26 AUG 2009

PROPOSAL FOR FEDERAL EVALUATION OF PROTOTYPE S-3B FIREFIGHTING AIRCRAFT

DESIGN REPORT AND AIRTANKER FLEET ANALYSIS

Argon ST Aircraft Systems

EXECUTIVE SUMMARY

Federal fire agencies face an ongoing challenge to fight fires with scarce airtanker assets tasked by a combination of local, state, federal, and DoD commitments. The complexity and difficulty of the situation promises to escalate as global climate change and population growth accelerate the wildfire threat. Meanwhile, world-wide military commitments will continue to place high utilization demands on current and future C-130E/H/J platforms, which form a crucial cornerstone of the nation's airtanker fleet.

This proposal is the culmination of prior USDA Forest Service interest and dialogue surrounding several previously submitted airtanker feasibility studies. It primarily stems from the 2007 Congressional Budget Conference, which authorized funding for a "Next Generation S-3B Fixed Wing Aerial Firefighting Tanker" program with stipulations that it would develop dual-use technologies applicable to both US Air Force Research and US Forest Service fire aviation missions. The S-3B, a multi-role maritime strike aircraft, was retired from US Navy operational service in early 2009 at only half its rated service life.

Argon ST's Multi Mission Conversion (MMC) aircraft program is a phased effort to develop a next-generation airtanker prototype suitable for evaluation by USFS while also researching airborne fluid dispensing technologies under AFRL sponsorship. Phase 1, a $3.2 million design, engineering, and manufacturing effort, is currently underway. At the conclusion of Phase 1, Argon ST will demonstrate a next-generation sensor system capable of several specialized crisis response and fire mapping roles. Argon ST has teamed with NASA's Glenn Research Center for access to a S-3B research aircraft. Phase 2 is a design, engineering, and airframe modification effort intended to provide a single S-3B airtanker prototype for USFS evaluation under joint NASA/AFRL sponsorship. NASA currently operates four S-3B research aircraft; the US Navy also plans to re-activate two to four additional aircraft for test range support in late 2009. The remaining S-3B fleet, stored at Davis-Monthan AFB, AZ, is immediately available for USFS usage and includes nearly 100 airframes and over $1 billion in aircraft, tooling, support, and spare parts assets—all transferrable to USFS at zero procurement cost.

Two volumes of this unsolicited proposal are submitted for USFS consideration; they serve both as a summary of previous work and as a proposal for the continuation of the S-3B airtanker prototype project. Volume 1 (this document) summarizes the technical findings of Phase 1 airtanker design and includes a suitability, life cycle cost, supportability, and maintainability analysis of the potential S-3B airtanker fleet. Volume 2 is a Cost Proposal describing the Phase 2 effort required to finalize the airtanker design, acquire an airframe, and modify a prototype.

The remainder of this volume provides a brief overview of the S-3B aircraft, its suitability as an airtanker, and an analysis of its life cycle costs as part of a national airtanker fleet. The most important conclusions assert that the S-3B airtanker is fully suitable for the fire aviation environment as a Type II (2000 gal. fire retardant capacity) airtanker, that it has a superior response time than any current or future airtanker, and that it is more cost- and fuel-efficient than larger Type I (3000+ gal.) airtankers or Very Large Airtankers (VLATs) like the B747 or DC10. Completion of Phase 2 and flight test of a S-3B airtanker prototype are intended to validate these conclusions.

Through submission of this unsolicited proposal, Argon ST requests that the USDA Forest Service assist in making government funds available for use in continuing S-3B airtanker prototype activities. Argon ST looks forward to continued contact with the USFS Fire and Aviation Office in support the nation's critically important airtanker fleet.

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1.0 BACKGROUND

The legacy of the 2002 Federal Aerial Firefighting Blue Ribbon Panel Report, combined with the cancellation of all 33 large airtanker contracts in 2004 continues to dramatically impact the nation's readiness for a growing wildland fire threat. With an aggressive and proactive vision that aviation "safety is not negotiable", Federal fire agencies are now challenged to fight fires with scarce airtanker assets tasked by a combination of local, state, federal, and DoD commitments. The complexity and difficulty of the situation promises to escalate as global climate change and population growth accelerate the wildfire threat while world-wide military commitments continue to require high utilization of current and future C-130 platforms.

This proposal is the culmination of prior USDA Forest Service interest and dialogue surrounding several previously submitted airtanker feasibility studies. It primarily stems from the 2007 Congressional Budget Conference, which authorized funding for a "Next Generation S-3B Fixed Wing Aerial Firefighting Tanker" program with stipulations that it would develop dual-use technologies applicable to both US Air Force Research and US Forest Service fire aviation missions.

Argon ST Aircraft Systems was awarded the program contract, which was transferred to joint Air Force Research Labs (AFRL) and Naval Air Systems Command (NAVAIR) sponsorship in January 2008. Argon ST's Multi Mission Conversion (MMC) aircraft program is a phased effort to develop a next-generation airtanker prototype suitable for evaluation by USFS while also researching airborne fluid dispensing technologies under AFRL sponsorship. Phase 1, a $2.7 million design, engineering, and manufacturing effort, is currently underway. At the conclusion of Phase 1, Argon ST will demonstrate a next-generation sensor pod capable of several specialized CBRNE response and fire mapping roles. Argon ST has teamed with NASA's Glenn Research Center for access to a testbed demonstrator aircraft. An outline of the Multi Mission Conversion program is shown below:

S-3B Multi-Mission Conversion (MMC) Research Program Overview

- **Phase 1: Fire-Mapping Technologies and Preliminary Airtanker Design (FY08-09)**
    - Design, fabrication, assembly, and test of Multi-Mission Hyperspectral Imaging (HSI) Pod
    - Design, fabrication, assembly, and test of flight-ready fire-mapping sensor system
    - Design and integration of ROVER air-to-ground firemapping video link
    - Airtanker Preliminary Design
- **Phase 2: Prototype Airtanker Engineering, Design, and Modification (FY10-11)**
    - Airtanker Preliminary Design Review (PDR)
    - Airtanker Critical Design Review (CDR)
    - Prototype S-3B airtanker airframe modification
- **Phase 3: Prototype Airtanker Flight Test and Certification (FY11)**
    - Airtanker ground/flight test and certification

Two volumes are submitted for USFS consideration; they serve both as a summary of previous work and as a proposal for the continuation of the S-3B airtanker prototype project. Volume 1 (this document) summarizes the technical findings of Phase 1 airtanker design and includes a suitability, life cycle cost, supportability, and maintainability analysis of the potential S-3B airtanker fleet. Volume 2 is a Cost Proposal describing the Phase 2 effort required to finalize the airtanker design, acquire an airframe, and modify a prototype S-3B airtanker. The prototype airtanker will be made available for USFS evaluation under joint AFRL/NASA sponsorship; NASA currently operates four S-3B research aircraft. The remainder of this volume provides a brief overview of the S-3B aircraft, its suitability as an airtanker, and an analysis of its life cycle costs as part of a national airtanker fleet.

Through submission of this unsolicited proposal, Argon ST requests that the USDA Forest Service assist in making government funds available for use in continuing S-3B airtanker prototype activities. Argon ST looks forward to continued contact with the USFS Fire and Aviation Office in support the nation's critically important airtanker fleet.

2.0 US NAVY S-3B AIRCRAFT OVERVIEW

Early into the MMC Program, Argon ST determined that most commercial derivative airframes were unable to withstand the demanding load environment associated with fire aviation missions over an acceptable airframe service life. Selection of a military, multi-mission, high performance, tactical aircraft for conversion was desired in order to allow a safe, cost-effective approach to fire aviation and research missions. Argon ST selected the US Navy's S-3B Viking aircraft, an immediately available, combat-proven, reliable, low-cost platform for conversion.

Argon ST's ongoing research and dialog with USFS revealed that any one of many low-risk approaches to S-3B airframe modification would yield a highly suitable platform capable of meeting or exceeding Type II (1800-2999 gal. payload) airtanker requirements.

2.1 Airframe Characteristics

The S-3B Viking is a subsonic aircraft with a conventional high-wing configuration and 15° sweep. Two GE TF-34 high-bypass turbofan engines are mounted in nacelles under the wings. Each uninstalled TF-34 is rated at 9,275 lbs. static sea level thrust.

S-3B Characteristics:

Length:
53 ft. 4 in.
Wingspan:
68 ft. 8 in.
Height:
22 ft. 9 in.

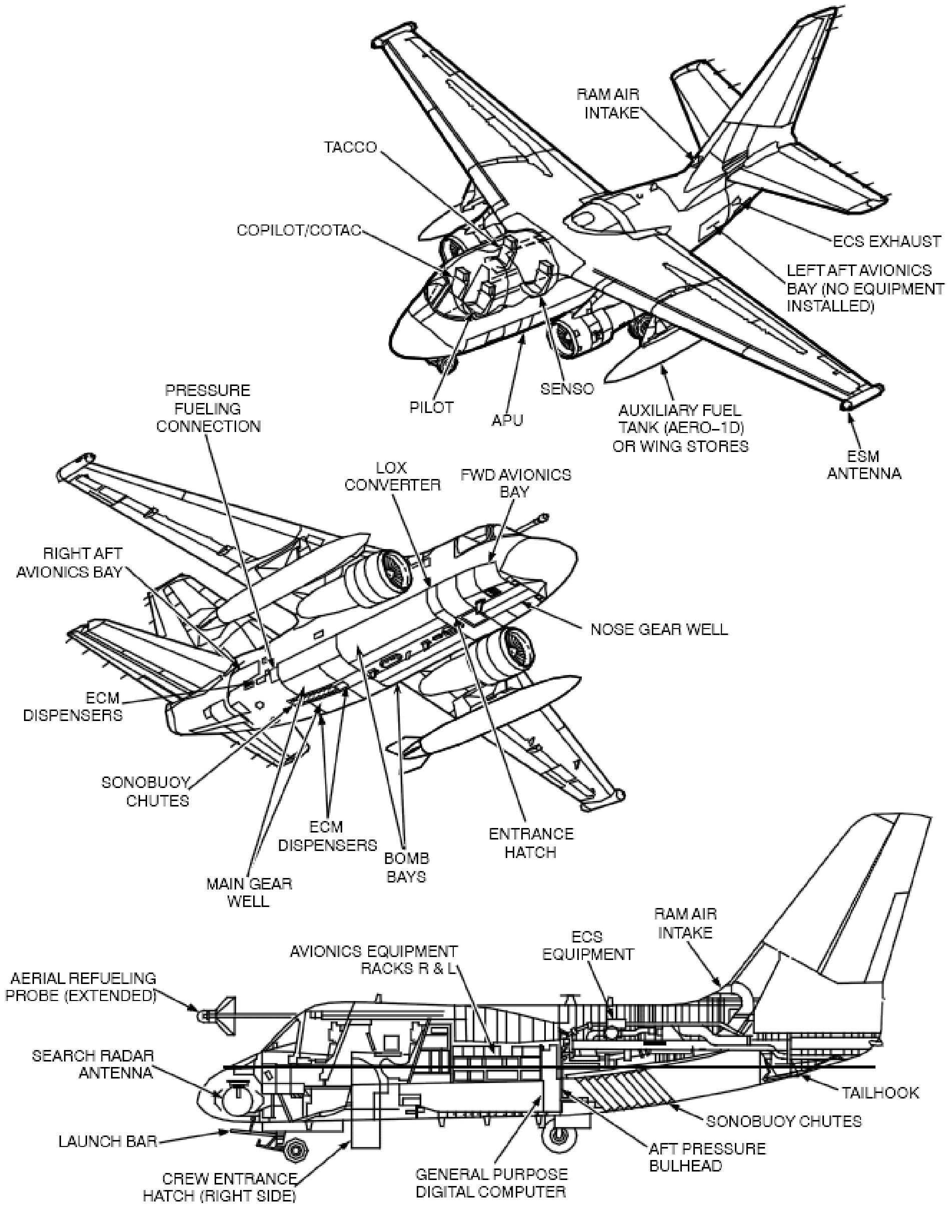
Basic Weight:
29,000 lb. (typical)
Max TOGW:
52,500 lb.

Max Speed (Vne):
450 KIAS (0.79M)
Maneuvering Limits:
-2.0g / +3.5g
Ceiling:
40,000 ft.

Internal Fuel:
13,144 lb. (1,933 gal.)
External Fuel:
3,604 lb. (530 gal.)

Loiter speed, 20k'
210 KTS
Approach speed:
115 KTS

Ferry Range:
3000+ nm
Endurance:
6+ hr. (unrefueled)



The aircraft seats a crew of four. Entry is via a hatch and ladder which folds out of the right lower fuselage just forward of the right engine nacelle.

Two underwing hardpoints can be used to carry tanks, general purpose and cluster bombs, missiles, rockets, storage pods, and sensor packages. The right wing pylon has a carriage limit of 2,500 lbs. The left wing pylon has a carriage limit of 2,850 lbs. The aircraft is fully aerobatic and capable of overhead maneuvers and inverted flight.

While the flight envelope includes a +3.5g maneuvering limit, this is only available at reduced aircraft weight (36,600 lbs. or below). At maximum takeoff gross weight (52,500 lbs.), the aircraft's positive maneuvering limit is still +2.5g and capable of maintaining a 60° angle-of-bank turn at 200 KIAS.

2.2 Differences Between the S-3B and Current Airtanker Aircraft

Argon ST's engineering analysis has determined that several significant advantages are inherent to the S-3B airframe compared to existing airtanker aircraft. The most important are summarized here:

The airframe was built for tactical, high-performance missions flown in profiles very similar to the fire aviation environment. The S-3B could be considered a near-purpose built aircraft for the fire aviation mission. It is a sea control aircraft designed for low-altitude maritime attack missions using missiles, torpedoes, bombs, rockets, or mines. It is not a transport aircraft nor was its design derived from a transport airframe. While capable of long-duration patrol missions, the aircraft's performance envelope exceeds that of typical patrol or transport aircraft. Its cockpit visibility, flight controls, and flying characteristics are optimized for low-level, maneuvering flight. The S-3B airframe and its structural fatigue life were designed around mission profiles where the majority of flight time is spent at altitudes below 5000' and airspeeds ranging from 110 to 450 KIAS.

Structural Fatigue Life Management Systems integrated into the baseline design allow detailed tracking of airframe fatigue on a mission-by-mission basis. The aircraft is configured with a Structural Data Recording Set (SDRS), which records in-flight fatigue data, as well as various aircraft flight parameters such as airspeed, altitude, and roll rate. The SDRS includes both airborne and ground support components, operates automatically inflight, and provides immediate visual warning in the cockpit when structural limit loads are exceeded ("over-g" and "overstress" events).

High dash speed coupled with low approach speed allows rapid transit with favorable payload delivery profiles. The aircraft's swept-wing configuration, spoilers, and electrically trimmed horizontal stabilizer enable maximum speeds up to 450 KIAS and 0.85 Mach with benign stability characteristics and minimal pilot workload. The wing supports a high-lift configuration with a combination of plain leading edge flaps and single slotted Fowler trailing edge flaps. Approach speeds are as low as 105 KIAS depending on aircraft configuration.

Upper and lower wing spoilers enable rapid, precise reduction of airspeed and altitude. Spoilers on the top and bottom portion of the wing serve as speedbrakes and, when actuated, significantly decrease wing lift and increase drag. This feature allows for rapid descent from altitude and precise airspeed control in descents. Proper use of spoilers, throttle settings, and pilot technique completely mitigates any turbofan engine "spool up" delays with the addition of power—a critical factor in the S-3B's aircraft carrier approach environment.

2.3 Structural Service Life

In 2004, the S-3B OEM supported a NAVAIR effort to validate the integrity of the S-3B airframe's overall structure beyond its original design lifetime of 12,000 flight hours. A Full Scale Fatigue Test (FSFT) program was conducted at the OEM's facilities in Marietta, Georgia. The two S-3B test articles were rigged with a tailored static-test structure to simulate the flying stresses encountered in typical fleet operations. Analysis of two full aircraft test articles was undertaken using more than 110 hydraulic jacks placed at cumulative load points to emulate high stress loads under varying conditions including; vertical gust, symmetric maneuver, asymmetric maneuver, lateral gust, and lateral maneuvers throughout the typical range of acceleration, deceleration, pitch, yaw, roll and combination maneuvers in X, Y, and Z axis. The S-3B test articles were tested to a total amount of cycle test hours (CTH) on the wings, empennage, and fuselage equivalent to two complete lifetimes. Severe flight loading criteria applied to the wing/fuselage test section were limited to 4.0g's which still exceeded the certified flight envelope of S-3B operation. Successful FSFT program empirical validation has resulted in approval of the S-3B to an operational lifetime of 23,000 flight hours. With the average S-3B airframe retired at 11,000-12,000 flight hours, the fleet has left service at only 50% of its rated airframe life. Since the FSFT measured S-3B fatigue life against a low altitude, dynamically maneuvering load spectrum and mission profile very similar to the fire aviation environment, the 23,000 flight hour limit is highly applicable to airtanker operations. In the words of the OEM FSFT Failure Analysis Report, "It would be conservative to use these hours to determine inspections or life limits on individual aircraft."

2.4 Safety Record

The S-3B aircraft is the safest maritime patrol aircraft in US Navy service, with a land-based Class A mishap rate lower than that of the Navy's P-3C aircraft fleet. The US Navy P-3C airframe is the successor to the P-3 aircraft currently employed as Federal firefighting airtankers.

Across the full span of its 21 years of operational service and 1.7 million accumulated flight hours, the S-3B was assessed to have a land-based operational Class A mishap rate of 1.06 per 100,000 flight hours. This mishap rate excludes 23% of overall S-3B Class A mishaps, which involved hazards associated with the ship-based aircraft carrier environment. Like most aircraft, the majority of S-3B Class A mishaps (57%) were caused by human factors.

The most prevalent of the limited system and mechanical failures in the S-3B's operational history were addressed in a series of comprehensive airframe upgrades, beginning in 1999. With the addition of a fully digital, dual-channel automatic flight control system and a one-time, fleet-wide inspection to correct improper hydraulic system maintenance procedures, the aircraft's already low mishap rate was further reduced. Overall, the S-3B's Class A mishap rate due to mechanical or system failures stands at 0.118 per 100,000 flight hours.

Safety is built into the S-3B aircraft by design with multiply redundant electrical, hydraulic, and flight control systems designed for failure tolerance in a combat environment. Safety features include:

– Dual redundant hydraulic flight control systems

– Independent emergency hydraulic pump
– Independent emergency flight control system (EFCS)
– Triple redundant electrical power systems including an Auxiliary Power Unit (APU)
– Dual redundant electrical pitch and roll trim systems, each with automatic fault detection
– Dual redundant, 4-axis digital autopilot system
– Excellent single-engine flight characteristics, including wave-off / go-around
– Automatic elevator bias to relieve stick loads during landing configuration transition
– Automatic thrust/pitch compensation to minimize pitch changes with power
– Direct lift control for precise glideslope management
– Dual redundant, digital yaw damper – including single-engine modes
– Dual controls, dual instrument panels, cockpit optimized for pilot/copilot CRM (Cockpit resource management)

The Navy-configured S-3B aircraft incorporates an emergency canopy jettison system along with ejection seats. Ejection seats are specifically required in the ship-based aircraft carrier environment to mitigate hazards specific to arrested landings, flight deck operation, and catapulted takeoffs. A utility, cargo, and transport variant of the aircraft, the US-3, was fielded in the 1980's-1990's with ejection seats removed but emergency canopy escape systems retained. In 2005, the US Navy proposed transfer of a land-based S-3B fleet to the US Coast Guard for maritime patrol, drug interdiction, and search-and-rescue (SAR) missions with the ejection seats removed. NASA's Glenn Research Center currently operates four S-3B aircraft and, pending additional airframe modification funding, plans to remove the ejection seat system from their land-based research aircraft. In order to reduce aircraft weight, maintenance costs, and flight/ground crew training costs, removal of the S-3B's ejection seat systems is therefore appropriate and recommended for any land-based operations, including fire aviation missions.

2.5 Cockpit Features

The S-3B flight deck features a side-by-side pilot and co-pilot configuration with full flight controls and instrumentation at each station. Under NAVAIR clearances, the aircraft is authorized for single-piloted flight with the aircraft commander at the left cockpit station and a non-pilot Naval Flight Officer at the right station. A 3-axis digital autopilot/auto-throttle system is installed, capable of hands-off waypoint steering, altitude hold, climb, descent, and approach modes. Navigation systems include integrated, dual redundant ring laser gyro/GPS systems, TACAN, and shipboard ILS.

The cockpit provides an excellent field of regard, with an unobstructed 180° horizontal field of view from the aircraft's 3 o'clock to 9 o'clock. Vertical vision is relatively unimpeded with a single 16" wide eyebrow instrument panel as the only obstruction to a full 100°

view from the nose to directly overhead. The entire cabin is pressurized and climate controlled.

Communications systems feature an integrated radio and cockpit intercom (ICS) capable of supporting simultaneous reception on two separate UHF radios along with separate VHF and HF radio sets. Comms are fully selectable for reception at each cockpit station.

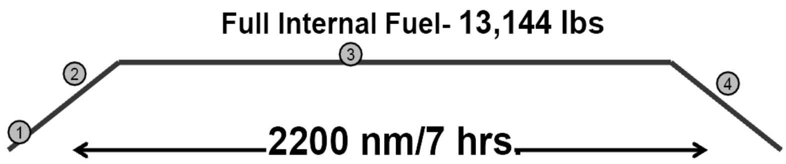
Modern ILS, VOR, VOR-DME, TCAS, Mode S, and other COTS instrumentation is compatible with the S-3B cockpit and was recently installed aboard a NASA S-3B research aircraft operated by the NASA Glenn Research Center. Cockpit upgrades include dual redundant Garmin GNS-430 units installed alongside the aircraft's native GPS/ring laser gyro systems. Navigation upgrades include FAA-certified VOR, ILS, and GPS systems with a Mode S transponder. The aircraft's liquid oxygen system was also replaced with a modular, low-cost gaseous system. Ejection seats, no longer required outside the aircraft's original carrier launch and recovery environment, will be removed. NASA's complete engineering and design packages are available at no cost to government S-3B users and contractors.

2.6 Flying Qualities

The S-3B was designed as a long range, high endurance aircraft with high speed dash capability for operation at low altitudes. Stability and handling characteristics are very favorable across the entire range of the aircraft's operating envelope. Leading and trailing edge flaps enhance stability and minimize pilot workload at low speeds. The aircraft's high bypass turbofan engines are optimized for low speed, low altitude operation.

The S-3B's is an all-weather capable aircraft with a ferry range that is superior to many commercial aircraft (small transport jets) of its weight class, while its speed is superior to turboprop aircraft with comparable fuel economy. Meanwhile, it possesses a favorable cockpit layout, maneuverability, and airframe durability unavailable in any commercial airframe. The aircraft's long range and high speed gives it immense flexibility for basing, both during and between missions. Maximum range performance is outlined below.

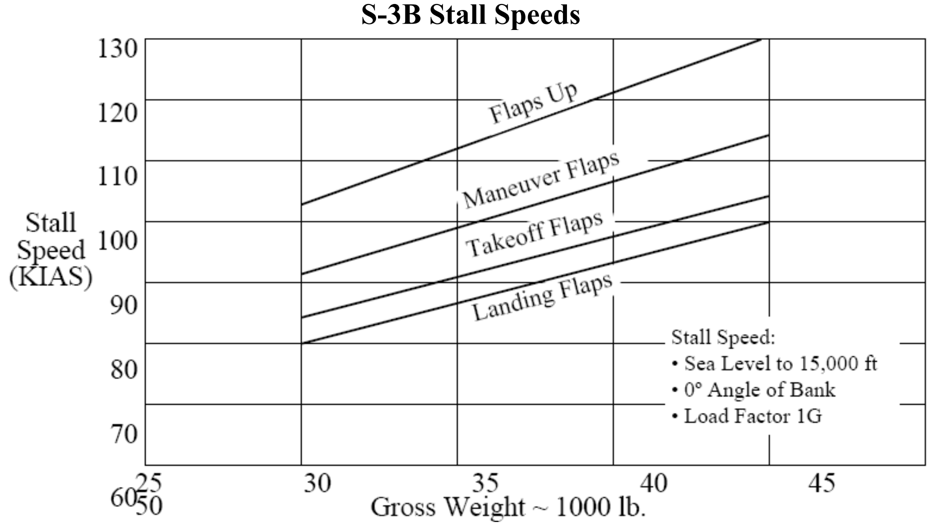
S-3B Maximum Range Profile



1. Takeoff and climb at max continuous power
2. Cruise, climb, and airspeed at max range profile
3. Maximum transit altitude 35,000'
4. Enroute descent and landing with 1,300 lbs. fuel reserve

The aircraft's leading and trailing edge flaps provide exceptional low-speed flight capabilities for a platform of its size, weight, maneuverability, and top speed. Ample stall warning is provided through a combination of airframe buffet and installed AOA (angle of attack) instrumentation. Directional control is maintained with minimum pilot workload throughout the low-speed envelope by a combination of the large vertical fin, hydraulically boosted rudder, and a dual channel, digital stability augmentation system (yaw damper). Automatic turn coordination is also provided by the yaw damper system. Single-engine flight is directionally stable at all speeds down to the stall speed of the aircraft. In other words, V_{MC} (the minimum controllable single-engine speed) is lower than V_{min} (the minimum 1g stall speed) for all aircraft configurations, making the aircraft an extremely safe and stable single-engine platform. S-3B stall speeds are summarized in the following chart:

S-3B Stall Speeds



2.7 Military Operating Costs and Maintainability

Navy S-3B deployment to Al Asad, Iraq '08 (VS-22)
100% mission availability in desert environment

Early introduction of the S-3A model aircraft into the Navy inventory faced maintenance challenges due to insufficient spare parts inventories in 1975. The majority of the aircraft's maintenance-intensive systems were upgraded or removed with introduction of the follow-on S-3B model in 1988. By 2006, the S-3B's operating costs declined so dramatically that it became the least expensive combat aircraft operated by the US Navy. The current platform enjoys the benefits of over 30 years of continuous improvement, numerous airframe changes, and equipment upgrades. In 2008, four S-3B aircraft deployed ashore to Al Asad, Iraq, where they operated for six months in austere, forward-deployed desert conditions. Nearly all maintenance was performed on open ramp areas routinely exposed to dust storms and temperatures exceeding 130°F. The four deployed S-3Bs maintained 100% mission availability while flying an average of 3 missions and 6 flight hours a day with no access to depot-level maintenance. Overall, the operating costs of these deployed S-3B aircraft were over 30% lower than those of the Navy's P-3C, which flew equivalent missions in the same region during the same timeframe.

2.8 Airframe and Support Facilities Availability

S-3B aircraft are immediately available for conversion. Retirement of the S-3B operational fleet concluded in early 2009 in order to accelerate US Navy F/A-18E/F/G Super Hornet and P-8 Poseidon MMA procurement programs. Several S-3B aircraft are already processed for storage even as remaining assets support limited US Navy flight test and NASA research missions. The average S-3B aircraft is being retired at only 50% of its rated airframe service life, with approximately 15 years life remaining at a use rate of 800 flight hours per year. The entire S-3B aircraft fleet presents USFS with an asset ready for immediate re-tasking to fire aviation missions at zero procurement cost. The total value of the S-3B fleet and its logistics, support, and training infrastructure exceed $1 billion. Due to the good condition of retired S-3B airframes, and the US Navy's investment in maximum preservation for much of the retired fleet, airframe re-activation costs are low. US Navy PMA-290 estimates place the re-activation cost per S-3B airframe at roughly 50% the costs associated with activating P-3 airframes.

Significant S-3B life-cycle support remains available for the aircraft despite its retirement from US Navy service. US Navy flight test squadrons and NASA's Glenn Research Center will continue to operate 6-8 S-3B aircraft through 2015. Maintenance depot facilities will remain open at NAS Jacksonville, FL, with industrial repair, re-work, and spare parts supply services available to S-3B aircraft operators. Training & simulator facilities will be available at NAS Pt. Mugu, CA for initial and recurrent training of maintenance and aircrew personnel. Engineering, analysis, and life cycle technical support are available at the NASA Glenn Research Center, NAS Pt. Mugu (Test & Evaluation Squadron VX-30), and NAS Patuxent River, MD (Naval Air Systems Command PMA-290). All Navy S-3B facilities and services are available to USFS personnel or USFS contractors.

3.0 S-3B PROTOTYPE AIRTANKER DESIGN

The objectives of the S-3B Phase I airtanker design effort were to analyze the feasibility of the aircraft as a suitable airtanker, determine the range of modification options available for maximum cost efficiency and lowest technical risk, and predict the performance of the most efficient design candidate.

Engineering work included a comprehensive design trade-off study, structural integration study, retardant tank loads and stress analysis, ground pattern performance analysis, and significant preliminary design work on the airtanker airframe and retardant tank/door systems. Multiple candidate S-3B airtanker configurations were considered and an optimal design was selected based on cost, performance, and maximum simplicity of airframe/tank integration.

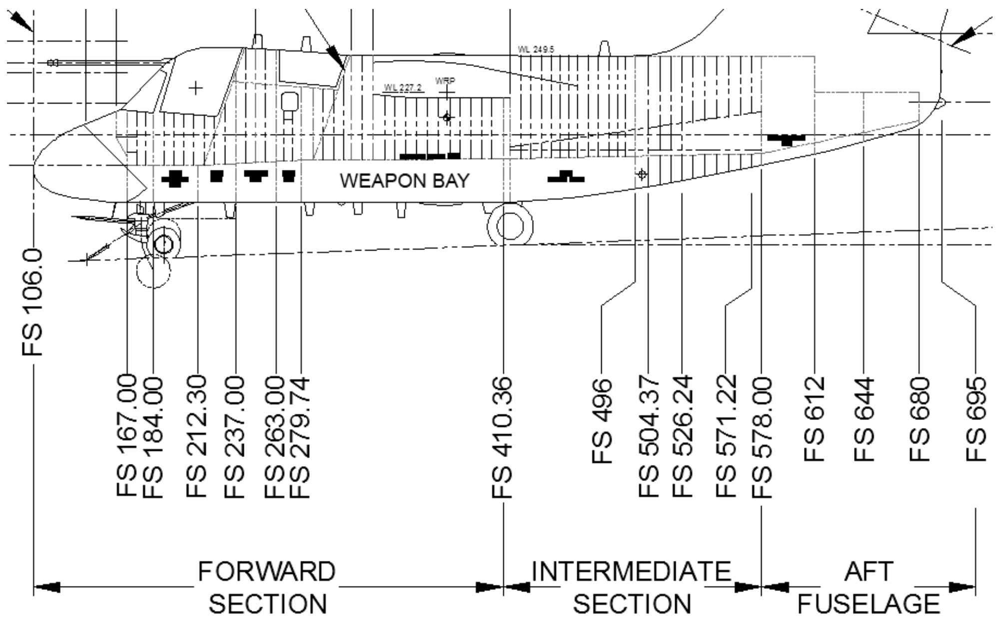
The prototype design effort analyzed over 45 US Navy publications and 120 OEM drawings to generate the most extensive S-3B airtanker engineering data package to date. Access to NAVAIR S-3B operational, maintenance, flight test, and engineering documentation was provided by Argon ST's US Air Force, NASA, and US Navy sponsors. Training, Standard Operating Procedures (SOP), performance, and flying qualities analysis was provided as Government Furnished Information through Argon ST's close ties with the S-3B aircrew, maintenance, and engineering support communities under AFRL sponsorship. Airtanker design requirements were generated based on Interagency Airtanker Board (IATB) multi-engine airtanker requirements, 2002 Airtanker Blue Ribbon Panel findings, airtanker industry best practices, and consultation with USFS and Cal Fire operators and officials.

The following section describes the design approach, candidate configurations, and final design candidate selected for the S-3B airtanker. Main attributes of the design are summarized, including its 2000 gal. retardant capacity, 450 KTS top speed, and 125-135 KTS drop speed.

3.1 Design Approach

While typical transport aircraft are designed for lower density load distributions along the fuselage and wing span, the S-3B is not, and certain portions of its center fuselage section are specifically configured for high density loads (torpedoes, bombs, and other heavy weapons). Analysis of the basic S-3B structure found advantages in using the existing load bearing structures and load paths associated with the forward fuselage section and weapon bay. Basic structural arrangement of the S-3B airframe is shown below:

Navy S-3B Structural Arrangement Overview



The area most suited for tank installation, venting, gating, and other payload systems picks up the aircraft's floor and keel structures in the vicinity of FS 279 through FS 410. Areas forward of FS 279 are not easily usable due to auxiliary power unit (APU) installation. Areas aft of FS 410 are not readily usable due to the main landing gear wells and pressure bulkhead structure. Twin keels run the length of the fuselage from the vicinity of FS 184 to FS 504. These twin keels, the aircraft floor (just above the weapon bay), and the pressure bulkhead structures form the primary longitudinal load path for the aircraft.

An iterative process was used to analyze multiple candidate arrangements of retardant tank systems integrated with a modified S-3B airframe. Each candidate design was evaluated against the following factors and requirements:

- The modified airframe and installed tank structures were designed to operate across the full US Navy S-3B flight envelope.
- No flight surface modifications were permitted for geometry interference relief or additional control authority.
- Drag count and aerodynamics associated with mating of any external tank systems were designed to be as minimal and low-profile as possible.
- Complexity of airframe modification including removal/replacement of structural components and re-routing of hydraulic, flight control, fuel, bleed air, and other systems was minimized as much as possible.
- Center of gravity (CG) for all airtanker configurations and load cases was designed to be within the allowable weight and balance envelope of the aircraft.
- The electrical system requirements definition included aircraft electrical system interface parameters, component duty cycles, AC, and DC power requirements.

- Cockpit installation and layout were considered for tank system controls and indicators.

Significant retardant tank engineering was performed to develop a tank system for the most promising S-3B airtanker design candidates. Preliminary tank designs considered:

- Static loads and stress analysis.
- Tank structure, materials, and interfaces
- Gating systems
- Venting systems
- Fill systems
- Aerodynamic fairings as required
- Air plenum components with inlets and exhausts for the venting system.
- Control systems, including:
    - Electro-hydraulic servo controlled hydraulics
    - Actuators
    - Electronic controllers for a constant flow rate system
    - Cockpit controls and indicators
    - Electrical and hydraulic interfaces
- Tank systems were designed to be loaded and unloaded readily from ground crew using standard diameter symmetrical locking couplings. An offloading feature was incorporated into each design.
- Tank pressurization loads were analyzed and a venting system designed to maintain greater than -.25 psi during all drops.
- The tank static flight loads definition considered aircraft inertial and aerodynamic loads with critical weights specified.
- The ground loads definition included landing, ground transport loads, fluid loading, and unloading loads.
- Tank designs included an emergency dump capability capable of emptying the system within 3 seconds.
- All tank systems were designed to provide coverage levels from .5 to 8 gpc as specified by the Interagency Airtanker Board (IAB) requirements.
- Ground pattern concentration predictions defined the interdependency between flow rates and ground pattern coverage levels through numerical analysis.

For each tank system, analytical tools were used to estimate ground pattern performance and ensure the design was compliant with IATB requirements. The following factors were analyzed:

- USFS requirements for ground pattern coverage levels at multiple settings.
- Tank/gating/door design, including ullage, tank shaping, and venting
- Speed & altitude of delivery profile
- Fluid Flow rate
- Fluid Volume
- Ground pattern density, line length, and width

3.2 Design Candidates

The Navy S-3B aircraft was found to be highly adaptable to the firefighting airtanker mission. Dozens of airframe/tank configurations were considered. Sixteen were found to meet IATB requirements and selected for in-depth analysis. Analysis showed that removal of Navy mission systems will yield a large and adaptable volume inside the forward fuselage structure capable of supporting over 2000 gal. retardant payloads in some configurations. The smallest retardant tank analyzed carried a payload of 1700 gallons. All configurations analyzed were within the S-3B aircraft's current weight, balance, and flight limitations envelope. The full description of all airtanker design work is detailed in over 250 pages of engineering reports submitted to Argon ST's AFRL sponsor and available at no cost to the USFS as Government Furnished Information (GFI).

3.3 Recommended Design Candidate

Each of the options studied were equally viable airtanker design approaches for the S-3B aircraft. They described multiple points in a design space of trade-offs between factors including structural weight, drag count, complexity, cost, payload, and future payload growth potential.

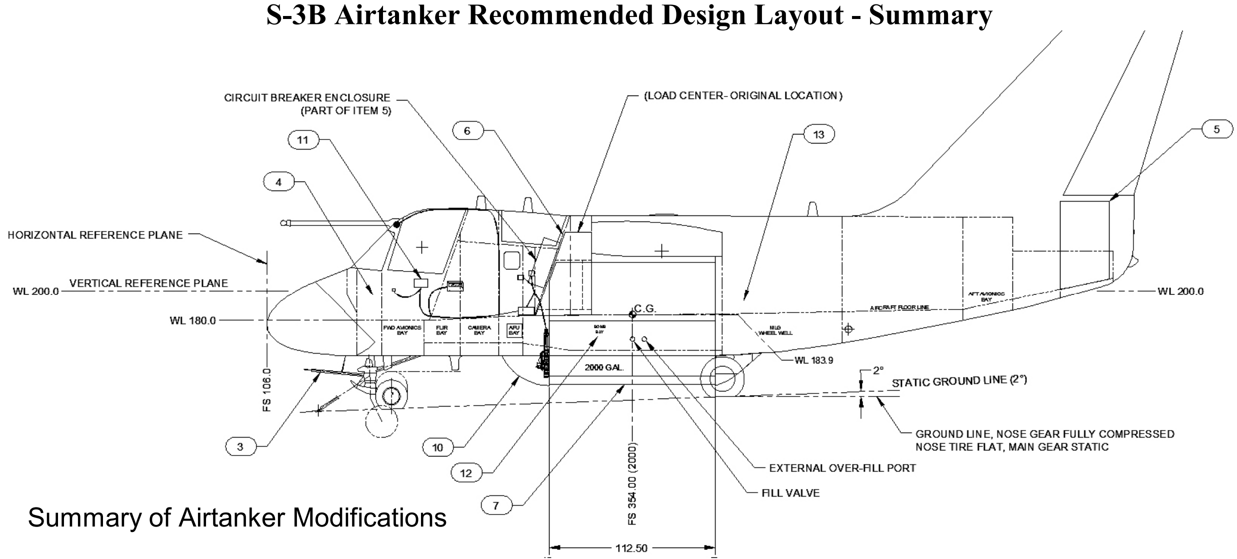
Analysis of current USFS airtanker operations, along with multiple conversations with USFS fire and aviation management officials leads Argon ST to conclude that the most appropriate S-3B airtanker design should include a 2000+ gallon payload capacity, internal tank structure, and minimal drag count. Low drag count forms a critical cornerstone of S-3B takeoff and dash performance, both of which allow the S-3B, as a Type II (1800-2999 gal. payload) airtanker, to perform at or above the delivery rates and cost efficiencies of existing Type I (3000 gal. payload and above) airtankers.

The remainder of this document therefore describes the recommended design. While the full engineering reports developed for the S-3B airtanker program include in-depth analysis on each of the design candidates, only the recommended design is described here for brevity.

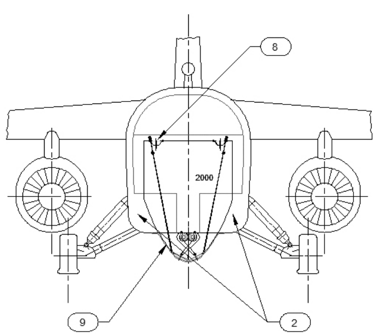
3.4 Airtanker Design Summary: Recommended Layout

The recommended S-3B airtanker design layout incorporates five major groups of modifications to the basic S-3B airframe: **Mission equipment stripping**, which removes unnecessary US Navy mission equipment to reduce basic airframe weight, **Electrical system modifications,** which remove unnecessary harnesses, load centers, and junction/breaker boxes while reinstalling new equipment in alternate locations, **Structural modifications**, which include removal of flooring, keel, and bulkhead structures along with installation of a new pressure bulkhead, **Tank installation,** which involves integration of the removable retardant tank system and fairings, and **Miscellaneous modifications,** which include re-routing of accessory equipment, hydraulic lines, and auxiliary bleed air ducting. Modifications are summarized below.

S-3B Airtanker Recommended Design Layout - Summary



Summary of Airtanker Modifications



1. 2000 USG removable tank assembly installed in forward fuselage
2. Structural, bleed air, and hydraulic line modifications
3. Launch bar partial removal (actuator and attach hardware retained)
4. Cockpit instrumentation and electrical system modifications
5. Electrical load centers (left/right) moved aft to ECS compartment
6. New pressure bulkhead (unpressurized tank compartment) installed
7. Tank door and center fairings installed
8. Tank venting system installed
9. Tank level sensor system installed
10. Tank forward and aft composite fairings installed
11. Tank electrical control and indicator system installed in cockpit
12. Weapon bay utility hydraulic lines modified for use by tank door actuators
13. Environmental control system supply ducting extended forward to new pressure bulkhead

Mission Equipment Stripping: Removal of the following systems is recommended for the USFS airtanker mission.

- Ejection seat systems
- Rear crew stations
- Catapult launch bar
- RADAR antenna, gimbal, support structure, waveguides, cabling, power, and control units
- FLIR turret, support structure, cabling, cooling, power, and control units
- Sonobouy chutes and launch systems
- MAD boom system (already removed in fleet aircraft flown after 1999).
- KY-58 communications security system control units and cabling
- AN/AYK-23 integrated mission computer, consoles, and displays
- SATCOM radios, modems, cabling, and antennas
- HAVEQUICK tactical radios, control units, security systems, and cabling
- Integrated armament control system (ARMCOS) control units and cabling
- Electronic countermeasures (ECM) system dispensers, control units, and cabling
- Electronic support (ESM) system wingtip pods, cabling, and control units
- Automatic carrier landing system (ACLS) control units, cabling, and antennas
- Wing weapon station pylon structures, cabling, and attachment hardware
- Inflight refueling probe, support structure, motor, and plumbing

After modification, the resulting S-3B airtanker basic empty weight is less than 24,000 lbs. Removal of weapon pylons alone reduces the aircraft drag count by 12 (to a level referred to in flight test data as "Configuration A"). Removal of external weapon system antennas and wingtip pods further reduces the aircraft's overall drag count below the Configuration A baseline flight tested by the US Navy. Despite the anticipation that actual S-3B airtanker drag counts will be lower, the Configuration A drag count was used to analyze the S-3B airtanker's performance—a conservative approach.

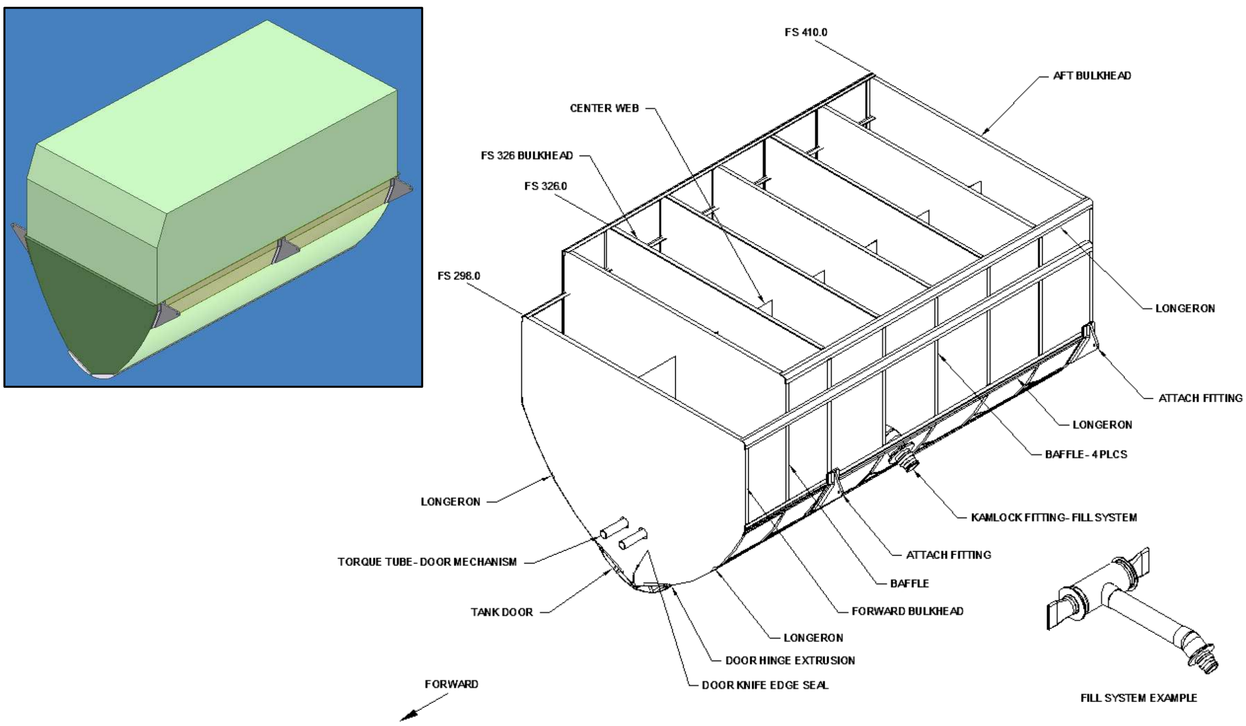
Electrical System Modifications: The basic S-3B aircraft contains four circuit breaker panels and over 320 individual circuit breakers. Over 125 breakers and their associated circuits, harnesses, terminal boards, and junction boxes will be removed. Remaining circuit breakers will be relocated forward of the retardant tank to a location accessible by the flight crew.

Structural Modifications: The tank unit is designed to be structurally integrated into the fuselage shell of the aircraft similar to other airtanker conversions. External fairing interfaces are designed to be attached to the frames of the fuselage shell where minimum reinforcement and modification will be required. Penetrations in the belly skin of the fuselage by attachment fittings will be required. Keelsons and floor beams will be removed to accommodate installation and removal of the tank unit.

The aft pressure bulkhead will be removed (though some structure will be retained for structural integrity) and replaced with a new angled pressure bulkhead just aft of the crew entry door.

Tank Installation: The retardant tank is installed as a single assembled unit. This maximizes head height to meet IAB flow rate requirements and incorporates some modularity design features facilitating the maintenance, repair, and overhaul (MRO) of tank units separately from the airframe. Six attach points, each with machined angle supports and clevis fittings, integrate the tank unit into the fuselage structure. The tank unit incorporates a hydraulically actuated constant flow door mechanism. The tank hopper is integrated into the airframe and replaces the lower fuselage structural integrity. The tank door dimensions provide the exit area needed to meet IAB flow rate requirements. The tank assembly general arrangement is shown below.

S-3B Airtanker 2000 USG Retardant Tank Unit



Miscellaneous Modifications: In addition to various cockpit, external antenna, and accessory wiring changes, several components will need to be relocated from the weapon bay area.

4.0 S-3B AIRTANKER SUITABILITY ANALYSIS

With the feasibility of the S-3B airtanker design and airframe modifications established, analysis was then conducted on the performance of the aircraft, its handling characteristics, tank system performance, and overall suitability for the airtanker mission. All flight characteristics of the S-3B airtanker were found to be suitable for the airtanker mission, with several design characteristics of the S-3B airframe providing advantages not available in current airtanker aircraft. Tank system performance was found to be fully IATB compliant for a Type II airtanker at all coverage levels. The suitability analysis included consideration of numerical methods, US Navy flight test data, S-3B technical publications, S-3B and airtanker pilot interviews, and simulator flights in the S-3B Operational Flight Trainer (OFT) located at the Sea Control Weapon School in Jacksonville, FL. The S-3B OFT was removed from NAS Jacksonville in 2009 and will be relocated to NAS Point Mugu, CA to support ongoing Navy S-3B operations.

S-3B Operational Flight Trainer (OFT), Sea Control Weapon School, NAS Jacksonville, FL (August 2007)

4.1 Fatigue Life in the Fire Aviation Environment

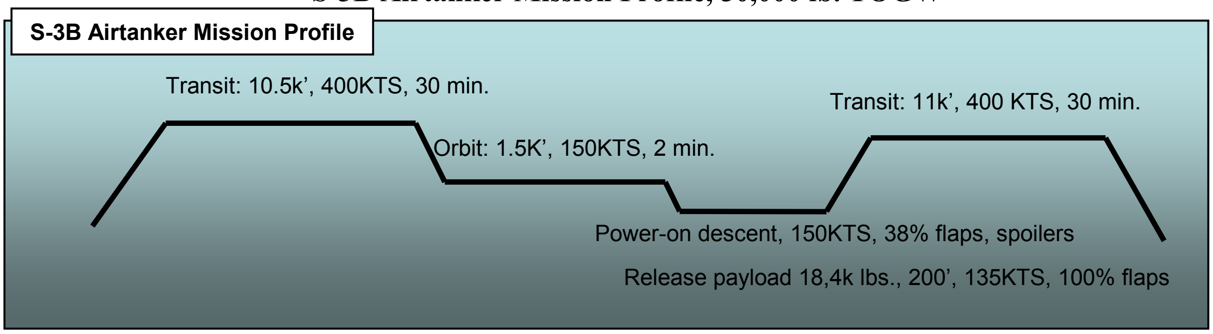
Airframe fatigue remains one of the greatest concerns for the nation's firefighting aircraft fleet. Numerous studies, working groups, and aircraft instrumentation programs have generated significant data and reports on the fire aviation loads environment, which were considered in an assessment of the S-3B aircraft's airframe fatigue life.

The S-3B fatigue life baseline certified by the OEM for its original military mission profiles is 23,000 hrs. S-3B airframes were retired from US Navy operational service with an average 11,000 hrs. remaining out of this certified OEM total. It is widely agreed that the fire aviation loads environment is more demanding than typical transport or military aircraft environments. Hence, one hour of fire aviation flight time is equivalent to more than one hour of military or transport aircraft flight time when determining fatigue life. With this in mind, S-3B aircraft modified for airtanker missions would be inspected, managed, and maintained on a schedule of "equivalent hours":

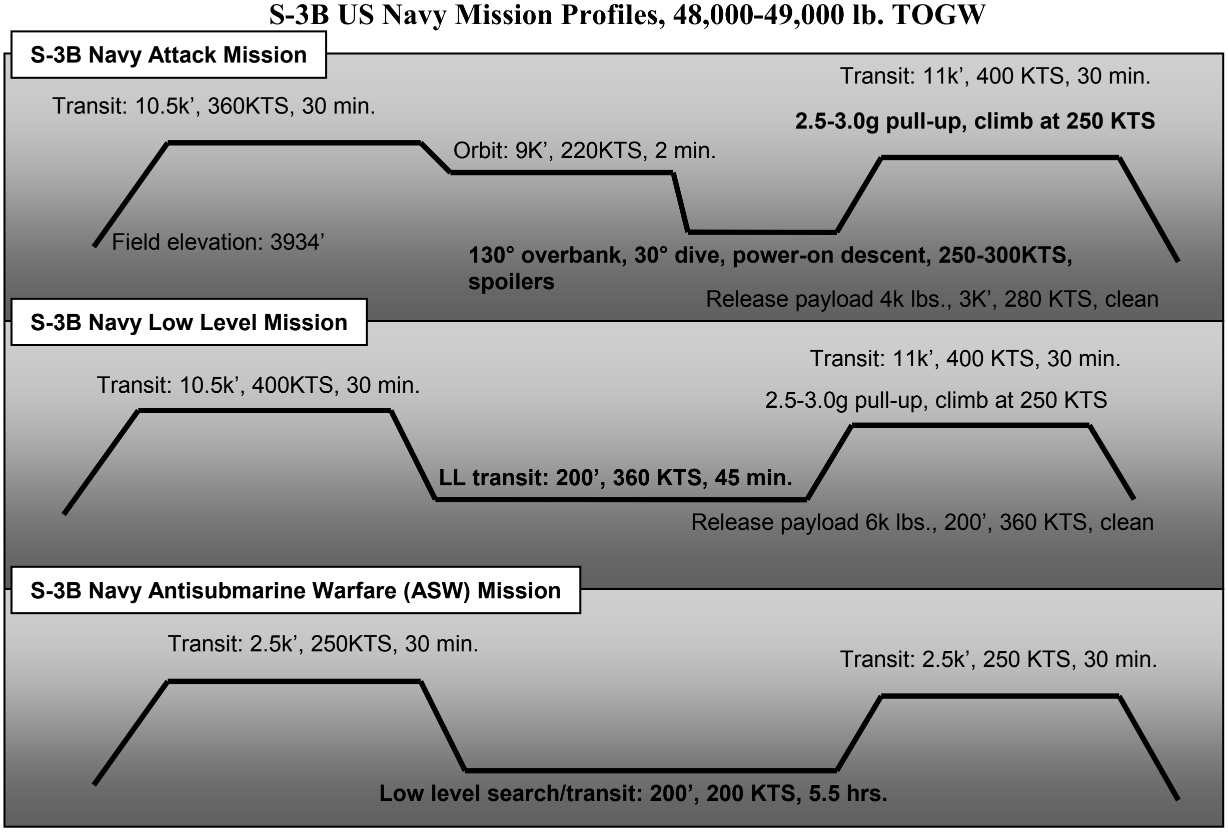
Equivalent Hours = (1.0 x Prior Military Hours) + (Severity Factor x Fire Aviation Hours)

This analysis approach parallels previous investigations conducted by the 2002 Airtanker Blue Ribbon Panel, the Consortium for Aerial Firefighting Evolution, and the aerospace industry. The Severity Factor depends on the fire aviation environment encountered on a typical mission, the design of the aircraft, and the loads environment to which the aircraft was originally certified. The more closely matched the aircraft's original, OEM-certified loads profile is to the fire aviation environment, the lower the magnitude of the Severity Factor. Representative airtanker mission profiles have been extensively documented. They were adapted to anticipated S-3B airtanker operations and compared to some of the S-3B's commonly flown military mission profiles. Note that these summaries are representative but by no means all-inclusive:

S-3B Airtanker Mission Profile, 50,000 lb. TOGW



S-3B US Navy Mission Profiles, 48,000-49,000 lb. TOGW



Comparison of the S-3B's OEM-certified US Navy missions and the anticipated airtanker mission profile reveals a high degree of similarity. The S-3B is already designed and certified by the OEM to fly low altitude missions with extended exposure to turbulence, gust loads, and low airspeeds with correspondingly high wing loading—a profile closely matched to the fire aviation environment. Further, the aircraft is certified to and routinely performs terrain avoidance, overbanking, steep dive, and 2.5-3.0g pullout maneuvers that generate dynamic loads in excess of any fire aviation maneuvers. The least dynamic loads environment experienced by the S-3B aircraft is associated with long-range ASW missions. Previous studies of less maneuverable, lower performance Navy piston-driven S-2 ASW aircraft have concluded that airtanker operations in mountainous terrain are 1.8-2.0 times as severe as typical ASW missions. A thorough follow-on fatigue analysis will be conducted for the S-3B as part of Phase 2 engineering activities, with a focus on the impact of rapid airframe weight changes caused by the release of retardant payload (18,400 lbs). However, comparison of the S-3B with previously analyzed aircraft suggests that the worst-case S-3B fatigue life Severity Factor will be on the order of 2.0 equivalent hours per fire aviation hour, derived from the S-3B's least dynamic ASW mission profile. Assuming above-average airtanker utilization rates of 360 flight hours per fire season, this gives the typical S-3B airframe over 15 years of safe operational airtanker life remaining. Further, the S-3B airtanker will retain its already-installed Structural Data Recording Set (SDRS) hardware for airframe-by-airframe, mission-by-mission evaluation of inflight loads. The data gathered via SDRS will enhance S-3B airtanker fatigue life management and operational safety.

4.2 Flying Qualities in the Fire Aviation Environment

Preliminary assessment of S-3B airtanker flying qualities considered previous airtanker feasibility studies, consultations with airtanker pilots, engineering analysis, S-3B technical publications, flight test data, and simulated airtanker missions flown in the S-3B Operational Flight Trainer (OFT). Assessments of the aircraft's stability characteristics, aerodynamic characteristics, single-engine performance, and overall suitability for flight in the Fire Traffic Area (FTA) are summarized here.

Stability Characteristics. No significant effects on the stability and control or handling qualities are predicted for any configuration. Preliminary weight and balance estimates were performed. While the CG of the full retardant payload is near the forward limit, relocation of the electrical load center hardware keeps the airtanker's CG within current S-3B limits for all weight, landing, and takeoff configurations. An automated elevator bias system reduces pilot longitudinal control workload during flap and speed transitions at high gross weights. The electrically trimmed horizontal stabilizer deflects the entire stabilizer surface, reducing trim drag and allowing ample pitch authority throughout the entire airtanker operational envelope. An automated thrust/pitch compensation system (TPC) reduces pilot workload by deflecting elevator surfaces in response to throttle movements, minimizing pitch changes due to engine thrust.

Aerodynamic Characteristics. The aerodynamic performance of the aircraft is predicted to be unaffected by the projected plan area of the external part of the airtanker configurations. Forward and aft fairings provide adequate aerodynamic profile smoothing. Aerodynamic smoothing in the longitudinal direction will reduce any drag increases to insignificant levels. Even with tank systems installed, overall drag count is expected to be less than the cleanest configuration considered in US Navy flight tests. Adjustments to the performance, stability and control, and handling qualities are expected to be minor. Aerodynamic effects will be analytically predicted and verified through flight test.

Single-engine performance. The basic S-3B airframe possesses exceptionally favorable single-engine flight characteristics, with V_{MC} lower than V_{MIN} in all flight configurations, including the candidate airtanker design. In other words, the aircraft will stall before it reaches its minimum directionally controllable airspeed in all single-engine flight situations. The critical performance limitation for the S-3B airtanker was found to be single-engine climb rate on takeoff. Engineering analysis and US Navy flight test data showed that the S-3B airtanker would meet IAB climb rate requirements of 100 fpm at 50,659 lb. TOGW with a 2000 gal. retardant payload. This climb rate was calculated using existing US Navy Configuration A drag data. The actual drag count of the S-3B airtanker will be less than that of Configuration A, making the actual airtanker climb rate greater than the conservative value calculated during initial analysis. Further, the S-3B airtanker is compatible with on-deck retardant jettison during engine-out takeoff. Jettison of the retardant load would increase safety margins during certain takeoff emergency situations, including engine-out.

Fire Traffic Area (FTA) suitability. Enroute to the FTA, the S-3B airtanker features a 2600 fpm climb rate through 10,000 ft. MSL, allowing rapid climb to efficient cruise altitudes. A pressurized, climate-controlled cockpit allows flight at or above 10,000 ft. MSL for unlimited periods without supplemental oxygen masks. At these higher altitudes the aircraft enjoys the advantage of higher true airspeeds exceeding 400KTS. Cruise altitude for most S-3B airtanker operations will range from 10,500' MSL to 25,000' MSL (FL250). If purely VFR operations are required, cruise altitudes below 18,000' MSL (FL180) would be feasible with less than a 10% reduction in fuel efficiency. The aircraft's high-bypass TF34 turbofan engines maintain 90% of their efficiency at sea level compared to maximum range cruise altitudes, making altitude selection mainly a choice of operational convenience and maximum desired transit speed.

Upon arrival at the FTA the aircraft's cockpit visibility enhances aircrew situational awareness (SA) of the fire area and assists in the tracking of other FTA traffic and air attack planes. The leading edge flaps can be configured for fuel efficient loitering at low airspeeds in the airtanker stack, while the 4-axis autopilot allows fully "hands-off" flight, reducing pilot workload and enhancing safety.

During approach and descent to the target area, use of the aircraft's upper and lower wing spoilers allows wings-level, precise airspeed management with controlled rates of descent up to 10,000 fpm. Adding power and retracting the spoilers during a moderate 1.5g pitch-up maneuver regains level flight in approximately 2 seconds.

The recommended configuration for final approach to the target area is 135 KIAS with leading and trailing edge flaps fully extended. Uphill drops are possible; safety margins, recommended airspeeds, and predicted climb rates are readily derived from existing S-3B flight manual documentation. Modification of the direct lift control system (DLC) controller logic to operate with the landing gear retracted will allow use of the system during airtanker operations. DLC allows precise speed and glidepath control at optimal power settings during retardant drops. Use of DLC and proper pilot technique will completely mitigate turbofan engine spool-up issues, just as it does in S-3B aircraft carrier approaches, where immediate availability of engine power is as essential as in the fire aviation environment. Stall speed in the retardant drop configuration is 105 KIAS, with a 25% stall margin and maneuverability available for terrain avoidance at the recommended drop airspeed (2g, 45 deg. AOB available in level flight).

Terrain clearance after the drop is enhanced by the aircraft's 3.5g maneuvering limit and automatic retraction of spoilers by the DLC system. Proper pilot technique during approach and exit makes engine power immediately available with negligible spool-up time.

4.3 Airtanker Performance Analysis

The S-3B airtanker's takeoff, cruise, retardant delivery, and ground pattern performance were evaluated through engineering analysis based on a combination of Navy flight test data, Operational Flight Trainer (OFT) mission simulations, and existing empirical airtanker performance data.

Takeoff Performance. Navy flight test data for the S-3B in drag Configuration A was used to estimate airtanker performance under similar conditions. The actual S-3B airtanker drag count will be lower than that tested in US Navy Configuration A; therefore this analysis represents a conservative performance estimate. Rotation speed, takeoff distance, refusal speed, and balanced field length (accelerate-stop distance, known as "critical field length" in US Navy terminology) were calculated. The results were compiled into a table of anticipated S-3B airtanker performance at airfields of interest to USFS. Since Navy flight test data and operating procedures utilize worst-case scenarios (single engine failure, partial brakes failure, partial speedbrakes failure, and no field arrestment), the performance figures calculated allowed a significant safety margin validated by hundreds of thousands of hours of "real world" S-3B land-based operations in high/hot/heavy conditions similar to those of the fire aviation environment.

S-3B simulator missions were flown to validate the suitability of existing US Navy takeoff procedures at high gross weights similar to those anticipated in USFS airtanker operations. Current US Navy flight manuals and procedures were deemed safe, efficient, and compatible with airtanker operations at the majority of current USFS fire aviation bases. When, at some USFS bases, safe S-3B operations were not deemed feasible due to insufficient runway length, the S-3B airtanker's speed allowed it to operate from nearby, larger airfields with an initial attack response time that was still superior to current turboprop airtankers.

Analysis of S-3B flight test data, TF34 engine performance data, and "real world" S-3B operations in high, hot, and heavy combat conditions similar to the fire aviation environment determined that no engine modifications or thrust reverser installations were necessary for the airtanker mission. A significant example of S-3B performance in the fire aviation environment was evident in a recent 2008 deployment of S-3B Navy aircraft to Al Asad Airfield, in Iraq. There, the aircraft successfully and routinely operated near their maximum rated gross weight in environmental conditions featuring 130°F runway temperatures and severe dust storms. Further, the S-3B's baseline TF34 engine is currently available in several upgraded models used in other military and commercial aircraft. Future TF34 engine upgrades to the S-3B airtanker would yield increases in thrust and engine power on the order of 25%-30%, with an attendant increase in payload capacity. Performance estimates documented in this report assume a baseline S-3B TF34 engine installation without upgrades.

Cruise Performance. One of the greatest advantages of the S-3B airtanker was found to be its high cruise speed and fuel efficiency. The aircraft was specifically designed for fuel efficiency, stable low altitude/low speed flight characteristics, and high dash speeds. These features are preserved in the S-3B airtanker design. The pressurized cabin allows extended flight above 10,000', which enables speeds in excess of the FAA-mandated 250 KIAS limit at lower altitudes. The highly efficient engines allow minimal fuel loads for one-way cruise legs as long as 450 nmi., which frees up weight for retardant payloads. As was the case with takeoff performance, flight test data used for the engineering analysis assumed a drag count higher than the actual S-3B airtanker configuration; therefore the airtanker performance will be superior to the figures shown below:

S-3B Cruise Performance

Airtanker Gross Weight:	50,659 lb.
Fuel:	6,875 lb.
Retardant:	18,600 lb. (2000 gal.)
Air Temperature at 10,000':	59° F (standard)
Enroute climb rate:	2,250 ft./min
Cruise altitude:	15,000 ft
Cruise airspeed:	324 KTAS
Cruise duration:	2.5 hrs
Cruise distance:	450 nmi
Reserve fuel:	1,000 lbs

Retardant Delivery. The S-3B airtanker's retardant delivery performance was analyzed at 125-135 KIAS, 200' AGL, with full leading and trailing edge flaps extended. US Navy flight test data and qualitative assessments of simulated retardant deliveries in the S-3B Operational Flight Trainer (OFT) provided the basis for analysis. Modification of the Direct Lift Control (DLC) system logic, which normally enables DLC operation only with the landing gear extended, was assumed to improve retardant delivery flying characteristics with the landing gear retracted. Use of DLC allows momentary or extended deployment of the aircraft's spoilers 4°-12° for precise glideslope and speed control at low approach speeds. Use of DLC along with proper pilot technique was found to completely mitigate any turbofan "spool-up" delays with the addition of engine power during simulated retardant drops, just as it does in the Navy S-3B aircraft carrier approach environment. Stall speed margins in the retardant delivery configuration exceeded 25% and are summarized below.

Airtanker Mission Speed Margins: mission full fuel, full payload

Configuration:	Full flaps
Mission weight:	50,659 lb.
Stall airspeed 1g:	105 KIAS
Stall airspeed 1.4g:	124 KIAS (45° bank angle)
Stall airspeed 2.0g:	147 KIAS (60° bank angle)
Recommended delivery airspeed:	135 KIAS (29% 1g Stall Speed Margin)

Ground Pattern Performance. Tank flow performance was characterized by the S-3B retardant tank's maximum average flow rate and flow characteristics. The maximum average flow rate indicated whether it would meet maximum IAB coverage level requirements. A tank flow analysis was conducted assuming incompressible one-dimensional, steady, frictionless flow to determine maximum flow rates. The actual flow from the tank is neither steady nor frictionless. However, experimental studies have shown that the maximum average flow rate calculated with a steady, frictionless flow assumption is a good indicator of the actual mean flow rate. The incompressible and one-dimensional assumption was therefore valid in this case. Empirical measurements have shown that the calculated mean flow rates correlate directly with retardant coverage level on the ground.

Analysis found that the S-3B airtanker produced a mean retardant flow rate of 1126.4 gps with a uniform, smoothly varying flow rate as the 2000 gal. retardant tank emptied its payload. Tank flow rates were compatible with installation of a constant flow rate door system for precise control of drop payloads and ground patterns.

The ground pattern performance of the internal tank configuration was based on the similarity in design to the IAB approved AUC C-130 airtanker. The tank configuration mean flows were estimated to meet IAB ground pattern requirements. All analysis was performed at a drop altitude of 200 ft AGL, which complies with the S-3B aircraft's currently certified operational limits in Navy use.

4.4 Comparison with Other Fixed Wing Airtankers

With preliminary design layout, performance, and suitability analysis completed, the S-3B airtanker was then compared to existing airtankers for a comparative assessment of effectiveness and economy.

A representative airtanker mission scenario was constructed based on existing USFS fire aviation CONOPS, using airtanker pilot interviews and the Interagency Aerial Supervision Guide as references. While 10 hours of continuous flight operations were assumed in the scenario, time was allocated between missions to accommodate crew switches in order to maintain FAA and USFS crew rest requirements. For simplicity, initial pre-flight and start-up procedures were assumed to be of equal duration for all aircraft. The representative mission scenario is detailed below.

Airtanker Mission Scenario:

- 100nm to incident area
- 5 min. delivery profile in FTA
- 100nm return to base
- 100 gpm retardant refill rate
- 10 min. on deck (taxi, checks)
- 10 hour fly day (sunrise-sunset)

Multiple airtankers were analyzed. The most significant and comparable airtanker platforms were found to be the P-3A, C-130H/J MAFFS II, S-2T, and AT-802. The C-27 Spartan was analyzed as a potential future airtanker option as it is compatible with roll-on/roll-off systems similar to C-130 MAFFS. The C-27's airtanker performance was based on existing cargo payload specifications and was provided for reference only; Argon ST performed no engineering analysis of the C-27's potential suitability as an airtanker platform.

Alternative Airtankers Analyzed:

P-3A Aero Union Airtanker

C-130H/J MAFFS II

S-2T Turbine Tracker

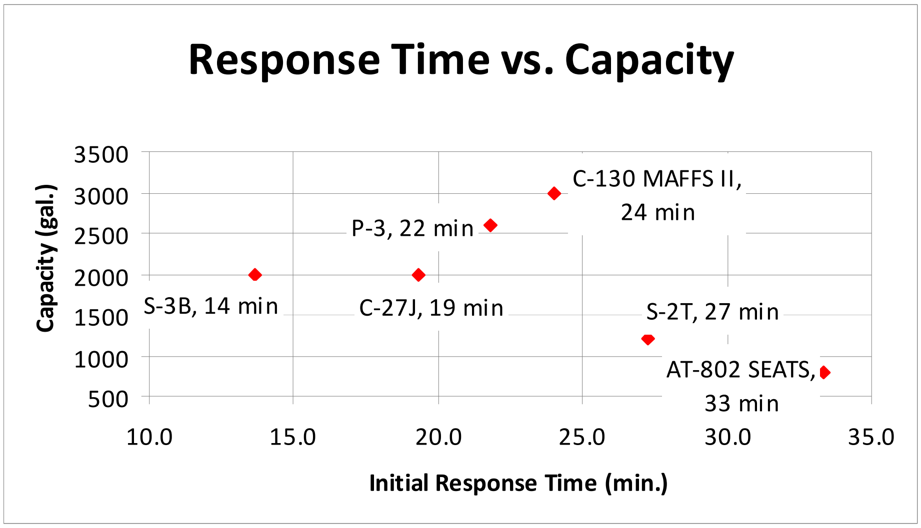
C-27 Spartan*

AT-802 SEATS

* Hypothetical airtanker, currently procured by DoD solely as a military transport aircraft

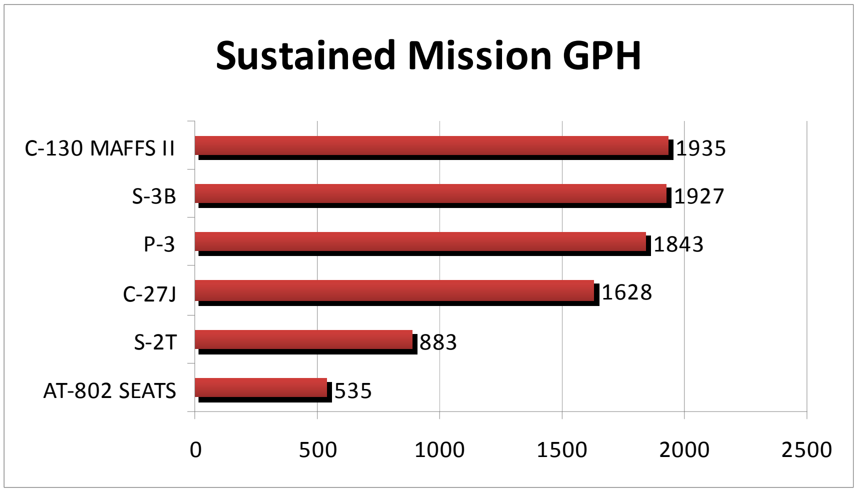
Initial Response Time. The S-3B airtanker's response time for initial attack missions was found to be significantly superior to that of existing airtanker platforms. In this regard, the S-3B's speed, which is superior to any airtanker platform of equivalent size and weight, provided a significant advantage. The S-3B airtanker provides an initial attack capability over 50% more responsive than the fastest existing airtanker, delivering 2000 gal. to a fire 100 nmi. away in only 14 minutes. Initial attack response times are summarized below:

Comparison of Airtanker Initial Attack Response Times



Extended Response Performance. The S-3B, as a Type 2 airtanker, was found to have superior extended response performance than most Type 1 airtankers. The only existing airtanker found to have superior extended response performance was the C-130 with MAFFS II installed, and in this case the difference between S-3B and C-130 airtanker performance was less than 1%. The S-3B airtanker's speed offset its lower payload capacity in the extended response role, allowing more retardant to be delivered per day of firefighting than with slower, higher capacity aircraft. While existing Type 1 airtankers might be able to lay down a longer line of retardant in one drop, the S-3B, over the course of the firefighting day, would be able to build a longer line through multiple drops and a faster turn-around time. Sustained retardant delivery in gallons per hour (gph) is shown in the chart below.

Comparison of Airtanker Extended Response Retardant Delivery



Operating Costs and Efficiency. The S-3B in US Navy service has an established track record of inexpensive operating costs with high dependability with low maintenance requirements, especially when contrasted with the P-3A, P-3C, and other multi-engine platforms. For example, NAVAIR data gathered on the S-3B and P-3C fleets in FY05-06 showed the S-3B aircraft to cost 27% less per flight hour than the P-3C on equivalent land-based missions.

To fully characterize the operating costs of the S-3B in fire aviation missions, an in-depth S-3B airtanker operating cost analysis was performed by Argon ST and its aerospace industry partners. This analysis is presented in detail in Section 5.0. It considered the full range of applicable S-3B maintenance requirements, tailored them to existing USFS fire aviation CONOPS, and estimated the flight hour and daily availability rates for a small (4 aircraft) S-3B airtanker contract under a Government-Owned, Contractor-Operated (GOCO) model similar to that used by CAL FIRE aircraft.

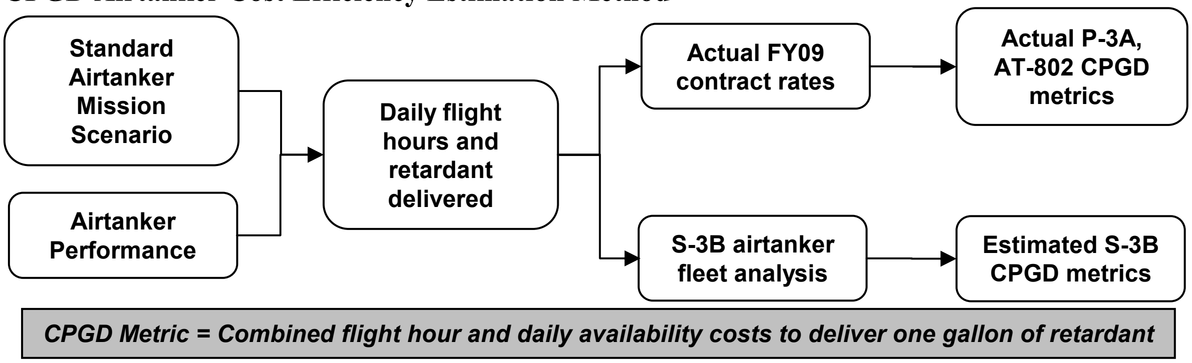
Comparison of P-3A, AT-802, and S-3B Airtanker Costs using CPGD Method

P-3 Airtanker actual FY09 contract rates		
CPFH	$7,183.00	per hr.
Daily availability	$13,411.00	per day
Missions per day	7	sorties
Payload per day	**18,200**	**gal./day**
Flight hours per day	5.74	hr.
Total cost per day	$54,655.54	
Daily CPGD	**$3.00**	**per gal.**
AT-802 Airtanker actual FY09 contract rates		
CPFH	$2,617.00	per hr.
Daily availability	$2,490.00	per day
Missions per day	7	sorties
Payload per day	**5,600**	**gal./day**
Flight hours per day	7.98	hr.
Total cost per day	$23,379.32	
Daily CPGD	**$4.17**	**per gal.**
S-3 Airtanker based on airtanker fleet analysis		
CPFH	$4,433.14	per hr.
Daily availability	$6,749.67	per day
Missions per day	10	sorties
Payload per day	**20,000**	**gal./day**
Flight hours per day	5.17	hr.
Total cost per day	$29,662.54	
Daily CPGD	**$1.48**	**per gal.**

The estimated S-3B airtanker operating costs were then compared against actual FY09 contract rates for P-3A and AT-802 airtankers and summarized in the table above.

Cost Per Gallon of Retardant Delivered. Consultation with USDA Forest Service representatives suggested a need for a common "benchmark" with which to measure and compare airtanker cost efficiency. Argon ST derived a Daily Cost Per Gallon Delivered (CPGD) method for this comparison, where the total costs to deliver a gallon of retardant were calculated on a daily basis for each airtanker platform. The airtanker mission scenario was used to generate daily flight hour and availability costs for each airtanker considered. Actual FY09 contract rates were used to generate P-3A and AT-802 costs. The S-3B airtanker fleet analysis (detailed in Section 8.0) was used to generate S-3B operating costs. A summary of the CPGD Method is shown below.

CPGD Airtanker Cost Efficiency Estimation Method



Cost Efficiency of S-3B Airtanker. The S-3B airtanker was found to be 51% more cost efficient than the P-3A and 65% more efficient than the AT-802 airtankers. In an extended response scenario, the S-3B delivered more retardant per day than the P-3 airtanker, at half the cost. Across the full scope of a typical fire season, a single S-3B airtanker was estimated to save over $1.1m in total costs compared to a P-3A in equivalent operations, while delivering a larger amount of retardant with a faster response time.

Comparison to C-130 MAFFS and MAFFS II. Flight hour and daily availability costs were not available for Argon ST to evaluate the cost efficiency of C-130 MAFFS/MAFFS II airtankers in a direct comparison to the S-3B using the CPGD method. However, comparison of certain fundamental attributes of the two airframes was possible in the absence of C-130 cost figures. A qualitative comparison suggested that the S-3B would be more cost efficient than C-130 MAFFS when considering several factors, including:

- **Flight and ground crew**: The S-3B airtanker requires an aircrew of one pilot with an optional copilot or observer. S-3B ground operations require a single plane captain and two final checkers. This personnel footprint, and its associated cost, is substantially smaller than that required for C-130 MAFFS operations.

- **Average fuel consumption per flight hour:** The S-3B consumes, on average, 30% less fuel per flight hour than a C-130 in equivalent flight operations. Analysis has shown that the S-3B airtanker's speed allows a rate of retardant delivery nearly equivalent to that of a C-130 MAFFS II airtanker. This suggests substantial fuel savings in S-3B airtanker operations compared to equivalent C-130 airtanker missions, a factor of critical interest in an era of highly unstable fuel prices.

4.5 Interagency Airtanker Board (IATB) Compliance Analysis

The S-3B airtanker is fully compliant with Interagency Airtanker Board (IATB) Section III (Multi-Engine Airtanker Requirements), as detailed below. Aircraft performance calculations used values for field elevation and outside air temperature (OAT) as directed by IATB documentation.

Paragraph A: Aircraft Certification. The S-3B airtanker will be certificated under Federal Air Regulations (FAR) to the same operating limitations imposed by its current US Navy flight certification or the FAR, whichever is more restrictive. The certification process is outlined in Section 5.0 of this document.

Paragraph B: Aircraft Ground Roll. The S-3B airtanker's ground roll with full payload is 4,050 ft., which is superior to the IATB 6,000 ft. requirement. Single-engine rate of climb, computed using drag Configuration A flight test data is 105 ft./min., which exceeds the IATB and FAR25 takeoff segment requirements. Actual single-engine rate of climb for the S-3B airtanker will be greater, and validated through further analysis and flight test.

Paragraph C: Congested Area. The S-3B airtanker accelerate-stop distance with full payload, a partial brake system failure, partial speedbrake system failure, single engine failure, and moderate brake application is 6,600 ft. This is within the 7,000 ft. IATB and FAR requirements for operations at congested airfields and was computed using more restrictive assumptions than are required by the IATB.

Paragraph D: Engines. The S-3B airtanker is a twin engine aircraft and does not require upgrades, modifications, or thrust reverser installations on its existing TF34 turbofan engines for the fire aviation mission.

Paragraph E: Retardant Release Effect on Flight Conditions. The S-3B airtanker recommended drop speed is equal to $1.29V_S$, which meets the IATB 1.25 V_S requirement and is less than the aircraft's design maneuvering speed (V_a). The S-3B airtanker's V_S is greater than V_{MC} for all retardant drop configurations, which meets the IATB requirement. The S-3B airtanker's center of gravity (CG) remains within the Navy-certified limits for longitudinal stability before, during, and after full retardant payload drop, providing positive longitudinal stability and stick-force gradients as required by IATB.

Paragraph F: Assymetric Power. The S-3B airtanker maintains the asymmetric power characteristics of the original Navy S-3B airframe, which is NAVAIR/MIL-F-8785A compliant and meets the IATB requirement.

Paragraph G: Climb Rate. The S-3B airtanker's enroute climb rate is 2,250 ft./min., which exceeds the IATB requirement of 100 ft./min.

Paragraph H: Descent. The S-3B airtanker, with throttles set mid-range, spoilers deployed 12°, and leading/trailing edge flaps fully extended can descend at a steady 2000 ft./min. while maintaining the recommended retardant drop speed. This performance, calculated using flight test data and validated in the S-3B Operational Flight Trainer, is superior to the IATB requirement.

Paragraph I: Stall Warning. The S-3B cockpit provides an Angle of Attack (AOA) gauge and Angle of Attack indexers at the pilot and co-pilot stations. Each instrument provides an indication of impending stall and aids in stall recovery. The S-3B's leading edge flaps, stall strips, and wing section provide further stall warning through airframe buffet. Stall is characterized by a moderate nose-down pitch, slight wing roll-off, or full back-stick with negative climb rate. All characteristics comply with IATB requirements.

Paragraph J: Longitudinal Control Force. The S-3B airtanker is anticipated to closely match the control force profile of the basic Navy S-3B. Hydraulically boosted control surfaces and electrical trim systems maintain less than 35 lb. control forces during all airtanker maneuvers, which complies with the IATB requirement.

Paragraph K: Aircraft Dynamic Stability. The S-3B airtanker's dynamic stability was not evaluated, but is anticipated to closely match that of the basic Navy S-3B airframe, which meets NAVAIR/MIL-F-8785A requirements and is IATB compliant.

Paragraph L: Carbon Monoxide/Dioxide. The S-3B airtanker retains the Navy S-3B cockpit pressurization, ventilation, and climate control system, which maintains a "shirt sleeve" environment and at least a 4000' cabin pressure elevation throughout the entire airtanker operational envelope. Supplemental oxygen systems will be retained in the airtanker configuration. Carbon monoxide concentration data are not currently available for the Navy S-3B or the airtanker S-3B.

Paragraph M: Aircraft Production. The S-3B aircraft is no longer in production, but over 50 airframes remain immediately available in AMARC storage; the full fleet includes nearly 100 airframes. Maintenance depot, training, simulator, and engineering support services remain available through the Naval Air Systems Command. An airtanker fleet of over 40 S-3B aircraft could be maintained for 15 years in compliance with IATB requirements.

Paragraph N: Damage Tolerance and Fatigue Evaluation. Existing US Navy S-3B maintenance inspection procedures would be tailored to the fire aviation environment. The aircraft's Structural Data Recording Set (SDRS) would be retained, allowing collection of hour-by-hour, mission-by-mission fatigue data on each airframe. Preliminary fire aviation fatigue life estimates were performed in accordance with IATB requirements based on available US Navy Full Scale Fatigue Test (FSFT) results.

Paragraph O: Field of Vision. The S-3B airtanker will retain the same cockpit field of vision configuration as the existing Navy S-3B aircraft. Cockpit field of view has not been measured using the Airtanker Cockpit Laser Visibility Evaluation Device, but exceeds the field of view in all existing multi-engine airtankers, and is anticipated to greatly exceed IATB requirements.

Paragraph P: Retardant/Suppressant Systems. The S-3B retardant tank layout was designed according to IATB Section VII specifications. Numerical analysis was performed to estimate tank performance, which was found to be fully IATB compliant.

5.0 S-3B AIRTANKER FLEET ANALYSIS

Sections 3.0 through 4.0 of this document described preliminary design work, engineering analysis, and technical findings from Phase 1 of the Air Force Research Lab's S-3B Multi-Mission Conversion Research Program. In early 2009, multiple conversations with USFS officials led Argon ST to conclude that further research into the S-3B airtanker's operating costs was required in order to fully address USFS interest. With this in mind, Argon ST and its aerospace industry partners conducted a detailed S-3B airtanker fleet analysis, which considered certification, supportability, basing, logistics, maintenance, repair, overhaul, and associated costs.

5.1 Certification

Argon ST recommends a fully FAA-compliant certification process for the S-3B airtanker parallel to the existing certifications for other military-derivative airtankers like the S-2T, P-2V, and P-3A. NAVAIR PMA-290 and AMARC officials have stated that S-3B airframes are not available for direct sale to civilian contractors, which necessitates a Government Owned, Contractor Operated (GOCO) certification and operating model, as described below.

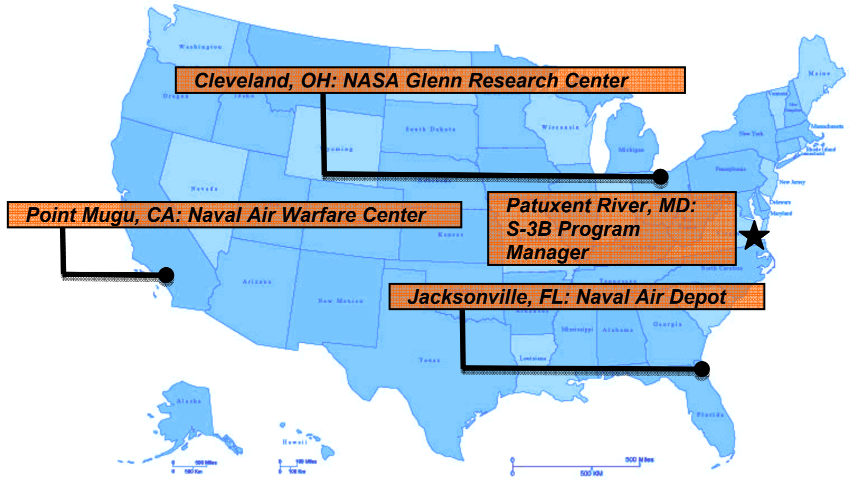
Prototype Engineering, Production, and Initial Certification. Argon ST recommends USDA Forest Service Fire & Aviation Management oversight of an integrated government/contractor engineering team for S-3B airtanker design, modifications, and certification. Engineering and manufacturing practices would comply with appropriate FARs under technical oversight of an FAA-qualified Designated Engineering Representative (DER) and Designated Airworthiness Representative (DAR). The S-3B airtanker could be certificated as a U.S. Government Public Use Aircraft or under a Restricted Category Special Airworthiness Certificate. In either case, a full FAA certification process would be performed as delineated in FAR Part 21. Engineering basis for the certification would include US Navy technical publications, US Navy flight test data, US Navy operating limitations, airtanker modification engineering data, and where required, additional flight test data collected during a prototype S-3B airtanker flight test series. Under this model, USFS approval of the S-3B airtanker's airworthiness (as required-- only applicable to Public Use aircraft) and all FAA certification would follow established procedures and regulations as delineated in the FAR. USFS would retain oversight authority and, with FAA assistance (audits, inspections, etc.), would ensure contractor compliance with FAA-mandated engineering, manufacturing, and operating practices.

Life-Cycle Support and Maintenance. Argon ST recommends utilization of a contracted operations and maintenance team for the S-3B airtanker, with USFS exercising oversight authority. Maintenance would be conducted by FAA-certified personnel and FAA-certified facilities in accordance with FAR Parts 91 and 125. Contract aircrew would be FAA rated pilots and crew members, with additional training, certification, and currency requirements as directed by the USFS in the Interagency Aerial Supervisor Guide and supporting documentation. This model is equivalent to Cal Fire aviation operations, where contract aircrew and maintenance personnel fly and maintain a state-owned aircraft fleet under the oversight of Cal Fire state employees. Unlike other military-derivative airtanker aircraft, the S-3B retains a significant depot maintenance, training, and logistics support base, which is available to USFS and its contractors, as described in the following section.

5.2 Supportability

The US Navy and NASA Glenn Research Center will continue operating substantial numbers of S-3B aircraft through at least 2015, affording USFS and its contractors access to the full range of S-3B life-cycle support. Numerous S-3B support facilities will remain available despite the aircraft's retirement from combat operations.

S-3B Life Cycle Support Facilities



S-3B Program Management Office, NAS Patuxent River, MD. The Naval Air System Command's (NAVAIR) S-3B Program Management Office is part of a staff of over 1,000 engineering support personnel assigned to the Maritime Patrol and Reconnaissance Aircraft program executive office. Engineering analysis, data packages, and other technical support services are available to USFS organizations and their contractors. Expertise includes areas of S-3B modernization and sustainment, propulsion and power, logistics management, depot maintenance, and in-service engineering.

Fleet Readiness Center Southeast (Maintenance Depot), NAS Jacksonville, FL. The S-3B maintenance depot, located at NAS Jacksonville, FL, provides an industrial capability for manufacturing and repairing S-3B airframe, engine, and other component parts. Services available to USFS organizations and contractors include seamless integrated off-flightline repair, in-service industrial scheduled inspections/modifications, and aircraft activation from AMARC storage.

Test and Evaluation Squadron THREE ZERO (VX-30), Naval Air Warfare Center Pt. Mugu, CA. The US Navy's Test and Evaluation Squadron VX-30 continues to operate S-3B aircraft and serves as the Naval Aviation Training, Safety, Operating Procedures, and Standardization (NATOPS) manager for training and safety oversight of Navy S-3B aircrews. Facilities include a S-3B Operational Flight Training (OFT) simulator recently moved from NAS Jacksonville, FL. In addition to the flight simulator, integrated training resources, including syllabi, instructors, computer-based training (CBT), publications, and instructors are available for use by USFS organizations and their contractors.

NASA Glenn Research Center, Cleveland, OH. NASA's Glenn Research Center, located at Lewis Field, develops advanced aeronautics technologies through research operations involving specially modified S-3B aircraft. Expertise includes areas of S-3B modification for land-based, civilian flight operations, including development of cockpit instrumentation upgrades, communications upgrades, navigation system modernization, FAA-certified oxygen system modifications, weapon systems removal, and ejection seat system removal. All engineering data packages involving S-3B airframe modifications are available at no cost to USFS organizations and contractors as Government Furnished Information.

5.3 Environmental Impact

Studies on military aviation and its environmental impacts have shown that the S-3B is more fuel efficient and produces significantly lower levels of pollutants than other military-derivative airtanker aircraft. Nitrogen Oxide gases (NOx), created by the high temperatures and pressures in jet fuel combustion, are the most difficult of the local air quality pollutants to control. NOx emissions are therefore a useful benchmark for evaluating the impact of aircraft fleets on local air quality. NOx pollutant levels produced by the S-3B during takeoff and landing segments are 75% lower than C-130 aircraft and are 95% lower than the pollutant levels associated with current-generation commercial transports like the B777 and VLAT (Very Large Airtanker) aircraft. S-3B flight operations produce significantly less airborne pollutants than those of any current or anticipated airtanker aircraft.

5.4 Basing

An exhaustive survey of current USFS airtanker bases was performed to evaluate the S-3B airtanker's suitability for basing at each airfield. The S-3B airtanker's response time and speed were also considered, allowing a preliminary recommendation of existing USFS bases suitable for S-3B airtanker operations. The recommended bases possessed suitable runway, taxiway, parking ramp areas, and services to accommodate an aircraft of the S-3B airtanker's weight and high performance.

The following USFS bases were recommended as candidates for S-3B airtanker:

- Lancaster, CA (WJF: General Wm J Fox Airfield)
- Fresno, CA (FAT: Fresno Yosemite)
- Klamath Falls, OR (LMT: Kingsley Field)
- Moses Lake, WA (MWH: Grant County Airport)
- Missoula, MT (MSO: Missoula International)
- Boise, ID (BOI: Boise Air Terminal)
- Knoxville, TN (TYS: McGhee Tyson Field)
- Lake City, FL (LCQ: Lake City Municipal)
- Albuquerque, NM (ABQ: Albuquerque International)
- Ft. Huachuca, AZ (FHU: Sierra Vista Municipal)
- Williams, AZ (CMR: H.A. Clark Memorial Field)
- McClellan, CA (MCC: Sacramento McClellan Air Park)*
- Colorado Springs, CO (COS: Colorado Springs Airport)*

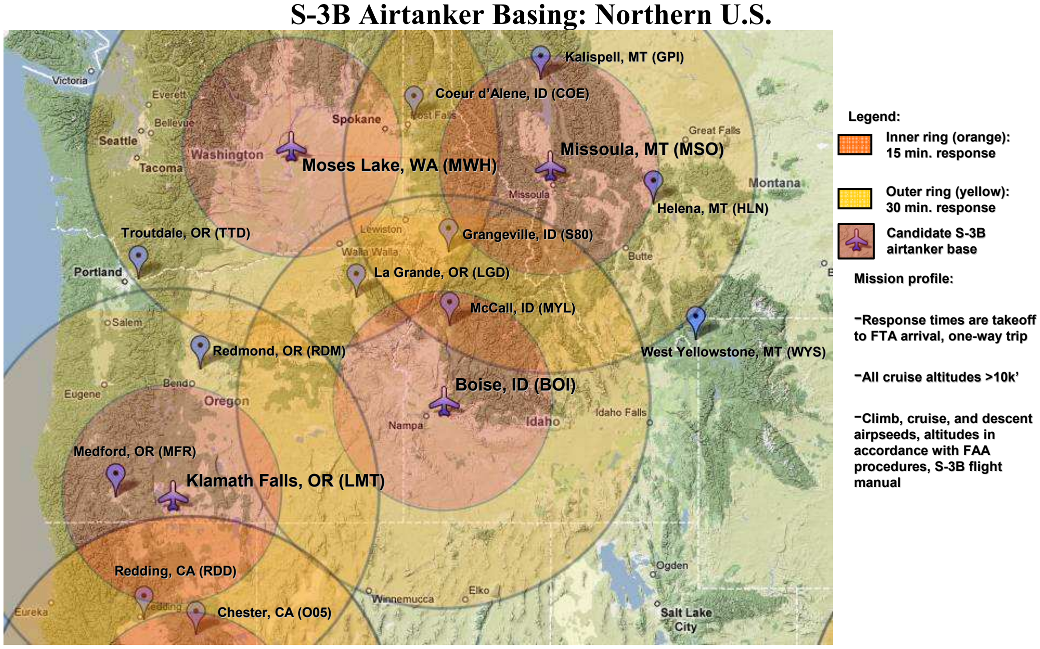
* Portable retardant mixing plant (PMP) capable airfield

For each recommended USFS base, 15 minute and 30 minute response time ranges were plotted. Other existing USFS bases were plotted for reference, which in subsequent analysis suggested that the S-3B airtanker's response speed would allow a flexible choice of basing while still maintaining superior response times.

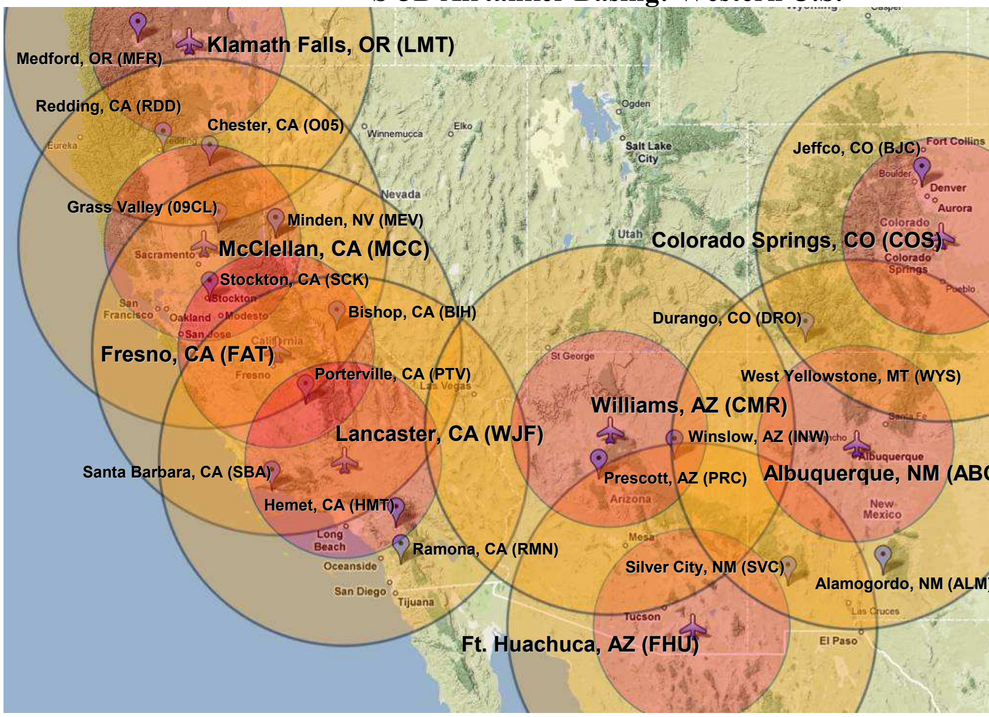
Analysis of S-3B airtanker basing in the western U.S. was particularly informative. In this case, only three S-3B airtanker facilities (WJF- Lancaster, FAT- Fresno, and MCC- McClellan) could provide 15 minute response to the most historically wildfire-prone areas of the California and 30 minute response across the entire state. Cal Fire currently supports a 20 minute response capability across the entire state of California with slower, less capable S-2T airtankers in an initial attack posture at 14 airfields. With recent USFS interest in a shift towards swift initial attack strategies, a 15-30 minute response capability supported by only *three* airfield facilities could be a powerful, infrastructure-efficient tool for knocking down wildfires before they become major incidents. Potential use of the S-3B airtanker in the Northern and Eastern U.S. was found to create similar opportunities for improved wildfire response with reduced, more flexible basing requirements.

The following three charts illustrate case studies for S-3B airtanker basing in the northern, western, and eastern US.

S-3B Airtanker Basing: Northern U.S.



S-3B Airtanker Basing: Western U.S.



Legend:

- Inner ring (orange): 15 min. response
- Outer ring (yellow): 30 min. response
- Candidate S-3B airtanker base

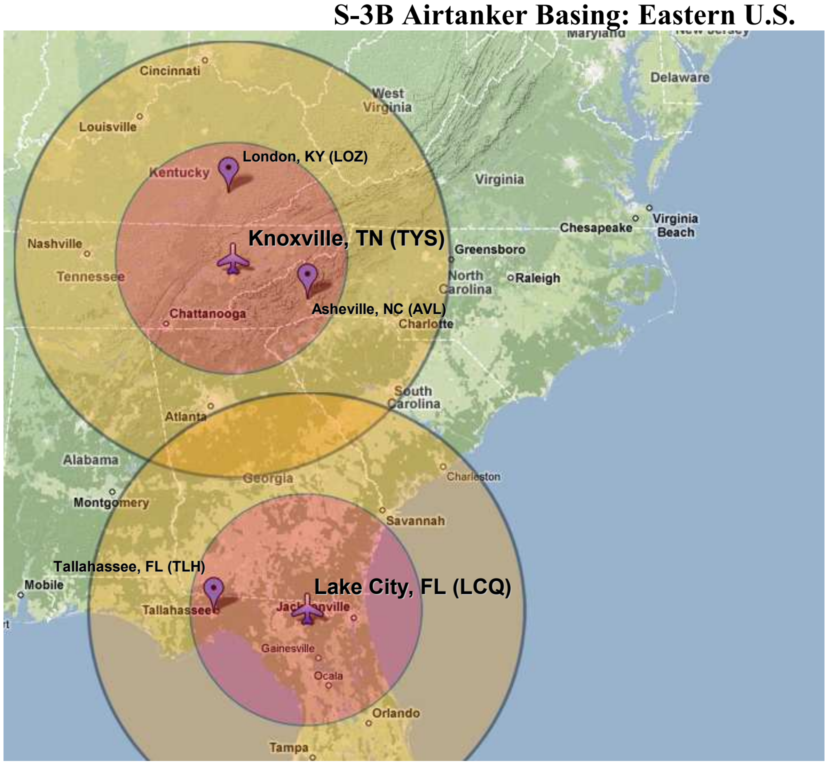
Mission profile:

-Response times are takeoff to FTA arrival, one-way trip

-All cruise altitudes >10k'

-Climb, cruise, and descent airspeeds, altitudes in accordance with FAA procedures, S-3B flight manual

S-3B Airtanker Basing: Eastern U.S.



Legend:

- Inner ring (orange): 15 min. response
- Outer ring (yellow): 30 min. response
- Candidate S-3B airtanker base

Mission profile:

-Response times are takeoff to FTA arrival, one-way trip

-All cruise altitudes >10k'

-Climb, cruise, and descent airpseeds, altitudes in accordance with FAA procedures, S-3B flight manual

5.5 S-3B Integrated Airtanker Operations and Maintenance Concept (IAMC)

Argon ST and its aerospace industry partners thoroughly analyzed the full life cycle of S-3B airtanker operations, maintenance, and logistics in support of the US Forest Service's fire aviation mission. Use of commercial and military best practices was considered under a Government Owned, Contractor Operated (GOCO) model, along with the imperative that safe conduct of all phases of operations be a priority concern. Initial development of organizational processes and a formal safety program was also performed to more clearly articulate the recommended concept of operations (CONOPS) for a USFS S-3B airtanker fleet. This documentation outlined a recommended Contractor Safety Philosophy, Safety Organization, General Safety Rules, Safety Training, Aviation Safety Program, Hazardous Materials, Hazard Communication Program, Fire and Emergency Evacuation Plan, Spill Prevention and Response Plan, Bomb Threat Response Plan, Personal Protective Equipment Plan, and General Mishap Response Plan. While some or all of these airtanker fleet functions may be subcontracted, the prime USFS contractor would remain ultimately responsible to the Forest Service and FAA for full compliance.

In addition, other documents pertaining to safe and efficient operations were outlined for incorporation into a recommended contractor aviation department organization. These included an Aircraft Mishap Plan, Training and Pilot Qualification Criteria, Procedures for Restart of Flight Operations, Aviation Maintenance Plan (AMP), Maintenance Quality Assurance (QA) Plan, various flight operations and aircraft limitations documents, and S-3B Airtanker Standard Operating Procedures (SOP).

The S-3B airtanker is anticipated to be a complex, high performance platform more advanced than any airtanker in USFS fire aviation service. Argon ST therefore strongly recommends operation of the aircraft by only the most highly qualified and trained airtanker aircrew, operations managers, and maintainers under a comprehensive maintenance and operations program emphasizing safety. Argon ST and its aerospace industry partners have started development of such a program, modeled on military S-3B operations tailored to the USFS fire aviation mission. For brevity, the full scope of this Integrated Airtanker Operations and Maintenance Concept (IAMC) is not included in this report, but is summarized in the following paragraphs.

While this information is presented in the context of overall structure and recommendations, Argon ST and its partners are poised to provide additional detail and implement the S-3B IAMC under the oversight of the USDA Forest Service.

Integrated Systems Approach to Aviation Safety and Quality Assurance. In order to provide a comprehensive source of operations, maintenance, administration, safety, quality assurance procedures and documentation – and to align any S-3B airtanker operator's procedures in accordance with the U.S. Government Public Use oversight inspection program, a standardized Safety and Quality Assurance System (S&QAS) must be organized by the Contractor into a "living" document that will treat safety and quality assurance as a comprehensive, integrated corporate system.

The "systems approach" provides both a high-level integrated overview document with detailed references as well as extractable working level documents that describe specific processes. All aspects of Contractor flight operations should be accessed or audited through the references listed in this document.

Operational Procedures. Standardization and safety will form the cornerstone of any successful Contractor S-3B airtanker operations. Formal documentation should be generated by the Contractor and approved by USFS Fire and Aviation Management personnel. These documents would describe in detail every aspect of Contractor Aircraft Operations, Maintenance and Administrative procedures. Operational procedures would be governed by multiple documents, including:

- Flight Operations Documents:
- Contractor Standard Operating Procedures (SOP)
- S-3B NATOPS Flight Manual (NAVAIR 01-S3AAB-1)
- Contractor S-3B Aircrew Checklist (NAVAIR 01-S3AAB-1B)
- Contractor Instructor Pilot Manual;
- Ground School Briefing Guides
- Individual Flight Briefing Guides
- S-3B Airtanker Pilot Qualification Program
- Mission Grade Sheets
- Fire Aviation Specific Instructions (SPINS)
- USFS Tasking Orders
- Contractor Pilot Qualification, Upgrade and Currency Procedures
- Federal Aviation Regulations (FARs)
- Retardant Drop System Operating Procedures and Limitations Manuals
- Various correspondence with the FAA regarding S-3B airtanker certification
- USFS S-3B Airtanker Contract documentation

Maintenance Procedures. S-3B airtanker maintenance activities should be governed by an integrated Contractor Aviation Maintenance Program (AMP) that is fully compliant with all applicable FARs and approved by USFS Fire and Aviation Management officials. Argon ST and its aerospace partners have assembled a preliminary outline of a recommended S-3B airtanker AMP based on analysis of FAA and NAVAIR documentation. Arranged in the same format as existing S-3B Navy maintenance documentation, Argon ST's S-3B airtanker AMP contains 30 chapters of guidance and is tailored to USFS fire aviation operations.

Airtanker Inspection Program. Inspection and maintenance concepts for this program will be developed using the policies and procedures of applicable US Navy directives, NAVAIR Instructions for the S-3B and Interagency Committee for Aviation Policy (ICAP) guidelines melded with standard civilian 14 CFR Part 91 guidelines for the inspection and safe operation of aircraft.

The Contractor Aircraft Inspection Program should be based on the manufacturer's Scheduled Inspection and Life Limited Component Removal requirements for the S-3B aircraft prescribed in NAVAIR01-S3AAB as described in the following documents:

- NAVAIR 01-S3IMC-6 Periodic Maintenance Information Cards
- NAVAIR 01-S3IMC-6-1 Preflight, Turnaround Check Lists
- NAVAIR 01-S3IMC-6-2 Daily maintenance requirements cards

- NAVAIR 01-S3IMC-6-4 Organizational / Intermediate / Depot Maintenance planned interval Requirements Cards (MRCs) S-3B

Operational Risk Management (ORM). Operational Risk Management (ORM) is a process used by the U.S. Military to enhance mission effectiveness and safety. Argon ST and its aerospace industry partners highly recommend that a robust ORM process be incorporated into certain aspects of any Contract S-3B airtanker S&QA Program. Representative websites for ORM information and implementation procedures include:

US Navy ORM Homepage:
http://www.safetycenter.navy.mil/orm/aviationorm/default.htm

Introduction to ORM:
http://www.safetycenter.navy.mil/orm/generalorm/downloads/introtoorm.doc

Implementing ORM in aviation organizations
http://www.safetycenter.navy.mil/orm/aviationorm/downloads/aviationorm.doc

The Contractor's S&QA Officer should develop a Plan of Action and Milestones for incorporating ORM into all S-3B airtanker operations.

Training and Qualifications. Contractor pilot training and qualifications should cover general aviation operating procedures, S-3B airtanker specifics, and mission dependent procedures as defined in interagency firefighting documents. Criteria and procedures should be defined in a series of Contractor airtanker training program documents and integrated with the aviation safety program.

Maintenance Training and Qualification: The Contractor maintenance effort will require a vast but well-known and proven number of different skills and personnel capabilities. Maintenance training and qualification involves both generic information applicable to all maintenance processes, and task-specific information. Training and qualification processes and criteria for the wide variety of maintenance skills required should be spelled out in detail in the Contractor Aviation Maintenance Plan (AMP).

Quality Assurance. The Contractor QA program shall encompass both an Aviation Department wide perspective directed by the Contractor's Safety and Quality Assurance Systems (S&QAS) Officer and individual directorate QA efforts. The Contractor's Aviation Department S&QAS Officer is responsible for management of this document. The Contractor Maintenance Quality Assurance Manager should report to the S&QAS regarding OSHA compliance and overall department S&QAS issues, and to the Contractor's Director of Maintenance for implementation and administration of the Aircraft Maintenance Plan (AMP) QA provisions.

Aviation Safety. An aggressive Aviation Safety Program has been shown to increase operational readiness and substantially reduce aircraft accident rates through standardization and training. This also significantly reduces the operating costs. Standards should be provided and appropriate training implemented for all phases of flight operations, preparation, maintenance, and operations relative to aircraft. Argon ST and its aerospace industry partners recommend the following structure for Contractor S-3B airtanker operations:

- The Contractor Director of Maintenance should be responsible for establishing standards for aircraft maintenance.
- The Contractor Flight Standards Officer should be responsible for establishing standards for aircrew qualifications, training, recurrent training, and flight operations.
- The Contractor Safety Officer will be responsible for monitoring the Aviation Safety Program, including:
    - Being familiar with Contractor aircraft, procedures, and regulations.
    - Conducting periodic flight safety training for flight personnel.
    - Ensuring adequate and prudent safety information is available to flight personnel.
    - Monitoring flight training to ensure safe practices.
    - Providing a Mishap Response Plan.
    - Being familiar with investigative techniques.
    - Investigating, or assisting with investigations of aircraft mishaps.
    - Advising the Aircraft Operations Officer, Chief of Maintenance, Chief Pilot, and Flight Standards Officer on matters of flight safety.

- The Aircraft Operations Officer should be responsible for maintaining, updating, and distributing as appropriate:
    - Naval Air Training and Operating Procedures Standardization documentation
    - A Standardization Program (NATOPS) manual or equivalent
    - Standard Operating Procedures (SOP) to include, at minimum:
        - General operations, including aircrew rest, brief and preflight preparation, and procedures for unsatisfactory flights.
        - Preflight, post-flight, and ground operations to include FOD prevention, aircraft preflight, ground procedures, and taxi, marshal, and night operations.
        - Local flight operations, including communications, takeoff, takeoff aborts, rejoin, formation procedures, fuel management, use of lights, communication equipment and frequencies, night operations, and special airspace use.
        - Cross country flight operations, detachment operations, flight hour accounting, aircraft discrepancies, and static display security and safety.
        - Emergency procedures, including lost communications, aircraft malfunctions, midair collisions, bird strikes, arrested landing, lost plane, ejection, and SAR procedures.
        - In-flight Guide, which provides important information needed while in flight such as frequencies, procedures, navigational procedures, and emergency procedures. It will supplement the S-3B NATOPS Pilot Pocket Checklist.

5.6 Operating Costs Analysis

Once the S-3B Integrated Airtanker Maintenance and Operations Concept were defined, Argon ST and its aerospace industry partners performed a detailed cost analysis to obtain anticipated contract rates for S-3B airtanker operations.

During the review and analysis of the FAA and NAVAIR documents, it was decided that the existing USN Maintenance Program for the S-3B is the best plan to follow; whether using an FAA approved maintenance plan under Restricted Category or flying Public Use. The US Navy's S-3B Integrated Maintenance Concept (IMC) is a superb program and should be adapted to Contractor operations and USFS requirements. In addition, the USN program should be tailored to fire aviation missions to reflect the man-hour reductions due to removal of many systems and the fact that there will be no carrier operations.

As a starting point, Argon ST and its aerospace industry partners anticipate a 20% reduction in man-hours required during the Planned Maintenance Interval (PMI 1-3) inspections compared with USN operations. In the USN program, PMI 1-3, there are 2,612 man-hours required. This can be reduced to approximately 2,075 man-hours by modifying the requirements reflecting changes to the configuration and no carrier operations. This reduction is reflected in the Per Flight-Hour Metrics provided. To get approval to modify the procedures, an experienced S-3 maintenance supervisor and an FAA Designated Engineering Representative (DER) should document the modifications and justify them; these resources are readily available on the Argon ST S-3B project team. For Public Use operation, it will be necessary to work with the Interagency Committee for Aviation Policy (ICAP) to obtain their endorsement for the modifications under USFS oversight.

Detailed operation cost estimates are available for consideration by USFS and other interested government organizations.

6.0 CONCLUSION

Argon ST, part of a joint AFRL/NAVAIR Government and industry team, has assembled a comprehensive engineering and life cycle analysis of the S-3B airtanker. The combined body of Government and industry sponsored work represents the most exhaustive and definitive analysis of S-3B airtanker suitability to date. It also encompasses a significant amount of preliminary airtanker design documentation, which is available to the USDA Forest Service as Government Furnished Information at no cost.

This proposal incorporates significant input from previous USDA Forest Service dialogue. Argon ST and its industry partners appreciate the insights of all USFS officials who offered feedback and take pride in a customer-oriented, mission-driven approach to development of the S-3B airtanker concept. The Government-sponsored data presented here represent the culmination of a 2007 Congressional Budget authorization for a "Next Generation S-3B Fixed Wing Aerial Firefighting Tanker" program which was sponsored by the US Air Force Research Laboratory and Naval Air Systems Command.

Argon ST asserts that the S-3B fleet, retired from US Navy operational service in early 2009 at only half its rated service life, represents a significant opportunity for USFS to inexpensively augment its existing fire aviation resources. The entire pool of US Navy S-3B assets, stored at Davis-Monthan AFB, AZ, is immediately available for USFS usage and includes nearly 100 airframes and over $1 billion in aircraft, tooling, support, and spare parts assets—all transferrable to USFS at zero procurement cost.

A preliminary design layout for the S-3B airtanker was assembled through a rigorous, iterative design process that considered dozens of candidate airframe modifications. Preliminary retardant tank design was conducted and validated through numerical analysis of retardant flow rates, ground pattern performance, and static structural loads/stress analysis. Engineering analysis found that the S-3B airtanker is capable of carrying 2000 gal. retardant payloads at speeds in excess of 400 KTS from existing USFS airfields.

A combination of Navy flight data, engineering analysis, preliminary design, cost analysis, and development of an Integrated Airtanker Operations and Maintenance Concept (IAMC) has shown that the S-3B airtanker offers significant benefits over existing contractor-operated airtankers. S-3B airtanker response time was found to be 50% superior to that the fastest USFS contractor-operated airtanker with 65% more cost efficiency measured in terms of dollars per gallon of retardant delivered. The S-3B airtanker was also found to deliver more retardant per day of firefighting than any existing USFS-contracted airtanker at lower cost. Preliminary analysis of the S-3B airtanker versus Federal C-130 MAFFS platforms suggested that the S-3B would deliver an equal amount of retardant per day of firefighting with significantly reduced fuel and manpower costs.

Structural service life, aerodynamic, flying qualities, propulsion, and performance factors were all considered in an evaluation of the preliminary S-3B airtanker design layout. All factors were found to be fully compliant with Interagency Airtanker Board (IATB) and FAA certification requirements. A conservative engineering analysis was used to substantiate these findings, and an optional engine upgrade path was identified for future performance increases. The S-3B aircraft's existing TF34 engines were found to be fully compatible with airtanker operations. The S-3B airframe was found to be capable of at least 15 years of USFS fire aviation service at above-average annual flight hour rates.

The S-3B airtanker, a high performance, complex airframe, will require a robust safety, training, maintenance, and operating procedures standardization program to ensure safe and efficient contractor operation in the fire aviation environment. Argon ST and its industry partners have developed a comprehensive Integrated Airtanker Operations and Maintenance Concept (IAMC) and outlined its most important features for USFS consideration. The IAMC formed the foundation of assumptions for detailed computation of estimated S-3B airtanker contract rates, which were compared against actual contract airtanker rates. The results showed that the S-3B would be more cost effective to operate than any existing contract airtanker, would require less basing infrastructure, and would provide an order-of-magnitude increase in the USDA Forest Service's ability to conduct timely initial attack on wildfires across the nation.

The time, capital, and engineering work invested in this document—provided through the effort of a joint Government/industry team—serves as an expression of Argon ST's commitment to the USDA Forest Service fire management mission and the personnel who work tirelessly in support of it. Argon ST believes that the conclusions presented in this proposal justify further investment in an S-3B airtanker prototype design program, which could be managed by the Air Force Research Laboratory as Phase 2 of the continuing S-3B Multi-Mission Conversion Research Program. With this in mind, Argon ST looks forward to continued contact with the USFS Fire and Aviation Management Office and further opportunities to support the nation's critically important airtanker fleet.

7.0 APPENDIX A: REFERENCES

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8.0 APPENDIX D: ABOUT ARGON ST, INC.

Argon ST is a leading developer of command, control, communications, computers, combat, intelligence, surveillance, and reconnaissance (C5ISR) systems that support operational commanders by producing and delivering information in time to impact critical decisions. Argon ST's C5ISR solutions are currently at work on land, at sea, and in the sky. We support a full range of military and strategic units, including surface, sub-surface, airborne, and land-based platforms that serve defense, homeland security, and international customer needs. In today's fast-paced and highly complex threat environments, Argon ST is driven by an overarching goal to help the warfighter make sense of the technology and threats facing our forces—and provide the capability to beat them.

About Aircraft Systems

Argon ST - Aircraft Systems (Ventura, California) was created to address unique airborne special missions. Aircraft Systems provides innovative and cost effective aircraft installation, operational, and support solutions to U.S. and foreign governments engaged in airborne missions which require advanced detection, analysis, identification, targeting, tracking, response, and networked connectivity capabilities aboard various types of multi-mission aircraft. Our design and engineering capabilities span the range of applied and theoretical disciplines associated with aerospace structures, mechanical systems, electrical systems, motion control, RF engineering, systems integration, and FAA/DoD airworthiness certification compliance. Our facilities and prototype manufacturing capabilities also include structures, mechanical, and electrical fabrication, assembly, test, evaluation and airworthiness compliance certification.