-hand side of the seat and is actuated by a striker mounted near the top of the right-hand seat rail. The purpose of this switch is to start the timing sequence. The switch also acts as a safety device. In the event that the thermal batteries are inadvertently activated on the ground, the recovery sequencer cannot fire any components because the switch is open. Also, removing the seat for maintenance will not start the timing sequence because the thermal batteries have not been activated by gas pressure from the rocket catapult.



Pitch stabilization control assembly. The pitch stabilization control assembly, which is mounted on the bottom of the seat, contains the gyro spin up gas generator, a piston and rack assembly, a gyro rotor assembly, the Vernier rocket, and the Vernier rocket control pulley assemblies. When the gyro spins up gas generator is fired, it develops enough ballistic pressure to shear a pin. The pin retains the gyro spin up piston gear and rack. When the pin shears, the notched piston and rack is fired across the gear surface of the gyro rotor. This firing of the piston and rack enables the rotor to attain a speed of 10,500 revolutions per minute. Pressure continues through the piston and rack chamber to move a second piston. Starting the second piston pulls a sear from the firing device, firing the Vernier rocket. The speed of the gyro rotor develops torque as the seat pitches forward or backward. This torque is used during ejection to direct the Vernier rocket thrust. A pulley system aims the thrust in a direction that lets the seat maintain proper pitch attitude.

Trajectory divergence rocket (TDR). The F-15B/D/E and the F-16 B/D use a trajectory divergence rocket, installed on the lower left- or right-hand side of the seat, to prevent a collision of the seats when both seats are ejected. The F-16 A/C uses the TDR to prevent contact of the seat and recovery parachute. The TDR is fired by an electrical signal from the recovery sequencer and upon actuation, rolls the seat to the right or left, depending on the rocket installation.



Drogue system. The drogue system slows down and stabilizes the seat during mode 2 and mode 3 ejection sequences. Because the drogue system is not needed during mode 1 ejection sequences, the drogue gun will not fire in this mode. The ACES II seat uses a drogue gun, which is electrically fired by the recovery sequencer as the seat reaches the top of the guide rails. Firing the drogue gun propels a slug to the rear which unlatches the drogue compartment cover and withdraws a 2-foot diameter extraction chute. The chute is withdrawn by means of a yoke line fastened between the slug and the chute. You can see in figure 4 that the extraction chute inflates right away and deploys a 3-foot diameter drogue parachute by means of a bridle line fastened between the two parachutes.

Drogue severance cutters. Once the seat has slowed down, two drogue severance cutters, which consist of a flexible linear shaped charge (FLSC) and a detonator charge with a dual bridge wire initiator, are electrically fired at the same time by the recovery sequencer. Upon activation, the FLSC severs the applicable drogue parachute bridle which releases the drogue parachute from the seat.

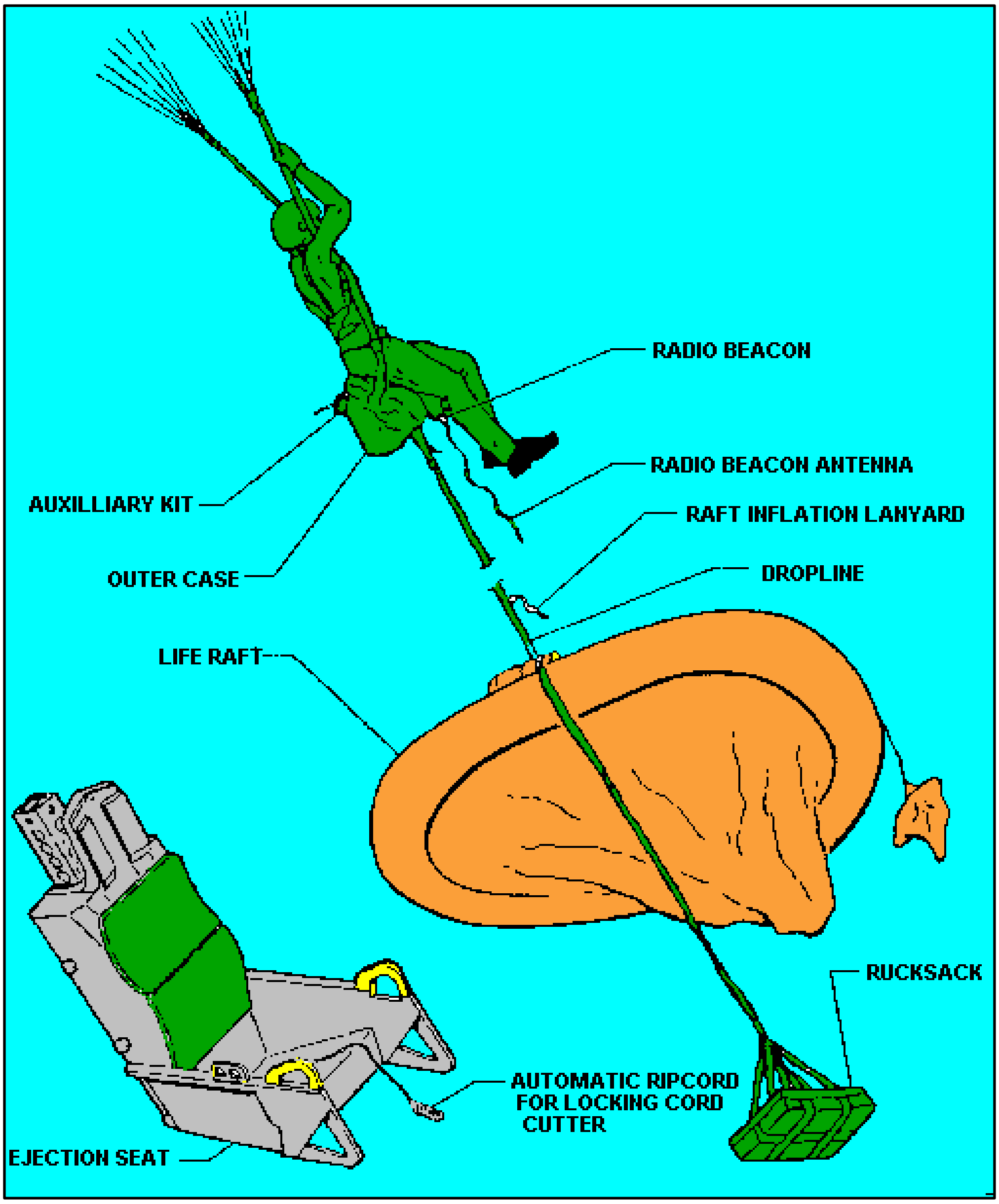
Parachute mortar assembly. The mortar assembly forcibly deploys the recovery parachute. It consists of inner and outer mortar tubes. The outer tube is attached to the recovery parachute canister and the inner tube is locked to the mortar disconnect by a lock pin that is connected to the restraint release bell crank. The mortar disconnect contains the parachute mortar cartridge which is fired by a signal from the recovery sequencer at a time determined by the mode of ejection. The cartridge develops ballistic pressure to propel the outer tube upward which pushes the canister from the seat, deploying the recovery parachute in a reefed or noninflated condition.

Pilot chute and recovery parachute. The pilot chute is packaged in a fabric enclosure at the top of the recovery parachute metal canister. The pilot chute deploys immediately to an inflated condition, except at zero speed. As the pilot chute deploys, the canister containing the recovery parachute is pulled to deploy the parachute. The suspension lines deploy first, then the canopy deploys skirt-first as the canister separates. The 28-foot diameter canopy of the recovery parachute is reefed, and contains dual reefing line cutters. The cutters are installed on opposite sides of the canopy. As the mortar outer tube moves away from the seat, lines attached between the mortar inner tube and each parachute reefing line cutter fire the cutters. After approximately 1.15 seconds, the reefing line is cut by the cutters, allowing the recovery parachute to fully deploy. Firing the cutters allows the parachute canopy to fully inflate. Two actuation lines are attached between the firing pins of each cutter and the applicable suspension lines as a backup. The backup lines enable the suspension lines to fire the cutters in the event that mortar extension fails to occur or the primary lanyard fails to actuate the cutters.

Restraint system. The restraint system consists of lap belts, inertia reel straps, and parachute risers. These items work together to keep the crewmember restrained to the seat until separation.

Restraint release system. The restraint release system releases the crewmember from the seat. The system consists of a bell crank, four lock pins, and a seat pan latch. When the bell crank is rotated, the seat pan unlatches and the lock pins are withdrawn from the lap belts, inertia reel straps, pilot recovery chute and mortar assembly. The restraint release system can be operated by a thruster during ejection, by an emergency restraint release handle during ground emergencies (this handle is not used if seats have been modified by TCTO 13A5-56-540, Restraint Emergency Release Handle and Backup Parachute Deployment System Modification), or by an equipment service release cable during maintenance.

Release thruster. The harness release thruster is electrically fired by the recovery sequencer. The thruster achieves crewmember separation by rotating the harness release bellcrank. This action pulls the lap belt and inertia reel strap locking pins and unlatches the seat pan. The thruster also unlocks the mortar assembly from the seat and allows for automatic deployment of the pilot and recovery parachutes in the event the mortar fails to fire during post-ejection. This backup feature isn't needed on seats modified by TCTO 13A5-56-540.



Survival kit. During crewmember separation the seat pan pivots.up and forward to allow withdrawal of the survival kit. The survival kit consists of a fabric case that houses the life raft, rucksack, and an auxiliary kit. In figure 5, you see that the life raft and rucksack are attached to the survival kit case by a dropline. The auxiliary kit is secured inside the survival kit and stores items that are needed to be retained by the crewmember. Also, the radio beacon transmitter is stored inside the survival kit and stays attached to the crewmember. A control lever, located on the front edge of the seat pan, allows the crewmember to select automatic or manual deployment of the kit. If automatic operation is selected, all of the equipment will deploy 4 seconds after crewmember separation in the configuration shown in figure 5. However, if manual operation is selected, the survival kit will stay together and remain attached to the crewmember.

Emergency oxygen system. During ejection, a lanyard attached to the aircraft floor, is pulled actuating the oxygen bottle to provide the crewmember with 10 minutes of oxygen during post-ejection. In addition, an emergency oxygen ring is provided for manual operation of the oxygen system should the automatic system fail during ejection or the normal aircraft oxygen system fail during flight.

Theory of operation

In the preceding section, we looked at some of the components that make up the ACES II ejection seat. Now that you have a general knowledge of these components, let's look at how they function together during an ejection.

Initiation. Pulling the firing control handles fires the ejection initiator which provides ballistic pressure to start the seat and canopy sequencing system. This system provides a time delay that allows the canopy to jettison before the rocket catapult. As the rocket catapult fires, pressure from the catapult is applied to a percussion device in the sequencer. Remember, the batteries provide no electrical power to operate the sequencer until they are fired by the hot gases the catapult.

As the seat travels up the rails, pitot tubes are exposed to the airstream. A static port on the environmental sensor monitors the pressure. Pitot and static pressure inputs are sensed by the speed and altitude transducers in the sensor and are supplied in turn to the sequencer to select the proper mode of ejection. The emergency oxygen supply is started by a lanyard connected between the oxygen cylinder and the cockpit. As the lower part of the seat nears the top of the guide mils, a sequence start switch on the seat is tumed on where switch actuating bellcrank contacts a striker on the right-hand guide rail. After a 0.18-second delay the sequencer provides an electrical signal that fires the gyro spinup gas generator. The generator develops enough pressure to shear a retaining pin. After the pin shears, the geared piston and rack are fired across the geared surface of the gyro rotor which develops a speed of 10,500 RPM to direct the thrust as the seat pitches forward or backward by means of a pulley system. The pressure then continues through the piston and rack chamber to move a second piston which pulls-a sear from the vemier rocket firing device, firing the rocket.

After a .040-second delay, the sequencer provides a signal that fires the trajectory divergence 'rocket on certain seam. The start of the other components depends on the mode of operation selected by the sequencer.

Mode 1 operation. Mode 1 operation is selected for speeds of less than 250 knots (KEAS) (at sea level) and for altitudes of 0 to 15,000 feet (nominal). Mode 1 operates minus extraction chute or drogue chute deployment. The mortar is fire~econd after the sequence start switch operates. As the mortar propels the pilot chute and recovery parachute away from the seat, the pilot chute is deployed, a 1.15-second time delay in each reefing line cutter is started. Even though the drogue parachute has not been deployed, the drogue severance cutters are fired 0.15 seconds after the recovery parachute mortar fires. 0.25 seconds after the mortar fires, the restraint release thruster fires and rotates the bell crank pulling the locking pins that secure the lap belts and inertia reel straps. As the recovery parachute deploys, the crewmember and survival kit are separated from the seat which activates the radio beacon remote switch. When the reefing line cutters fire (1.15 seconds after the mortar fires), the recovery parachute fully inflates. If automatic survival kit deployment has been selected, the kit will open 4 seconds after seat and person separation allowing the life raft and rucksack to deploy.

Mode 2 operation. Mode 2 operation is selected for speeds above 250 knots (KEAS) (at sea level) and for altitudes of 0 to 15,000 feet. Extraction chute and drogue Chute deployment begin at the start of the recovery sequence. An electrical signal from the sequencer fires the drogue gun cartridge which propels the slug from the gun. The drogue gun slug deploys the extraction parachute which deploys the drogue parachute. The mortar is fired by a signal from the sequencer after the extraction and drogue chute deploy. The drogue severance cutters are fired by the sequencer 0. 15 seconds after the mortar is fired. Recovery parachute deployment and seat and person separation then occur as described for mode 1.

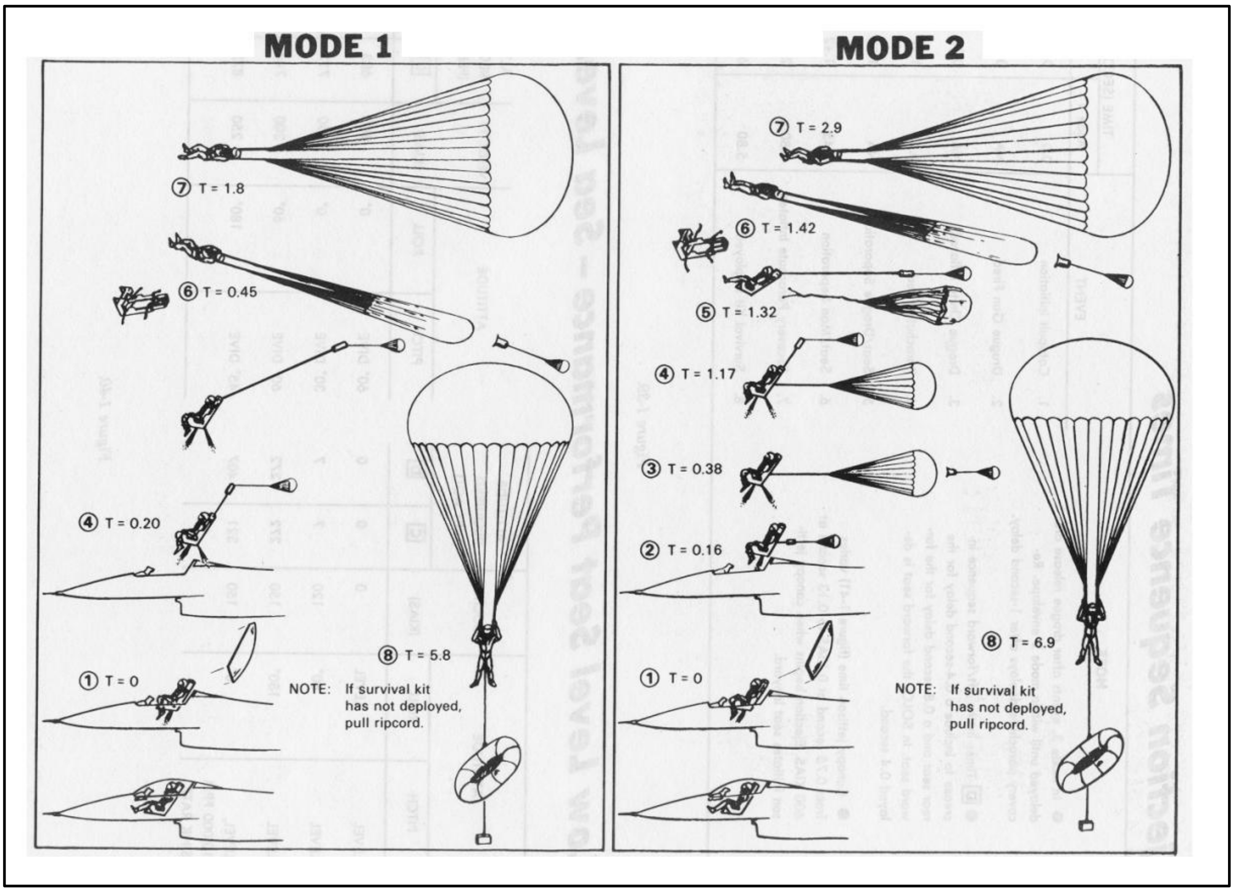
Mode 3 operation. Mode 3 operation depends on speed and altitude. During mode 3 operation, the sequence of events occur as described for mode 2 except deployment of the pilot chute and recovery parachute, seat and person separation, and firing of the drogue severance cutters are delayed until mode 2 speed and altitude conditions are met.

Parachute deployment/seat and person separation systems. Prior to accomplishment of TCTO 13A5-56-540, if the automatic recovery sequence is not completed and/or started, backup systems operate as follows:

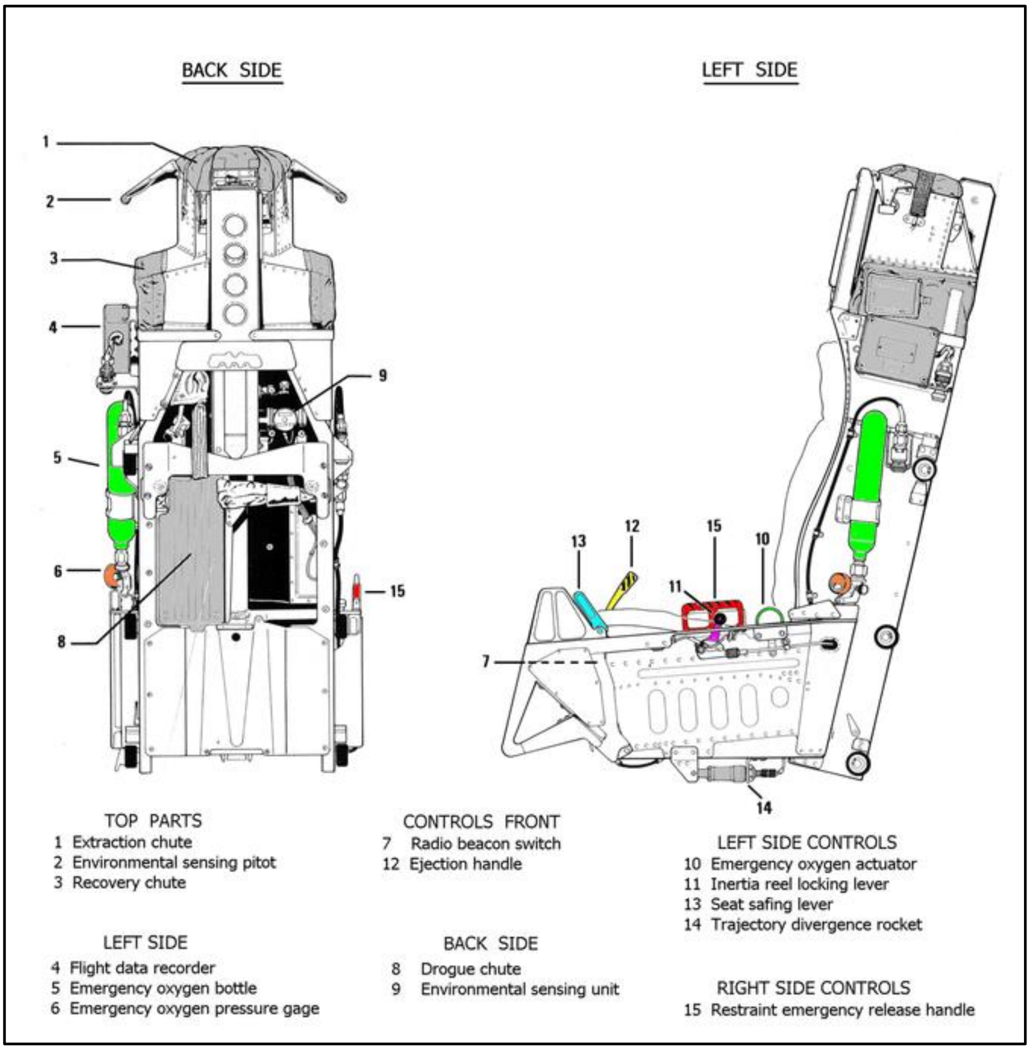
If automatic firing of the mortar does not occur, deployment of the pilot chute and recovery parachute is automatic. This deployment occurs when the restraint release thruster is fired.

If the sequencer fails to operate and/or fails to complete an automatic recovery sequence, manual deployment of the pilot chute and recovery parachute and seat and person separation can be done at the same time. These actions are done by pulling the emergency restraint release handle and at the same time pushing up on the parachute mounted pitot tubes.

After accomplishment of TCTO 13A5-56-540, if automatic firing of the parachute mortar is not initiated by the primary mortar cartridge, a backup mortar cartridge can be used to initiate the parachute mortar. The crewmember initiates the manual mode by pulling up on the Emergency Manual chute handle. This action activates a thermal battery via a cable assembly that releases a firing pin. The firing pin strikes a primer in the emergency power supply battery. The resultant electrical pulse from the battery ignites the backup mortar cartridge ballistically deploying the parachute.



MODE 1
⑦ T = 1.8
⑥ T = 0.45
④ T = 0.20
① T = 0
⑧ T = 5.8
NOTE: If survival kit has not deployed, pull ripcord.
MODE 2
⑦ T = 2.9
⑥ T = 1.42
⑤ T = 1.32
④ T = 1.17
③ T = 0.38
② T = 0.16
① T = 0
⑧ T = 6.9
NOTE: If survival kit has not deployed, pull ripcord.

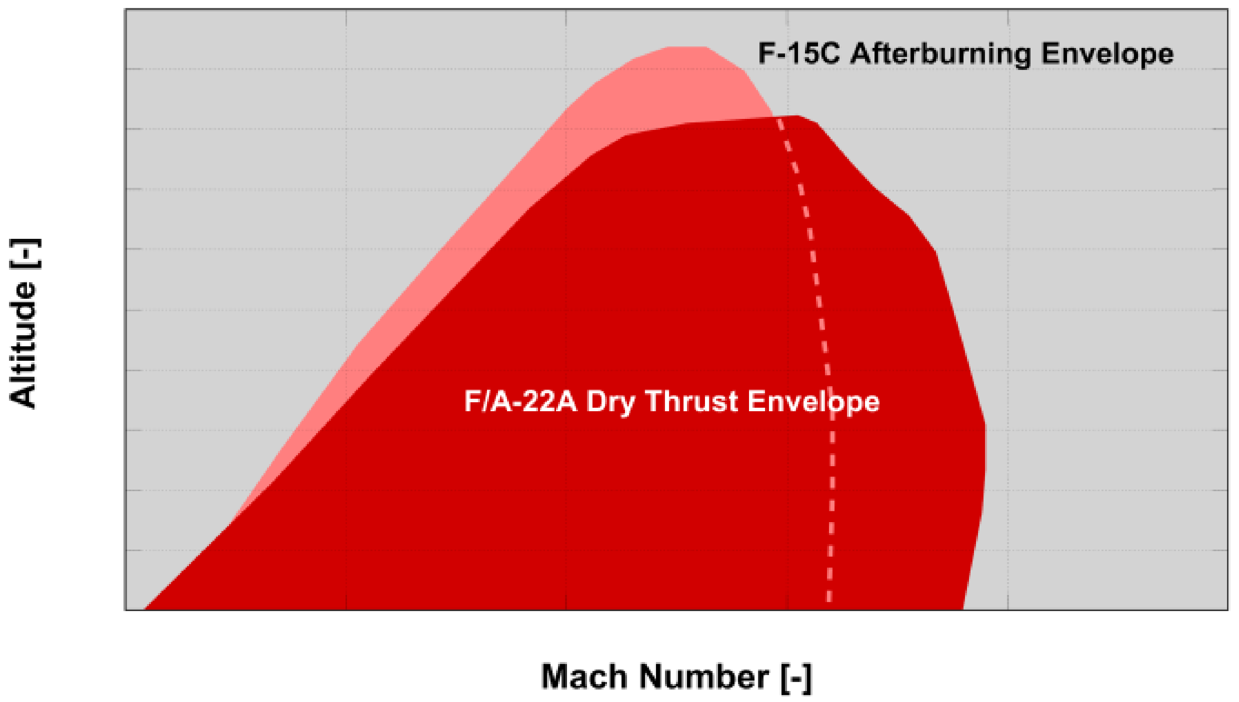


BACK SIDE
LEFT SIDE
TOP PARTS
1 Extraction chute
2 Environmental sensing pitot
3 Recovery chute
CONTROLS FRONT
7 Radio beacon switch
12 Ejection handle
LEFT SIDE CONTROLS
10 Emergency oxygen actuator
11 Inertia reel locking lever
13 Seat safing lever
14 Trajectory divergence rocket
LEFT SIDE
4 Flight data recorder
5 Emergency oxygen bottle
6 Emergency oxygen pressure gage
BACK SIDE
8 Drogue chute
9 Environmental sensing unit
RIGHT SIDE CONTROLS
15 Restraint emergency release handle

Flight Characteristics

The raw aerodynamic performance of the F-22A was without precedent. In military (dry) thrust setting the F-22A could cover the whole afterburning performance envelope of the F-15 - or advanced Sukhois, both still the highest performing energy fighters widely deployed. The F-22A was rated for 9G at combat weights.

With 20,650 lb. of internal fuel, the F-22A internally carried 88 per cent of the fuel in a CFT-equipped F-15E, with no drag penalty, yet with four 592 USG drop tanks, a total fuel load of 36,515 lb. could be carried, 6 per cent more than the internal fuel of the larger F-111.

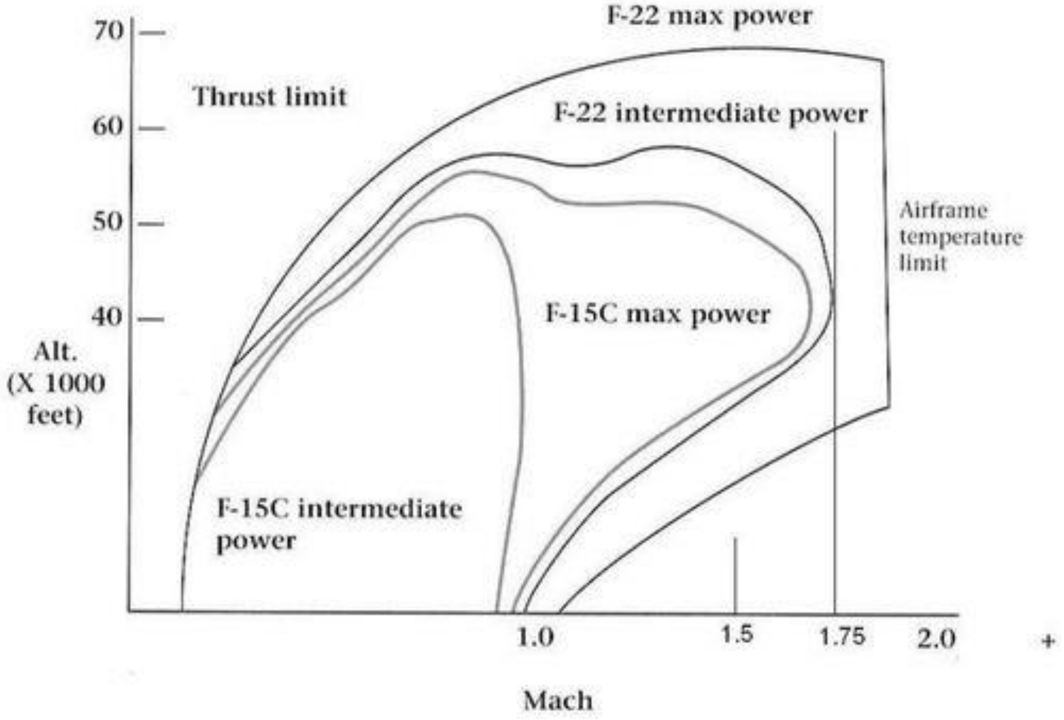


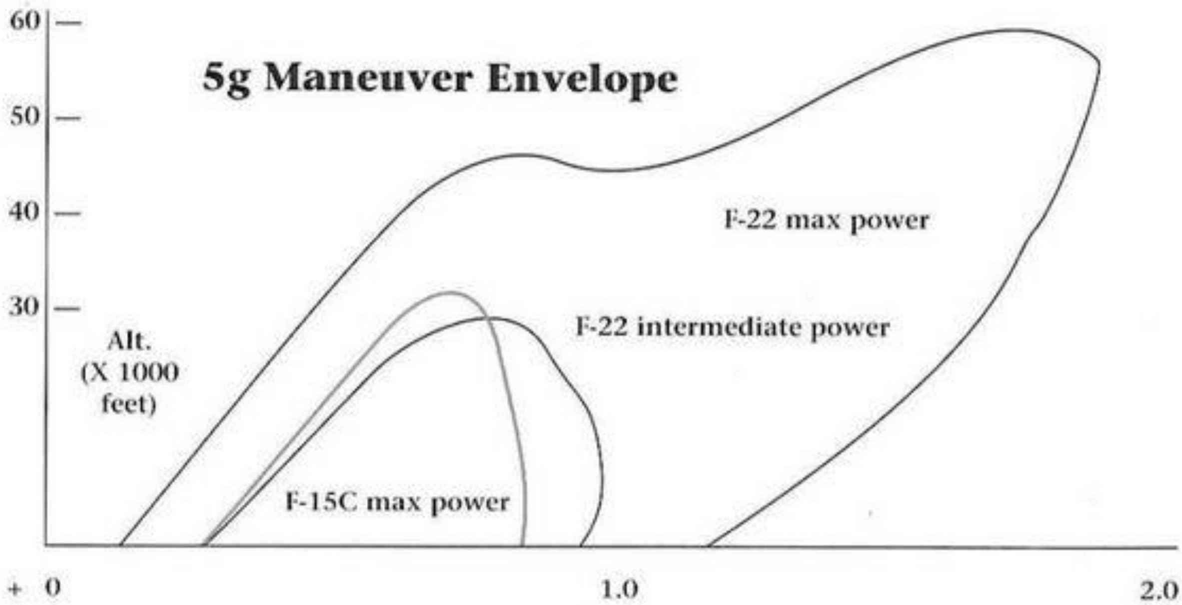
F/A-22A Military Thrust Envelope vs F-15C

Refined supersonic aerodynamics allowed the F-22A to exceed Mach 1.5 in military thrust at altitude - the exact top speed in dry thrust has never been disclosed. In early trials, F-15 chase aircraft could not keep up, and test pilots soon reported instances where even modest heading changes by F-22A prototypes in head-to-head engagement geometries caused opposing teen series fighters to abort engagements entirely - an experience historically seen only in engagements against Foxbats and Foxhounds.

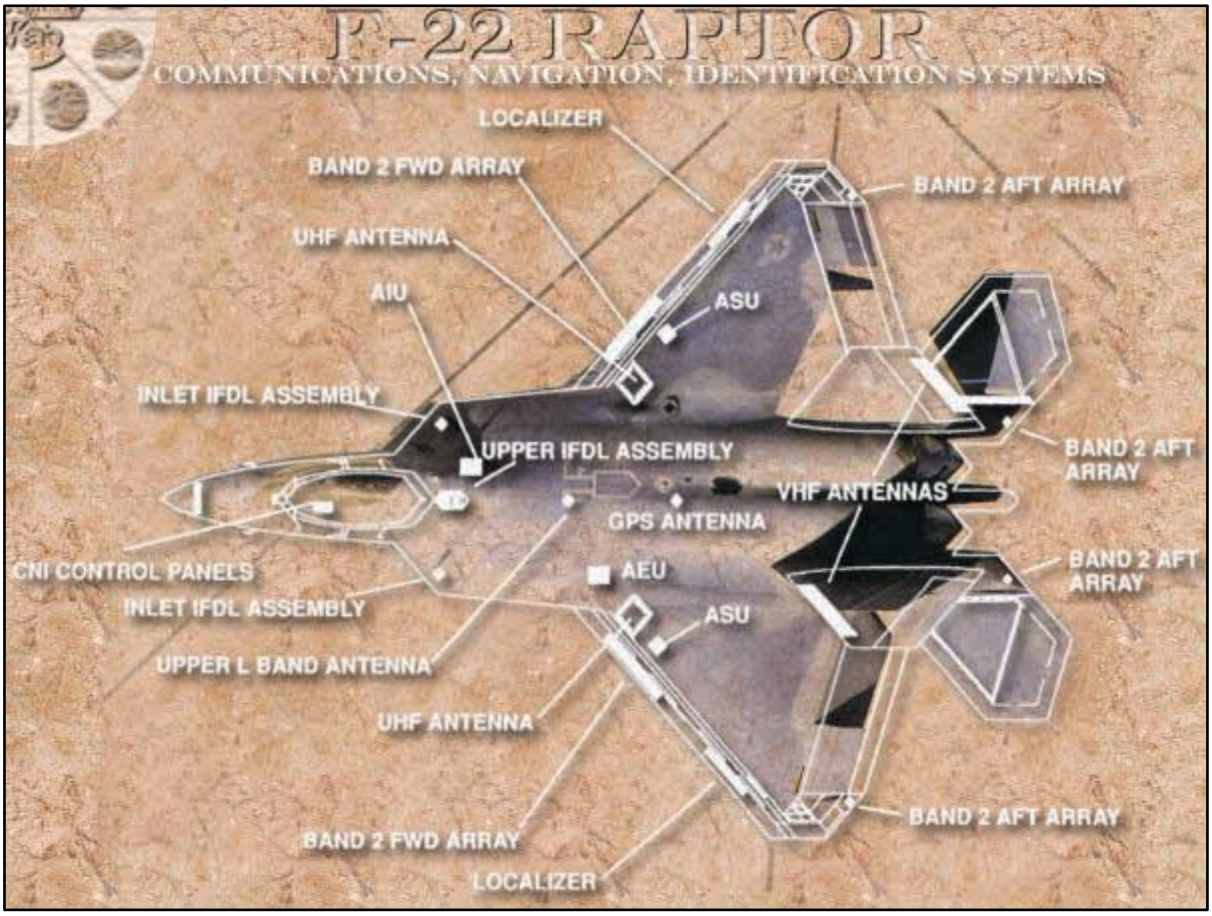
In the simplest of terms, the supercruising F-22A kinematically defeated all opposing fighters, and even without stealth would kinematically defeat most existing surface-to-air missile types. The only design with the potential to kinematically challenge today's F-22A are advanced derivatives of the Su-30 fitted with supercruising AL-41F fans, the Russian equivalent to the F119-PW-100 engine in the F-22A, and an LRIP production item since 2004.

Level Flight Envelope

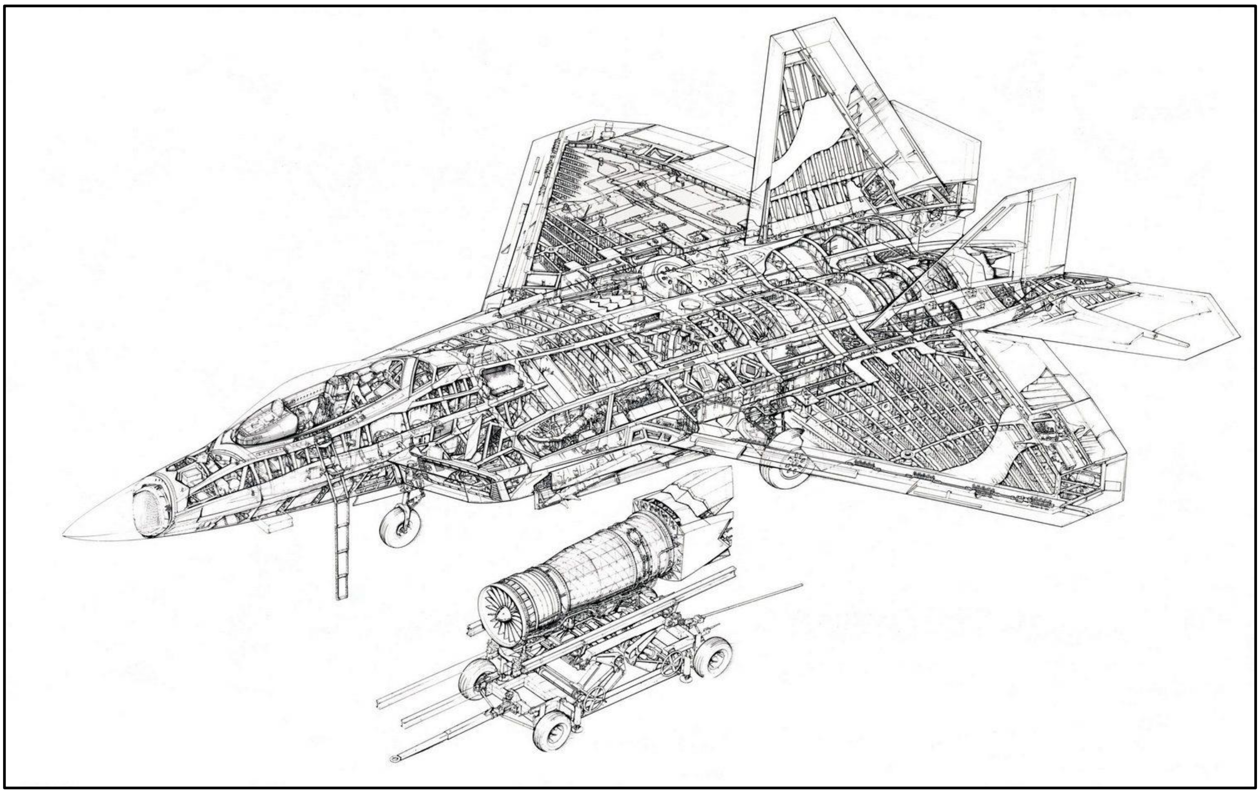


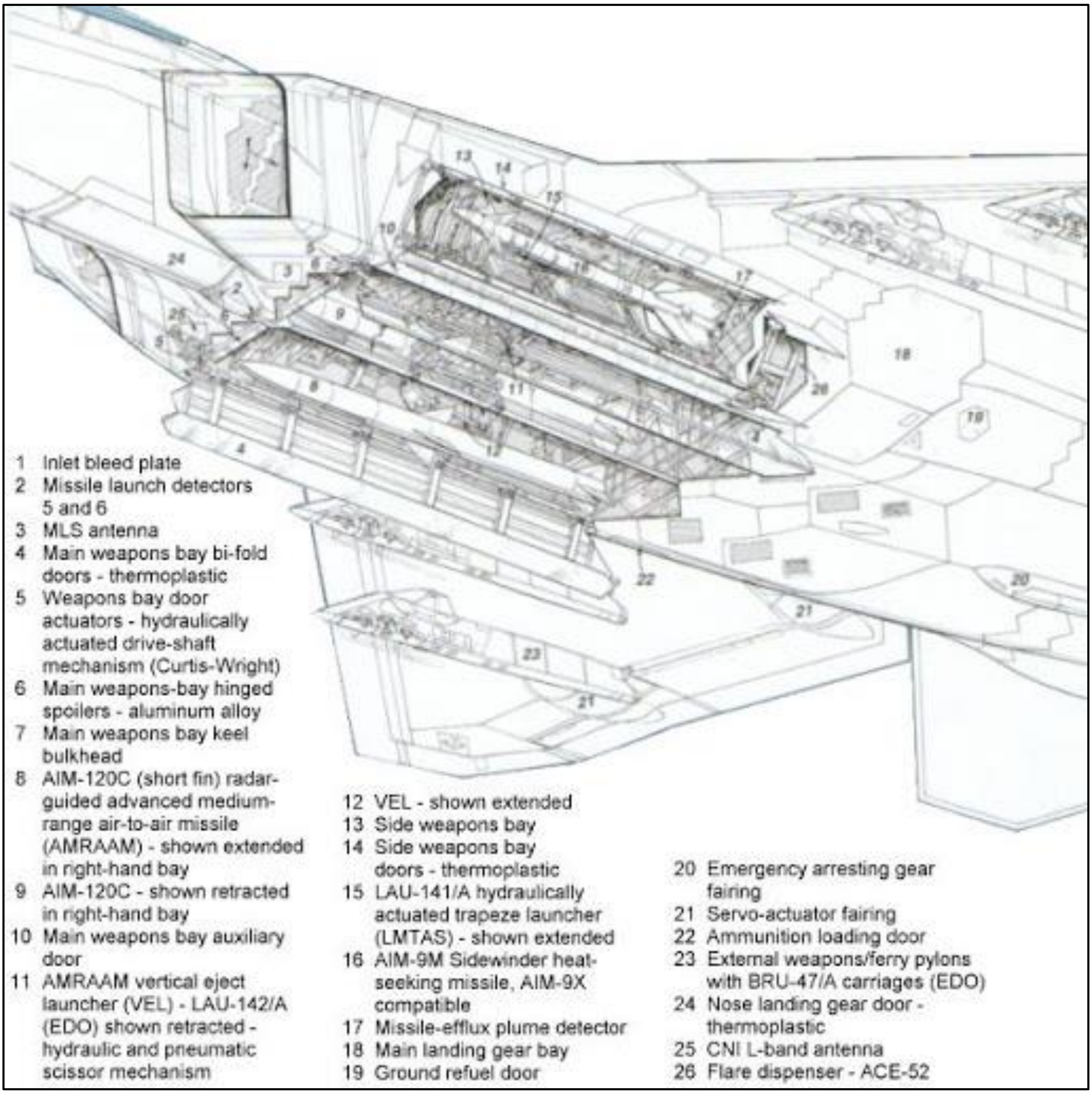


APPENDIX



F-22 RAPTOR
COMMUNICATIONS, NAVIGATION, IDENTIFICATION SYSTEMS
LOCALIZER
BAND 2 FWD ARRAY
BAND 2 AFT ARRAY
UHF ANTENNA
AIU
ASU
INLET IFDL ASSEMBLY
UPPER IFDL ASSEMBLY
BAND 2 AFT ARRAY
VHF ANTENNAS
GPS ANTENNA
CNI CONTROL PANELS
AEU
BAND 2 AFT ARRAY
INLET IFDL ASSEMBLY
ASU
UPPER L BAND ANTENNA
UHF ANTENNA
BAND 2 FWD ARRAY
BAND 2 AFT ARRAY
LOCALIZER




1 Inlet bleed plate
2 Missile launch detectors 5 and 6
3 MLS antenna
4 Main weapons bay bi-fold doors - thermoplastic
5 Weapons bay door actuators - hydraulically actuated drive-shaft mechanism (Curtis-Wright)
6 Main weapons-bay hinged spoilers - aluminum alloy
7 Main weapons bay keel bulkhead
8 AIM-120C (short fin) radar-guided advanced medium-range air-to-air missile (AMRAAM) - shown extended in right-hand bay
9 AIM-120C - shown retracted in right-hand bay
10 Main weapons bay auxiliary door
11 AMRAAM vertical eject launcher (VEL) - LAU-142/A (EDO) shown retracted - hydraulic and pneumatic scissor mechanism
12 VEL - shown extended
13 Side weapons bay
14 Side weapons bay doors - thermoplastic
15 LAU-141/A hydraulically actuated trapeze launcher (LMTAS) - shown extended
16 AIM-9M Sidewinder heat-seeking missile, AIM-9X compatible
17 Missile-efflux plume detector
18 Main landing gear bay
19 Ground refuel door
20 Emergency arresting gear fairing
21 Servo-actuator fairing
22 Ammunition loading door
23 External weapons/ferry pylons with BRU-47/A carriages (EDO)
24 Nose landing gear door - thermoplastic
25 CNI L-band antenna
26 Flare dispenser - ACE-52

AIRCRAFT HAZARDS

F-22A

INLET, EXHAUST AND RADAR HAZARDS

WARNING

Personnel should use extreme caution when approaching the inlet area when engines are operating. Maintain a safe zone perpendicular to and forward of the inlets instead of determining a 45 degree arc. Failure to maintain or be aware of the 25 foot arc could cause injury or death to personnel. Loose clothing and no hat zone extends to 200 feet.

WARNING

Personnel should use extreme caution when approaching the exhaust area which encompasses an arc of 250 feet aft of the engine nozzles.

WARNING

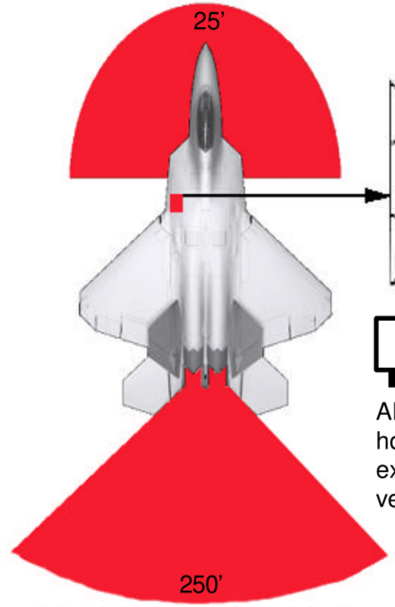
SES (Stored Energy System) exhaust is located at the left lower wing root above the main landing gear doors. This exhaust is extremely hot during APU starts or when the SES is activated during an emergency.

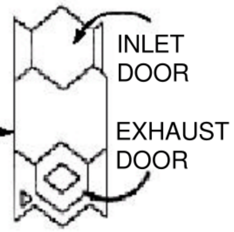
WARNING

Low power radar emissions may be encountered during an emergency. The danger area for these emissions is a 4 foot back arc and a 4 foot front arc for the system check area. The actual high power and scan radiation area is 300 feet. Approach with extreme caution as if the radar is operating. RF energy can cause accidental firing of ejection seats, canopy and ignition of fuel vapors. Distances are conservative personnel exposure limitations.

NOTES:

- ECM emissions are not expected to be encountered.
- A clear zone means for personnel to avoid these areas.

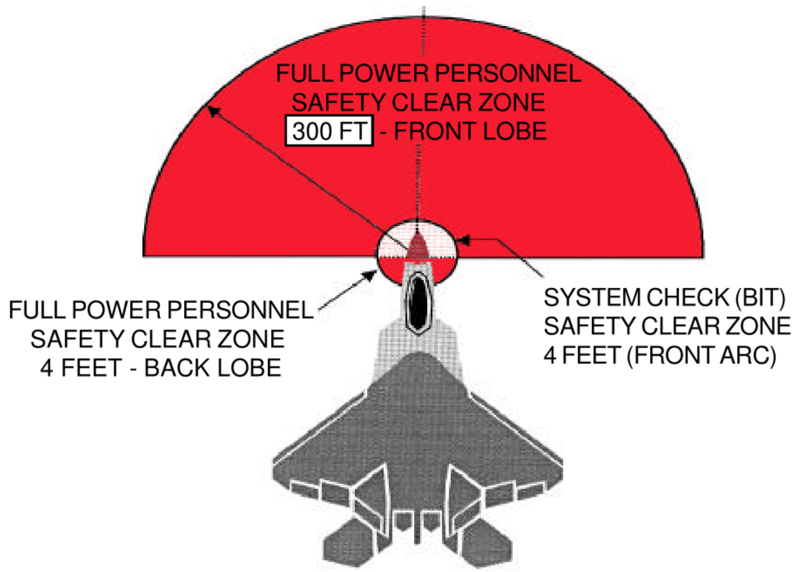




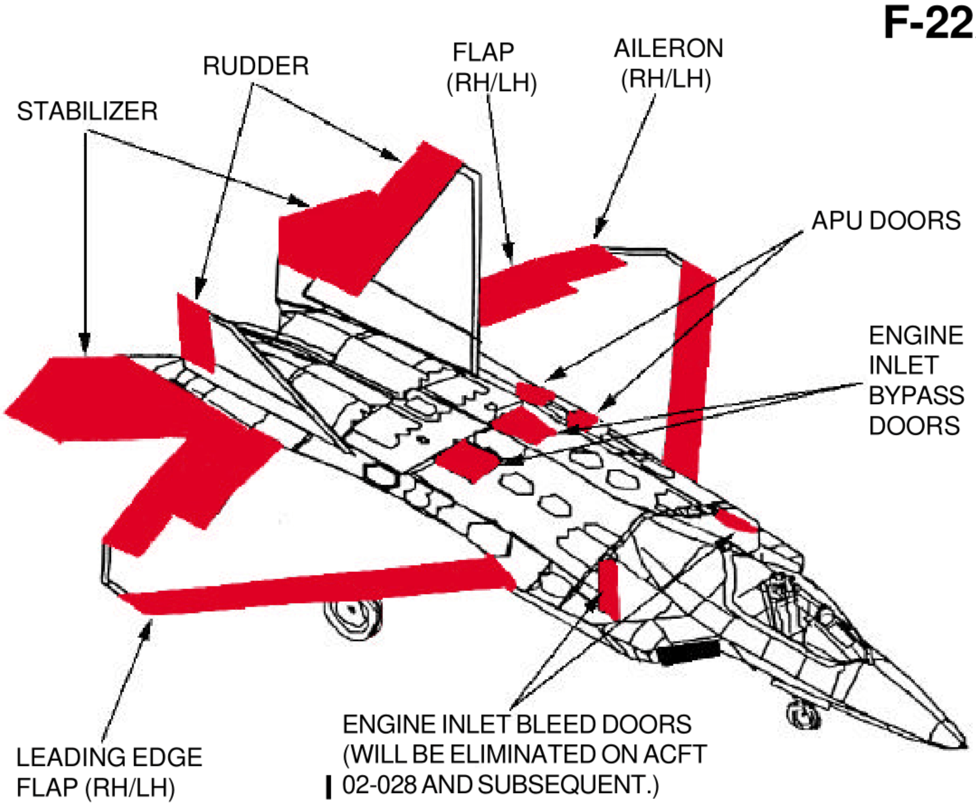
WARNING

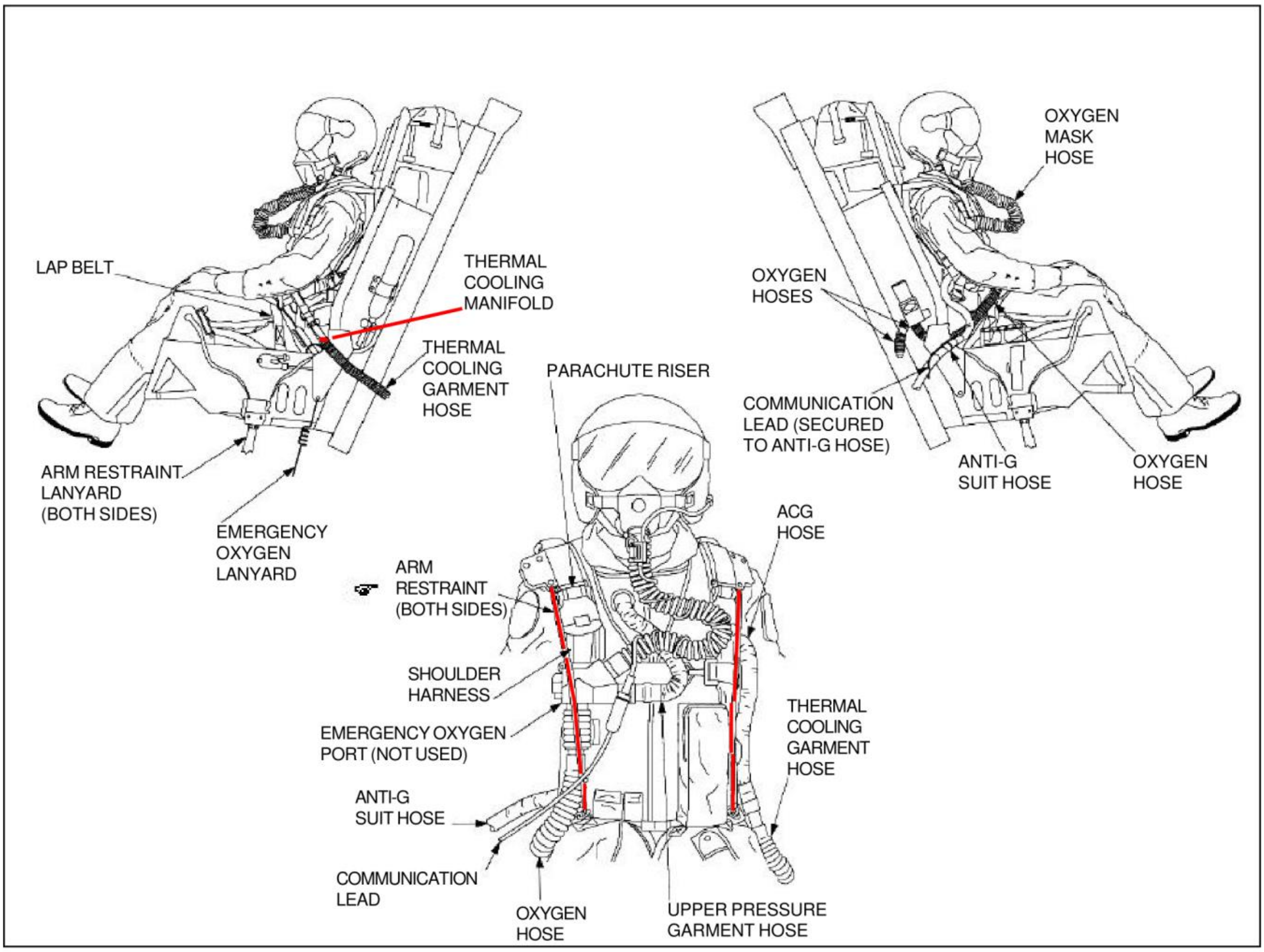
APU exhaust is very hot. Both inlet and exhaust doors have very sharp edges.

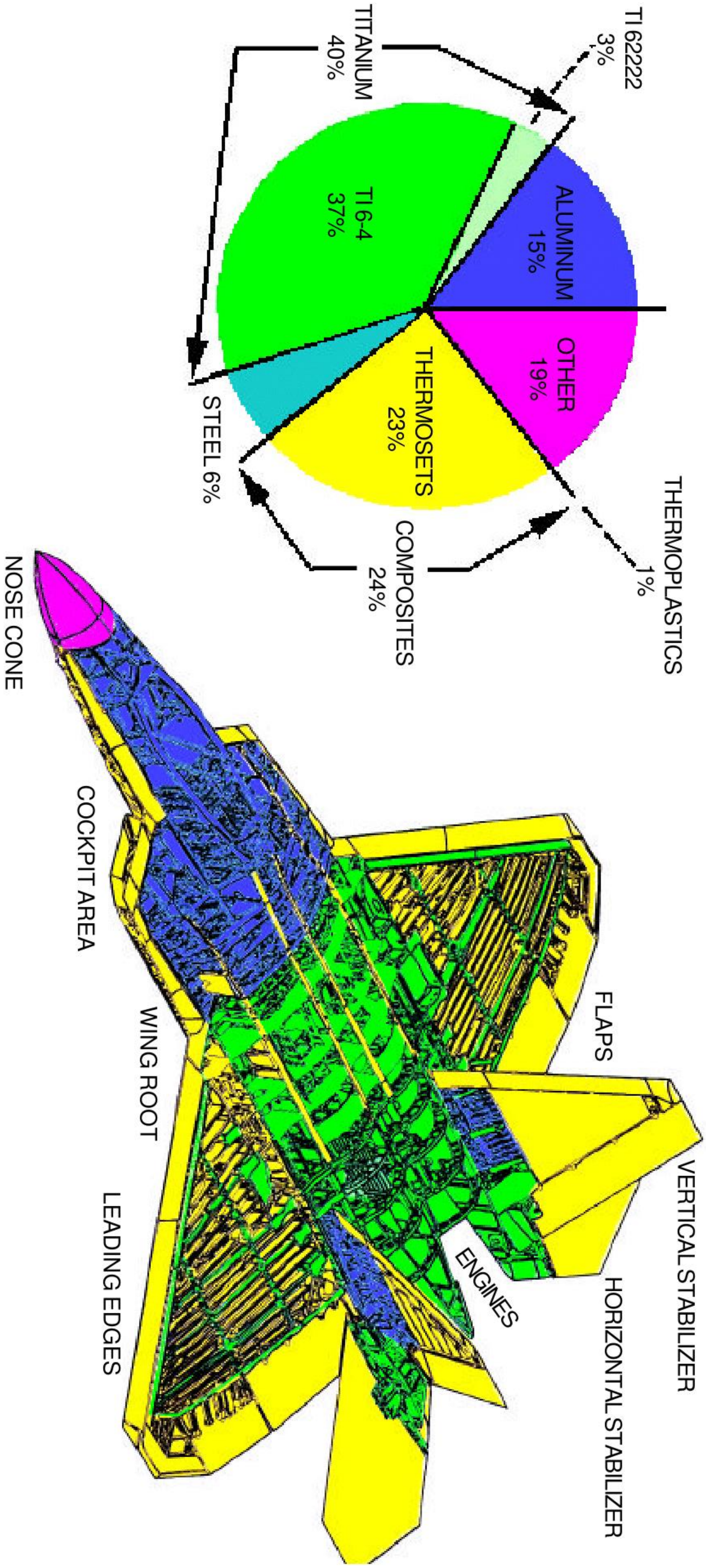
LH SIDE ABOVE WEAPONS BAY

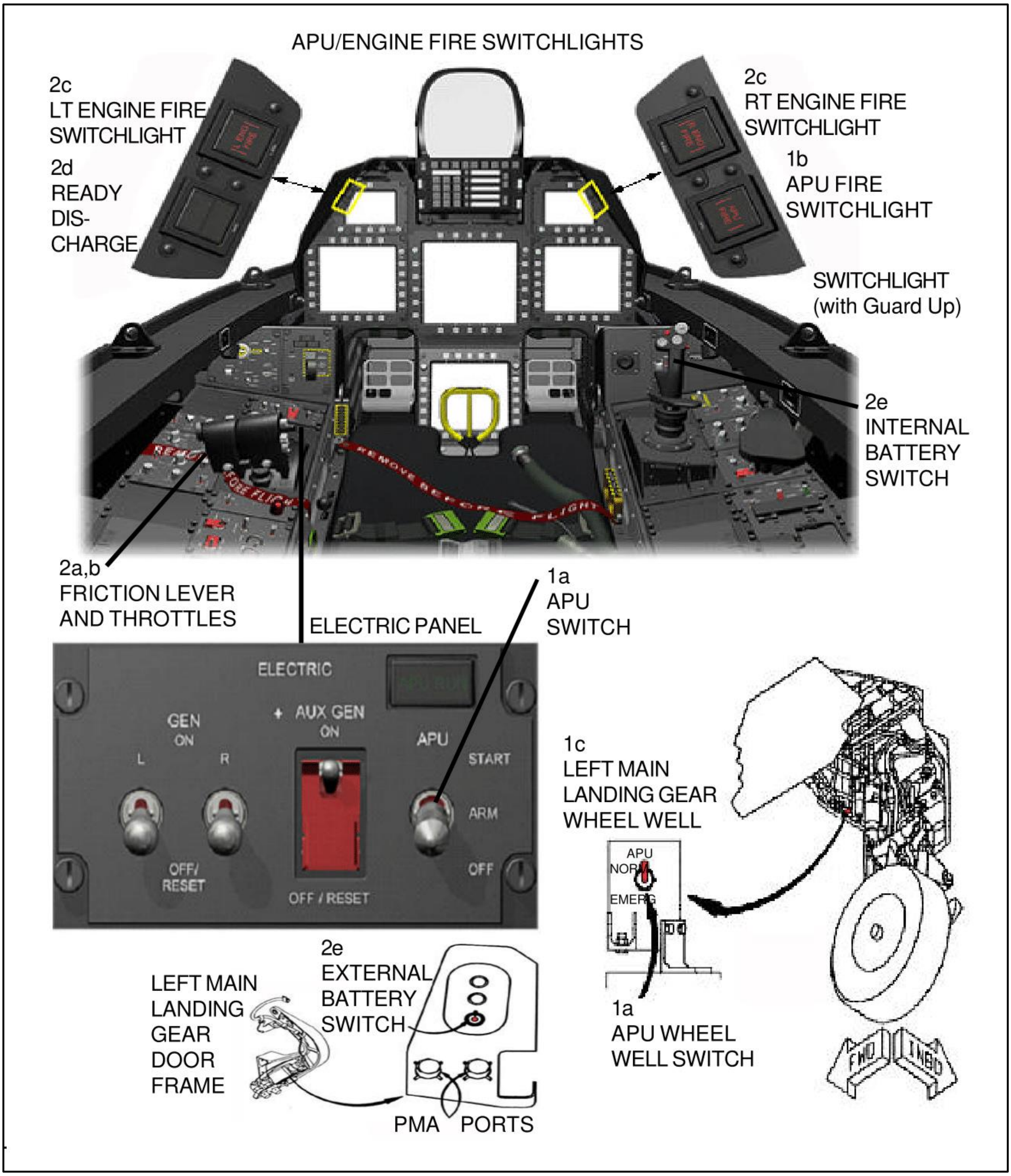


F-22A


RUDDER
FLAP
(RH/LH)
AILERON
(RH/LH)
STABILIZER
APU DOORS
ENGINE
INLET
BYPASS
DOORS
LEADING EDGE
FLAP (RH/LH)
ENGINE INLET BLEED DOORS
(WILL BE ELIMINATED ON ACFT
02-028 AND SUBSEQUENT.)


LAP BELT
THERMAL
COOLING
MANIFOLD
THERMAL
COOLING
GARMENT
HOSE
ARM RESTRAINT
LANYARD
(BOTH SIDES)
EMERGENCY
OXYGEN
LANYARD
PARACHUTE RISER
OXYGEN
MASK
HOSE
OXYGEN
HOSES
COMMUNICATION
LEAD (SECURED
TO ANTI-G HOSE)
ANTI-G
SUIT HOSE
OXYGEN
HOSE
ACG
HOSE
ARM
RESTRAINT
(BOTH SIDES)
SHOULDER
HARNESS
EMERGENCY OXYGEN
PORT (NOT USED)
THERMAL
COOLING
GARMENT
HOSE
ANTI-G
SUIT HOSE
COMMUNICATION
LEAD
OXYGEN
HOSE
UPPER PRESSURE
GARMENT HOSE


TI 62222
3%
TITANIUM
40%
ALUMINUM
15%
TI6-4
37%
OTHER
19%
THERMOSETS
23%
STEEL 6%
THERMOPLASTICS
1%
COMPOSITES
24%
NOSE CONE
COCKPIT AREA
FLAPS
WING ROOT
VERTICAL STABILIZER
ENGINES
HORIZONTAL STABILIZER
LEADING EDGES


APU/ENGINE FIRE SWITCHLIGHTS
2c
LT ENGINE FIRE SWITCHLIGHT
2d
READY DIS-CHARGE
2c
RT ENGINE FIRE SWITCHLIGHT
1b
APU FIRE SWITCHLIGHT
SWITCHLIGHT (with Guard Up)
2e
INTERNAL BATTERY SWITCH
2a,b
FRICTION LEVER AND THROTTLES
ELECTRIC PANEL
1a
APU SWITCH
ELECTRIC
GEN
ON
L
R
OFF/ RESET
AUX GEN
ON
OFF / RESET
APU
START
ARM
OFF
1c
LEFT MAIN LANDING GEAR WHEEL WELL
APU
NORM
EMERG
1a
APU WHEEL WELL SWITCH
FWD
INBD
LEFT MAIN LANDING GEAR DOOR FRAME
2e
EXTERNAL BATTERY SWITCH
PMA
PORTS