A PRELIMINARY DESIGN STUDY OF A JOINT PRIMARY AIRCRAFT TRAINER (JPAT)

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Abstract

The sponsors for the 1992/1993 AIAA United Technologies / Pratt & Whitney Undergraduate Individual Student Aircraft Design Competition requested proposals for a Joint Primary Aircraft Trainer (JPAT). The PT-3 Merlin is the title of the 1st place proposal submitted to meet the AIAA requirements. The proposal consists of the design, performance, construction and cost of a modern technology monoplane with a single turbofan engine.

Summary and Interpretation of RFP

The 1993 Individual Undergraduate RFP[1] calls for the design proposal for a Joint Primary Aircraft Trainer (JPAT). This aircraft will be chosen from a design that will meet the needs and specifications of both the Air Force and the Navy to replace the T-37 and the T-34C. Production can be expected to begin in the mid-1990-s for a contract of approximately 800 units.

The RFP states that the JPAT design must be a modern technology monoplane with a single turboprop or turbofan gas-turbine engine. The training airplane must have high performance characteristics, natural longitudinal and directional stability, and upright spin recovery characteristics. Furthermore, the aircraft must be easily accessible and maintained. Additional technical and performance requirements for the JPAT design are listed in Reference 1.

Mission Profile

The mission profile required for the JPAT design is listed in Table 1. Since the RFP requests a military trainer, the mission profile depicted in Table 1 represents a mission which could be consistent with fighter aircraft. From the mission profile, the aircraft design begins with a preliminary sizing to meet the mission requirements. The class of airplane requested combined with the results of the preliminary sizing determine the overall configuration of the airplane.

Sizing

The preliminary sizing of the PT-3 Merlin is based on statistical methods found in Reference 2. The estimated takeoff and empty weight relationship for the PT-3 Merlin is derived using weight regression coefficients based on statistical data from similar aircraft. Fifteen aircraft are compared based on configuration, mission and weight.

Table 1: Design Mission Profile

Mission Phase	Definition
A.	Self start, warm-up, taxi, takeoff from a 5,000 ft. runway at sea level, no wind, no flaps. Fuel for this segment shall assume five minutes at intermediate (military) power, no range credit.
B.	Climb at best rate to 15,000 ft. MSL.
C.	Cruise at speed for best range 40 NM at greater than 169 KT TAS.
D.	Maneuver at 200 KT TAS at 15,000 ft. MSL at +2G for 60 minutes. Assume power setting for steady level 2G turns as constant.
E.	Cruise back at speed for best range 40 NM at greater than 169 KT TAS.
F.	Descend to sea level and perform takeoff/landing practice pattern for 25 minutes. Assume power approach configuration, gear and flaps down, and power for trimmed level flight at sea level, 1.15 stall airspeed constant for full time. No range credit.
G.	Final landing, taxi 10 minutes, and shutdown. Assume idle power is constant. Fuel remaining shall be that required for 30 minutes cruising at speed for best range at 5,000 ft. MSL. Touchdown speed at stall not greater that 110 KT.

Fuel weight for the PT-3 Merlin is estimated from fuel fractions determined from the mission specification listed in the RFP. The RFP states that the designed trainer is required to meet climb and maneuver capabilities consistent with WW II fighters. The performance characteristics of the JPAT trainer are listed as follows:

• Max. Speed:	400 mph
• Cruise Speed:	300 mph
• Climb Rate:	3,000 ft/min

With the above performance assumptions for the PT-3 Merlin and methods listed in Reference 2, the mission fuel fractions for the trainer are listed in Table 2.

Table 2: Mission Weight Fractions

Mission Profile	W_{i+1}/W_i	Mission Profile	W_{i+1}/W_i
Warm-up	0.990	Maneuver	0.918
Taxi	0.990	Cruise	0.985
Takeoff	0.990	Descent	0.990
Climb	0.994	Takeoff/ Land Prac	0.943
Cruise	0.985	Land/Taxi/ Reserves	0.925

With the mission fuel fractions and weight regression coefficients determined from studies conducted on similar aircraft and WW II fighters, the Class I weights for the PT-3 Merlin are as follows:

• Weight of Crew (2):	450 lbs.
• Weight of Baggage:	50 lbs.
• Weight of Fuel (usable + reserves):	1,373 lbs.
• Weight of Trapped Fuel and Oil:	27 lbs.
• Empty Weight:	3,400 lbs.
• **Takeoff Weight**	**5,300 lbs.**

From the estimated takeoff weight for the PT-3 Merlin, wing size and required engine thrust for the trainer can be determined by performing a study comparing wing loading to thrust to weight ratio. Figure 1 displays how wing loading varies with thrust to weight ratio for varying requirements stated in the RFP. As can be seen from the figure, the wing and engine size for the PT-3 Merlin is determined from the following assumptions:

• Wing Loading:	40 psf.
• Wing Area:	133 sq. ft.
• Thrust to Weight Ratio:	0.35
• Takeoff Engine Thrust	1,855 lbs.

Configuration

The configuration requirements stated in the RFP constrain the PT-3 Merlin to a two place tandem, single gas-turbine engine, tricycle geared monoplane. The configuration design for the trainer entailed placement and sizing of the wing, engine, and landing gear. Possible configurations for the PT-3 Merlin ranged from conventional to asymmetric configurations. The results of the configuration design study for the PT-3 Merlin resulted in a mid wing jet with a V-tail and the engine podded on the top of the fuselage. The geometric parameters for the trainer are listed in Table 3.

Wing Design

Although the RFP dictated that the trainer must be a monoplane, the placement and geometry of the wing is determined by the designer. Due to the placement of the landing gear (discussed later), the wing is placed at the mid-fuselage to avoid interference with the fuselage mounted gear. The quarter-chord sweep angle of the wing is slightly negative (-4.0 deg.). The negative sweep angle design consideration is a result of a weight and balance analysis. The forward sweep of the wing places the aerodynamic center of the airplane to reduce longitudinal stability. The slightly forward sweep of the wing also decreases wing tip stall and allows for improved low speed lateral controllability over straight or swept aft wings. The taper ratio and thickness ratios of the wing are based on designs of similar aircraft and to offer adequate volume for fuel inside the wing torque box. The geometry of the PT-3 Merlin wing is displayed in Figure 2.

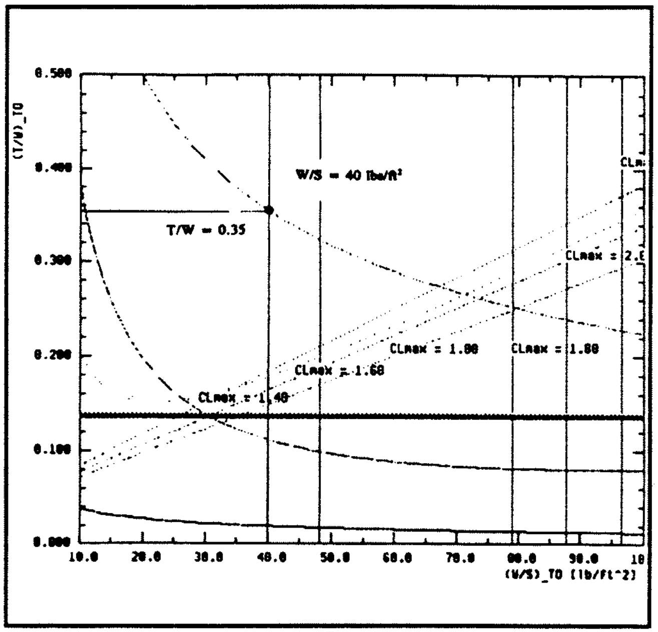

Figure 1: Performance Sizing Matching Graph

The flap placement and sizing and airfoil selection is a result of a high lift study conducted on the AAA program[9]. The RFP requires the trainer to takeoff from a 5,000 ft. runway without the use of flaps. From the results of the study, a lift coefficient of 1.6 is needed for takeoff for the Merlin. A NACA 65 series airfoil for the wing allows the trainer to meet the RFP requirement. Landing requirements found in the RFP state that the trainer must be able to conduct takeoff/landing practice at 1.15 stall airspeed with a stall speed not greater than 110 kts. However, unlike takeoff requirements, flaps are to be used during landing scenarios. The landing requirements for the PT-3 Merlin are met with plain flaps over 47.2% of the wing semi-span at 20 degrees of deflection.

Empennage

The V-tail configuration for the PT-3 Merlin allows the engine to be place on top of the fuselage without exhaust and empennage interference. The V-tail empennage may also contain improvements in structural weight over conventional configurations comprised of

Table 3: Geometric Parameters for the PT-3 Merlin

Fuselage	
Length	30.0 ft.
Height (at canopy)	5.7 ft.
Width	4.0 ft.
Crew	2
Pressurization	30,000 ft.
Wing	
Area	133 sq. ft.
Span	25.8 ft.
Aspect Ratio	5
Taper Ratio	0.35
Quarter-Chord Sweep	-4.0 deg.
Dihedral Angle	3.0 deg.
Twist Angle	0.0 deg.
Thickness Ratio (root, tip)	15%, 12%
Airfoil	65_A2XX
Flap Type	Plain
V-Tail (vertical projection)	
Area	25 sq. ft.
Aspect Ratio	1.9
Taper Ratio	0.5
Quarter-Chord Sweep	26.3 deg.
V-Tail (horizontal projection)	
Area	20 sq. ft.
Aspect Ratio	3.0
Taper Ratio	0.5
Quarter-Chord Sweep	25.0 deg.

separate vertical and horizontal surfaces. The V-tail is sized aerodynamically as a separate horizontal and vertical tail, but with only one surface structurally. Spin recovery is also a consideration for choosing the V-tail over conventional planforms.

Landing Gear

The use of a tricycle type landing gear for the design of the JPAT trainer is one of the requirements listed in the RFP. The placement of the tricycle landing gear is designed to be supported solely by the fuselage. Other options for the main gear included a structural connection of the main struts to the wing torque box. A wing mounted configuration would have reduced the wing bending moment of the wing, but flush retraction of the gear would require structural holes in the wing torque box. This options is considered costly compared to the fuselage mounted gear.

The landing gear retraction is accomplished with electric actuators for both the nose and the main gear. The hingeline for the main strut is at approximately a 45 degree angle. The nose gear resembles a conventional configuration. The landing gear for the Merlin must is

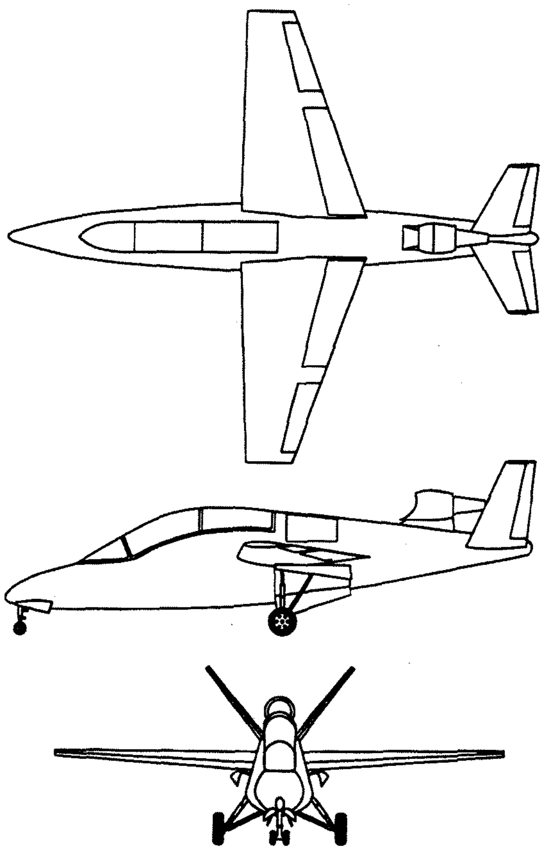

Figure 2: Three-View of the PT-3 Merlin

also designed for lateral-directional stability. The RFP states that the trainer is required to taxi at 10 KT with a 90 deg. cross wind of 40 KT without tipover or weather cocking.

Engine Placement

The propulsion system proposed for the PT-3 Merlin is comprised of a turbofan as suggested by the RFP. The PT-3 Merlin is designed with the welfare of the future fighter pilot in mind. The proposed contract date for the Merlin is in the mid 1990's and like today, most fighters are using turbojet propulsion systems. Therefore, a turbofan trainer could better prepare the students for jet airplane handling qualities so that transition to a turbojet fighter will be easier and faster.

The primary motivation behind the top fuselage mounted installation of the propulsion system on the PT-3 Merlin is accessibility. The trainer must be "exceptionally easy to maintain" and not require jacking of the airplane for engine placement, as indicated by the requirements in the RFP[1]. A podded engine is assumed to be more accessible than an engine buried in the fuselage. The RFP also requires that the trainer must be single engine. This limits a fuselage mounted pod to be place on either the side, top, or bottom of the fuselage. A bottom mounted engine requires protection from Foreign Object Damage (FOD) and extra length and weight to the landing gear. A single engine on either side of the fuselage produces asymmetric yawing moments on the airplane and may flame out in an adverse angle of sideslip. Therefore, the engine is podded on top of the fuselage on the PT-3 Merlin. A side view of the engine installation is displayed in Figure 3. As can be seen from the figure, a six foot male can easily reach the engine for maintenance with the aid of a small rise or step ladder. Replacement of the engine can be accomplished with the aid of a loading cart through the span of the V-tail without any disassembly of the remaining structure.

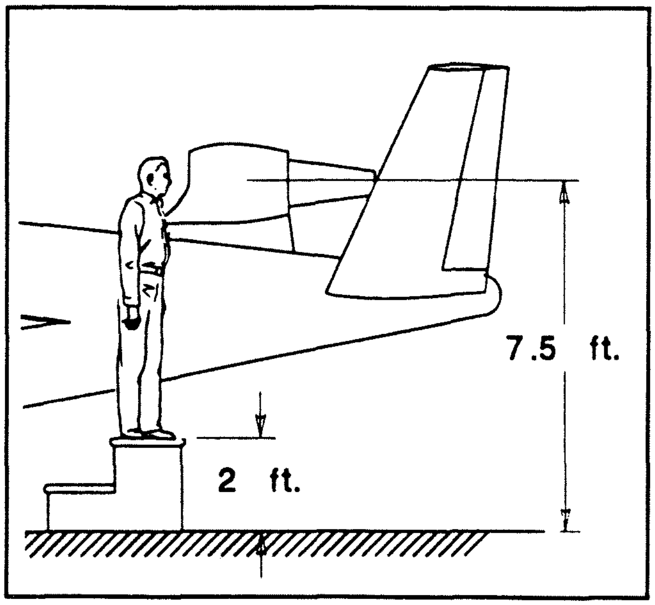

Figure 3: Engine Accessibility

Cockpit Layout

The two place tandem cockpit found in the PT-3 Merlin meets the requirements for placement, clearances, and accessibility as requested by the RFP. Accessibility into the cockpit is achieved with flush mounted steps embedded into the side of the fuselage. The steps are deployed and retracted with the use of small electric actuators controlled within the cockpit. The steps are spaced to allow easy access for a 5 ft. tall female as indicated by the RFP. The cockpit instruments are incorporated into high technology displays. Computerized flat screens displaying the required information for flight will replace conventional dials and gages.

Systems

The tree major systems for the PT-3 Merlin include the flight control system, electrical system and fuel system. The systems are simple in design to minimize cost and complexity.

Flight Control System

The flight control system for the PT-3 Merlin is composed of a simple mechanical system of cables and pulleys. The Merlin also has natural longitudinal and directional stability and will not require a stability augmentation system, further minimizing the cost of the airplane. The primary flight control system includes mechanical links to the following control surfaces:

- Ruddervators (V-tail control surfaces)
- Ailerons
- Flaps

The secondary flight control system sets the trim tabs.

Electrical System

The electrical system for the PT-3 Merlin includes the following components:

- Batteries
- Engine Starter
- Gear Retraction
- Cockpit Access Deployment
- Generator
- Cockpit Display Computer
- Flight Data Recorder
- Lights (Landing, Taxi, Navigation, Strobe)

Fuel

The fuel for the PT-3 Merlin is stored in the torque box of the wing. The 1372 pounds of fuel required for the trainer to meet the mission profile in Reference 1 requires 28 cubic feet of storage. A single refueling point is located on the port wing.

Structural Composition

As stated in the RFP, the JPAT design must include provisions to meet requirements for a low cost and rugged aircraft. To meet these requirements, the primary structure for the Merlin will be designed and constructed with methods similar to present day, conventional aircraft. The primary load bearing structure for the trainer will be composed of a series of frames and longerons attached to a load bearing skin. The sizing and placement for the structural members has been based on methods found in Reference 4.

Fuselage Structural Arrangement

The structural layout for the fuselage airframe is comprised of frames with 2 inches of depth and spaced 20 inches apart. The size and locations for the frames is chosen from page 124 of Reference 4. These values are listed for trainers and fighters. Extra or heavier frames are added to the fuselage structure to support the structure and loads for the wing, nacelle, empennage, and landing gear.

The RFP also requires the cockpit to be pressurized for training operations to 30,000 feet. Due to limited space inside the fuselage, the forward and aft pressure bulkheads are designed to be flat. This arrangement for the pressure bulkheads may result in a small weight penalty.

Wing and Empennage Structural Arrangement

The structural arrangements for the wing and empennage are comprised primarily of a forward spar, aft spar, and a series of ribs. The front spar extends throughout the wing at 20% of the local chord and the aft spar is placed at 69%. The aft spar is placed to allow clearance for 30% chord control surfaces. The spars add to the structure of the wing torque box and extend through the fuselage. The general spar arrangement as found in the wing is also present in the V-tail. The ribs for the wing are spaced at 24 inch intervals while the ribs in the V-tail are spaced at 12 inch intervals. Longerons for both the wing and the empennage are spaced at intervals of 10 inches.

Material Selection

Due to the low cost requirement listed in the RFP, the primary and secondary structure for the fuselage, wing and empennage will be manufactured from aluminum alloys, primarily 2024 ST. This material selection is consistent with other present day aircraft and will negate the need to develop new material specifically for this aircraft.

Hail Damage Resistance

The trainer design must meet hail strike requirements when parked, according to the RFP. Specifically, the RFP states that the upper skin of the aircraft must be strong enough to withstand 3/4" diameter hail without permanent deformation. However, this requirement mandates either a thicker and heavier aluminum skin or the development and testing of a composite material which may add to the cost of the aircraft. Therefore, the designer of the Merlin has chosen to leave the hail protection required for the aircraft on the ground. A specially designed, light weight and flexible tarp will be supplied with the aircraft. This tarp will be easily and quickly deployed onto the aircraft when needed for hail storms and can be stored on the ground to minimize equipment weight for the aircraft. Space will also be provided for the on-board storage of the tarp, if so desired, in the storage compartment above the wing.

Component Weight Breakdown

The component weight estimation described in Reference 10 and applied to the analysis of the PT-3 Merlin is based on statistical data and equations derived from similar military trainers and fighters. The method entails the use of statistical percentages of component weights to gross takeoff weight. Once component weights are estimated with the statistical percentages, an iterative process is used to tailor the weight estimation to the given airplane.

Structural Weight

The structural weight of the PT-3 Merlin includes the following components:

- Wing Weight
- Empennage Weight
- Fuselage Weight
- Nacelle Weight
- Landing Gear Weight

Once the mission requirements of a given airplane are determined, the structure for that airplane must be sized and designed accordingly. In a Class II structural weight estimation, a study comparing velocity and load factor can be conducted. In the course of the study, a V-n diagram is constructed which can be used to determine the load factors and corresponding velocities for which the airplane structure is designed. For the PT-3 Merlin, the RFP requires a highly maneuverable and rugged military trainer. Specifically, the Merlin should be designed for limit load factors of +6G and -3G at full takeoff gross weight. The results of the V-n Study of the PT-3 Merlin are displayed in Figure 4.

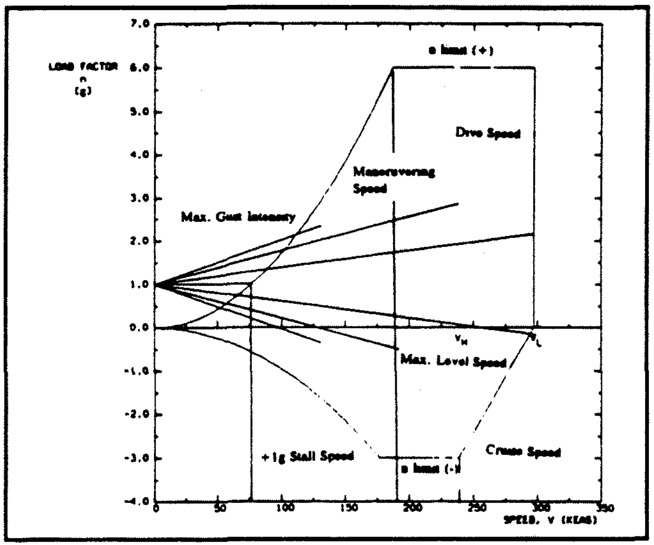

Figure 4: V-n Diagram

From Figure 4, the structural design velocities for the PT-3 Merlin are as follows:

+1g Stall Speed	80 KEAS
Maneuvering Speed:	190 KEAS
Cruise Speed:	240 KEAS
Dive Speed:	290 KEAS

With the design load factors and velocities determined in the V-n diagram, a statistically determined estimation of the structural weight for the PT-3 Merlin is given in Table 4.

Table 4: Structural Weight of the PT-3 Merlin

Structural Component	**Weight (lbs)**
Wing	739
Empennage (V-tail)	139
Fuselage	767
Nacelle	67
Landing Gear (total)	333
Total	**2,045**

Power plant Weight

The power plant weight of the PT-3 Merlin is determined with the aid of sizing equations given with the engine data included with the RFP. For a takeoff thrust of 1,855 lbs, engine weight as derived by the equations is 255 lbs. Since the weight of the engine is determined without the process described in Reference 10, the engine weight is not included in the weight iteration process.

Fixed Equipment Weight

The fixed equipment weight for the PT-3 Merlin includes the weights of the following systems:

- Flight Control System
- Instrumentation, Avionics and Electronics
- Electrical System
- Pressurization Equipment
- Oxygen System
- Furnishings
- Baggage
- Operational Items
- Paint

The results of the statistical estimation of the fixed equipment, based on Reference 10, are listed in Table 5.

Total Weight

The total empty weight of the PT-3 Merlin includes the weight of the structure, power plant and fixed equipment. From the sum of the empty weight, trapped fuel and oil weight, payload and crew weight, the total takeoff weight of the trainer can be determined. Table 6 lists the final weight breakdown for the PT-3 Merlin.

Table 5: Fixed Equipment Weights for the PT-3 Merlin

Component	**Weight (lbs)**
Control System	355
Instrumentation	152
Electrical System	238
Pressurization	113
Oxygen System	47
Furnishings	114
Operational Items	27
Paint	53
Total	**1,149**

Table 6: Weight breakdown for the PT-3 Merlin

Component	**Weight (lbs)**
Structural	2,045
Power plant	225
Fixed Equipment	1,149
Empty Weight	**3,399**
Fuel	1,371
Trapped Fuel and Oil	27
Payload	50
Crew	450
Takeoff Weight	**5,297**

Stability and Control

The aerodynamic forces and moments acting on the PT-3 Merlin in flight are estimated with theoretical methods listed in Reference 12 and with the AAA[9] program. For the analysis, six forces and moments, listed below, are assumed to be acting on the aircraft:

- Drag
- Side Force
- Lift
- Roll
- Pitch
- Yaw

Expressions for the forces and moments are analyzed for two scenarios:

1. Steady State Flight
2. Perturbed State Flight

Steady state assumes straight and level flight. For this flight phase, the aerodynamic forces and moments are analyzed as derivatives dependent on angle of attack, sideslip angle (small angles) and control surface deflection. Perturbed state flight stability studies change in the aerodynamic forces and moment of an airplane in a steady state flight due to a sudden change in the following motions:

- Forward Velocity
- Side Velocity
- Downward Velocity
- Roll Rate
- Pitch Rate
- Yaw Rate

Both scenarios described in Reference 12 use a component breakdown approach for determining the derivatives. The stability derivatives are estimated by summing the various component contributions of the wing, horizontal tail, etc.

A requirement of the RFP is that the trainer be stable both longitudinally and directionally. For a measure of longitudinal stability, the pitching moment due to angle of attack of the trainer can be divided by the lift curve slope and multiplied by -1.0 to obtain the static margin. This value is the distance between the center of gravity and the airplane aerodynamic center as a fraction of the mean geometric chord[12]. The static margins for the PT-3 Merlin for the three flight conditions are calculated as follows:

• Takeoff:	0.08
• Cruise:	0.07
• Landing:	0.08

For a longitudinally inherently stable airplane, as suggested by Reference 3, the static margin should be approximately between 0.05 and 0.10.

To determine the directional stability of the PT-3 Merlin, the yawing moment due to sideslip derivative must be studied. Reference 3 suggests a value for this derivative of at least 0.057 rad^{-1}. The yawing moment due to sideslip for the JPAT train are estimated as follows:

• Takeoff:	0.065 (1/rad)
• Cruise:	0.067 (1/rad)
• Landing:	0.068 (1/rad)

Further details concerning stability and control derivatives and dynamic stability can be found in Reference 18.

Spin Recovery

A requirement listed in the RFP states that the trainer must contain acceptable spin recovery characteristics. The geometry of the empennage and respective control surfaces of an airplane have the most effect on the ability of the aircraft to recover from a spin. As can be seen from Figure 5, the horizontal stabilizer on conventional airplanes can shield the vertical tail and rudder. The wake produced by the stabilizer can diminish or eliminate any rudder control power needed for spin recovery.

The V-tail configuration for the PT-3 Merlin allows horizontal and vertical stabilizers for the trainer to be mere projections of the same structure. Therefore, the effect of horizontal stabilizer washout on the rudder is eliminated. In addition, the two halves of the V-tail act as two separate vertical tails. If one vertical projection is shielded (i.e. from fuselage or nacelle), then the other rudder can still be effective.

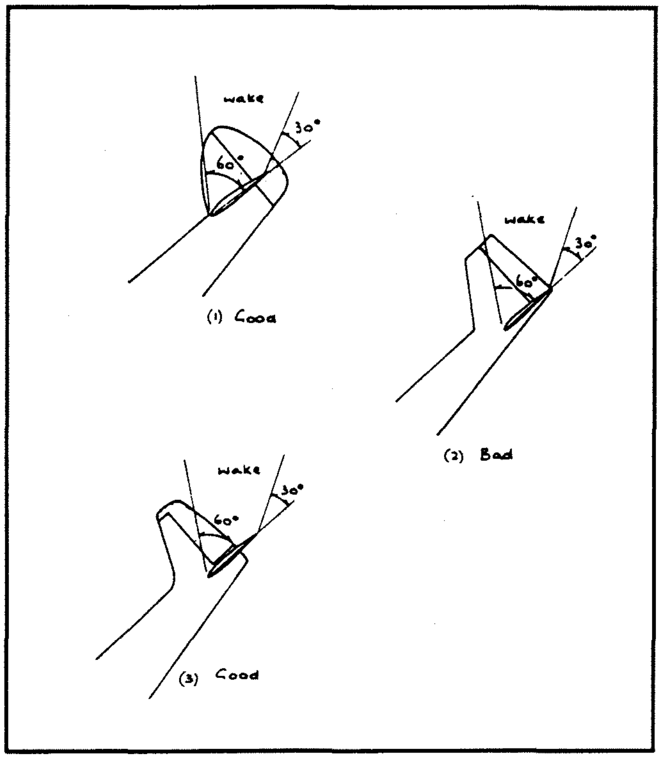

Figure 5: Horizontal Stabilizer Shielding upon the Rudder[14]

Another aspect of spin for an airplane is spin departure. Not only must an airplane be designed to be able to effectively recover from a spin, but it must also be designed to resist the tendency to initiate a spin. According to Reference 4, the spin departure characteristics of an airplane can be predicted by determining the *dynamic* yawing moment due to sideslip derivative of the airplane. Based on moments of inertia, this derivative must be positive for the airplane to have desirable spin departure characteristics. For the PT-3 Merlin, the dynamic yawing moment due to sideslip derivative is positive for all angles of attack above -20 degrees.

Performance

The methods used to determine basic performance characteristics of the PT-3 Merlin are based on simple aerodynamic principles and statistics found in References 9 and 15.

Takeoff

The RFP states in the mission profile that the trainer must be able to takeoff from a 5,000 foot runway at sea level conditions without the use of flaps. The predicted maximum lift coefficient for the trainer without flaps is 1.6, based on statistical methods found in Reference 11. At full takeoff weight of 5,300 lbs. at sea level, this yields a stall speed for the Merlin of 86 kts and a takeoff velocity of 96 kts, based on a 10% safety margin. Using the scaled engine data supplied with the RFP, the takeoff thrust for the trainer is estimated to be 1,600 lbs. At this thrust setting, the PT-3 Merlin requires a takeoff field length of 2,600 ft.

Climb

The average climb rate for the PT-3 Merlin is 3,000 ft/min. The Merlin is designed with this climb rate at maximum continuous thrust to meet the requirements of the RFP. This climb rate is consistent with WWII fighters.

Cruise and Maneuvering

The RFP requires the trainer to cruise at best range at 15,000 ft. The best range velocity for the Merlin is 260 kts with a lift to drag ratio or approximately 13 as found from the cruise drag polar described in Reference 18. The cruise velocity and L/D for the Merlin are consistent with WWII fighters and similar military trainers as required by the RFP. The maximum level speed for the trainer is 400 kts and is determined from the thrust available curve also found in Reference 18. The maneuver speed for the PT-3 Merlin is 200 kts for +2G turns.

Landing

The landing requirement for the trainer, as listed in the RFP, is within 5,000 ft at sea level with flaps. With an assumed clean lift coefficient of 1.6, the lift coefficient with 20 degrees of flaps is estimated to be 2.0. With a landing weight of 4,000 lbs, the stall speed for the Merlin is 68 kts. This stall speed is well below the maximum 110 kt stall speed required in the RFP. The landing airspeed is 78 kts, consistent with the $1.15V_{stall}$ also listed in the RFP. Assuming conventional brakes, the landing distance for the trainer is 1,440 feet.

Cost Analysis

The procedure and assumptions used to predict the cost of the PT-3 Merlin are based on methods found in Reference 16.

Research, Development, Test and Evaluation Cost

The profit a manufacturer makes on the production of an airplane is the difference between the price of developing and producing the aircraft and the price at which the aircraft can be sold. The simple design of the PT-3 Merlin combined with conventional production techniques and materials are driving factors to decrease the manufacturer's RDTE cost of the aircraft. To predict the RDTE cost of the PT-3 Merlin the following assumptions are made:

• Number of Aircraft Produced in RDTE Phase	6
• Production Year	1995
• Materials	Conventional
• Cost per Engine	$170,000
• Airplane Price	$2,030,000
• Avionics Cost	$406,000

Based on these assumptions, the total RDTE costs for the trainer are as follows:

• Test and Facilities Cost	$58,200,000
• RDTE Profit (10%)	$7,760,000
• Finance Cost (15%)	$11,600,000
• **RDTE Cost:**	**$77,600,000**

Operation Cost

The operation cost once an aircraft is produced is based on the materials and labor needed for upkeep and maintenance to keep the aircraft operational. For the PT-3 Merlin, the following assumptions are made to determine the operating cost for the trainer:

• Average Mission Time:	2 hrs
• Flight Hours per Year:	800 hrs/year
• Price of Fuel, 1995	$1.50/gal
• Operating Life:	20 years
• Loss Rate per Year:	1
• Crew Salary (2):	$70,000/year
• Maintenance hrs / Flight Hour:	6

With the above assumptions, the operating cost for the Merlin can be estimate as follows:

• Missions / Year	400
• Fuel and Oil Cost:	$1,680,000,000
• Program Cost of Air Crew	$5,600,000,000
• Program Cost of Maintenance Crew:	$3,060,000,000
• **Operating Cost:**	**$2,060 / hour**

Acquisition Cost

The acquisition cost for a given airplane is the cost to manufacture the airplane and the manufacturer's profit. For the estimation of the acquisition cost for the PT-3 Merlin, the following assumptions are made:

• Total Number of Airplanes Produced	800
• Airplane Manufacturing Rate (15 yrs):	4.44 units/mon
• Hours of Testing:	20

The cost for manufacturing the 800 aircraft required by the RFP is given as follows:

• Airframe Engineering and Design Cost:	$10,900,000
• Labor Cost	$270,000,000

Cost of Materials	$163,000,000
Cost of Tooling	$30,000,000
Quality Control	$35,100,000
Airplane Production Cost	$956,000,000
Production Flight Cost	$54,300,000
Manufacturing Profit (10%)	$120,000,000
Manufacturing Finance Cost (15%)	$181,000,000
Manufacturing Cost:	$1,210,000,000

- **Acquisition Cost: $1,330,000,000**

The unit price for the aircraft can be found by the sum of the acquisition cost and the RDTE cost divided by the number of aircraft sold. For 800 units of the PT-3 Merlin, the unit price is:

- **Estimated Price: $1,750,000**

Life Cycle Cost

The life cycle cost for an airplane program is the sum of the RDTE, operation, acquisition, and disposal cost. As recommended by Reference 16, the disposal cost for an airplane is approximately 1% of the life cycle cost. For the PT-3 Merlin, the life cycle cost can be estimated as follows:

RDTE Cost:	$77,600,000
Operating Cost:	$22,000,000,000
Acquisition Cost:	$1,330,000,000
Disposal Cost:	$263,000,000

- **Life Cycle Cost: $23,600,000,000**

Conclusions and Recommendations

The preliminary design of the PT-3 Merlin has met or exceeded all of the requirements listed in the RFP. The sizing and performance of the Merlin is consistent with other military trainers and WWII fighters. However, unlike most other trainers, the PT-3 Merlin is easily accessible for maintenance and pilot ingress and egress. The top-mounted power plant for the trainer can be easily reached and replace without the need for disassembly of the surrounding structure. The V-tail configuration may aid in the reduction in structural weight and allows for increased controllability in spin recovery. the oversized wings allow for lower stall speeds and the forward sweep increases lateral controllability at those lower speeds. Hail protection is supplied as a removable tarp which can be stored on the ground to reduce the empty weight of the aircraft. Finally, the simple design and use of conventional materials reduces the acquisition and life cycle costs of the aircraft program.

If further work is to be completed on the design of the PT-3 Merlin, several aspects of the preliminary design must be studied in further detail. Most importantly, proper sizing of the engine must be supplied for accurate thrust to weight ratios and center of gravity estimations. The power plant sizing supplied with the RFP seems to be inaccurate for the thrust to weight ratio needed for the PT-3 Merlin. In addition, the actual material selection and weight analysis of the hail protection tarp will have to be analyzed. The possibility of stowing the tarp with the pilot luggage (if desired) could alter the center of gravity of the airplane. Finally, a more detailed account for the systems (i.e. flight control, electrical, fuel, etc.) will have to be produced. Clearances between the systems and major structural members will have to be analyzed.

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