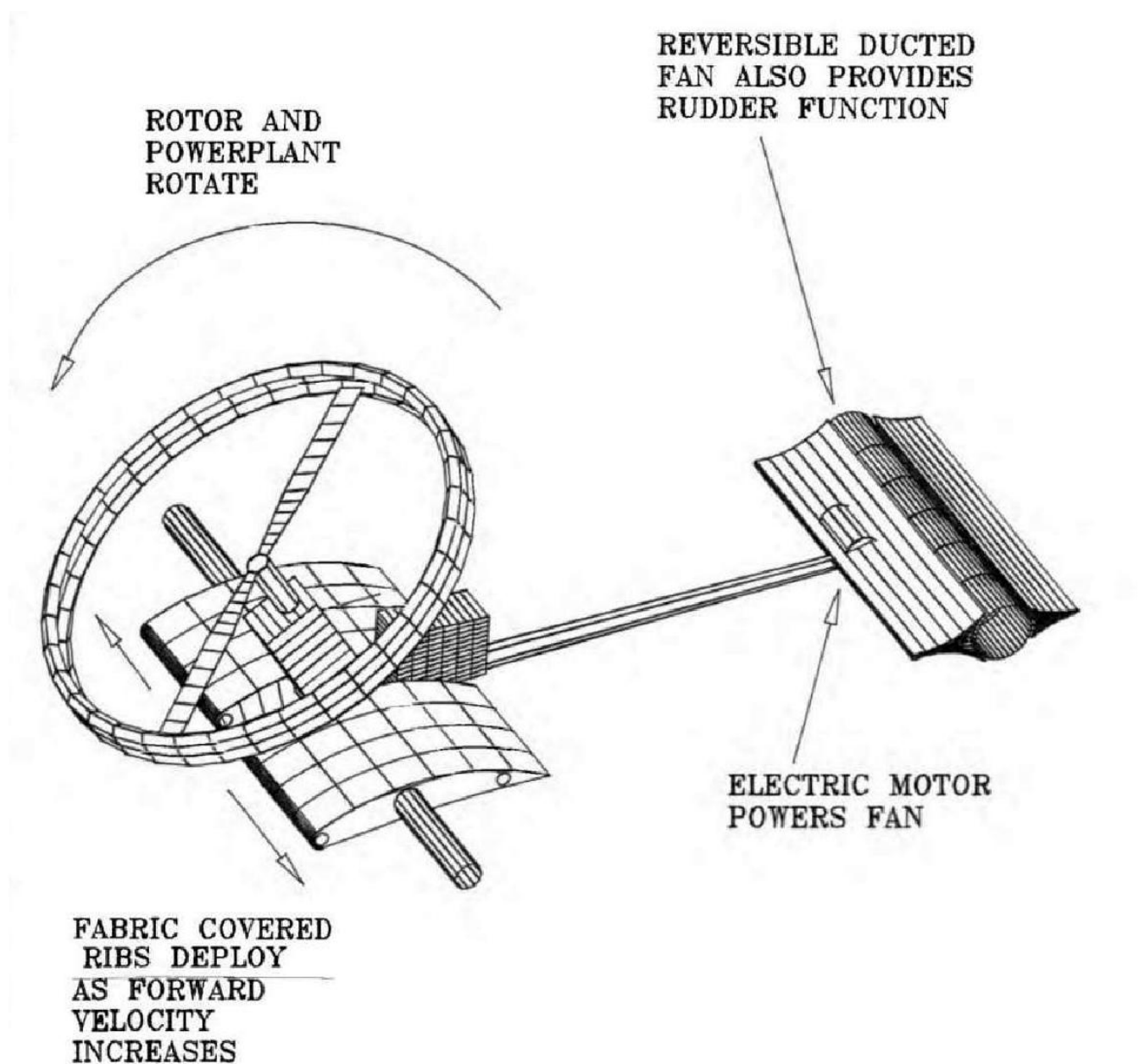




VTOL drone with extending wings

A vertical takeoff and landing drone that can change the aspect ratio of its wings.



Back in 1992 a couple consultant pals and I filed for a Small Business Innovation Research (SBIR) program grant of \$50,000. All these years later I cringe at the writing, but stand by

what turned out to be an idea ahead of its time. In addition to vertical takeoff and landing (VTOL), the craft would lengthen its wingspan so it could hover for long periods.

TOPIC NUMBER: N92-129

PROPOSAL TITLE: Articulated, Deployable Wing VTOL Aircraft

FIRM NAME: Rako Electronics

PHASE I or II PROPOSAL: 1

Technical Abstract (Limit your abstract to 200 words with no classified or proprietary information/data.)

This proposal describes a remotely piloted aircraft that is capable of verticle takeoff and landing (VTOL). The vehicle is also capable of high speed flight in the "dash" mode. In addition, the craft can sustain flight for extended periods in a "loiter" mode. The aircraft accomplishes these diverse requirements by adapting its architecture to the task as needed. In hover situations such as takeoff and landing, the vehicle has an overhead rotor like a helicopter. As forward velocity increases, the craft's rotor articulates to become a propeller. In conjunction with this, fabric covered wing ribs are deployed to provide lift. In the loiter mode the wing ribs are further deployed until the craft resembles a sailplane.

Anticipated Benefits/Potential Commercial Applications of the Research or Development

The proposed research will quantify the performance and the cost to build the aircraft. The craft would have a multiplicity of uses by various government agencies. Commercial applications include traffic reconnaissance, search and rescue, scientific data gathering, crop dusting, general aviation ect.

List a maximum of 8 Key Words that describe the Project.

VTOL Aircraft Drone UAV Rotorcraft

The requirements for this craft result in conflicting architectures and design parameters. The fact that the vehicle is remotely piloted exacerbates the situation. The VTOL specification implies a helicopter. The forward dash requirement would imply a low drag, high wing loaded plane such as a fighter. The long on-station loiter time suggests a sailplane. The safety desires would prohibit thrust or VTOL augmentation with rocket boosters. Remote operation stresses the need for a relatively stable craft.

Although electronic stability augmentation will be considered to assist in VTOL operation, we feel that an inherently stable platform is a much more viable approach. Electronic stabilization and automatic takeoff and landing would be available for critical situations or novice operators. The vehicle is conceived such that it requires skills typical of commercial radio controlled aircraft. These skills are by no means trivial (especially for rotorcraft), but they are certainly achievable. There already exists a pool of competent pilots, many of these in the armed forces.

The conflicting design requirements rules out the use of a "compromise" vehicle with electronic or mechanical kludges to achieve, at best, marginal performance. We propose a "polymorph" craft. This vehicle will change its form as required to achieve the design goals. This means the proposed vehicle will:

- 1) Takeoff and land like a helicopter.
- 2) Dash like a fighter.
- 3) Loiter like a sailplane.
- 4) Present minimal danger to personnel.
- 5) Be simple.
- 6) Be stealthy

Let us first look at the requirements for a helicopter. Figure 1 shows a "quintessential" rotorcraft. The body of the craft is a sphere to minimize forces due to gusting winds and the rotor downwash. Requirement 5, be simple, rules out the use of counter-rotating rotors to eliminate torque reaction. The craft has a reaction prop supported by a boom. Ideally, this boom would be infinitely thin and infinitely stiff in bending and torsion.

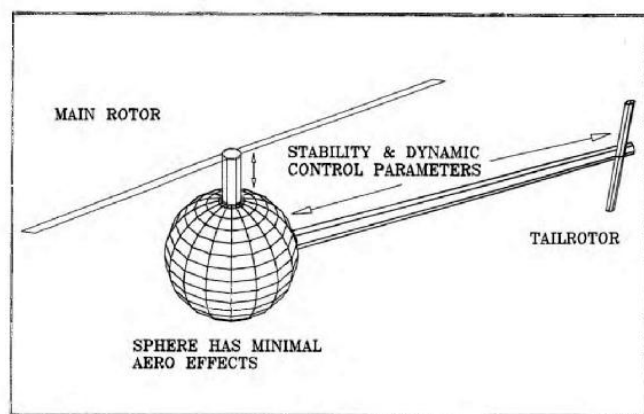


Figure 1.

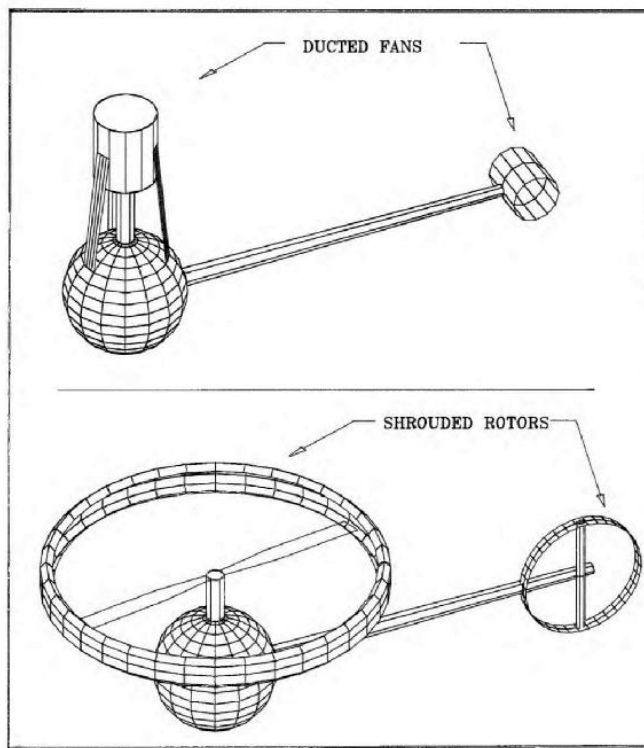


Figure 2.

An immediate problem is the danger from the rotor. Using a turbojet would only substitute burns for lacerations. A turboshaft powered rotor would risk both. We propose the lift is provided by a piston driven, ducted fan or shrouded rotor. The potential configurations are shown in Figure 2.

At this point the vehicle is a somewhat large model helicopter with a commensurate level of cost and complexity. It should be noted that low observability will be provided by the use of composites in the structure and radar absorbing material around the engine. It is expected that the RAM and the ducted fan or shrouded rotor will also reduce acoustic observability.

Once the vehicle is airborne it must convert itself into a high speed aircraft. Considerable thought and discussion of this requirement resulted in the novel approach depicted in Figures 3 through 6.

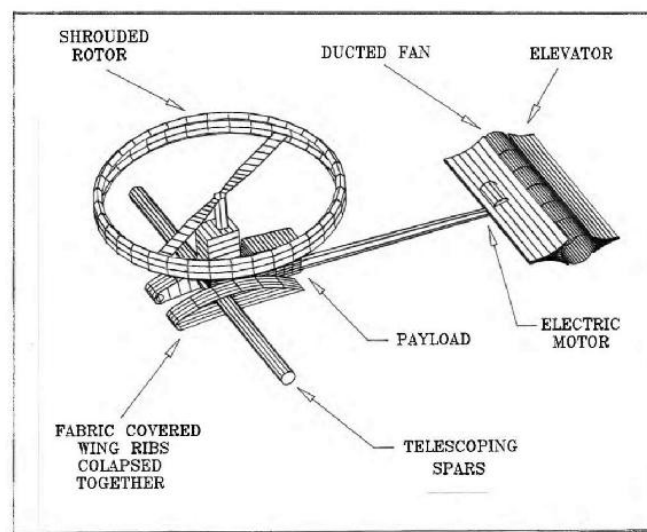


Figure 3.

The craft has a series of fabric covered ribs collapsed together alongside the power-plant. The tail-rotor function is combined with the elevator function of an airplane. The tail-rotor fan is powered by an electric motor to allow for

the most versatile servo-control operation. The particular configuration shown uses a shrouded rotor and a ducted fan tail-rotor. There are spars extending from the side of the vehicle. The payload is carried behind the engine. This configuration provides the minimum aerodynamic interaction with gusting winds and the rotor downwash.

Figure 4 shows the craft in transition to dash mode. The craft deploys fabric covered wing ribs as its forward velocity increases. This is achieved by extending the ribs along spars which extend out of the fuselage. The overhead rotor tilts forward until it becomes a propeller. It is anticipated that the entire powerplant will tilt with the rotor in order to keep things simple. The electric motor that powers the tailrotor fan is reversible. This allows it to function as a rudder in the dash and loiter modes. It is expected that the wing span will be dynamically controlled in order to maximize transition stability and dash speed as the need may be.

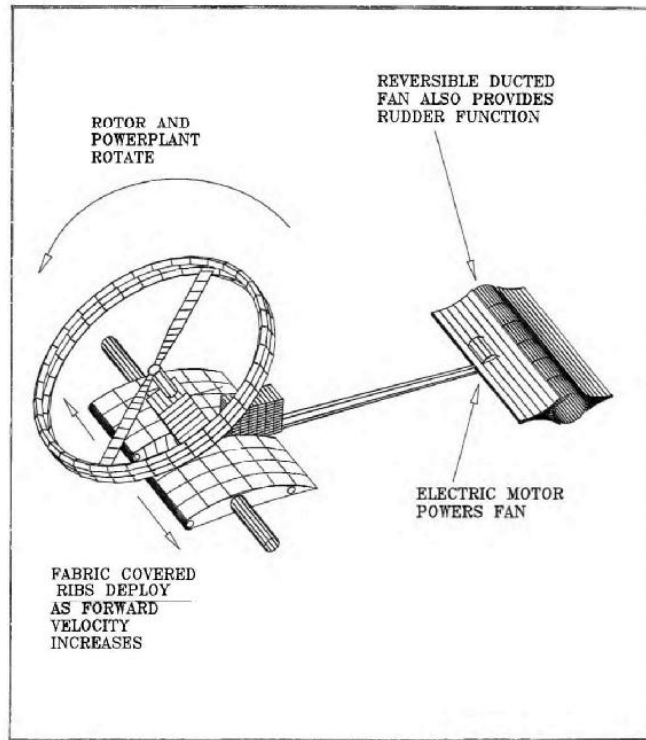


Figure 4.

The vehicle in dash mode is shown in figure 5. The wings have deployed and the rotor is now functioning as a prop. In this configuration the craft has the stability and control of a conventional high speed prop driven aircraft. The adjustable pitch of the rotor is used to optimize performance.

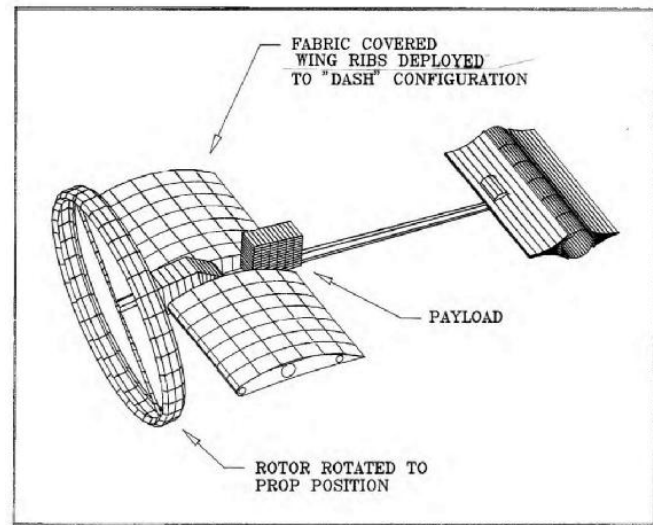


Figure 5.

The requirement for a long loiter time is achieved by further extending the spars as shown in figure 6. The variable pitch rotor is adjusted to minimize fuel consumption.

If takeoff and landings need to be very precisely controlled further electronic systems will be added. A laser beam homing system is envisaged. The beam from a laser diode will be projected vertically. On a ship this would result in the beam not moving relative to the ships structure and rigging. The craft will have sensors on its underside to detect the beam. The control algorithm will cause the craft to always maintain the beam at the center of its sensor. The rotor thrust is altered under servo or operator control to effect takeoff and landing. It is anticipated that the transitional time between grounded and dash would be less than a few seconds.

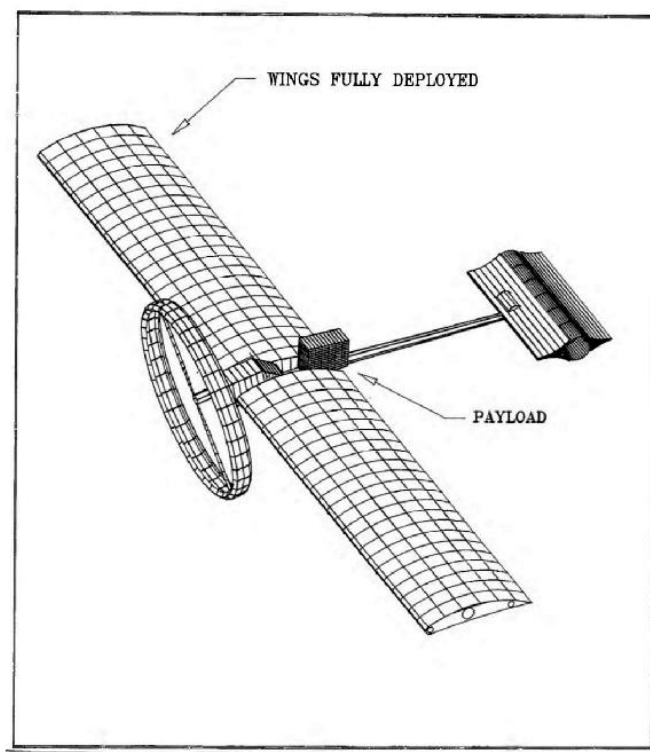


Figure 6

d. Phase one technical objectives.

1. 1) proportion space and weight figures for the engine, payload, power generation, system electronics, fuel and structure.
2. 2) Perform design calculations to achieve performance and stability requirements for the three operating modes.
3. 3) Modify space and weight figures as appropriate.
4. 4) fabricate a non flying 1/4 scale model of the system
5. 5 design the minimums system electronics including algorithm pseudocode. Deliver block diagrams and schematics.
6. 6) Create a block diagram of the takeoff and landing assist electronics.

e. Phase I work plan.

- Week 1 Request available power-plant information from the Navy. Request payload volume and outline from the Navy. Review literature. Review existing power-plants, rotor-heads etc.
- Week 2 Size motor horsepower requirements. Size rotor and fan thrust requirements.
- Week 3 Select rotor/fan system. Design or design in rotor system, pitch control.
- Week 4 Select wing airfoil. design wing ribs, spar and retract mechanism.
- Week 5 Design tail section. Design tail rotor/fan.
- Week 6 Design fuselage hinge mechanism.
- Week 7 Design stability enhancement electronic system
- Week 8 As above.
- Week 9 Do first cut master layout.
- Week 10 Analyze structure (FEI as required)
- Week 11 Analyze aerodynamic performance and stability.
- Week 12 Adjust weights and structure accordingly.
- Week 13 Review with Navy and optimize performance.
- Week 14 Build form only 1/4 scale model.
- Week 15 Conceive electronic stability augmentation system.
- Week 16 Analyze system parameters.
- Week 17 Refine design. Design conceptual system for guidance augmentation.

- Week 18 Assemble documentation package.
- Week 19 Prepare construction plan for prototype. Do manufacturability analysis.
- Week 20 Prepare test plan.
- Week 21 Prepare cost estimate for parts, labor and investment.
- Week 22 Prepare Phase II funding request.
- Week 23 Prepare final report.
- Week 24 As above.
- Week 25 As above.
- Week 26 Review with Navy. Respond to and requests.

Deliverables:

1. 1) Vehicle master layout.
2. 2) Aerodynamic Analysis.
3. 3) Structural Analysis.
4. 4) 1/4 scale model (non functional).
5. 5) Electrical/electronic block diagrams.
6. 6) Construction plan.
7. 7) Manufacturability analysis.
8. 8) Test plan.
9. 9) Cost estimate for implementation.
10. 10) Phase II funding request.
11. 11) Final report.

f. Related Work.

Proposing activity is working on a kit plane concept vehicle which includes some of the features of the proposed craft. Although this vehicle does not have VTOL capability it is a STOL craft. The aerodynamic analysis and structural analysis is similar. The principal investigator has designed several electronic control systems. These systems are in use in the automotive, industrial and aerospace industries.

g. Relationship with Future Research or Research and Development.

1. 1) The anticipated result of this research is the quantification of the performance and cost to build of the proposed craft. This will allow evaluation of the concept by other agencies and other sources of funding. It will also position the proposing firm to compete against larger firms in the Phase II development.
2. 2) The significance of the Phase I effort is that it will minimize any technical risks associated with the concept. There should be no "dead ends" or "show stoppers" once Phase II is undertaken. The Phase I effort should also identify which components of the design require the most attention in Phase II. This will provide a mission statement and a sense of importance in the future research and development.

h. Potential Post Applications.

1. 1) The proposed project will serve to deepen the understanding of VTOL concepts. It will broaden the scope of available design expertise available to all branches of the federal government. The application of a design which meets such stringent requirements will extend to many other less demanding applications. Agencies other than the armed forces which may benefit include the DEA, CIA, FBI, NSA, FCC, USDA, and others.
2. 2) The proposed craft has several commercial applications. These include traffic reconnaissance, search and rescue, crop dusting, general aviation, scientific data gathering and wind shear detection.

i. Key Personnel.

Paul Rako

Mr. Rako is the owner of the proposing firm. He has been an engineering consultant for 10 years. Prior to that, he was a design engineer at ESL division of TRW. He has also been an automotive design engineer for both General Motors and Ford. He was educated by General Motors' co-operative program at the General Motors Institute in Flint, Michigan. Mr Rako's firm specializes in the design of complete "turn-key" systems for military, industrial and commercial clients. He has designed both airborne and spaceborne electronic systems. He has an avid interest in both general aviation and RC modeling.

Bob Dible is electrical engineer with almost 20 years experience. He has designed several military systems including space systems. He is a champion radio controlled aircraft pilot competing nationally in the Formula 1 class. Bob constructs his own craft and has an excellent intuitive feel for aerodynamics and airworthiness. He has a BSEE from Kansas State University.

Andy Masto is a mechanical engineer with a degree in aeronautical engineering from UCLA. He has 20 years experience in design and project management. He is an expert in finite element analysis.

j. Facilities/Equipment

The proposing firm has a 1500 square foot design and prototype center in Sunnyvale California. Design tools include several computers with both electrical and mechanical software applications. Among these are Autocad, Procad, Orcad, PADS, COSMOS and others. An E-size plotter is used for output.

A 100,000 page component and system library is maintained. There is a complete lab with scopes, spectrum analyzers and other test equipment. There is no requirements foreseen that would require the purchase of additional equipment. The facilities meet all environmental laws for the federal, California, Santa Clara County and Sunnyvale governments. These laws encompass airborne emissions, waterborne effluents, external radiation levels, outdoor noise, solid and bulk waste disposal practices, and the handling and storage of toxic waste. Compliance is insured through biannual inspections conducted by the Sunnyvale Department of Public Safety.

k. Consultants

Proposing firm does not anticipate the need for consultants.

l. Prior, Current or Pending Support.

There is no prior, current or pending support.

m. Cost proposal

Cost Breakdown Items:

1. Rako Electronics
2. 1161 Tasman Drive
P.O. Box 61387
Sunnyvale, CA 94088
3. Work to be done at: As above.
4. Articulated, deployable wing VTOL aircraft.
5. N92-129 Vertical Takeoff and Landing
Unmanned Aerial Vehicle for Maritime and
Close Combat Applications.
6. Total cost: \$ 49,668
7. Direct material costs:
 - a. Purchased parts- \$ 0
 - b. Subcontracted - 0
 - c. Other
 - (1) Raw Materials 650
 - (2) Std cmmrcl 0
 - (3) Interdiv xfer 0
 - d. Total - 650

8. Material overhead rate (%22) \$793

9. Direct labor

a. Engineering 500 hr @ \$50/hr = \$25,000

Technician 20 hr @ \$50/hr = 1,000

Proj manage 130 hr @ \$50/hr = 6,500

b. Total 32,500

10. Labor overhead:

a. Rate: 35% of 650 hr

b. Total labor overhead: \$ 11,375

11. Special testing 0

12. Special Equipment 0

13. Travel 0

14. Consultants 0

15. ODC 0

16. G&A

a. Rate: 12%

b. Total 4,000

17. Royalties: 0

18. Fee/profit 1,000

19. Total Estimate cost: \$ 49,668

signed _____

Date _____

Paul J. Rako, Owner

21. a. Has any executive agency of the United States government performed any review of your records in connection with any other government prime contract or subcontract within the past 12 months?

No

b. Will you require the use of any government property in the performance of this proposal?

Yes

Describe:

1) Drawing of requisite payload volume, outline center of gravity etc.

2) Drawing & specs of applicable piston driven powerplants including conceptual ones for heavy fuel powerplants.

c. Do you require government contract financing to perform this proposed contract.?

Yes

Type: 85% monthly progress payments

15% completion

\$1000 profit at completion.

22. Type of contract: Firm Fixed Price.

N92-129

TITLE: Vertical Takeoff and Landing
Unmanned Aerial Vehicle for Maritime and
Close Combat Applications

CATEGORY: Advanced Development

OBJECTIVE: Develop and demonstrate a safe,
high forward speed, vertical takeoff and landing
(VTOL) unmanned aerial
vehicle for maritime and close combat
applications.

DESCRIPTION: Next generation UAVs will be
required to operate safely and efficiently from
available deck space on
small surface combatants, and from small
clearings or other restricted areas during
amphibious close combat operations
onshore. The constraints of limited deck space
on most surface combatants, with proximity of
above-deck rigging and other
superstructures, will require a true VTOL class
air vehicle for launch and recovery. Support for
urban combat and other
onshore operations with a mobile landing force
also mandates a UAV system which requires
minimum landing and takeoff
area, with little or no surface preparation before
use. Current VTOL UAV designs have
inadequate safety features
necessary to operate in confined spaces, and
most lack the forward transition speed to
rapidly reach a desired target area.
The air vehicle design must ensure the safety
and protection of operating personnel and
nearby equipment during launch and
recovery. This advanced design must also
exceed the forward speed and maneuver
capabilities of present VTOL UAVs.
Improved forward speed and maneuver
capabilities are required to increase
survivability in the anticipated hostile anti
aircraft combat environment.

This forward speed capability must be coupled
with appropriate inflight stability, so that the
gimbal stabilization requirement for onboard
imaging sensors is minimized. The vehicle
gross takeoff weight shall not
exceed 400 pounds, with a 100 pound payload
(control avionics and sensors) and fuel
included. The required radius of
operation is 100 nautical miles, with a desired
maximum on-station loiter time of 8 hours.
Operating altitudes range from a
hover in ground effect to a minimum in-transit
cruise altitude of 10,000 ft AGL. Efficient
forward dash speed operation of
at least 90 knots TAS is required, with higher
speed desire. Design features for reduced
vehicle radar and infrared
signatures are also desired to further increase
expected combat survivability.
Phase I: Identify and evaluate innovative
concepts that provide a safe, high speed, VTOL
unmanned aerial vehicle
for maritime and amphibious close combat
applications. Develop a plan to mature the
design and demonstrate a full scale
flight vehicle over the entire projected
operating envelope.
Phase II: Develop and demonstrate prototype
equipment for the air vehicle design proposed
under Phase I.