24th Annual AHS Student Design Competition

2007 Request for Proposal (RFP)

for

Advanced Deployable Compact Rotorcraft

in support of

Special Operation Forces

Sponsored by

Sikorsky Aircraft

and

"The Nightstalkers (160th Special Operations Aviation Regiment) specialize in night operations, where their advantages in sensors, navigational equipment, weapons, and crew skills can translate into a significant edge in combat. If they have a shortcoming, it is their small numbers and their need for infrastructure and support (basing, logistics, etc.), which can limit their usefulness in expeditionary environments."

Tom Clancy

"Special Forces – A Guided Tour of U.S. Army Special Forces"

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Section 1 – Basic Proposal Information

1. Rules

a. Competition categories include:

- Graduate Student Category
- Undergraduate Student Category
- New Entrant Category

The “New Entrant” category is open to all schools (graduate and undergraduate) that have not participated in at least 2 of the prior 3 competitions).

b. All undergraduate and graduate students may participate in this competition. Schools are encouraged to form project teams. The maximum number of students on each team is 10.

c. The classification of a team is determined by the highest education level of any member of the team. Part-time students may participate at the appropriate graduate or undergraduate level.

d. “New Entrant” team proposals will be judged at the appropriate graduate or undergraduate level, and evaluated for the best “New Entrant” category from the group of all New Entry teams.

e. Only one design proposal may be submitted by each student or team, however a university or college may submit multiple proposals.

f. Final proposals must be submitted to AHS International in digital format readable using Adobe Acrobat (requests for exceptions will be considered in advance). All documents submitted shall use a font size of at least 10 point and a spacing that is legible and enhances document presentation.

g. Graduate category submissions shall be not more than 100 pages and undergraduate submissions shall be no more than 50 pages (including all figures, drawings, photographs, and appendices). The cover page, table of contents, lists of figures/tables, nomenclature, and references are not to be considered part of the page limit. Pages shall be 8½ x 11 inches, with the exception that 8 pages may be larger fold-out pages up to a maximum size of 11 x 17 inches.

h. The Final Proposal must include a self-contained Executive Summary briefing, in PowerPoint format, limited to no more than 20 pages. This summary is not to be considered part of the page limit.

i. For all submittals, an inside cover page must include the printed name, educational level and signature of each student who participated. Submittals *must* be the work of the students, but guidance may come from Faculty Advisor(s), and must be acknowledged on this signature page. Design projects for which any student receives academic credit must be identified as such on this signature page.

j. If any student or design team withdraws their project from the competition, the student or team leader must notify the AHS National Headquarters Office immediately in writing.

2. Awards

The submittals will be judged in 2 primary categories:

Graduate Category:

- 1st place - $1300
- 2nd place - $650

Undergraduate Category:

- 1st place - $700
- 2nd place - $350

In addition, the best new entrant will be awarded $500. Certificates will be presented to each member of the winning team and to their faculty advisors for display at the school. The 1st place winner, or a team representative, in each category will be expected to present a technical summary of their design at the 2008 AHS International Annual Forum. Presenters will receive complimentary registration and Sikorsky Aircraft will reimburse up to $1000 in expenses to help defray the cost of attendance.

3. Schedule

Scheduled milestones and deadline dates for submission of the proposal and related material are as follows:

a. AHS Issue of Request for Proposal (RFP) .... August 18, 2006
b. Submit Letter of Intent to Participate .... February 16, 2007
c. Teams Submit Requests for Information/Clarification .... by February 16, 2007
d. AHS Issue Responses to Questions .... by March 16, 2007
e. Teams Submit Final Proposals ....by June 01, 2007
f. Sikorsky Notifies AHS of Results .... August 10, 2007
g. AHS Announces Winners.. August 17, 2007
h. Winning Teams Present Executive Summary at AHS Forum 64 .... May, 2008

All questions and requests for information/clarification that are submitted by teams to AHS will be distributed with answers to all participating teams. The proposal must be postmarked by June 01, 2007.

4. Contacts

All correspondence will be directed to:

Kim Smith, Deputy Director
AHS International
217 N. Washington Street
Alexandria, VA 22314

Phone: (703) 684-6777
Fax: (703) 739-9279
Email: kim@vtol.org

5. Evaluation Criteria

The proposals will be judged based on 4 primary categories, with weighting factors specified in brackets:

a. Technical Content (40 points)

- Design meets RFP technical requirements
- Assumptions are clearly stated and logical
- A clear understanding of design tools is evident
- Major technical issues are considered
- Appropriate trade studies are performed to direct/support the design process
- Well balanced and appropriate substantiation of complete system
- Technical drawings are clear, descriptive and accurately describe the complete aircraft (including relevant subsystems)

b. Organization & Presentation (15 points)

- Self contained Executive Summary which contains all pertinent information and makes a compelling case for why the proposal should win
- Introduction clearly describes the major features of the proposed aircraft
- Proposal is well organized so that all pertinent and required information is readily accessible and in a logical order (continuity of topics)
- Figures, graphs and tables are uncluttered and easy to read and understand
- All previous relevant work cited
- Overall quality and presentation of report

c. Originality (20 points)

- Vehicle aesthetics
- Solution demonstrates originality and shows imagination

d. Application & Feasibility (25 points)

- Technology levels used are justified and substantiated
- Identification and discussion of high risk technological areas
- Influence of affordability considerations on the design process

- Influence of reliability and maintainability on the design process, including life cycle support
- Consideration of manufacturing methods and materials on the design process, including modularity and lean implementation
- An appreciation of how the vehicle will be used by the operator is demonstrated
- Consideration of additional applications other than those specified in the RFP
- A path to production ready technology is identified

6. Proposal Requirements

The proposal response needs to communicate a description of the design concepts and the associated performance criteria (or metrics) to substantiate the assumptions and data used and the resulting predicted performance, weight, and cost. The following should be used as guidance while developing a response to this Request For Proposal (RFP):

1. Demonstrate a thorough understanding of the RFP requirements.
2. Describe the proposed technical approach that complies with the requirements specified in the RFP. Technical justification for the selection of materials and technologies is expected. Clarity and completeness of the technical approach will be a primary factor in evaluation of the proposals.
3. Identify and discuss critical technical problem areas in detail. Descriptions, method of attack, system analysis, sketches, drawings, and discussions of new approaches should be presented in sufficient detail in order to assist in the engineering evaluation of the submitted proposal. Exceptions to RFP technical requirements must be identified and justified.
4. Describe the results of tradeoff studies performed to arrive at the final design. Include a description of each trade and a thorough list of assumptions. Provide a brief description of the tools and methods used to develop the design.
5. The data package which must be provided in the proposal is described in Section 2.

The proposal package must also contain an Executive Summary Briefing that presents a compelling story for selecting your design concept. It should highlight critical requirements, trade studies conducted, and summarize the aircraft concept design and capabilities.

Judging will focus on innovative solutions, system performance, and system value.

Section 2 – Design Objectives and Requirements

1. Background

The 9/11 Commission Report recommended that responsibility for directing and executing paramilitary operations should be shifted from the CIA to the U.S. Special Operations Command (USSOCOM). The U.S. strategy for pursuing the war on international terrorism involves a variety of missions conducted by military and civilian intelligence personnel characterized as" special operations" or paramilitary operations.

Special operations are "operations conducted in hostile, denied, or politically sensitive environments to achieve military, diplomatic, informational, and/or economic objectives employing military capabilities for which there is no broad conventional force requirement." Special operations are distinguishable from regular military operations by (among other things) operational techniques and modes of employment. Special operation missions are frequently *clandestine* — designed in such a way as to avoid detection; and on occasion, *covert*--- designed to conceal the identity of the sponsor to avoid directly implicating governments.

2. Overview of Operations

Special Operations Forces (SOF) teams are frequently required to operate from the maritime environment. Case in point: 1) people are the primary source of conflict; 2) 70% of the world's population lives within 200 miles of the sea; 3) 80% of the world's capitals are located within 300 miles of a coastline. Additionally, many of the world's strategic sea lines of communication (SLOC) lie within littoral regions. SLOC's are critical to sustaining the world's economies, trade, and communications; hence they are extremely lucrative targets to terrorists, anarchist, and rogue leaders. Logically then, most of the conflict and chaos in the 21st century will continue to originate where the world's oceans meet its land masses --- the "littorals".

SOF maritime approach and recovery is, out of necessity, via a submersible watercraft; evolving from the concepts developed by underwater demolition teams during World War II. Current day operations involve transporting the SOF team via submarine into the objective area. From a submerged location off the coast, the team exits the submarine and moves ashore carried by an underwater vehicle(s). After hiding their vehicles, they move to their objective, carry out the assigned mission, return to their vehicles, and recover back to the submarine.

The major advantage of the submersible approach is stealth. However, this advantage brings with it some serious operational challenges. First and foremost, the watercraft is useless in aiding the teams move to the objective and as a result the team must rely on alternate forms of transportation when ashore. Options range from foot-mobile to vehicular methods. If the objective is relatively close to the shore, the team does not require a vehicle. If however, the objective is some distance away, the logistics of the operation increase in terms of coordination (complexity) and risk.

Furthermore, there is a time consideration as the team moves from the maritime to the terrain environment. The underwater vehicles must be secured and hidden until they return. While the actual time impact is not significant, a better solution would eliminate this step.

3. Design Objectives

Approach and Recovery Vehicle (ARV)

The primary objective of this RFP is the design of an advanced manned Approach and Recovery Vehicle (ARV) that is capable of operating from a submersible vehicle in support of Special Operations Forces. Using the ARV, SOF teams would move directly from a submerged submarine to the objective as swiftly as possible and then recover back to the submarine without being detected. The ARV must be capable of vertical takeoff and landing (VTOL) and will have an initial operational capability (IOC) in 2020.

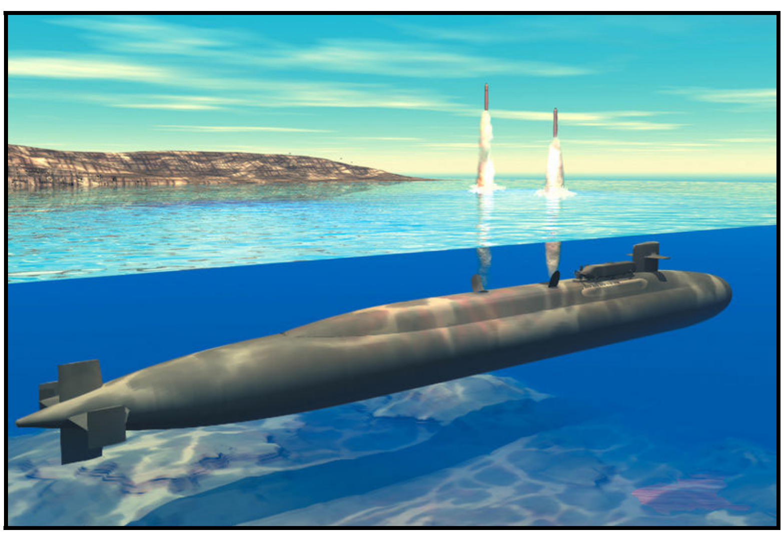
Unmanned Escort Vehicle (UEV)

The secondary objective, for GRADUATE TEAMS only, is the design of an advanced Unmanned Escort Vehicle (UEV) that is capable of supporting the operations of the ARV. For SOF teams, enhanced situational awareness (achieved by accurate, timely intelligence) is essential, not only for mission success, but also to ensure the team’s safety and survival. While the approach and recovery vehicle will be capable of receiving real-time information exchange via the global information grid, SOF missions are often decentralized operations, operating without the sensor assets available in larger joint operations. Hence, SOF teams require an organic surveillance and reconnaissance capability.

The UEV will be an aerial sensor acting as an "eye in the sky" for the SOF teams. As such, it must be capable of operating via pre-programmed instructions, or operator initiated instructions, providing electro-optical (EO) and infrared (IR) sensors and a laser designation capability. The UEV must be capable of vertical takeoff and landing and will also have an initial operational capability (IOC) in 2020.

4. Submersible Ship Aircraft Carrier (SSCN)

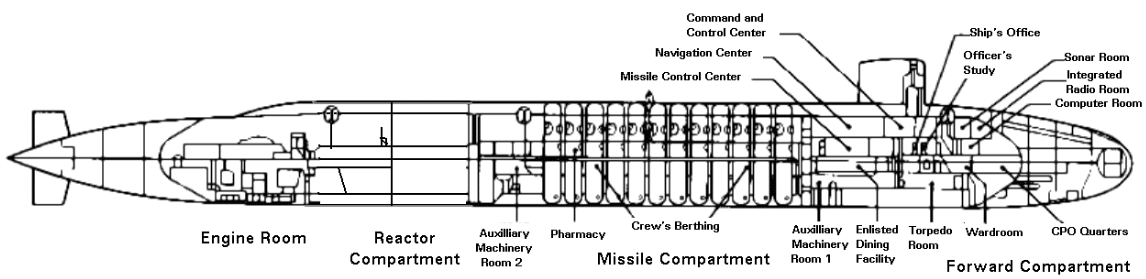
The primary sea basing platform for the ARV/UEV systems will be a retrofitted Ohio class SSGN submarine. Existing Ohio class SSBN's have 24 Trident missile silos. The upgraded Ohio class SSGN's are currently being retrofitted to replace their Trident missile silos with either missile canisters capable of firing conventionally armed cruise missiles, or configuring existing tubes for Special Operations Forces. The retrofit envisioned by this RFP is a more comprehensive conversion of the missile silos on an SSBN or SSGN to aircraft hangars on a new SSCN. The new SSCN will be configured to enable the operation (launch and recovery) of rotorcraft in support of SOF while the submarine is submerged (i.e. at periscope depth).



The Ohio class SSBN missile silos are sized to house a single UGM-133 Trident D-5 missile. Basic dimensions and weight of the Trident missile are:

Length	44 ft (13.42 m)
Body Diameter	6.92 ft (2.11 m)
Launch Weight	130,271 lbs (59,090 kg)

The new SSCN submarine will make use of the space currently dedicated to missile silos to form aircraft hangars that can be used to launch and recover the ARV or UEV. As a result the stowed dimensions of the ARV/UEV will have to be minimized to optimize space utilization aboard the SSCN. The volume used by the Trident missile silos can be fully used in support of new aircraft hangars, however submarine configurations that utilize fewer silos are preferable. Note that it will be necessary to leave 4 missile silos intact to support firing of either Tridents or Tomahawk cruise missiles, which leaves a total of 20 missile silos for conversion.



A basic description of the configuration of the new SSCN to support launch and recovery of the proposed ARV and/or UEV is required. In particular the focus of this effort should be on the efficient use of available volume aboard the SSCN.

5. Aircraft Launch and Recovery

A primary goal of this RFP, in addition to the design of the ARV/UEV, is to develop an efficient launch and recovery system that will enable the ARV/UEV to be launched while the SSCN is at periscope depth (~50ft). Therefore, teams are required to describe how the ARV/UEV vehicles will get from a submerged SSCN to the surface (launch) and then from the surface back aboard a submerged SSCN (recovery). The only restrictions on the launch and recovery system is that it must utilize the internal volume of an Ohio class submarine, no external add-ons are permitted.

In terms of launch and recovery times:

- The vehicles shall be capable of launching within 30 minutes of receipt of tasking.
- The vehicles shall be capable of launching within 10 minutes after being positioned on the waters surface.
- Following landing, the vehicles shall be capable of receding beneath the waters surface within 10 minutes.

An automatic takeoff and landing system should be used for normal launching and recovery of the vehicles, both at sea and on land. A manual interface should be incorporated to enable takeoff aborts and/or recovery wave-offs in the event of emergencies. The ARV must be operable by personnel who are not trained as pilots.

The vehicles shall also have the capability to automatically recover to pre-designated locations (ground or water) during an emergency. This mode will enable the vehicles to safely recover to areas that will allow for retrieval by ground or naval forces.

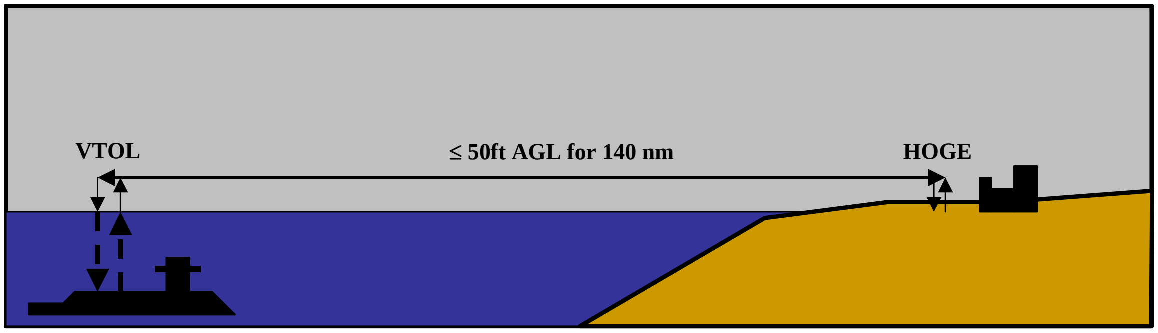
Automatic recovery mode shall be engaged when:

- Operator initiated, or
- Critical systems are disabled from battle damage, or
- In the absence of other instructions, the data link connection is lost and not reacquired within a predetermined period of time.

Note that if blades/wings need to be folded, automatic fold should be employed.

6. Mission Profiles

The primary design mission for the ARV involves launching from an SSCN operating at periscope depth, cruising at low altitude to distances up to 140nm, performing a mid-mission HOGE, and returning back to the submarine. A primary goal is to remain undetected throughout the entire mission, since the mission is in support of special operations forces. A mission profile is described in detail below:



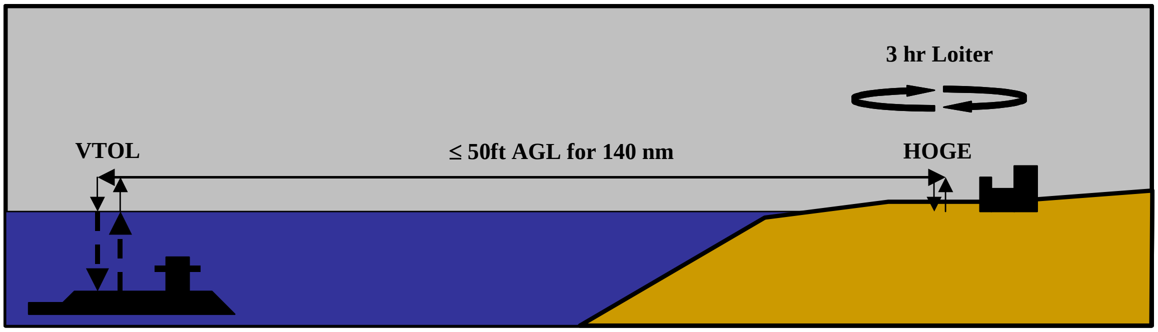
ARV Mission Profile

Segment	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Units**
Type	Idle	HOGE	Cruise	HOGE	Cruise	HOGE	Reserve	-
Speed	0	0	V_{br-99}	0	V_{br-99}	0	V_{be}	ktas
Time	4	2	-	4	-	2	20	min
Range	-	-	140	-	140	-	-	nm
Altitude	0	0	0	0	0	0	0	ft
Temperature	102.92	102.92	102.92	102.92	102.92	102.92	102.92	°F
Engine Rating	IRP	MRP	MCP	MRP	MCP	MRP	MCP	-

Where V_{br-99} is defined as the speed for 99% of best specific range and V_{be} is defined as the speed for best endurance. Additional requirements for the primary ARV design mission include:

- Payload = 800 lbs including pilots (no payload drop for sizing mission).
- A hover-out-of-ground-effect capability at 6k/95 (6000ft/95ºF).

The primary design mission for the UEV involves launching from an SSCN operating at periscope depth, cruising at low altitude to distances up to 140nm, performing a mid-mission loiter, and returning back to the submarine. A goal is to remain undetected throughout the entire mission, since this is in support of special operations forces. A mission profile is described in detail below:



UEV Mission Profile

Segment	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Units**
Type	Idle	HOGE	Cruise	Loiter	Cruise	HOGE	Reserve	-
Speed	0	0	$V_{br\text{-}99}$	V_{be}	$V_{br\text{-}99}$	0	V_{be}	ktas
Time	4	2	-	180	-	2	20	min
Range	-	-	140	-	140	-	-	nm
Altitude	0	0	0	0	0	0	0	ft
Temperature	102.92	102.92	102.92	102.92	102.92	102.92	102.92	°F
Engine Rating	IRP	MRP	MCP	MCP	MCP	MRP	MCP	-

Where $V_{br\text{-}99}$ is defined as the speed for 99% of the best specific range and V_{be} is defined as the speed for best endurance. Additional requirements for the primary UEV design mission include:

- Payload = 600 lbs (modular mission payload of sensors/weapons).
- A hover-out-of-ground-effect capability at 6k/95 (6000ft/95ºF).

7. Weights

Additional weight data that may be helpful in sizing the VTOL vehicles is listed below:

- Crew = 270 lbs each (2 crew for the ARV)
- Avionics = 300 lbs
- ARV Payload = 260 lbs (mission equipment)
- UEV Payload = 600 lbs
- Contingency = 5% of empty weight

8. Survivability

The vehicles shall utilize advanced susceptibility reduction techniques to enhance mission survivability. Visual, acoustic, infrared (IR) and radar signatures should be minimized. Particular attention should be given to minimizing acoustic signatures for both vehicles. Vulnerability reduction techniques should also be utilized to limit the effects of combat damage to critical components and subsystems that are essential for the safe return of the flight vehicles.

9. Advanced Scaleable Engine Data

Advanced scaleable engine data is provided for use in this design competition. The data provided is based on advanced engine technology levels that are likely to be representative of engine technology in 2020. It is strongly recommended that this engine data be used, however if existing engine designs are used then assume a 20% reduction in engine SFC and a 20% increase in power-to-weight. All data is static and uninstalled.

Advanced Engine Data for SL/ISA Conditions

Engine Rating	Duration	Power Available (hp)	SFC (lb/hp.hr)
OEI	30 sec	1,049	0.360
MRP	2 min	1,002	0.361
IRP	30 min	934	0.365
MCP	continuous	764	0.379
Part Power	-	501	0.426
Idle	-	200	0.672

Advanced Engine Data for SL/Hot (0ft/102.92°F) Conditions

Engine Rating	Duration	Power Available (hp)	SFC (lb/hp.hr)
OEI	30 sec	867	0.373
MRP	2 min	820	0.377
IRP	30 min	758	0.384
MCP	continuous	619	0.404
Part Power	-	410	0.466
Idle	-	164	0.784

Advanced Engine Data for 6k/95 (6,000ft/95°F) Conditions

Engine Rating	**Duration**	**Power Available (hp)**	**SFC (lb/hp.hr)**
OEI	30 sec	707	0.371
MRP	2 min	664	0.376
IRP	30 min	611	0.383
MCP	continuous	504	0.402
Part Power	-	332	0.463
Idle	-	133	0.777

The ram power increase with speed may be assumed as:

$$\frac{P_V}{P_{static}} = \left[1 + 0.195 \cdot M_\infty^{\ 2}\right]^{3.5}$$

where P_V is the power available at speed, P_{static} is the power available under static conditions and M_∞ is the freestream Mach number.

The effect of engine scaling on SFC can be assumed as:

$$SFC_{corr} = \frac{-0.00932 \cdot ESF^2 + 0.865 \cdot ESF + 0.445}{ESF + 0.301}$$

where SFC_{corr} is an SFC correction factor that can be multiplied by the baseline core engine SFC's and ESF is the engine scaling factor which is defined as:

$$ESF = \frac{MRP_{actual}}{MRP_{baseline}}$$

where $MRP_{baseline}$ = 1,002 hp.

The effect of RPM variations on both specific fuel consumption and power available can be assumed as:

$$SFC_{corr} = -1.211 \cdot RPM_{FR}^{\ 3} + 4.281 \cdot RPM_{FR}^{\ 2} - 5.104 \cdot RPM_{FR} + 3.034$$

$$SHP_{corr} = 1.143 \cdot RPM_{FR}^{\ 3} - 3.907 \cdot RPM_{FR}^{\ 2} + 4.580 \cdot RPM_{FR} - 0.816$$

where SHP_{corr} is an SHP available correction factor that can be multiplied by the MRP power available and RPM_{FR} is the rpm fraction which is defined as:

$$RPM_{FR} = \frac{RPM_{actual}}{RPM_{100\%}}$$

where $RPM_{100\%}$ = 18,000 rpm.

Engine residual thrust can be estimated as: $T_{res} = 0.094 \cdot SHP$, where SHP is defined as the installed power of the engine.

Engine weight can be estimated from the following equation:

$$W_{engine} = N_{eng} \left[\frac{0.1054 \cdot \left(\frac{MCP}{N_{eng}} \right)^2 + 358 \cdot \left(\frac{MCP}{N_{eng}} \right) + 2.757 \times 10^4}{\left(\frac{MCP}{N_{eng}} \right) + 1180} \right] \text{ (lbs)}$$

where N_{eng} is the number of engines and MCP is the uninstalled-SLS engine power available for the scaled engine (no rpm or ram effects).

Engine envelope dimensions can be estimated from the following equations:

$$\text{Diameter} = 2.117 \cdot MRP^{0.3704} \text{ (in)}$$

$$\text{Length} = 2.622 \cdot MRP^{0.4148} \text{ (in)}$$

where MRP is the uninstalled MRP defined at SL/ISA static conditions.

Additional engine data is listed below:

- Engine RPM = 18,000 rpm at 100% N_r
- Fuel density = 6.7 lb/gal (JP-8) and oil density = 8.4 lb/gal

10. Air Transportability

The ability of SOF aviation assets to be rapidly deployed in theater is essential. Therefore the proposed ARV/UEV aircraft should be able to be rolled-on/rolled-off a C-130J aircraft. Basic internal cabin dimensions for a C-130J (excluding flight deck) are listed below:

Length (excl. ramp)	40 ft (12.19 m)
Length (incl. ramp)	50.25 ft (15.32 m)
Width (max)	10.25 ft (3.12 m)
Height (max)	9 ft (2.74 m)
Volume (total usable)	4,551 ft^3 (128.9 m^3)

11. Additional Design Requirements

Both flight vehicles must be:

- 100% mission capable in all global environments including maritime, artic, tropical, and desert.
- impervious to the effects of sea water.
- able to remain afloat in sea state 3 for not less than 30 minutes.
- offer a high degree of availability and reliability.

The ARV must:

- have lighting compatible with night vision devices.
- a crashworthy fuel system.
- be mission configurable to allow for transport of one or both of the crew as injured personnel.
- have mission equipment capabilities consistent with:
    - Infrared/low light imaging.
    - All weather, day-night, pilotage.

- Over the horizon, jam resistant communications (voice, data, imaging).
- Compatible with all available net-centric services (real-time information exchange).
- Wireless communications (voice, data imaging) between other approach and recovery vehicles or personnel up to ranges of 100 meters.

The UEV must:

- be capable of programming mission planning data prior to launch.
- be capable of re-planning the mission while the vehicle is in flight.
- incorporate a tactical data link to provide command, control, communications (C3) and data exchange. The data link will support video, data and telemetry communications between the UEV and ARV, and only video and data communications to the network. The UEV will use the Tactical Common Data Link (TCDL), a digital data link operating in the Ku frequency band.
- have an embedded VHF and UHF radio relay capability that will augment the system's tactical communications, assisting in overcoming line-of-sight (LOS) problems for the teams.

12. System Design Optimization and Affordability (Graduate Category Only)

There are many measures by which system value and efficiency can be assessed. The primary metric that will be used to judge system value for this design competition will be:

- The total number of SOF soldiers that can be deployed to a range of 140 nm from a single SSCN in a 6 hour time window while providing UEV support at the 140 nm range location (one UEV must be in the air providing support to ground forces at all times). Assume that both ARV crew members can be dropped off at the mid-mission point, and that a 4 minute hover is required to unload the crew. Use the primary design missions for performance estimates.

This metric will require design teams to maximize the number of vehicles onboard a retrofitted Ohio class SSCN submarine, minimize the launch and recovery times, and optimize vehicle performance (trade speed versus size).

Qualitative measures of system affordability should include (but not be limited to):

- Engine size and number of engines,
- Empty weight,
- System commonality (drive system, engines, blades, wing, etc.), and
- System complexity.

The teams are expected to estimate the cost (acquisition and cash direct operating costs) of the VTOL platforms, however no cost estimate of the retrofitted Ohio class submarine is expected. The focus of system cost minimization should be qualitative in nature.