16th Annual Student Design Competition

1999 Request for Proposals

High-Speed VSTOL Personal Transport

Sponsored by

AHS International

and

Bell Helicopter TEXTRON

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1. Participation

All graduate and undergraduate students may participate in this competition. Part time students may participate at the appropriate graduate or undergraduate level. Schools are encouraged to form project teams, although individual entrants may participate. The highest education level on the team will determine the classification of the design team. There is no limit on the number of students on a team. Air vehicle designs *must* be the work of the students. Guidance may be provided by faculty advisors and should be acknowledged.

Air vehicle design projects used as part of organized curriculum requirements or class work are eligible and encouraged to enter this competition.

The AHS must be notified of the intent to submit a proposal in accordance with the schedule in section 4. Each individual or team may submit only one proposal, however, any number of proposals may be submitted from any school. If any student or team wishes to withdraw from the competition, they must notify the AHS National Headquarters immediately in writing.

2. Awards

Graduate Category:

- 1st place - $1000
- 2nd place - $500

Undergraduate Category:

- 1st place - $1000
- 2nd place - $500

In addition, the best new entrant (1st or 2nd year of participation) in each category will also be awarded $500.

Certificates will be presented to the winners and to their faculty advisors for display at the school. In the case of teams, each member will receive a certificate. The 1st place winner, or a representative if a team, in each category will be expected to present a technical summary of their design at the 2000 AHS Annual Forum. The 1st place winners will receive complimentary registration to the 2000 AHS Annual Forum and Bell Helicopter will provide $1000 to help defray the cost of attendance.

3. Evaluation Criteria

The proposal will be judged in 4 categories with the following weighting factors:

A. Technical Content (40 points)

- Design meets RFP requirements
- Assumptions are clearly stated and logical
- All major technical issues are considered
- Appropriate trade studies are performed to direct the design process
- Well balanced and appropriate substantiation of complete aircraft and subsystems
- Technical drawings are clear, descriptive, and represent a realistic design

B. Application & Feasibility (25 points)

- Technology levels used are justified and substantiated
- Affordability considerations influenced the design process
- Reliability and maintainability features influenced the design process
- Manufacturing methods and materials are considered in the design process
- Proposal shows an appreciation for the operation of the aircraft
- Consideration of missions beyond the RFP

C. Originality (20 points)

- Aircraft concept is innovative and shows the use of imagination in treatment of problems
- Aesthetically pleasing lines and features

D. Organization & Presentation (15 points)

- Meets all format and content requirements
- Self-contained Executive Summary contains all pertinent information and a compelling case as to why the proposal should win.
- Proposal is well organized so that all information is readily accessible and in a logical sequence
- Clear and uncluttered graphs and drawings

4. Schedule

Request for information and clarification	Up to April 16, 1999
Submit Letter of Intent to Propose	April 16, 1999
Submit 6 copies of proposal (postmark date)	July 2, 1999
Bell notifies AHS of winners	August 9, 1999
AHS announces winners	August 13, 1999
Presentation of winning papers at AHS Forum	May 2000

5. Contacts

All correspondence will be mailed to the following address:

Deputy Director
AHS
217 N. Washington St
Alexandria, VA, 22314

Telephone number: (703) 684-6777
Fax number: (703) 739-9279

6. Proposal Requirements

Six copies of the proposal must be submitted to the AHS.

The proposal is not to exceed 100 typewritten 8½ x 11 or A4 pages, with a font of not less than 11 pt 1½ spaced, and will contain:

A. The following 7 items which are not numbered and not included in the page limit -
   - Cover page with the name of the school and the judging category
   - Page carrying the names and signatures of all members of the team
   - Table of Contents
   - List of Figures
   - List of Tables
   - List of Symbols and Abbreviations
   - Proposal Requirements Matrix

B. Executive Summary not to exceed 4 pages (including figures)

C. Table of Physical Data listing -
   - Major dimensions
   - Gross weight, empty weight, and useful load
   - Fuel capacity
   - Engine TO (5 min) and MCP ratings
   - Transmission ratings

D. MIL-STD-1374 Weight Statement

E. Recurring Cost Breakdown

F. Performance Charts -
   - HOGE altitude vs. gross weight
   - Payload vs. range
   - Altitude vs. maximum continuous speed

G. Drawings -
   - General Arrangement fold-out drawing on 1 or 2 sheets of 11x17 paper showing major dimensions and alternate modes (if applicable)
   - Inboard Profile fold-out drawing on 11x17 paper showing the size and location of major aircraft features and systems
   - Drive system schematic with gear ratios and shaft speeds

H. A description of the process by which the configuration was selected, a description of the technical approach and the design features of the air vehicle, and an explanation of the analyses supporting the design data. Special attention will be paid to the proposed manufacturing processes.

The proposal should convey an understanding of the RFP requirements, the significance of the various design features of the air vehicle, and the analysis used to select and design those features.

7. Design Objectives and Requirements

The recent recurrence of interest in the general aviation marketplace has been accompanied by the aging of existing light helicopter and airplane fleets, and there is a perception that a market may exist for a new VTOL 4-6 place aircraft. Market studies have shown that in order to persuade current aircraft owners to make the commitment to a new vehicle in numbers large enough to warrant today's high development costs, the vehicle must have significantly better performance at little or no increase in price over existing 4-6 place turbine helicopters. These helicopters are typically capable of 110 - 130 kt, and the proposed significant advance has been set to at least a 180 kt cruise and a 540 nm absolute (dry-tank) range at some altitude below 10,000 ft. The aircraft must be designed in accordance with FAR parts 23 & 27 and other appropriate standards. Other performance and configuration features and standards must be consistent with comparable light airplanes and helicopters.

In order to meet stringent manufacturing cost restrictions, specific attention must be paid to minimizing the number of man-hours required to fabricate components. Manufacturing processes should be identified for the airframe. Features of the drivetrain and systems that reduce their costs should be identified.

8. Data Package

8.1 Powerplant

For such an airframe project, a parallel engine development would be undertaken. For a user-selected takeoff power P_{TO} between 200 and 1000 kW, this engine would have the following characteristics:

SL ISA Uninstalled Takeoff power (kW) P_{TO} = given

SL ISA Maximum Continuous power (kW) $P_{MC} = 0.8\ P_{TO}$

The above powers available vary at altitude in direct proportional to the density ratio (σ).

Specific Fuel Consumption @ P_{TO} (μg/J)	W_{FTO}	$= 300 \times P_{TO}^{-0.2}$
SFC @ any power P_X and altitude (μg/J)	W_{FX}	$= W_{FTO} \times (2\ (P_X/P_{TO})^2 - 4(P_X/P_{TO}) + 3) \times \sqrt{\sigma}$
Engine Mass (kg)	M_E	$= 20 + 0.12\ P_{TO}$
Engine Length (m)	L_E	$= 0.4 + 0.0006\ P_{TO}$
Engine Diameter (m)	D_E	$= 0.2 + 0.0005\ P_{TO}$
Output shaft speed (rpm)	N_E	= 21,000
Engine Cost ($^{99})		$= 200 \times P_{TO}$

8.2 Weights

Pilot and passengers	75 kg each
Baggage allowance	20 kg/person (inc. pilot)
Avionics Package	55 kg (inc. IFR avionics and flight instruments)

A fuel specific density of 0.81 (Jet-A) is to be used.

8.3 Cost

The following cost estimating relationships may be used to analyze design trades using existing technology levels. The equations provide an average recurring cost to manufacture a specific quantity of a commercial aircraft to be certified in accordance with Parts 23 & 27. To estimate the selling price of the aircraft, the total cost result should be increased by 50% to account for tooling amortization and profit.

The equations are based on historical cost data and use weight (in kg), total production quantity, and production rate as primary cost drivers. Additional variables are used to adjust for differences in manufacturing complexities between various design parameters. These equations may be modified to account for the use of new or unusual manufacturing technology. Changes must be substantiated.

Estimates should be based on manufacturing 300 aircraft at a rate of 60 aircraft per year.

8.3.1 Global Variables

Prodq = Total production quantity

Prodr = Production rate per year

8.3.2 Wing Group

Average Wing Cost = $3{,}500 \times \text{Weight}^{.9} \times \text{Kmat} \times (\text{Prodq} \times \text{Prodr})^{-.12}$

Where: Weight = Weight of wing

Kmat = Wing material factor

- Metal = 1
- Composite (Assembly similar to metal) = 1.6
- Composite (Large single-cure parts) = 1.1
- Composite (Accepting 15% weight penalty over metal) = 0.75

8.3.3 Rotor System Group

Average Rotor System Cost = $1{,}500 \times \text{Weight}^{.7} \times \text{Kyokmat} \times \text{Bldno}^{.2} \times \text{Kbldmat} \times \text{Kappl} \times (\text{Prodq} \times \text{Prodr})^{-.08}$

where: Weight = Predicted weight of the Rotor System

Kyokmat = Yoke material factor

- Al = 1
- Steel = 1.7
- Titanium = 2.3
- Composite = 2.8

Bldno = Number of main rotor blades (total for multiple rotors)

Kbldmat = Blade Material Factor

- Metal = 1
- Composite = 1.6

Kappl = Main rotor system application

Helicopter = 1

Tiltrotor = 1.4

8.3.4 Tail Group

Average Vertical Stabilizer Cost = 1,000 x Weight x Kmat x Kvstr x (Prodq x Prodr)$^{-.09}$

Where: Weight = Weight of the vertical stabilizer

Kmat = Vertical stabilizer material factor

- Metal = 1
- Composite (Assembly similar to metal) = 1.6
- Composite (Large single-cure parts) = 1.1
- Composite (Accepting 15% weight penalty over metal) = 0.75

Kvstr = Tailrotor mounting factor

- With no tailrotor or tailrotor mounted on tailboom = 1
- with tailrotor mounted on vertical stabilizer = 1.5

Average Horizontal Stabilizer Cost = 1,000 x Weight x Kmat x (Prodq x Prodr)$^{-.08}$

Where: Weight = Weight of horizontal stabilizer

Kmat = Horizontal stabilizer material factor

- Metal = 1
- Composite (Assembly similar to metal) = 1.6
- Composite (Large single-cure parts) = 1.1
- Composite (Accepting 15% weight penalty over metal) = 0.75

If applicable:

Average Tailrotor Cost = 2,500 x Weight$^{.7}$ x Kyokmat x Kbldmat x Bldno$^{.9}$ x (Prodq x Prodr)$^{-.08}$

Where: Weight = Weight of tailrotor

Kyokmat = Tailrotor yoke material factor

- Aluminum = 1
- Steel = 1.7
- Titanium = 2.3
- Composite = 2.8

Kbldmat = Tailrotor blade material factor

- Metal = 1
- Composite = 1.6

Bldno = number of tailrotor blades

8.3.5 Body Group

Average Fuselage Cost = 10,000 x Weight$^{.8}$ x Kmat x (Prodq x Prodr)$^{-.13}$

Where: Weight = Weight of fuselage

Kmat = Fuselage material factor

Metal = 1

Composite (Assembly similar to metal) = 1.6

Composite (Large single-cure parts) = 1.1

Composite (Accepting 15% weight penalty over metal) = 0.75

8.3.6 Landing Gear Group

Average Landing Gear Cost = 5,000 x $Weight^{.5}$ x Klgtyp x $(Prodq \times Prodr)^{-.08}$

Where: Weight = Weight of landing gear

Klgtyp = Landing gear type

Skid gear = 1

Fixed wheel = 1.5

Retractable = 2.0

8.3.7 Nacelle Group

Average Nacelle Cost = 5,000 x $Weight^{.8}$ x Kappl x $Noeng^{.1}$ x $(Prodq \times Prodr)^{-.12}$

Where: Weight = Weight of nacelles

Kappl = Nacelle application factor

Helicopter = 1

Tiltrotor = 1.2

Noeng = Number of engines

8.3.8 Air Induction Group

Average Air Induct Cost = 5,000 x $Weight^{.8}$ x Kappl x $Noeng^{.5}$ x $(Prodq \times Prodr)^{-.09}$

Where: Weight = Weight of inlets

Kappl = Nacelle application

Helicopter = 1

Tiltrotor = 1.2

Noeng = Number of engines

8.3.9 Propulsion Group

Average Engine Installation Cost = (2,000 x $Weight^{.7}$ x $Noeng^{.8}$x $(Prodq \times Prodr)^{-.06}$) + Engine Cost

Where: Weight = Weight of propulsion system

Noeng = Number of engines

Average Drive System Cost = 2,500 x $Weight^{.9}$ x $Noeng^{.4}$ x $(Prodq \times Prodr)^{-.07}$

Where: Weight = Weight of drive system

Noeng = Number of engines

8.3.10 Flight Controls Group

Average Flight Control System Cost = 300 x $Weight^{1.0}$ x $Bldno^{.5}$ x Kcontyp x Kappl x $(Prodq \times Prodr)^{-.06}$

Where: Weight = Weight of flight control system

Bldno = Number of main rotor blades

Kcontyp = Flight control type factor

Mechanical = 1

Fly-by-wire = 1.5

Kappl = Application factor

Helicopter = 1

Tiltrotor = 1.5

8.3.11 Instrument Group

Average Instrument System Cost = 1,500 x $Weight^{1.0}$ x Ktype x $(Prodq \times Prodr)^{-.06}$

Where: Weight = Weight of instrument system

Ktype = Instrument type factor

Mechanical = 1

Electronic (EFIS, IIDS) = 4

8.3.12 Hydraulics Group

Average Hydraulic System Cost = 1,000 x $Weight^{1.0}$ x $(Prodq \times Prodr)^{-.07}$

Where: Weight = Weight of hydraulic system

8.3.13 Electrical Group

Average Electric System Cost = 2,000 x $Weight^{.9}$ x Kappl x $(Prodq \times Prodr)^{-.10}$

Where: Weight = Weight of electric system

Kappl = Application factor

Helicopter = 1

Tiltrotor = 1.2

8.3.14 Avionics Group

Average Avionics System Cost = 2,500 x $Weight^{1.0}$ x $(Prodq \times Prodr)^{-.08}$

Where: Weight = Weight of avionics system

8.3.15 Furnishings and Equipment Group

Average Furnishings System Cost = 500 x $Weight^{1.1}$ x $(Prodq \times Prodr)^{-.08}$

Where: Weight = Weight of furnishing and equipment

8.3.16 Air Conditioning Group

Average Air Conditioning System Cost = 2,000 x $Weight^{.8}$ x Kecu x $(Prodq \times Prodr)^{-.06}$

Where: Weight = Weight of air conditioning system

Kecu = Environmental control unit factor

Without ECU = 1

With ECU = 1.9

8.3.17 Load and Handling Group

Average Load & Handling System Cost = 2,000 x $Weight^{.8}$ x $(Prodq \times Prodr)^{-.10}$

Where: Weight = Weight of load & handling system

8.3.18 Final Assembly

Average Final Assembly Cost = 30,000 x $Weight^{.4}$ x $Engno^{.9}$ x Kfusmat x $(Prodq \times Prodr)^{-.15}$

Where: Weight = Total empty weight of aircraft

Engno = Number of engines

Kfusmat = Fuselage material factor

Metal = 1

Composite = .9

8.3.19 System Components

The following information indicates the subsystem components that make up the system level components above. Note that some of the subsystem components may not be necessary in the proposed designed.

Wing

- Wing Primary & Secondary Structure

Rotor

- Hub
- Blades
- Spinner
- Rotor Coupling
- Rotor Vibration Suppression

Tail

- Vertical Stabilizer
- Horizontal Stabilizer
- Tailrotor

Body

- Fuselage (Less Floor)

Floor - Cockpit
Floor - Cargo
Sponson
Crew Doors
Passenger/Cargo Doors
Baggage Compartment Door
Aft Cargo Door
Access Doors
Windshield/Windows
Tailboom
Pylon Vibration Suppression

Landing Gear

Skid Gear
Main Wheel Gear
Aux Wheel Gear
Tail Bumper

Nacelle

Firewall
Nacelle/Cowl
Engine Mounts
Support Structure
Conversion Spindle

Air Induction

Air Inlet
Inlet Part Separator

Propulsion

Engine
Engine Installation
Ejector
Tailpipe
Engine Controls
Engine. Start System
Propeller/Fan
Engine Cooling & Wash
Lubrication System
Fuel System

Drive System

Main Transmission
Proprotor Gearbox
Tilt Axis Gearbox
Mid-Wing Gearbox
Speed Reduct Gearbox

- Freewheel Unit
- Accessory Gearbox
- Rotor Brake
- Tailrotor 90 Deg Gearbox
- Tailrotor Intermediate Gearbox
- Engine. Input Shaft
- Engine Nosebox/Bevel Gearbox
- Combining Gearbox
- Main Rotor Mast
- Tailrotor Driveshaft
- Interconnect Driveshaft
- Tilt Axis Gearbox Driveshaft

Flight Controls

- Cockpit Controls
- Automatic Flight Control System
  - Automatic Flight Control System Equipment
  - Fly-By-Wire Wiring
- Non-Rotating Controls
- Rotating Controls
  - Main Rotor
  - Tail Rotor
- Rudder Actuator & Controls
- Elevator Controls
- Main Rotor Hydraulic Actuators
- Flap/Flaperon Actuators
- Pylon Conversion Setup

Instruments

Hydraulics

Electrical

- Generator/Alternator
- Battery
- Transformer/Rectifier
- Inverter
- Distribution

Avionics

- Equipment
- Installation

Furnishings & Equipment

- Crew Seats
- Passenger Seats
- Fire Extinguisher System
- Soundproofing

Furnishings

Air Conditioning

Bleed Air/Heat Defog

Environmental Control Unit

Anti-Icing

Load & Handling

Final Assembly

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